Transmission Lines Edit Log PhL 9.3.13

This is a full year of history of my work in lines doc. I cycle round and round throught the Chapters and Appendices, iteratively improving things, constantly adding new Appendices to clean up confusions, removing bugs and paradoxes. I would guess that I dealt with perhaps 100 distinct "issues", some more serious than others. There are perhaps 5 total collapses followed by recoveries. The TOC below is pretty hard to interpret, the pathway threading through a year of editing is very non-linear.

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Initial Preparation Phase, Sept 3, 2013 : Cosmetic Repairs

I am just pondering putting out this doc on line. I am not sure what it really has to say, and as usual, I never know that until I completely study the whole thing. So I will at least start that process. The doc called "plan for updating Galois" shows the steps needed to assemble and then adjust the text into a single large file. Similar instructions are at the start of the spectral edit log. The first step is just to assemble everything into one file.

• **Assemble** all **6 chapters** into a new container doc. There are 6 chapters, and the doc is now 66 pages after doing this (appendices not added yet). I really should get the appendices in there so formatting will include them. There are **7 appendices**, so doc is now 95 pages after then are appended. They are appended in the correct order!

• Use **the organizer** to bring in ALL styles from normal.dot, let them override existing styles in the doc. For starters, this gets the main text to be my usual "normal" style, TNR 11 point, proper spacing, and so on. After doing this, the main text looks the way I want.

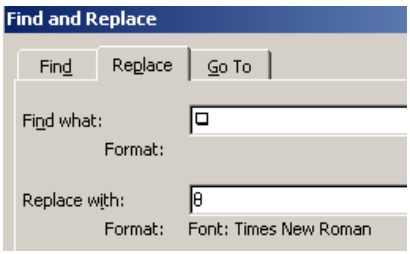
Equations have many problems. I think the first issue is to fix all Greek letters and there are many.

Greek Letters. Each one requires a custom solution sometimes!

I think I just have to do them one at a time. It is unclear what font the existing Greek letters are in!

$$[\ B(r+dr)\ (r+dr) - B(r)\ r]\ \theta \ = (\mu\mu_0\ \sigma)E(r)\ [\ r\theta\ dr\ ] \qquad (6)$$

A θ is F071 for example. But a modern symbol θ is hex 28! A modern TNR θ is 3B8. A simple replace does not work. It is claiming that the original Greeks are from some font called "e". But this method does work



where I select the strange θ and paste in the upper box, then type a normal θ and paste in the lower box AND this extra step is needed: specify TNR for the replacement font. Before doing all thetas, you have top open all field codes. But some of the θ's are in font e, and others in font symbol, so had to do replace both ways.

Next do σ: there were 175 of these starting in symbol. Then 38 of a second kind.

Next do ρ: did 104 of those

Next do μ: did 246 of those. But then 98 more of some different kind of μ.

Next do ε. did 235 of those. Then 77 of a second kind.

Next do φ. did 335 of those. Then 20 of a second kind.

Next do δ. did 81 of those. Then 17 of a second kind.

Next do β. did 282 of those. Then 39 of a second kind.

Next do π. Did 75 of those. Then 163 of a second kind.

Next do ω. Did 245 of those. Then 40 of a second kind.

Next do λ. Did 54 of those.

Next do ∂. Did 8 of those. Then did 340 of a second kind.

Next do Λ. Did 24 of those.

Next do ∞. Did 48 of those.

Next do ξ. Did 29 of those.

Next do ∇. For some reason this does not work as a replacement character! Control-Alt-Shift d. I cannot find how this symbol works. It is the "del" symbol. There is nothing like that in my macro list. Witzend sees no relevant hit on "del". So how did I do this? Go back to the subscripts doc and see what other "methods" I used. OK, the ∇ keystroke was set in the "insert symbol dialog shortcut key" deal. I see it right there. It is symbol font, char code is 00D1. So how can I get a specific key code like this into the edit and replace dialog? Subscript shows typing alt0209 does it on the keypad.

Problem solved: This symbol is in symbol font, not TNR, despite the fact that it says TNR when you select it! So in the replace thing, don't format the replacement char as TNR!

Next do ∇. Did 75 of these. Really want them bold though. So I made them bold. I can change it back later if I don't like it. Did 9 more of a second kind.

Next do γ. Did 15 of these.

Next do ν. Did 11 of these.

Next do ψ. Did 7 of these.

Next do α. Did 17 of these.

Equation Fonts.

Some of my equations are in "equation" style. Here is what works best. Select a word of normal text somewhere, then bring up styles panel, pick equation style, right click "update to match selection:. This seems to fix this type of equation everywhere.

Next, do the same thing with "e" style.

Subscripts and Superscripts.

Save file first since this may screw things up. It fails to handle subscript T correctly even when I do exactly what Galois says. T is F054. Let's try replacing these T's with regular T's. Did that, and it replaced 18 of those. Now retry subscripts. It did 2338 of them! But it did not get them all! There are now some subscripts in "e" style. If you delete e style, THEN redo the subscript thing, it gets these guys. This picked up another 625 subscripts.

Superscripts should work in a single shot now that I have deleted the "e" and "equation" styles after converting earlier all their instances to normal style. It did 1571 of these.

I now close field codes and take a long look. What still needs to be done?

Well, the fact is that you now just have to go through all equations and make hand repairs as needed. That is a whole 'nother phase which I must now embark upon. So break time. This is 110 pages of equations I have to manually review!!!!

Equation editor keeps launching as if I double clicked on an equation. How can I turn that off?

Equation appearance scan and cosmetic repair

Ch 1
- 1.1 OK
- 1.2 OK
- 1.3 OK
- 1.4 OK
- 1.5 OK

Ch 2
- 2.1 OK took a long time, only to page 12 out of 110!
- 2.2 OK, another long time
- 2.3 OK
- 2.4 OK up to page 19 of 110 !!!

Ch3
- 3.1 OK
- 3.2 OK
- 3.3 OK
- 3.4 OK
- 3.5 OK
- 3.6 OK
- 3.7 OK
- 3.8 OK

Ch 4
- 4.1 OK but many edits!
- 4.2 OK, getting worn down, only on page 43
- 4.3 OK
- 4.4 OK
- 4.5 OK and a lot of edits
- 4.6 OK and lots of edits
- 4.7 OK

Ch 5
- 5.1 OK
- 5.2 OK
- 5.3 OK
- 5.4 OK

Ch 6
- opening OK
- 6.1 OK
- 6.2 OK
- 6.3 OK

6.4 OK

done with the formal chapters. Now come the appendices, all 7 of them.

App 1.1 Gauge Invariance -- OK

Appendix 1.2: The Complex Dielectric Constant.

1. OK
2. OK

Appendix 2.1: DC Properties of a Wire

1. OK
2. OK
3.
   - 3.1 OK
   - 3.2 OK
4.
   - 4.1 OK
   - 4.2 OK
   - 4.3 OK

All along the way I am finding many spelling typos!

Appendix 2.2: Electric Field in a Round Wire

OK

Appendix 3.1: Surface Charge

OK

Appendix 3.2: Waveguides

OK

Appendix 4.1: Chapter 4 Support

OK

All done with my "cosmetic equation" pass.

Comments on Xmission Lines:

• I don't really remember doing this thing, but I do remember being confused by the King book. I must have spend hundreds of hours deriving all the equations, I sure hope I have backing for these derivations, otherwise I get to do them all over again.

• It really is an ambitious topic I think for me to be doing then. I guess the justification is we wanted to learn about coax cable and serial digital video. This work might have actually been useful to Philips, but of course our outpost and its possible work was of no interest to anyone, we were just a small toy football

tossed about by demoted managers. I think it is good to put this on line where at least it is visible, whereas as a binder on my shelf it is completely defunct. [Agreed! 10/19/14]

• Since I wrote this, I did a lot of study of "potential theory" in Stakgold. I wonder if that affects anything in this Lines doc? [it affected a lot]

• Various drawings (perhaps all) need to be redrawn.

Section Numbering and Equation Numbers.

I think I will keep it exactly as I have it rather than try to standardize it into one of my more usual forms. Just now I entered all the appropriate TOC headers, looks like a real doc now. But it sure would be hard to find an equation in this doc given its reference! Near impossible. Unless you installed detailed header headings for each subsection, that might be a way out. But that requires each thing be a real section. Maybe the easier thing to do is enhance so (1) becomes (1.1.1) and so on, ugly as it is.

Went though all and changed (2) to (2.2.2) so last number is never changed. This way I can fix all the references in line when I feel like it.

Now format all equations as in Galois without actually sliding equation numbers over yet. DONE
Now align all equation numbers (there are a lot!!!) DONE.

I just did a **first pass through Appendix A** on gauge invariance, not a bad place to start on this doc. My Stakgold readings have added some new information and I will have to rewrite parts of this appendix, but I won't do a super fancy job on it, I will just avoid saying wrong things. You have to relabel references to the equations locally.

Sunday Sept 8.

After a major battle, I think I got **appendix A** under control. This concerns gauge invariance, SI units, unique solutions, boundary conditions, and lots of stuff. Working notes are in a file called "uniqueness of Poisson.doc". Tomorrow I can finally "move on" to the next battle. I have then so far processed a total of 9 out of 119 pages!

Monday Sept 9, 2013

I just did about 2500 replacements of double space with single space, since I now want a single space after each sentence.

Let's try to do **Appendix B 1.2** since this is also referenced from Chapter 1.

App B 1.2
Section 1: verified all equations, took a little work, all are OK
Section 2: pretty easy, conclude no oscillatory free charge in medium.

Is this totally clear to me? Suppose plates are capacitor are driven by $e^{j\omega t}$ voltage. Continuity must always be true at any time instant. We have J = σE and charges ARE moving in the medium and there is a current. But the charge density I would say was always 0 due to balance. then dρ/dt = 0 and div J = 0 and this current has no divergence. I think I have the point wrong maybe? Looking at the numbers, I would say that you CAN have free charge for up to a few hours in poly. But is this true if the plates are alternating potential? Which way does the charge "run" ?

OK, I rewrote the last paragraph of this section so conclusions are better stated.

Section 3. Done. Everything needs references which I can install later, marked in red.

First Reading Pass, Sept 9, 2013

I am now ready to dive into Chapter 1 for the first time, since all its related appendices have been reviewed. The only previous pass above was just cosmetic and there was no content analysis.

Chapter 1

Section 1.1

Many problems right off the bat. First, μ and ε have unclear definitions so I mark them in red, and this then has implications for Appendix A which I may have to redo yet again. But the larger foggy idea is this notion of J_a as an "applied current". It makes no sense at all! Does it mean surface current? What author's use this J_a idea? King does not use this notion as best I can see. I will have to put Section 1.1 on hold for now since this J_a and ρ_a stuff is so poorly presented!

Section 1.2. My implication is that ρ_a and J_a only exist at "boundaries". I will derive the first two equations here later, but I'm sure they are right, and it is then true that whatever J_a is, it "drives" H.

Section 1.3. More confusion with specifying the components of the four vector A^μ. I now have velocity v floating around in places. This all needs to be cleaned up. But I think the general point is made OK, the details are confused.

Section 1.4. OK, but lots of stuff is not derived here.

Section 1.5 More on J_a being applied to conductors. I think the idea is that J_a really is the conductor surface current, where as the other J = σE is the "transverse" current in the medium between the conductors if that medium conducts. It is getting a little clearer now, but I am still far away.

This concludes my first reading of Chapter 1. I could go do repairs right now, but I think it would be wiser to continue on in my "first cut" content review. There may be important points that are made which will influence my repairs of Chapter 1.

So I want to start into Chapter 2, but it has 2 appendices that must be attacked first, so I guess I will launch into **Appendix C** which is 2.1.

Appendix C 2.1.

Section 1. All just fine.
Section 2. Seems OK, I fixed a small error.
Section 3
Section 3.1 Calculation of the internal inductance of a round wire.
Section 3.2. Wow, I have certainly forgotten all this stuff. I think it is OK.
Section 4
Section 4.1. Plan of attack.
Section 4.2 Put a length cutoff Λ on the wire.
Section 4.3. Avoiding the divergence problem, two methods are submitted.

OK, I have to take this as only a first cut through this appendix since nothing is derived. I will need to write a whole shadow document in which I derive all my equations or at least verify them.

Next comes **appendix D** on the round wire in more detail and perhaps general ω. I can see many weeks doing some of this every day. Don't forget to do other things please, just as one does at any job.

Tuesday Sept 10, 2013

Appendix D 2.2.
opening section
How can surface impedance be non-uniform in cross section?? Item 3.
Section 1 here I just assume a certain wave solution form. β and β_d are different.
Partial Waves. OK
Charge Pumping BC.
(D.1.7) no current outside wire? Have we assumed $\sigma = 0$ for the dielectric?
final comment is interesting but confusing to me.
The E_z solution
Why is $\beta >> \beta_d$? $\beta = \omega \sqrt{\mu\mu_0\xi}$ so mainly this is a claim about ξ from $\xi \equiv [\varepsilon\varepsilon_0 + \sigma/(j\omega)]$, so in the conductor, σ is very large and then roughly $\xi = \sigma/j\omega$ and $\beta^2 = -\omega^2\mu_c\mu_0\sigma^2/\omega^2$ which is large and real. In the dielectric $\beta_d^2 = \omega^2 \mu_d\mu_0\varepsilon\varepsilon_0$ which is also real and I guess is small for $\omega <$ some value.
Section 2.
The E_r solution. OK, an amazing amount of work here. Is this original work by me?
The E_φ solution. OK, and I have a conjecture at the end that could be better substantiated.
What we really need is external verification of whatever results I come up with at the end!
Application of the Boundary Conditions. OK, I now claim to have all three field components.
Section 3 statement of the results. OK, but again, does any source confirm this?
Comments about the solution. OK
Section 4 on low frequency limit.
Section 5. What about φ, A and B ? Done.

OUCH! This is a HUGE appendix with tons of claimed equations. I am actually trying to solve for the E and B fields inside a round wire which is part of a transmission line, so the problem does not have azimuthal symmetry. Where did I come up with this solution method? I give no references. Perhaps in

some other section I will give a reference. Page 99 to page 110, this is a 12 page appendix of solid equations. The title is a little misleading.

I have now finished the two appendices associated with Section 2, so I guess my next step is Chapter 2.

Chapter 2: The Round Wire.

opening text: I give a general reference to Matick Chapter 4.

Section 2.1 I use the Maxell curl equations to "solve" the round wire in isolation so it has azisym, maybe this point is not strongly enough made.

Section 2.2 is really about skin depth, maybe adjust the title.

Section 2.3 is on surface impedance. Title is apt, and I get the results.

Section 2.4 OK and done with Chapter 2! Whew!!

All this stuff and I have only *started* into this six Chapter document.

I guess my next step is the Two Chapter 3 appendices and then start into Chapter 3 "Preliminaries". But why not wrote some little **section overviews** for Chapter 2 and its two appendices. Done.

Weds Sept 11, 2013.

I will first write overviews for Chapter 1 and its two appendices. Done. These overviews are now stored in a separate overview document.

I next want to read through Chapter 3, but first it has two appendices so I will do those first.

Appendix E 3.1: Surface Charge

I have done the usual cosmetic edits then read this appendix. One item not really addressed is why the electron density does not go out into the vacuum between the plates (work potential?). I show possible charge distributions only into the metal conductors of this capacitor. Why did I do that? Should I show potential expo distributions on both sides of each surface. There is a huge difference in σ in the two media. I guess in between the plates if we have $\sigma = 0$ then $\lambda_D = \infty$ and then $\rho(x) = \rho(0)\, e^0$ and we don't get a drop off, so THAT is not the answer. Maybe there are no carriers in the gap. I really do need to address these questions, but will put that off onto my task stack because right now I am just doing a read through. I wonder if anything I saw in this appendix is correct? Where did I get it from? No references.

Appendix F 3.2: Waveguides

Part 1: OK, but equation 8 is missing. A little waveguide on xmsn line idea.

Part 2: the angle θ interpretation. I think this section is OK. I don't know what TEM is here.

Now I am ready for a first reading of Chapter 3. Did the cosmetic fixes of equation alignment. This is a very long chapter! Maybe 19 pages, that is going to take some time.

Chapter 3: Preliminaries

Section 3.1: No charge inside a conductor. Seems OK. It is the same calculation done in Appendix B but without ε present. Why am I doing the same thing twice? That appendix section seemed out of place anyway, so maybe I will delete it ******.

Section 3.2. Surface charge layer thickness. I don't understand my word "screened". This whole section is again a repeat of stuff said in Appendix E, and there is the same lack of clarity as to which side of the surface! Need to remove the repetition and clarify the side issue *******

Section 3.3 Loss Tangent. In (3.3.2) I am defining $\tan_L$ here *differently* than in Appendix B, not good. I think σ_{eff} is also different. This section needs attention !! ********

Section 3.4 some facts at a conductor/dielectric interface. did not study. The normal E field is must larger on the dielectric side.

Section 3.5 talks about the relative sizes of fields at and near the conductor surface. I guess the surface is where all the action takes place, so I keep talking about the surface. I will have to ponder the very many claims of this section! We do arrive at a TEM mode though.

Section 3.6. now taking about the real world conductors. A new table with superscript references. But in subsection (a), why do I say "in contrast". In the opening paragraph there is just a single conductor. This is a lot of "qualitative" discussion about sizes of things, I bet I once worked pretty hard on this.

Thurs Sept 12, 2013.

Section 3.7.

I need to state clearly what field components are continuous through the boundary of a conductor, I don't see this except for H_φ.

Section 3.7. The first long text section is I think OK. Figures are OK.

Low freq limit: OK, but I seem to have right and left wrong in two places. *******

Section 3.8 done! not bad.

So what exactly has happened in this Chapter 3? Most of it studies the fields and currents near the surfaces of the conductors of a transmission line. Which fields are big, which are small? Focus is on the TEM mode of propagation, ideal and non-ideal. Lots of facts like transverse fields pattern is a constant apart from overall amplitude. The longitudinal picture is also studied. I am of course confused by the displacement current, have to review that concept ******. And still not happy with my "applied current" concept which is basic to everything. But for now we plod onward!

Chapter 4 This is going to be another LONG chapter.

Section 4.1. OK through 4.1.3 where no approximations yet made other than transverse separation of variables. // Then OK through the end. First mention of large λ limit.

Section 4.2. I obtain an expression for C and G of a transmission line in the long λ limit. Appendix 4.1 is referenced (which I have not yet read through).

Section 4.3. Very brief, we are duping previous φ section here for A_z.

Section 4.4 Now we have an expression for L_e defined by $\Delta A_z = L_e\, i(z)$.

Section 4.5 OK, I have now derived the transmission line equations in box (4.5.21).

The next two sections will be standard examples.

Section 4.6 far spaced twin-lead

Section 4.7 coaxial cable.

So I now have to wonder: what else is there to do? I have obtained the official transmission line equations and have done two examples. I have not dealt with arbitrary cross sections however.

Let's just move on to Chapter 5 to get to the endgame.

Chapter 5

Section 5.1 Philosophy. Comments here on J_a as "applied", take note. Looking at 4.3.1 for example, although I did not label the current with an a, J_{z1} is an example of an applied current and it is the current in the conductor. And in 4.1.1 I have an applied charge density which really is on the surface only. If I didn't apply something, the conductors would just sit there in neutral. // OK, this is much better than I at first thought. I really do address that fact that in reality $\mathbf{J_a} = 0$ and $\rho_a = 0$.

Section 5.2 Helmholtz equation. Good through 5.2.22 and continuing on. OK, I made it through!

Section 5.3.

The eigenvalue problem. Lots of words, no examples, see Matick for examples.

Line parameters. k^2 gives zy, form for potentials, then value of K.

Equality of...: OK

Comparison: OK

Rubber sheeting: OK

Nature of : OK

Self Consistent Currents: OK

Caveat on Accuracy

Section 5.4. Approximate Transverse Solution. Set up as a 2D Laplace problem assuming $Z_i = 0$.

Something is wrong around (5.4.12). Seems to me that oscillatory in transverse dimensions would be a high frequency thing, not a low frequency thing. $\beta^2 = \omega^2 \mu\mu_0\xi$ so large β does with large ω. Sot he ending of Chapter 5 sort of collapsed for me. But I forge on ahead into the very last chapter.

Chapter 6. An Example.

6.1. I show why the fundy solution in 2D is ln(r) and not 1/r, just a brute force thing.

6.2 The Circles stuff. I leaned a lot about this since 1991, may add something.

6.3 Aligning the circles.

6.4 Reduction to special cases

Tues Sept 17, 2013. Resuming after a **5 day Kent visit,** we did the side deck repair.

Second Editing Pass: the J_a problem is noted Sept 17, 2013

Chapter 1 and Appendix A: Jacksonization and SI units.

OK, where should I start now that I have made a first reading pass? My biggest concern is the J_a and ρ_a business. [the applied sources issue]nother weak link is the displacement current concept. This latter idea

is explained in 2.1.3 where it is just the second RHS term of the Maxwell curl B equation. There is also the matter of units to deal with! Maybe that is the easiest item to get cleaned up.

Units. the Jackson books are green (1962), red (1975) and blue (1998) and I have all three in some form. In the blue book the first 10 chapters are in SI units. He uses -SI and -G as a units reminder. He says this is in the "running head" of each left hand page. the right pages have odd page numbers in the actual book, and the even page numbers are left hand pages with the little -SI markings. It happens that things come up the other way when I do two-up in djvu. There is no preference for adjusting this which is fine.

So I think this blue Jackson is an excellent reference for units. Now I need to find a precise page number for each equation. First, the four Maxwell equations.

About μ and ε. I now see why Jackson does not use dimensionless μ and ε as I first did. If you insist on using dimensionless μ and ε, you end up with the ugly $\varepsilon\varepsilon_0$ and $\mu\mu_0$ combinations everywhere! I think it would be best if I did a global repair in this regard and then I am entirely consistent with Jackson units.

Let's try to do a global fix on this in a scratch doc and see what happens. Open field codes. It is going to work just fine I think. So let's now make this global change for real throughout! This means my new doc will differ from the original in this regard everywhere.

There were 78 replacements of $\varepsilon\varepsilon_0$ by ε.

There were 105 replacements of $\mu\mu_0$ by μ.

I am confused now by $\mathbf{J} = \sigma\mathbf{E}$. How does this relate to J_a?

OK: I have now done a complete rewrite of the small opening **section 1.1.** The units are now solidly linked to blue Jackson and I use the same ε and μ as Jackson, and I have already adjusted globally for this last fact. Earlier things were wobbly, I wasn't sure I was using SI units, the ε_0 and μ_0 factors were messy.

Appendix A. Let's just verify things from a units aspect. But potentials have not yet been mentioned, so can't do it yet.

11AM. I have now done a serious rewrite of **section 1.2**, getting units right. I did the derivation work in a separate doc to have a tracing path. Still not clear about $\mathbf{J_a}$ and ρ_a but am at least closer.

Started into the little special relativity note, but I really have to go back to Appendix A first I think. I have to get this thing fully cleaned up in terms of units and then I can ponder the four vector A^μ.

I have now made another pass through all of Appendix A and it is now good on SI units.

Weds Sept 18, 2013

Back to relativistic note above (1.3.7). Something is wrong with μ and ε in the two equations! Let's try a quick dimensions check:

$$(\nabla^2 - \mu\varepsilon\ \partial_t^2)\ \mathbf{A} = -\mu\mathbf{J_T} \qquad (1.3.7)$$

$$(\ L^{-2} - T^2L^{-2}\ T^{-2})\ \text{amp-henry/m} = 4\pi \times 10^{-7}\ \text{henry/m} * \text{amp/m}^2$$

LHS = amp -henry/m^3 RHS = amp-henry/m^3 check

$$(\nabla^2 - \mu\varepsilon\ \partial_t^2)\ \varphi = -(1/\varepsilon)\rho_T \qquad (1.3.8)$$

LHS = volts/m^2 RHS = $(8.8541877 \times 10^{-12})^{-1}$ m/farad * coulomb/m^3

This last says volt = coulomb/farad which agrees with Q = CV that coulomb = farad-volt. So both equations are OK on units.

How then do I make the 4-vectors? I think elements of a 4-vector should have the same units, so that is a problem with my (t,x,y,z) discussion. Should be something like (ct,x,y,z) where v is some velocity. Let's try an Appendix A rewrite with that in mind using separate scratch doc.

Let's now check units on the gauge transformation: (which I just modified second line)

$$A'^i = A^i + \partial_i\Lambda = A^i - \partial^i\Lambda \qquad i = 1,2,3$$
$$\varphi' = \varphi - \partial_t\Lambda \qquad (A.7.1)$$

First line: here we need dim(Λ)/L = dim(A) so dim(Λ) = L dim(A) = m amp-henry/m = amp-henry

Second line: sec^{-1} dim(Λ) = dim(φ) = volts so dim(Λ) = volt-sec

So is it true that

amp-henry = volt-sec ?

I can use henry = ohm-sec so state this question as

amp-ohm-sec = volt-sec

Well, amp-ohm = volt, so OK. I have now corrected A.7.3 to read

$$\text{div } \mathbf{A}' = -\frac{1}{c^2}\ \partial_t\varphi'. \qquad (A.7.3)$$

I have added units for A, φ and Λ into the doc and Jackson references. Appendix A (7) is now fully updated.

NOW let's go back and look at that Chapter 1 "note" on relativity. It looks good and I end up with

$$\Box A^\mu = \mu_0 J^\mu \qquad \text{where} \qquad \Box \equiv \partial_\mu\partial^\mu = \frac{1}{c^2}\partial_t^2 - \nabla^2$$

Let's check units on this in the spatial components

$1/m^2$ * amp-henry/m = henry/m * coul/(m^2sec)

or

amp = coul/(sec)

Appendix A and Chapter 1 continues

OK, things are going well, but I still have a **fuzzy** item regarding that function f(x) of Appendix A and whether or not there is a prime on φ' .

I have now combined Appendix A items 4 and 5 into a single new item 4 and I have maintained my convention on the primes. Now let's go after the fuzzy thing. In the Lorentz section now 6, I show that the Lorentz gauge $\partial_\mu A'^\mu = 0$ result in

$$\text{div } \mathbf{A}' = -\frac{1}{c^2}\,\partial_t \varphi'. \qquad \text{(A.7.3)}$$

This seems to say that we have

$$f = -\frac{1}{c^2}\,\partial_t \varphi'$$

But if I only have **A** and φ, how do I come up with the right φ' to put in here? Well, $\varphi' = \varphi - \partial_t \Lambda$ and

$$\Lambda(\mathbf{x}) = -\frac{1}{4\pi}\int d^3\mathbf{x}' \frac{f(\mathbf{x}')}{|\mathbf{x} - \mathbf{x}'|}$$

(A.2.3)

but then I have an infinite loop. I don't know f, so cannot compute Λ, so cannot determine φ'. *This* is the thing that is **fuzzy** and is blocking my progress. Maybe I can use Maxell's equations somehow. We do have all these facts:

$\mathbf{B} = \text{curl } \mathbf{A}' = \text{curl } \mathbf{A}$
$\mathbf{E} = -\text{grad } \varphi' - \partial\mathbf{A}'/\partial t = -\text{grad } \varphi - \partial\mathbf{A}/\partial t$
$\nabla^2 \Lambda = f$
$\mathbf{A}' = \mathbf{A} + \text{grad } \Lambda$
$\varphi' = \varphi - \partial_t \Lambda$ (A.4.1)
$\text{curl } \mathbf{E} = -\partial\mathbf{B}/\partial t$ Maxwell curl E equation (1.1.2)

Just play around a bit and try to find a way to determine f.

$$\nabla^2 \Lambda = -\frac{1}{c^2}\,\partial_t \varphi' = -\frac{1}{c^2}\,\partial_t[\varphi - \partial_t \Lambda]$$

$$(\nabla^2 - \frac{1}{c^2}\partial_t^2)\Lambda = -\frac{1}{c^2}\partial_t\varphi$$

$$-\Box\,\Lambda = -\frac{1}{c^2}\partial_t\varphi$$

Now Stak considers just this equation on page 61 Vol II where he writes

$$(\partial_t^2 - c^2\nabla^2)\,u = q \qquad (5.141)$$

He then defines a Green's equation for this (Green's is C for Causal)

$$(\partial_t^2 - c^2\nabla^2)\,C = \delta(\mathbf{x})\delta(t) \qquad C \equiv 0 \text{ for } t < 0 \qquad (5.142)$$

and the solution is this

$$C(\mathbf{x},t;\,\mathbf{x}',t') = 1/(4\pi r)\,\delta(t-t'-r) \qquad (5.152)$$

So it seems to me that you could write your solution as

$$u(\mathbf{x},t) = \int d^3x' \int dt'\;\; C(\mathbf{x},t;\,\mathbf{x}',t') \;\; = \;\; \int d^3x' \int dt'\;\; 1/(4\pi r)\,\delta(t-t'-r) \;\; = \;\; \int d^3x'\;\; 1/(4\pi r) \qquad t = t'-r$$

Maybe this is the retarded potential thing?

OK again. I have added a <u>new final section to Appendix A on the fuzzy problem</u> I have been having with the Lorentz gauge. Time to move on! I hope I am finally done with all this add-on relativity stuff.

Thurs Sept 19, 2013

Well, new problem. I have the <u>retarded potential stuff</u> in there twice, Ch 1 and App A. Will clean up.

$$\Lambda(\mathbf{x},t) \;=\; \int d^3x' \int dt'\; g(\mathbf{x},t;\,\mathbf{x}',t')\;\partial_{t'}\varphi(\mathbf{x}',t')$$

If we apply c^2 box to both sides we get

$$c^2\,\Box\,\Lambda(x,t) = \int d^3x' \int dt'\; c^2\,\Box g(\mathbf{x},t;\,\mathbf{x}',t')\;\partial_{t'}\varphi(\mathbf{x}',t')$$

$$= \int d^3x' \int dt'\; \delta(\mathbf{x}-\mathbf{x}')\delta(t-t')\;\partial_{t'}\varphi(\mathbf{x}',t')$$

$$= \partial_t\varphi(\mathbf{x},t) \qquad \text{which is A.7.2}$$

So now insert the propagator

$$c^2\,\Lambda(\mathbf{x},t) = \int d^3x' \int dt'\, c^2\, g(\mathbf{x},t;\,\mathbf{x}',t')\,\partial_{t'}\varphi(\mathbf{x}',t')$$

$$= \int d^3x' \int dt'\ (1/4\pi R)\delta(t-t'-R/c)\,\partial_{t'}\varphi(\mathbf{x}',t')$$

$$= \int d^3x'\,(1/4\pi R)\,\partial_{t'}\varphi(\mathbf{x}',t-R/c)$$

so that

$$\Lambda(\mathbf{x},t) = \frac{1}{4\pi c^2} \int d^3x' \frac{\partial_t\varphi(\mathbf{x}',t-R/c)}{|\mathbf{x}-\mathbf{x}'|}$$

Let's do a units check on this thing. We had in (1.3.1)

φ = scalar potential (volts)

And from (A.4.1) we have Λ = volt-sec (I will write that in)

Thus, our Λ solution looks like this

volt-sec = $m^{-2}s^2\ m^3\ s^{-1}m^{-1}$ volts = volt-sec // checks

Next I need to repair Chapter 1.4 on retarded potentials. DONE.

Thurs Sept 20, 2013

I am now going to reread Appendix A and Chapter 1 through 1.4 one more time. This is where my heavy duty theory is being used, and I want to make sure it is done right.

Question: should I use $\delta(\mathbf{x}-\mathbf{x}')$ or $\delta^{(3)}(\mathbf{x}-\mathbf{x}')$? I like the former I think. **** [I went with the former] .

Starting a reread of App A and then Ch 1 thru 1.4:

Fact 0. I think this section is quite good, packing in lots of useful info to a newbie reader.
Fact 1. Also good, makes use of Fact 0, building a tower here.
Fact 2: I like it.
Fact 3: I like it too, it really is similar to Fact 1 as I state.
Fact 4: Short and is the top of the little logic pyramid I constructed from earlier facts. Gauges.
5. Gauge Invariance. fleshed this tiny section out with a comment on Weyl and word gauge.
6. Lorentz gauge and QED, just fine.
7. Detail on how to find Λ for Lorentz Gauge.

Comment: Apart from a spelling check, this is the last time I will proof Appendix A [ha!]. It is good, all the equation numbers are correct, alignment is correct.

I just added subsection headings to Appendix A and gave equation numbers to the four Facts.

Now on to a reading of Chapter 1 through 1.4.

1.1 OK
1.2 OK
1.3 OK finally.
1.4 OK

Now ready to break new ground in my Chapter 1 review. // Tennis and back //

1.5 Ouch! I need to FT from t to ω and I never even mention it! Also, I need to make my connection to King, I give no ref! Work to do here!

Sat Sept 21, 2013

Taking a first look at King. He does use β instead of k for the Helmholtz parameter on page 9. King also uses **i** in place of **J** and King uses n for surface charge density. King tries to use bold font for complex versions of μ and ν ≡ 1/μ, it is rather confusing. It is possible for μ to be complex. Page 11 (23) and (24) are King's versions of my (1.5.7) and (1.5.8).

I am still very unhappy about my J_a and J_T type subscripts. This needs to be make sharp and clean, but I guess I will continue on for a while longer to see how things are used.

Meanwhile, I spend all day and finally decided to write Appendix H on the δ(**r**) details, since I refer to this at least twice in the document. It is suddenly 4 PM, and I have only moved a baby step forward. I think section 1.5 is better now, but the fuzzy $\mathbf{J}_a$ and ρ_a plague continues. [ongoing] I will continue to ignore it and try to move forward.

Chapter 2: Starting now a reading of **Chapter 2**
opening: OK
2.1 STOP

I claim that ε= 1 in a metal like copper, where is that from? I get results like this

- plasma frequency ω_p

$$\epsilon(\omega) = 1 - \frac{\omega_p^2}{\omega^2 + i\omega\Gamma} \qquad \omega_p^2 = \frac{Nq^2}{\epsilon_0 m}$$

for a metal treated as a free electron gas. I think ω_p is optical, so ε(ω) is some large negative number at RF frequencies. Kittel talks about this on page 270. Can I just avoid talking about ε in a metal?

On page 118 Matick claims $\varepsilon = \varepsilon_0$ for metal and in fact he has the example I used below (2.1.4), but Matick does not provide any support for $\varepsilon = \varepsilon_0$. I will just fudge this as Matick did.

Sun Sept 22, 2013

Continuing in Chap 2.

2.1 finally finished this, all equations being tracked in the equations verification doc. I decided to replace β by k since this seems more standard to me for a Helmholtz thing. But will this cause trouble later on? Let's take a peek ahead now. I use a k in 4.6.10 . **OUCH**! It will cause trouble later, so lets get all my new k's back to β's as in King. But single word k does not pick up my k^2 so go do those by hand right now. // I think I restored them all. Added King comment on why I use β.

At this point I have the E and B field in the round wire with our solution set. I guess I could have just made the assumption that E and B are not functions of z just like that. *******

I still have no plots of J(r). // OK, I have worked down now through equation (2.2.7), added good Maple plots of field drop-off due to skin effect. Next comes the little table which I may do as a plot.

Made it through section 2.1 *and* 2.2 finally, more graphs, all equations checked. It took me this entire day to firm up these two sections with full derivation tracking in a separate doc. I did find some errors. Tomorrow we dive into 2.3 I guess. Maybe some appendices instead.

Mon Sept 23, 2013

Let's move ahead in Chap 2 and ignore appendices for now.

Section 2.3. My first inclination is to just yank out the following section (blue) including my attempt to repair it

---

More generally, as for example a complicated wave traveling down a wire of a transmission line, one might in general have a current density $J_z = J(r,\theta,z)$ and then a total current $I = I(z)$. In this case

$$Z_s(\theta,z) = -(dV/dz)(\theta,z)/I(z)$$

$$V(\theta) = -\int_0^L dV = -\int_0^L (dV/dz)(\theta,z)\,dz = \int_0^L I(z)\ Z_s(\theta,z)\,dz$$

In a more complex situation, where $J = J(r,\theta,z)$ and then $I = I(z)$, the impedance measured by the two probes spaced a small distance dz apart would be a function of φ and z, giving $Z_s(\theta,z)$ and then

$$V(\theta) = \int_0^L I(z)\ Z_s(\theta,z)dz$$

$$Z = V/I = \int_0^L Z_s(z,\varphi)\, dz$$

The total wire impedance Z is still V/I and is a constant and cannot depend on φ and z. The surface impedance is a more local concept, and one that plays a role in transmission line attenuation. The general relation between Z and Z_s follows from (2.3.1) which says that $dV(z) = - Z_s(\varphi,z)I(z)\, dz$. Integration gives,

$$Z = V/I = (1/I) \int_0^L dz\, [- Z_s(z,\varphi)/ I(z)] \qquad (2.3.3)$$

If the two endplates are perfect conductors, then they are equipotential surfaces, so then V cannot be a function of φ. One can select an arbitrary φ to make the above computation. I(z) is the total current in the wire at position z which in general can be non-constant.

I found the original 1892 Kelvin address where he introduces the Kelvin functions this way in his Appendix. (from Google books

„ ber and bei denote two functions defined as follows:—

$$\text{ber}\, q = 1 - \frac{q^4}{2^2 4^2} + \frac{q^8}{2^2 4^2 6^2 8^2} - \&c.;$$

$$\text{bei}\, q = \frac{q^2}{2^2} - \frac{q^6}{2^2 4^2 6^2} + \&c.$$

The Proceedings of the Institution of Electrical Engineers, Volume 18

Lord Kelvin (William Thomson) introduced the ber and bei notation for these functions while considering the same problem we are dealing with here. The functions appear in the Appendix of his very lengthy 1889 inaugural address when he become president of the Institute of Electrical Engineers (see Refs)

„ ber and bei denote two functions defined as follows:—

$$\text{ber}\, q = 1 - \frac{q^4}{2^2 4^2} + \frac{q^8}{2^2 4^2 6^2 8^2} - \&c.;$$

$$\text{bei}\, q = \frac{q^2}{2^2} - \frac{q^6}{2^2 4^2 6^2} + \&c.$$

Thomson, W.T. (Lord Kelvin), *"Ether, Electricity and Ponderable Matter"*, The Proceedings of the Institution of Electrical Engineers (founded 1871), Volume 18 (1889), No 77, pp 4-37. The Appendix begins on page 35. Google Books has an unrestricted scan of a Harvard library copy of Vol. 18 which can be downloaded in PDF format: http://books.google.com/books?id=Wy89AAAAYAAJ

That address is entitled "Ether, Electricity and Ponderable Matter" and appears here. DONE

I am now going to get rid of $\sqrt{-j}$ everywhere since I know it is ambiguous.

OK, 2:15 PM I have battled my way through section 2.3 completely. It was interesting. I still want to make some plots perhaps. Maybe plot Re and Im parts of (2.3.8). Do for various δ values as before, I think this will improve this section a lot. I tied down the (1+j) formula with Matick

Plotting: I want to plot this:

$$Z_s(\omega) = (-j\omega\mu/2\pi a\beta)\,[\,J_0(\beta a) / J_1(\beta a)\,] \qquad (2.3.7)$$

but I don't want ω sitting in there. So use these facts:

$$\beta \equiv e^{j3\pi/4}\sqrt{\omega\mu\sigma}$$

$$\delta = \sqrt{2/\omega\mu\sigma} \qquad \delta^2 = 2/\omega\mu\sigma \qquad \omega\mu\sigma = 2/\delta^2$$

Then I have

$$\beta = e^{j3\pi/4}\,(\sqrt{2}\,/\delta)$$

$$\omega\mu = 2/(\sigma\delta^2)$$

Then our factor becomes

$$(-j\omega\mu/2\pi a\beta) = \frac{-j\omega\mu}{2\pi a\beta} = \frac{-j2/(\sigma\delta^2)}{2\pi a\, e^{j3\pi/4}\,(\sqrt{2}\,/\delta)} = \frac{-j2}{2\pi a\sigma\delta^2\, e^{j3\pi/4}\,(\sqrt{2}\,/\delta)} = \frac{-j2}{2\pi a\sigma\delta\, e^{j3\pi/4}\,(\sqrt{2}\,)}$$

$$= \frac{-j}{e^{j3\pi/4}\sqrt{2}\;\pi a\sigma\delta} = e^{j\pi 3/4} / (\sqrt{2}\,\pi a\sigma\delta)$$

The phasor simplifies like so

$$e^{-j\pi/2}\, e^{-j3\pi/4} = e^{-j5\pi/4} = e^{-j\pi[2-3/4]} = e^{j\pi 3/4}$$

But I knew that $e^{j\pi 3/4}$ is a square root of -j, so result is obvious.

OK OK. I have made various changes and the plot is done in lines2.mws. Broke out three subsections. This really is a detailed study of the round wire, I must say. Matick Chapter 4 is all about surface impedance in various situations, including a round wire. Added note to that effect.

I read through qualitative Section 2.4 and it is OK, so once again, I am done with Chapter 2, a long haul. I need to so something with the Figure numbers in this entire paper!

Note: I am fuzzy about why in the round wire I did not allow things to vary in z. Also, the usual J_a fuzziness still survives. We are still at a modest (for me) 134 page doc length.

Tues Sept 24, 2013

Started reading yesterday's sections and got confused about my little loop drawings and vectors which have complex components so can't really "point" somewhere as I keep saying. I finally clarified this I think completely with a simple comment which is not in the doc, but it took me a long time to find the right comment to make. Even did a separate doc for a while. Today was also a deck painting day and a PT day progress was minimal. Will try tomorrow for more traction.

Weds Sept 25, 2013.

I rethought the real and complex fields stuff and convinced myself that E and B should always have a constant relative phase of $\pi/2$ at any point in space for a monochrome solution at ω. But when I look at my round wire solution, I find that the phase is constant for large ω, but not for low ω. So I guess I will spend today stuck on resolving this contradiction.

Cherie visit and Jim Memorial Thurs-Sat

Sun Sept 29, 2013

Today I edited the new Section 1.7 several times and then installed it. I still have not finished reviewing my confused doc notes on complex E and B but hope that will now be easy to do.

Mon Sept 30, 2013

Going through my complex E and B doc, and making more changes and additions to Section 1.7, good to do this!

****** Add comments in the round wire section to show that all Maxwell are satisfied.

****** Add comment saying why Bessel I and K functions are different from ber and bei.

Went through contradiction bug doc and round wire ponderings doc. Everything is resolved, so I can finally get back to Section 2 on the round wire!

But I am so stale now I guess I have to reread Section 1 yet again to get the wheel turning again.

1.1 OK.

1.2 OK and short
1.3 OK including relativity piece.
1.4 OK
1.5 OK, using k^2 as H parameter here.
1.6 OK
1.7 OK

So that review did not take very long. I notice k^2 used, may conflict later with β^2.

Intro section: OK
2.1. OK, took a while, I think it is all clear now.
2.2 I added much more to this section today, including the exact solutions and plots of same.

Tomorrow I will resume with Section 2.3. I think I am finally on the move again.

Tues Oct 1, 2013

2.3 opening text OK
(a) formula OK
(b) low ω limit OK
(c) high ω limit OK
(d) make code look nicer please. Done OK
2.4 Qualitative not bad OK

So once again I have finished Chapter 2 (ignoring all appendices so far).

Appendix B. [this later went away, replaced by magnetization appendix B]
section 1: made lots of edits to make things more clear
section 2: rewrote this a bit, it is now more convincing that $\rho = 0$ inside any medium.
section 3: fixed it up as well
I then shuffled the ordering of the sections and text blocks, I think it is better now. Added references.

I think I next have to battle Appendix C, and I know it is going to take a while.

1. DC R of a wire. Fine.
2. DC Z_s of a wire
3. DC inductance of a round wire
3.1 OK, lots of edits and improvement.
3.2 continue here Weds.

Weds Oct 2, 2013

Appendix C and D

Working on Section 3.2 of Appendix C. I found this result.

http://www.technick.net/public/code/cp_dpage.php?aiocp_dp=util_inductance_circle

$$L_{circle} \approx N^2 R \mu_0 \mu_r \left[\ln\left(\frac{8R}{a}\right) - 2 \right]$$

Luckily this calculation is in blue Jackson and the answer is

$L = N^2 \mu_0 R [\ln(8R/a) - 7/4]$

which includes the internal inductance. If we subject out the internal inductance, we get the result quoted above from the website.

I have greatly improved Section 3.2, and am ready to move on.

4 opening text OK
- 4.1 overview of "the plan", seems pretty clear.
- 4.2 the divergence problem. I added a Reader Exercise here with solutions in verification doe. I am quite happy now with this section, took most of the day.
- 4.3 expressible

Example: done!

I have vastly improved this Appendix C and it is done! I will proof it tomorrow, now 9 PM.

Thurs Oct 3, 2013

I just reread App C, made some small edits, trying to reduce "we" slightly but not entirely.

Appendix D: Opening comments OK. This is an ambitious appendix it says.

1. General Method. A long painful section, but now everything is derived in line.

At this point I have solved for E_z inside the round wire in a general situation, not symmetrical, by using my little partial wave expansion. My result is compatible with the round wire symmetric E_z solution. It now remains to find the other two field components. This will no doubt be similarly painful.

2. Opening text : now OK
   - The E_r solution: now OK
   - The E_φ solution: now OK
   - Application of boundary conditions.

I have battled my way through this long section, with Maple help and added text. I did not find any major errors. I am wondering where I got all this fancy stuff from !!??? Time for a break.

OK, back and I have derived the constants in the boundary condition section, but now Red Rock time. // Red Rock cancelled due to no parking.

Fri Oct 4, 2013

Look at the second BC that $E_\varphi(r=a,m) = 0$. This is a tangential field, not allowed to exist in a static situation, but perhaps in a dynamic one as being treated here. It would cause J_φ. I think I have already assumed that we have equipotentials on cross sections, maybe I should stress that more. We are looking for solutions in which this is true. // Added this to the list of assumptions at the start.

Project: Need to renumber subsections in Appendix A, repair all equations numbers in that Appendix, and then repair all references to that Appendix. Just a busy work task ********* [I left it with Section A.0]

I just repaired labeling in appendix sections to make everything consistent.

Task right now: reread App D down through those constants a_m and K_m and add new equation numbers and fix all references. It is a mess right now.

Massive renumbering of equations in Appendix D

D.1 opening done
- (a) done, thru D.1.7
- (b) done, thru D.1.11
- (c) done, thru D.1.19

D.2 opening done, thru D.2.4
- (a) done, thru D.2.16

Sat Oct 5, 2013

Continuing on Appendix D in a separate working file. Doing a few checks in the verifications file. I cleaned up the equations summary. I added a section on fields outside the wires, since that seemed an obvious thing to do. App D is still in a separate document and it is getting longer daily.

Appendix D: 2.2

D.2 continued
- (b) done
- (c) done. BC's

D.3 new section added on the E_φ Helm and how it all luckily works!

D.4 this was most of today's work getting things all cleaned up.

D.5 more work still to verify these low ω limits, see verif doc for both this and D.4

D.6 a reader exercise which I have begin, brings in the Euler equation

D.7 holding off on this since it refers to Chap 3 and beyond.

Appendix E and F

I will now give a shot on **Appendix E** on surface charge.

Why do I show no charge in the dielectric? I need to say something about this. Work function? If we consider div **J** = $-\partial_t\rho$ and if J = 0, then ρ cannot change. But I argued earlier that ρ = 0 inside the

conductor as well. Well, I will just read on. Where did I get this from??? I am running aground here right off the bat. OK, handle id Fick's Law for diffusion.

I am removing this equation because I cannot support it

$D = (kT\tau/m)$ = diffusion coefficient (k = Boltzmann constant)

But I now see that this is what you get if you equate my two versions of Debye length. So put it back.

OK, I am now happy with Appendix E. It has a very limited purpose which I think I fulfill OK. I added comments on the dielectric side of the boundary. I checked all the math, added support for that. Will draw a new picture tomorrow.

I like Appendix E, it is good to have it there.

Sun Oct 6, 2013

I thought I had some gas kinetic notes, but could not find any. Also, could not find APL radio photo.

Updated the App E figure.

Appendix F which is App 3.2
opening: OK
F.1 Why do normal B fields vanish at metal surface?

Imagine x,y,z system centered at a point on a surface where z is the normal. We have

curl $\mathbf{E} = -\partial\mathbf{B}/\partial t$

$\partial_x E_y - \partial_y E_x = -\partial_t B_z$

But if $E_y = E_x \equiv 0$, then we get $-\partial_t B_z = 0$ which implies in time B_z= constant.

OK F.1 is OK and I think pretty good, a whole theory of waveguides in 1 minute.

Appendix F which is App 3.2
opening: OK
F.1 good, OK
F.2

STOP. I have the wrong sign in my assumed wave motion form, I want to use $e^{j(kx-\omega t)}$ since this is in my waves book and in Jackson. But EE people like the other sign so $e^{i\omega t}$. I have to choose. DONE and I added a convention comment somewhere.

I have now finished appendix F. The last few paragraphs are a mystery since they refer to Ch 3 which I have not yet reviewed. Since E and F are the only Ch 3 appendices (formerly 3.1 and 3.1), I think I am now ready to dive into Chapter 3.

Chapter 3

Chapter 3 no opening text
3.1 Why no ρ inside a conductor. OK, I think this is the first time I have made this argument.

I don't understand the word "screened". I know that inner electrons screen a nuclear charge, that usage makes sense.

Chapter 3 no opening text
3.1 Why no ρ inside a conductor. OK, I think this is the first time I have made this argument.
3.2 Why thin surface charge, just quotes from Appendix E which is fine.
3.3

Loss tangent is appearing again. Is this redundant? $\tan_L$ is the same as in Appendix B.
OK, done now with 3.3, added data reference and did Maple table to replace manual one.

shows $H_{||}$ = continuous through surface

Battled my way now through Section 3.4 as well, so here we are

Chapter 3 no opening text
3.1 Why no ρ inside a conductor. OK, I think this is the first time I have made this argument.
3.2 Why thin surface charge, just quotes from Appendix E which is fine. OK
3.3 Added Maple table, other changes, OK
3.4 Added picture, checked all the claims, and there are several, OK.

We are now coming to what I know is a high pain section, so break time first. // OK we are back. Yes, this qualitative section is brutal and there is lots of arm-waving.

OK, I battled through Section 3.5 and changed the region order to match the order of the comments on each region, duh.

Chapter 3 no opening text
3.1 Why no ρ inside a conductor. OK, I think this is the first time I have made this argument.
3.2 Why thin surface charge, just quotes from Appendix E which is fine. OK
3.3 Added Maple table, other changes, OK
3.4 Added picture, checked all the claims, and there are several, OK.
3.5 more brutal stuff, IDEAL xmission line characteristics in a Table. Painful.
3.6 table has superscripts each needing a section
(a) OK
(b) stopped cold by notion of 100 mA current between conductors!

If I = 100 mA peak going down the transmission line in the z direction, why is the displacement current across the line also 100 mA? I know the displacement current is roughly $\omega\varepsilon_d E_{Nd}$ from (3.4.2), and this is just outside the conductor surface. I know that E_{Nd} there comes from the surface charge n. I am very confused by this right now. I can skip this question and move on, but I am tired and it is 9 PM with dentist on tap manana. Quitting time has arrived.

Mon Oct 7, 2013

I did another pass through the "ideal" section 3.5 to make the 27 table entries more convincing.

I am not happy about not knowing the general magnitude of the displacement current between the conductors, whereas I is the total current going "down" one of the conductors, so I will hold on my review and "read ahead" into section 3.7 where supposedly this question is answered.

Tues Oct 8, 2013

The more I read in Section 3 around Fig 2, the less I like it! In particular, I am unclear about the magnitudes of things, such as surface charge accumulation and such as transverse current which would be the displacement current through the dielectric. This whole section seems amateurish compared to earlier stuff. I think I will start up a separate doc on this to see what I can nail down.

Weds Oct 9, 2013

I wrote "confusions in Chap 3" and found that some of my statements are just plain wrong, and that there is no really obvious way to show that $E_r << E_z$ inside a transmission line conductor as I have been claiming. However, the Appendix D round wire "solution" does have this feature, so I appeal to this round wire case now as my IDEAL section 3.5 discussion. At least this lets me continue my review without allowing wrong statements to exist in the reviewed text! So I will try to avoid further sidetracking on this issue and try to plough ahead again tomorrow, is now 8 PM.

Thurs Oct 10, 2013

I have backed up a bit and reviewed both section 3.4 and 3.5, and now on to 3.6. Did edits to adjust for new boundary rules added yesterday. Removing this 2nd paragraph since it has no support:

" Note: J_z will be non-uniform if the surface charge is non-uniform [a major issue!] This non-uniformity of J_z is therefore most noticeable in fat, closely spaced conductors, and it causes the surface impedance to vary somewhat with point of contact."

Section 3.6

opening comments OK. Now superscript comments:

(a) I hacked this 3" section into shape, not too bad now, just an example.

(b) pausing here:

The loss tangent is ε"/ε' for a dielectric where -ε" is the imaginary part of ε due to loss mechanisms in the dielectric. Eq (3.3.4) does say $\sigma_{eff} = (\sigma + \omega\varepsilon' \tan_L)$ to account for this effect, and the σ term can be neglected for a dielectric since 10^{-15} for poly.

The displacement current on the other hand is jωε**E** as shown in (2.1.3) and this has nothing to do with loss mechanisms in the dielectric. Since ε" << ε', we can say ε ≈ ε' so displacement is jωε'**E.**

Calculation: $\omega = 2\pi f = 2\pi\ 10^9$ and $\varepsilon \approx \varepsilon' \approx 2.3\ \varepsilon_0$ and $\varepsilon_0 = 8.8541877 \times 10^{-12}$ so we find

$\sigma_{eff} = (\sigma + \omega\varepsilon' \tan_L)$

$= 10^{-15} + 2\pi\ 10^9 * 2.3 * 8.85 \times 10^{-12} * 2 \times 10^{-4}$

$= 10^{-15} + (2\pi * 2.3 * 8.85 * 2 \times 10^{-7}) \approx (2\pi * 2.3 * 8.85 * 2 \times 10^{-7})$

$= 255.78 \times 10^{-7} = 2.5 \times 10^{-5}$

which verifies my quoted result, I added more detail. I am tossing out this strange paragraph:

"Since this current has a resistive phase, we included it in Table 2 for J_r in region 3 [seems illogical] . If the transmission line carries 100 mA of current, then the displacement current flowing across one half wavelength worth of transmission line is 100 mA (why? put this question on hold for a while), and the leakage current is 20 μA over this same distance. This leakage current must be fed by a small radial current J_r within the conductor surface of the same size. "

Ouch! My next fiasco is that my entire B_z leakage argument is wrong. I tried to argue that leakage current across the dielectric causes a B_z small magnetic field. I said to make a loop around a half wave of action in the z direction, with this leakage current passing through the loop. But the contributions of the four sides of this loop all cancel out!

OK I have rescued B_z with a new loop picture, and will now throw out the following junk:

"We can estimate the size of this B field relative to the main B_φ field as follows

loop around one conductor in transverse plane: $p \langle H_\varphi \rangle \sim I$, p = perimeter

loop around one half wave in z direction: $2\ (\lambda/2) \langle H_z \rangle = I_{leak}$

Thus,

$$B_z / B_\varphi \approx H_z / H_\varphi = (\lambda/p)\ (I_{leak}/I) = (\lambda/p) \tan_L \leq 2 \times 10^{-5} \qquad (3.6.3)$$

Here we assume , consistent with the transmission line limit, that $(\lambda/p) \geq 10$. "

Moving onward. I see now in (d) yet another attempt on my part to show $J_r << J_z$ inside the conductor. I must have been concerned about this argument when I wrote this thing circa 1991.

Question: Suppose I is the z directed total current in each conductor. Could the transverse displacement current by larger than I ? Let's talk max values. I think I could make this argument.

Maybe I can rejuvinate my old arguments after all. My first encounter with this subject is with the last paragraph of Section 3.5 which I will reconsider in a moment. Now into Section 3.6 where we

Estimate of J_r under the surface. Each conductor of a transmission line carries some current I.

STOP. It is 4:30 PM and my whole tower of cards has just tumbled down again. I realize I have no idea what "displacement current" is or how it fits in, though I make all kinds of claims about it. My writing is totally out of control and without any real meaning, it is just BS!

I thought it had something to do with a capacitor, as if the electric wire current converted to a displacement current through the cap's dielectric. But show me an equation which says that is so! In a cap, you just build up charge on the two plates and as you do that, the E field gets larger between the plates. Yes, there will at this time be some $\partial_t \mathbf{D}$ between the plates. Yes, this does appear in the Maxwell curl H equation and in $\oint \mathbf{H} \bullet d\mathbf{s} = \int_S [\partial_t \mathbf{D} + \mathbf{J_T}] \bullet d\mathbf{A}$. So yes, this will make a circular H field out there on the edges of the dielectric region, as if it were a piece of wire. yes, in my 3.4.2 you can say the displacement current dominates, and you can say

$$(j\omega\varepsilon_d)E_{Nd} \approx (\sigma_c)E_{Nc}$$

displacement current $\approx$ real current in conductor radial

What does this say in the time domain?

$$\varepsilon_d \partial_t E_{Nd} = \sigma_c E_c$$

The radial conductor current feeds the *rate of change* of the E field in the dielectric.

Ouch! I have not accounted for phase shifts in my time-domain pictures. the E and B fields do not max at the same time. I should have known that. The jω factor always means ∂_t and phase shift 90 degrees, so IO will need to make all new pictures. The original one in the doc is completely wrong!! Enough for today.

Fri Oct 11, 2013

I went to bed with a major paradox wherein I had a violation of div J current conservation. I reviewed this carefully in document "paradoxes applying div J...". Along the way, I did the plane wave solution to Maxwell's equations. This paradox went away when I repaired my picture, putting the J_r and J_z curves into their proper locations in the drawing. This was a great relief. Along the way I also did some "reading ahead" in lines just to see where I am going, and it was quite interesting, and I think it is quite good too.

I then "backed up" yet again and redid section 3.6 for the REAL line. Each time I "red" the individual items in the table. This time I realized a mistake from last time: Yes, displacement current >> leakage across the dielectric, but it is the displacement current that causes B_z not the leakage, so I repaired my little picture. But then this displacement current is present also for the IDEAL line, so I now have to back up more and try to clean up this mess.

I am iterating back and forth between IDEAL and REAL.

Will now do a final read-through of these two sections, redding items as I go.

Section 3.3 on loss tangent: did some edits, it is fine, not really relevant right now.

Section 3.4 on displacement current. it is just fine.

Section 3.5 just fine, the ideal table gets filled in.

Section 3.6. Filled in the real table, only sections a,b,c still exist. **Tomorrow** I will knock out (saving) my big thing on $J_r << J_z$ since it will reappear later in the next section where I will put my fancy picture.

Sat Oct 12, 2013

I have decided to just removed the third numeric table. It is confusing to present, and the numbers are only meaningful for one tiny example, who cares. I will save it in the old Jr argument doc.

In fact the two sections ideal and real don't add much, but I guess they serve as a reader exercise in applying lots of ideas, such as continuity of $E_{||}$ and dielectric current. Added an opening paragraph regarding why these two sections are present (they caused me lots of pain, but ferreted out things I was confused above.). We now move on:

Section 3.7

Removing this paragraph, replaced it with another

Discussion: For sinusoidal excitation, the TEM mode on a transmission line is a wave pattern that moves down the line in z. At any instant in time, as one scans in z one sees the overall amplitude of the structure rise and fall and then invert for another rise and fall over each wavelength λ of transmission line. Since there is some loss in a real transmission line, the scale of the cross sectional shape may gradually reduce as z increases. Apart from the scale factor, the shape of the field structure is a constant in z. Later we will see that this shape can be found by solving a certain 2D Helmholtz equation, and we find that the shape is determined entirely by the boundaries of the conductors.

Similarly, if one sits at a particular value of z and watches the wave go by in time, the scale of the cross sectional field does this same rise, fall, invert, rise and fall over each period T, but the shape itself does not change. As ω is altered, the speed of the rise and fall is altered, but again the shape is constant.

One should not confuse the constancy of the cross sectional field shape with the possible decay of the longitudinal shape of a pulse going down the line in z.

Fact 1: OK

Fact 2: OK

Fact 3: rewrote and now OK
Fact 4: a bit of a battle, but I cleaned it up.
Fig 1 discussion: it is OK, but need to redraw the figure.

Just removed this paragraph:

Understanding the low frequency limit.

Fig 2 provides a way to understand the extreme *low* frequency limit of a transmission line. At very low ω, the length L of the entire transmission line becomes much less than λ. In this case, one can think of the entire transmission line as being say 1 mm long in Fig 2. As the field pattern moves over such a transmission line, the line is so short that everything is a constant at all z on the line.

Instead of thinking of the transmission line as being fixed and the E and B fields moving to the right in Figure 2 at the speed of light, it is perhaps easier to think of the field pattern as fixed, and the little 1 mm long transmission line is moving to the right in Fig 2.

For example, if 7.5 volts DC is applied to a terminated 75 ohm transmission line, 100 mA flows, and it is as if the entire line is located at position z=0 in Figure 2 [needs to be marked more clearly!] . The current is completely longitudinal, and the E and B fields are very large.

If this DC is raised to a very low frequency ω, then one can think of the 1 mm long transmission line moving to the right in Figure 2. When it reaches the point $z = \lambda/4$, the longitudinal current is zero and the fields are also 0. At this point, there is a small transverse current in the transmission line which feeds the very small displacement current in the dielectric.

[I don't like the above discussion one bit!]

OK, by 7:30 PM I have battled my way down to Fact 4 in Section 3.8. This is the last section of Chapter 3. I want to argue that only A_z is significant. I base my argument on a certain equation that involves the "applied current". Later I am going to argue that A is going to be a solution of a homo wave equation where there are no applied currents. My whole argument here seems very wobbly, and it is tied in with the whole "applied current" concept which is itself wobbly and poorly supported in my entire doc.

I could skip this section for now and just assume that A_z is all there is, make it an ansatz and then see what falls out. But maybe I should clean up this applied business, I have to do it at some point. It is probably a Stak boundary condition issue. Maybe I can make that link now that I know all about Stak.

Nevertheless, I have finally gotten the two "tables" of Section 3.5 and 3.6 stabilized with reasonable qualitative arguments, though I had to defer $J_r << J_z$ until my fancy picture was drawn out. I have all the field pictures updated and the new one integrated into the doc, and I have that J_r/J_z ratio argument finally made. I could not make it until I had the current phases drawn correctly!!! I just don't have any other way to do this. I sure hope when I do an actual example that things will pan out compared to the tables. I did a lot today, even though Chapter 3 is still not completed.

So my next task is to figure out this applied currents and charges idea.

Sun Oct 13, 2013

• Went through all Word docs in lines folder and "reviewed" then, put all reviewed docs into a new "reviewed folder". It was just time to clean up a bit before going on with today's new docs.

• Installed Appendix D which I had been delaying for no good reason.

• Made a long term backup of lines after installing App D So if I have a disaster, this backup gets me up to today at 7 AM. // Then after the next • item I replaced this with a 12 noon backup.

• I studied the issue of trying the Smythian Form method for App D, and found that the general vector Helmholtz equation is not even separable, so there are no atomic forms, so you cannot use this method to solve the problem. But you can still expand on $e^{im\varphi}$ even though these are not part of the atomic form. I took a passing look at the vector spherical harmonics and decided they have no bearing on things. This just served to add support to the method of solution which I used.

• I also pondered the round wire issue that for m > 1 all the charge moments η_m are free parameters. I concluded that they get SET when you make that round wire part of a transmission line and you then solve that problem. I should add a comment to this effect somewhere. ******** [it is clearly stated]

So all this stuff has distracted me from my desire to work on the "applied J_a " business which I will now turn to. It is 11:30 AM after an early 6AM start.

The Ja Business, first King Library Trip, Chapter 4 work, Oct 13, 2013

This turned out to be MAJOR MAJOR, see separate doc. I was fooling myself with this strange J_a and ρ_a business, and it has to be completely rooted out! This is going to require a monstrous document-wide editing session that may take several days. But it also makes things MUCH better and I have more Jackson verification points.

Before starting into this, I will do another major backup at 7:30 PM today 10/13/13. DONE.

I will now start into this massive editing task and try to get some done tonight.

Section 1.1: done, many edits to remove T's, it is much better now.

etc.

I got to the start of section 1.5 and have had no problems, I think this is a great improvement. Toward the end of Section 1.5 I have a conflict with King and that has to be resolved before I can continue. He has his complex β in his potential equations, whereas I have the non-complex β. This is a cause for concern. I now see that King uses that other gauge choice! have to deal with all of this.

Mon Oct 14, 2013

The big edit continues, I will add a new section for the King gauge. I am going to edit App A right now since it is so relevant to gauges.

Review of Appendix A.

Poisson section, fine

A.1 OK

A.2 OK

A.3 OK

Pause. If div **A'** = div **A** + g(x), why don't **E** and **B** change? This is non-trivial to show, I don't have a one line proof. But App A.4 gives the proof and I can refer there.

A.4 OK

A.5 OK

A.6 OK, I like this section a lot.

A.7 OK, and I added a rock in pond picture.

This concludes my review of Appendix A with respect to this major edit pass. It is fine as is.

I have now run into problems with the wave equations and the King gauge, I guess it had to happen. I am unable to confirm King's equations, they just seem wrong to me. I plan now to put a hold here, and jump down to Chapter 4 and try to verify its equations. I started a whole new King doc. In my first web search, I could not find anybody else using the King gauge. This gauge leads to wave equations that are non-symmetric in ρ and **J** and I don't like them. I am having trouble finding a book on transmission lines that does the Maxwell theory with the King gauge. I am burned out at 3 PM on this stuff. I know it is the Achilles Heel of my entire lines doc.

Library Trip. I decided to make one of my rare Marriott visits. A card is now $100! I found King's book in the TK section along with a ton of books about power transmission lines, including many versions of the Lineman's Handbook. Sparse offerings. I found a thin book by Vago that had the King gauge stated, but called it the Lorentz gauge.

$$\mathrm{div}\mathbf{A} = \frac{\partial A}{\partial z} = -\mu\sigma\varphi - \mu\varepsilon\frac{\partial \varphi}{\partial t} \qquad (2.89)$$

This book states the homo A wave equation with the complex β, but never seemed to use if for anything. I then moved to the QC section where Jackson lives and perused a lot of books there, The books have a lot to say about waveguides, but not much about transmission lines. The usual RCLG stuff appears many places, but Vago had a little field section. I parked across from Law, and did a fast walk. This trip was a sort of "due diligence", just to make sure there was not some obvious source sitting there.

One Vago idea (I photo'd a few pages) relates to integrating A around a loop and talks about the concept of the A flux through that loop being inductance somehow. The idea is really

$$\text{curl } \mathbf{E} = -\partial_t \mathbf{B} \quad \Leftrightarrow \quad \oint \mathbf{E} \bullet d\mathbf{s} = -\partial_t [\int_S \mathbf{B} \bullet d\mathbf{A}] \qquad (1.1.17)$$

$$\text{curl } \mathbf{A} = \mathbf{B} \qquad \Leftrightarrow \qquad \oint \mathbf{A} \bullet d\mathbf{s} = \int_S \mathbf{B} \bullet d\mathbf{A} \qquad (1.1.17)$$

so yes, it is just magnetic flux which has units amp-henry/m^2 times area and then flux is amp-henry. One of my connections to L is that $V = L\partial_t I$ so volts = L amp/sec and L = volts-sec/amp = ohm-sec = henry of course. What is Vago doing here:

The integral of the vector potential **A** over the loop of width dz shown in *Fig. 2.2* Ψdz is the magnetic flux through the loop:

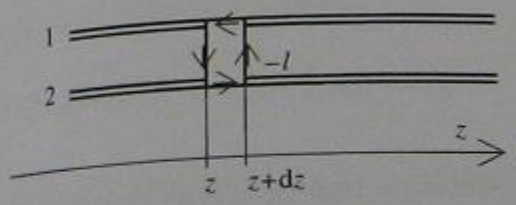


Fig. 2.2

$$\oint_l \mathbf{A} \cdot d\mathbf{l} = (A_1 - A_2)dz = \Psi dz = iL'_e dz. \qquad (2.101)$$

He claims the magnetic flux through the loop is ψdz?

Question: What is the connection between inductance and magnetic flux?

Well, I red blue Jackson on this a bit, there is this notion that L = mag_flux/ I that Jackson claims is a bit problematical. He does a derivation that seems pretty obscure.

Well I just looked at Bleaney and am finally reminded of the most basic definitions

L = flux through loop / I
M_{ij} = flux through loop $_i$ / I_j

and that of course is all Vago is saying I guess this will help me soon.

Tues Oct 15, 2013

I will try to review the development of the TL equations in Chap 4, assuming the real β.

Chapter 4
Opening text OK
4.1 Near 4.1.8 I have to break and go look at Appendix G

At this point I found some math errors which I will have to repair, relating to the overall factors in the series for φ. But for the moment, I will let these errors exist and continue on, since I am trying to resolve the King gauge issue. I may want to replace K with the H Hankel.

I am down to (4.2.5) and things are fine, I suspect my math error does not affect the m = 0 term which is the only term kept in the TL limit. So I continue there.

Repair needed on Appendix B. I added a new equation C' = q_{eff}/V which I can then use in Chap 4.

Status 9 AM: I am happy with Section 4.2 although work is still needed as shown in red. I will continue along here after doing some Janet books. // This consumed the rest of the day.

Weds Oct 16, 2013

Resume in Chap 4.

Section 4.3.

Here I claim exact parallel treatment and quickly get to a result for A_{z1}.

Section 4.4.

Now I think some rewrite is needed after 4.4.3. I need a better approach to inductance. Maybe this is where the little loop comes into play, shown in gray above as 2.101.

OK, I added that Vago picture and have greatly improved the motivation for calling a certain integral L_e. It is entirely real if μ is real. So far so good, but I don't yes see how conductor resistance is going to arrive!

Section 4.5. The classic transmission line equations.

Below (4.5.5) why do I suddenly bring up the subject of surface impedance? I want to know about the line as a whole, not just the surface. But yes, the field is at the surface, and it varies inside the wire, so what are you going to do, average E_z in the wire? OK for now, leave as is.

I have now arrived at (4.5.9) and as expected, I end up with G = 0 for resistive conductance across the dielectric. I now have to see where this got lost. The problem is really in the V side of things, not the W side.

Maybe it has to do with "voltmeter voltage". Here is the sequence of things:

$$\varphi_1(\mathbf{x}) = \frac{1}{4\pi\varepsilon}\int \rho_1(\mathbf{x}')\,\frac{e^{-j\beta R}}{R}\,dx'dy'dz' \qquad R \equiv |\mathbf{x} - \mathbf{x}'| \quad \text{due to } C_1 \tag{4.1.1}$$

$$\varphi_2(\mathbf{x}) = \frac{1}{4\pi\varepsilon}\int \rho_2(\mathbf{x}')\,\frac{e^{-j\beta R}}{R}\,dx'dy'dz' \qquad R \equiv |\mathbf{x} - \mathbf{x}'| \quad \text{due to } C_2 \tag{4.1.1}$$

$$\varphi_{12}(x,y,z) = \varphi_1(\mathbf{x}) + \varphi_2(\mathbf{x})$$

$$V(z) = \varphi_{12}(\mathbf{x}_1) - \varphi_{12}(\mathbf{x}_2)$$

At this point, V(z) is due to propagation to so speak through the dielectric from each chunk of surface charge. the propagator is $e^{-j\beta R}/R$ which has real β and which therefore "does not see" the σ of the dielectric. This of course goes back to

$$(\nabla^2 + \beta^2)\,\varphi(\mathbf{x},\omega) = -(1/\varepsilon)\rho_T(\mathbf{x},\omega) \qquad (1.5.3)$$

which says that in this gauge, φ does not see σ of the dielectric. This is an artifact like in the Coulomb gauge where the artifact is that things are instantaneous with no velocity of medium retardation.

So for THIS potential in THIS Lorenz gauge, V(z) does not know about σ of dielectric. I suspect then that V(z) is not the voltmeter voltage! We are into it now!

So what is the meaning of "voltmeter voltage? It cannot align with just any potential φ!

I think I should review the capacitor of Appendix B in more detail since that is a prototype n=2 situation having a conducting dielectric. // That is done, I am burning lots of fuel on this right now.

Thurs Oct 17, 2013 Did AARP review all day.

Fri Oct 18, 2013

Still mystified by the King gauge, I have started a close reading (with full derivations) of a few pages of King's book where I think he applies his equations. The derivations are in "grind through...doc".

I ground through King page 13 through half of p 17. For this simple example, King has extracted the three parameters of interest which are G,C and L_e. His analysis did not incorporate a series resistance element. Everything was based on the mystery equations (23) and (24), including their complex ξ and ν factors!

I feel the need to finish this section, since the TL equations are coming soon. But I see how he has fully depended on the two solutions so I *am* going to have to figure those out!! I do have a dim idea, but will put it on hold till I finish this King section.

Sat Oct 19, 2013

Continuing on King page 17. // Progressing along, but am now confused: in my surface impedance versus total impedance of a short piece of wire, where is inductance hiding? // OK, I have now finished off Section 4 of King which was my goal. I learned that King has other books (Ref 9) that may give a derivation of his equations (23) and (24). One is King "Electromagnetic Engineering" of 1945. Note Kings full name which is Ronold Wyeth Percival King . It is a google book with no insides. It might be 2 volumes. Marriott has this book in the ARC,



The book is on sale at various places, used of course.

King's Works, my Reading of his Theory Sections, my Two King Mysteries

Ronold Wyeth Percival King (September 19, 1905 - April 10, 2006)

So King was already age 65 in 1970 when I did my independent study with him.

So once again I am left with my major problem. We have these various equations

$\beta^2 = \mu\varepsilon\omega^2 - j\omega\mu\sigma = \omega^2\mu\,\xi$

$(\nabla^2 + \beta^2)\,\mathbf{A} = 0$ or $(\nabla^2 + \omega^2\mu\,\xi)\,\mathbf{A} = 0$ (1.3.15)"

$(\nabla^2 + \beta^2)\varphi = -\rho/\varepsilon$ or $(\nabla^2 + \omega^2\mu\,\xi)\,\varphi = -\rho/\varepsilon$ (1.3.16)"

$\mathrm{div}\mathbf{A} = -j\omega\mu\varepsilon\varphi - \mu\sigma\varphi = -j(\mu\omega)[\,\varepsilon + \sigma/j\omega]\;\varphi = -(j\mu\omega\xi)\varphi$

$= (-j/\omega)\,\mu\omega^2\xi\,\varphi = (-j/\omega)\,\beta^2\,\varphi$ agrees with King sec 3 (8b) (1.3.17)"

He claims to have this solution to $(\nabla^2 + \beta^2)\,\varphi = -\rho/\varepsilon$:

$$\varphi(\mathbf{x}) = \frac{1}{4\pi\xi}\int_{C_1}\rho(\mathbf{x}')\,\frac{e^{-j\beta R}}{R}\,dV'$$

But even for this equation, where does the ξ come from? I know this much:

$-(\nabla^2 + \beta^2)g(\mathbf{x},\mathbf{x}') = \delta(\mathbf{x}-\mathbf{x}')$ where $\lim_{|\mathbf{x}|\to\infty} g(\mathbf{x},\mathbf{x}') = 0$. (1.5.7)

$$g(\mathbf{x},\mathbf{x}') = \frac{1}{4\pi}\,\frac{e^{-j\beta R}}{R} \qquad R = |\mathbf{x} - \mathbf{x}'| \tag{1.5.8}$$

So this would result in a leading factor $\frac{1}{4\pi\varepsilon}$. You would have to have

$$\text{div } E = \rho/\xi$$

which means you would have to have

$$D = \xi E.$$

Maybe I should take a trip to the ARC. // I did and saw a lot, see separate doc. But here are some bullets that I learned on this trip.

• He lived 1905-2006, a full 101 years.

• The integrals I am concerned about he calls "Helmholtz Integrals", and of course that goes with the Helmholtz equation as I call it.

• He points out that you get the boundary terms just as Stak does it using the fancy Green's Theorem, and I can ponder this.

• He wrote a 1986 text book with another author Shiela Pressad, when he was age 81.

• His 12 books are, in chrono order:

electromag engineering 1945	this is the only book that talks about the ξ issue
TL, antennas and wave guides 1945	// ARC, took only a quick look
TL theory 1955 the book I have	
theory of antennas with charts 1956	quotes the fancy Helm integral, showed Greens fcnts
I think this was the huge fat book jammed with equations.	
scattering and diffraction 1959	// not relevant
arrays of cyl dipoles 1968	
antennas and waves 1969	// not there // this is where I met him, age 63 maybe
tables of antenna stuff 1971	// just tables, no theory
antennas in matter 1981	// I never looked at this one
funda EM theory and apps 1986	// nice book, but the trick is used and not explained
lateral EM waves 1992	// not relevant
cyl antennas and arrays 2002 (age 97)	// I did not look at this one

• Something is odd with his medium boundary conditions that include ξ, I will ponder.

• The stacks have maybe 1000 books on antennas and antenna theory. That is the place to go if you ever get interested in that subject.

The bottom line is this: I learned some new things, he did in fact at least address the Mystery Issue, but the mystery is not explained to my satisfaction so I will have to continue to ponder it.

Sun Oct 20, 2013

My giant King snag continues to halt progress, but I have a possible idea. I now think it is all in those boundary conditions somehow which arise Green's Theorem. This notion has come and gone several times now, but after perusing King's work yesterday, the notion is back. One hint is the fact that ξ appears in his set of media boundary BC's.

$$\epsilon_0(\hat{n}_1,\mathbf{E}_1) + \xi_2(\hat{n}_2,\mathbf{E}_2) = -\bar{n}_1 \qquad (32a)$$
$$[\hat{n}_1,\mathbf{E}_1] + [\hat{n}_2,\mathbf{E}_2] = 0 \qquad (32b)$$
$$\nu_0[\hat{n}_1,\mathbf{B}_1] + \nu_2[\hat{n}_2,\mathbf{B}_2] = -\overline{\mathbf{n}_m\mathbf{v}_1} \qquad (32c)$$
$$(\hat{n}_1,\mathbf{B}_1) + (\hat{n}_2,\mathbf{B}_2) = 0 \qquad (32d)$$

I need to learn where these conditions are coming from. As a second issue, somehow it must be possible to simulate the effect of a conductor in terms of a thin surface current, although the skin effect tends to do that anyway. The charge is already on the boundary.

Mon Oct 21, 2013

Worked in bed this AM on some questions related to the King problem. I now realize that the P&P statement of equations,

We obtain the symmetrical set of equations:

$$\nabla^2\mathbf{A} - \mu\epsilon\frac{\partial^2\mathbf{A}}{\partial t^2} - \mu\sigma\frac{\partial\mathbf{A}}{\partial t} = -\mu\mathbf{j}', \qquad (14\text{–}4)$$

$$\nabla^2\phi - \mu\epsilon\frac{\partial^2\phi}{\partial t^2} - \mu\sigma\frac{\partial\phi}{\partial t} = -\rho/\epsilon. \qquad (14\text{–}5)$$

does not really answer my question. Here is the reason why. The problem has two different media with different parameters. You cannot regard (14-4) as a viable equation unless it is valid in both media at the same time, but really it is a different equation in each medium with different μ, ε,σ and j' values in each. Although "the PDE is local but the solution is global", that fact only applies if your point of interest lies in the same medium as the sources. For a transmission line with fat conductors not doing skin effect, the source j' at some point in a conductor interior has to "propagate" first to the boundary with one propagator, and then to get the effect in the other medium, one has to compute the propagation from every point on the boundary. Basically, there will be reflection and refraction at the boundary so you cannot just use the dielectric propagator and propagate j' directly. You might do this if you assumed extreme skin effect, so then j' exists just on the conductor side of the boundary and maybe then you can use the dielectric propagator as is. Another question: What happens if the conductor lies on the line of sight from a piece of surface current source j' to the observation point x ? Can you still assume simple propagation through the dielectric? These are not easy questions for me to answer.

Remember that I have two King problems, One is the above described issue with j'. The other problem is why King has the complex ξ sitting in his integral solution to 14-5. I think this is related to the King BC set I found and copied which involves ξ at a boundary.

The upshot is that I have to study this a lot more. I need to study the conducting capacitor again to see if I can make ξ appear somewhere. And then there are the Green's Theorem boundary terms to consider. It

is going to be a long haul, so I have been trying to dispatch unrelated tasks. This is likely to continue into January and maybe beyond. I will lose 3 weeks due to Xmas MRL stuff, when all costs are added in.

I started a doc called "King meets Stak" and in that doc I asked a few questions which brings in the Stak work I did. Does a conductor "obstruct" a propagator? What is the capacitance of some arbitrary set of conductors for a transmission line? How would you compute it, that is to say. Just doing this tiny amount burned me up for the day, it is now 6 PM. Nothing has been cleared up really, a no-progress day.

Tues Oct 22, 2013

I continue today in King meets Stak. I reread yesterday's stuff, edited, it still holds. I then looked at the boundary between two conducting dielectrics and for the first time ever was able to duplicate the King BC's in which ξ appears! Action item: update lines to show this extra result *******.

Weds Oct 23, 2013

Did the charge-in-two-dielectrics problem to learn how E fields refract at a boundary. This included a nice Maple plot using work I did for the charged iris.

Thurs Oct 24, 2013

Am still pursuing my two "King problems"

(1) how to deal with j as source in conductor in terms of propagator integral for A_z

(2) how to deal with ξ in same integral for φ

Tues Oct 29, 2013

I have missed some log entries. Yesterday I was working in the puzzles doc and got confused about the meaning of the equation of continuity. That led to a separate doc of that title, and I think that is now all cleared up, so I will resume in the middle of puzzles where I left off with this confusion. Now 3 PM. // I finished off the puzzles, adding a few more with solutions. I think I have now dealt with the two big King mystery questions, and I am ready to get back to editing the lines doc again. It was a long side track.

Weds Oct 30, 2013

Will start yet once again on an edit pass, with my "new knowledge" of how things work.

I just did a massive rewrite of Section 1.1 adding many things

- better notes on things like ρ_{free}, displacement current, etc
- new subheadings
- note on all the polarization related equations
- adding the King boundary condition and quoted from his book

I have added various references, and then did another pass on Section 1.1. I want this to be a very solid platform before I build the next floor of the building.

Section 1.2 is OK as is.

Section 1.3 is OK.

Section 1.4 is OK

Section 1.5 is OK except at the end.

Section 1.6 replaces the previous rump section that did ω-space wave equations for the fields, which is not incorporated into Section 1.5. The new Section 1.6 is my puzzles explanation of the King Helmholtz integral.

Thurs Oct 31, 2013

I think I have found a simple way to derive the King A equation, and am now installing this into Chapter 1 section 1.3. // It is done, I think Section 1.3 is good, but the approximation needs discussion. Section 1.4 is still OK as stated.

Now I am back to the King (1/4πξ) and its possible connection with my Appendix B.

But then I realized I redid Appendix G and forgot to install the repair. So let's install that right now (this is just the G.1 repair, I hold off on the G.2 repair).

Status: I have been trying to recover the parallel plate capacitor from those K functions and it is a mess. I think I need now to rewrite Chapter 4 to make it simple.

Fri Nov 1, 2013

I went through King's first example again in his book. This time I realized that the phase shift between V and Q does NOT arise from the complex exponent but in fact does arise from his having the ξ parameter in the φ denominator. When I compare his work with my toy conducting capacitor example, I notice that in my toy solution, I basically add the resistance element "by hand" when I do this:

Now "turn on the conductivity" so the latent resistor appears. Then

$I = j\omega nA + V/R \qquad R = s/(\sigma A) \qquad$ // since $R = V/I_R = Es/JA = (s/A)(E/J) = (s/A)(1/\sigma) = s/(A\sigma)$

or

$$I = j\omega nA + VA\sigma/s \; . \qquad \text{(B.2)}$$

That is to say, I "manually" add the V/R current term to jωnA and that then causes the phase shift and I end up with Q = V [Aξ/s] and then this gives the correct complex admittance, or C' if you will.

Maybe King is just doing the same thing by adding that denominator manually to his φ integral. It would only "apply" in his transverse application with V and so on.

I do think the toy capacitor plate problem contains the solution to his ξ King mystery.

As of 3:15 PM, I have gone nowhere on the 1/ξ King factor mystery. I see why I want it. I look at BC at conductor/dielectric interface and I keep getting one after another contradiction. Something is just plain

missing in my picture. It has been missing now for 22 years and continues to be missing! I seem to be unable to crack this contradiction nut. Marilyn is here.

On the white board, I have identified <u>two types of surface charge</u>. One I call n_f is the actual charge density on the surface. The other n' is the "transport charge" inside the conductor. In the conductor there is a current J_{tot} which feeds the dielectric current $\partial_t D + J_c = \varepsilon\partial_t E + \sigma E$ where σ and E and ε are of the dielectric. Current balance at the boundary says that $J_{tot} = \varepsilon\partial_t E + \sigma E = (j\omega\varepsilon + \sigma)E = j\omega\xi E$. If we write this current as $J_{tot} = \partial_t n'$, we get $j\omega n' = j\omega\xi E$ or $n' = \xi E$ and we then have a charge n' which is out of phase with E. The problem is understanding the meaning of n'. If we make a unit area patch in the just inside the conductor surface, then n' is the amount of charge per second that passes through that area. It is easy to show that

$$n_f = (\varepsilon/\xi)n'$$

Now correspondingly we could say $\rho_f = (\varepsilon/\xi)\rho'$ and then we get

$$\varphi(\mathbf{x}) = \frac{1}{4\pi\varepsilon}\int \rho_f(\mathbf{x}',\omega)\frac{e^{-j\beta(\omega)R1}}{R_1}\,dV'$$

$$\varphi(\mathbf{x}) = \frac{1}{4\pi\xi}\int \rho'(\mathbf{x}',\omega)\frac{e^{-j\beta(\omega)R1}}{R_1}\,dV'$$

This means that <u>in the King formula, the charge density ρ' is really the transport charge density</u> which has the relation $J_{tot,c,n} = \partial_t n' = j\omega n'$. So this n' is in quadrature with the conductor current, whereas n_f is out of phase with the conductor current but in phase with E, φ and V. It is true that

$$\int_{C1} \partial_t n'\,dA = I_t =$$

the total transverse current emitting from a cross section of C_1 per unit length in z.

I presume this current is fed by longitudinal current $I = I_t$ in the conductor. If we write
$I = I_t = \partial_t Q$ then we have

$$Q = \int_{C1} n'\,dA$$

and then this Q is in phase with n' and then our complex capacitance is QV = C' . In a capacitor we expect to have $I = C'\partial_t V = j\omega C'V$ and we expect that leakage conductance in the dielectric will cause I and V to not be exactly out of phase.

If we put a prescribed current I into a transmission line conductor, it is associated with jωn' and not with n_f . So perhaps when a transmission line problem is set up,

Sat Nov 2, 2013

Starting noon after M gone. How to present the transport charge argument? // Well, I think I did something reasonable with this King #2 issue. I then went on to start my King #1 issue analysis in Section 1.6 which is now underway in situ. Time is 8:30PM will stop.

Sun Nov 3, 2013.

Snow flurries noted, clocks fall back. [the first winter of lines doc]

• In my Section 1.6 discussion, is it possible that the Helmholtz BV problem for A is exactly the same as for φ, and I might say A_z = A on one conductor and -A on the other conductor, and then you really do have a Dirichlet problem albeit a Helmholtz one? Keep this question on a back burner. Right now I don't have a reason for the A and -A, whereas I am always happy with V and -V for φ.

• I say that we have a different propagator $e^{-j\beta R}/R$ in each region since $\beta_i^2 = \omega^2 \mu_i \xi_i$, but when it comes to the actual x line parameters, I use $e^{-j\beta R} = 1$ so that should not matter!

Consider again:

$$\beta^2 = \mu\varepsilon\omega^2 - j\omega\mu\sigma = \omega^2\mu(\varepsilon - j\sigma/\omega) = \omega^2\mu\,\xi \qquad \xi \equiv \varepsilon - j\sigma/\omega \quad . \qquad (1.5.1)$$

In a conductor since σ is huge, we have ξ huge and β is huge. Then $e^{-j\beta R}$ for characteristic distances R cannot be considered $e^{-j\beta R} \approx 1$, so my bullet above is wrong!

OK, I have been honing Section 1.6 to not get too involved, but to make the point that you don't have a simple Helmholtz equation to solve.

I have now added the P&P verification of the time domain inhomo wave equations with their j' current and their comment which I quoted.

So I think all the ingredients are now in the Chapter 1 soup, finally. I now need to reread the thing and make it consistent and remove redundant remarks. Chapter 1 is p 4-36 = 33 long pages!

But maybe I should redo Chapter 4 FIRST, because it may require more changes in Chapter 1. But it would be nice to first have those equation numbers stable in chapter 1. So more Chapter 1 proofing:

Section 1.1 reread: 31 equations

(a) OK

(b) OK, I did not gather the integral forms for a summary

(c) OK.

OK, I do think section 1.1 is pretty good since it summarizes the most important E&M result we will need, and derives everything from scratch except the two math theorems.

Section 1.2. OK, very short

Section 1.3

(a) wave equation derivations

(b) OK, and added the Lorenz note here with a Nevels reference, fixed my PDF bug in Word!

(c) OK.

How about the Maxwell equations in covariant form?

$$= \begin{pmatrix} 0 & -E_x & -E_y & -E_z \\ E_x & 0 & -B_z & B_y \\ E_y & B_z & 0 & -B_x \\ E_z & -B_y & B_x & 0 \end{pmatrix}$$

OK, I added a section on this to my relativity note.

So now I have done still more in Section 1.3. I think it is stable through the end of 1.4. A lot of major equation renumbering.

Section 1.4. OK

Section 1.5

(a) OK

(b) OK

(c) OK

(d) OK

Section 1.6. Resume here tomorrow. The Monster has grown to 191 pages (so far).

King Mystery #1 and #2 are solved, regions and n_c => Chapter 1 repairs, Nov 4, 2013

Mon Nov 4, 2013.

Today I had a very major breakthrough on the King problem #1 as to how to handle the currents. This is the very first time I have ever understood this, and there is now no need for any "surface current approximation" or any of that stuff. The results now will apply to "fat conductors" as well as thin and skin effect conductors!!! I would guess it has taken me a whole month to find this delicate logic threading which gives the answer. This also resolves the ancient problem of those "applied currents" $\mathbf{J_a}$ which I had in my original lines document.

So today I first rewrote Section 1.3 (c) with this new stuff. I was then able to throw out section (d) since its material is now at the end of section (c).

This brings us to Section 1.4 which is the retarded solution distraction and I will leave it where it is.

This takes me to Section 1.5 where I start into the ω-space version of things. That is where I will pick up after "lunch anyone?" .

If one peruses the web and books in the library, one finds a lot of discussion of waveguides which use the wave equations directly for **E** and **B**, since the waveguide wall boundary condition **E** = 0 is so handy, and one finds an astounding amount of information on antennas and radiation. But transmission lines *per se* do not get a lot of coverage. Etc Etc maybe in the intro.

Section 1.5 is now done once again.

Section 1.6 on that surface approximation gets through out!

Section 1.7 then gets backed up to be 1.6 where it once was. Changed enums whole doc.

Status 5:30 PM. Once again, I think I am done with Chapter 1. It is pretty heavy on wave equations

Question: What happens if you were to use the Fourier Cosine Transform.

$$X_c(\omega) = 2 \int_0^\infty dt\, x(t) \cos(\omega t) \qquad \text{Fourier Cosine Transform}$$

$$x(t) = (1/\pi) \int_0^\infty d\omega\, X_c(\omega) \cos(\omega t) \qquad (1.7)$$

Then what happens if we assume

$$\mathbf{e(x,t)} = \cos[\omega_1 t + \varphi(\mathbf{x},\omega_1)]\, \boldsymbol{e}(\mathbf{x},\omega_1)$$

Then we get

$$\mathbf{E}_c(\omega) = 2 \int_0^\infty dt \cos[\omega_1 t + \varphi(\mathbf{x},\omega_1)]\, \boldsymbol{e}(\mathbf{x},\omega_1) \cos(\omega t)$$

$$= 2\, \boldsymbol{e}(\mathbf{x},\omega_1) \int_0^\infty dt \cos[\omega_1 t + \varphi(\mathbf{x},\omega_1)] \cos(\omega t)$$

OK, this is a no fly zone. Fourier Cosine only works on even functions and **e(x,t)** is not even. The above integral

So where should I go next armed with this newly polished up Chapter 1? I am worried about the Appendices right now, they have gone stale.

I think A is probably OK but let's go read it right now.

I have gotten through A.4 and it seems OK. A.5 OK. A.6 OK.

Question: is the Lorenz gauge unique, or is it a continuum of gauges? Suppose we have

$$\text{div}\, \mathbf{A} = -\frac{1}{c^2}\, \partial_t \varphi \qquad \text{or} \qquad \partial_\mu A^\mu = 0$$

This just says A^{μ} is any function which has a zero 4-divergence. How can I show there are lots of such functions. Write A' = A + ΔA and φ' = φ + Δφ. Then we need

$$\text{div}\ \Delta A = -\frac{1}{c^2}\ \partial_t\ \Delta\varphi$$

OKOK, I have this nailed and added a comment in A.6.

OK, I think Appendix A is now OK. I had to fix up the Lorenz stuff and had to add the idea that it is not unique, but the whole thing still holds together and is I think a unique piece of work. I would be surprised to see these questions asked and answered the way I have done it. I did not do a detailed enum check, but I made no adjustments to what was there, no equations added or deleted.

I think Appendix B is going to be much more relevant to Chapter 1 and I will save it for tomorrow. Maybe things are finally on the move again!

Tues Nov 5, 2013.

Appendix B. Well,. this deals with $n_{eff} = n_s(\xi/\varepsilon)$ so this is going to be a repeat of what I have now already said in Section 1.5 (c) but I said it there in a more general sense. Maybe App B is doing to completely disappear. [it did]Clearly $n_{eff} = n_c$. Somehow I had this right all along maybe in Chapter 4. I like the explanation of $1/4\pi\xi$ being in line where reader is forced to understand it. The loss tangent stuff never got used anywhere really. So let's maybe skip App B right now and have it marked for removal.

Just spotted a bug with symbol J_d in that $1/4\pi\xi$ section. Spent at least an hour cleaning this up with more precise notation, all done.

I now want to jump down to Chapter 3 and skip the round wire for now.

3.1 excellent, and I improved notation
3.2 excellent, but refers to Appendix E which I will do soon.
3.3 shows that σ in a dielectric is really σ_{eff} which can be much larger than actual ε. I need to ponder this a bit, which σ do I mean when I talk about the dielectric's σ in the TL work??

Also, I do the loss tangent in full here and make no reference to Appendix B which also talks about loss tangent. So another reason to dump Appendix B!

3.4 I think this needs a rework in light of what I added to Chapter 1.
OK this has been repaired with minimal impact, and I get to make use of King's $\xi_1 E_{n1} = \xi_2 E_{n2}$ which I derived in Chapter. 1, So I think 3.4 is a fine section and I changed its title.

STOP. I am now going to need the Chapter 2 round wire results for this qualitative section, so hold on Chapter 3 and jump back to Chapter 2.

Chapter 2

2.1 has a sentence that needs reconsideration, but we can continue anyway. I just repaired it by adding a little extra at the end of Section 1.5. So now 2.1 is just fine!

I just added a quick section showing how δ is pretty obvious in a 1D Helmholtz problem.

2.2 Just added the NIST reference, that took a while.

(a) OK on Kelvin functions

(b) (c) (d). This stuff is all unaffected by Chap 1 changes.

What is missing here is a more obvious explanation of the skin depth in the sense of Jackson where I recall he had the plane wave hit a conductor. Maybe the basic idea is that at large ω, there just isn't time for anything to happen inside?? It would be good to add some nice argument *******.

2.3 resume after feeding.

(a) OK, the little picture is for no variation in z, but my red question is a good one.

Question: Why isn't there some mention here of the wire's inductance which you would think would be part of its impedance. [this is resolved]

Where is the inductance hiding? Is it inside Z_s and Z ? Well (2.3.11) shows that Z_s is in fact very complex so Z_s and Z are complex. the "inductance" appears when you make a circuit model or when you use the A_z loop formula. I don't think I need to say anything about inductance but yes, it is included in the Z_s as its imaginary part more or less. I wonder if it includes external and internal inductance? Check back on this later *********

(b) low ω limit of Z_s , very good, now $L_{internal}$ appears.

(c) hi ε limit of Z_s with Matick tie ins.

(d) plots of surface impedance for the round wire

All this stuff stays as it was, no effect from changes in Chapter 1, so we continue on.

2.4 is OK, quite short, qualitative only. It does have a comment in red that I want to study later.

This concludes my review of Chapter 2 on the round wire. It is chock full of stuff. Now I can continue where I left off in Chapter 3.

Section 3.5 and 3.6 are unbelievably tedious to read. I have made an argument for every entry in my table. I added a comment to warn the reader about this fact. But I read them and had to make some updates. The little green loop in the figure is no longer used I think, but will hold off erasing it for a while. When I first wrote this, I did not have the E and B field boundary equations cleanly written down as I now do.

Section 3.7.

(a) I like these Facts, they are well stated.

(b) is good, I had to flip the B direction in the second figure and adjust enum references.

(c) is good as well, explaining the 3D fancy picture I made.

Section 3.8

Fact 7 Proof A I don't follow.
Proof B is OK
Proof C I fixed up so now OK.

I can come back and fix up Proof A, or if not, I can just get rid of it.

I want very much now to get rolling in Chapter 4 since this is the chapter that ties back to my reworked chapter 1. I guess I will start on this tomorrow, now it is 8 PM.

First work on the μ issue, Nov 6, 2013

Weds Nov 6, 2013.

I think I may have the wrong μ in my King A equation, check on this please. My derivation very clearly shows that the μ's with the J'as are μ in the conductor region, not in the dielectric region. See (1.3.23). But now look at the Panofsky equation. It shows the same μ on both sides of the equation! I think I am right here because I have actually done a derivation. Is there something wrong with my (1.3.3)? I have a careful derivation of that equation as well. The result is B = curl A, not H = curl A. Here are the steps, and these steps take place in a specific "region" of interest. So in (1.3.3) all the μ's are the same μ.

curl $\mathbf{H} = \partial_t \mathbf{D} + \mathbf{J}$ // Maxwell (1.1.1)

$(1/\mu)$ curl curl $\mathbf{A} = \mu\varepsilon\, \partial_t \mathbf{E} + \mathbf{J}$ // $\mathbf{H} = \mathbf{B}/\mu$, $\mathbf{B}$ = curl $\mathbf{A}$ from (1.3.1), and $\mathbf{D} = \varepsilon\mathbf{E}$

grad div$\mathbf{A} - \nabla^2\mathbf{A} = \mu\varepsilon\, \partial_t[-$ grad $\varphi - \partial_t \mathbf{A}] + \mu\mathbf{J}$ // vector identity and $\mathbf{E} = -$ grad $\varphi - \partial_t\mathbf{A}$

$(\nabla^2 - \mu\varepsilon\, \partial_t^2)\, \mathbf{A} =$ grad $[\mu\varepsilon\, \partial_t\varphi +$ div$\mathbf{A}\,] - \mu\mathbf{J}$ (1.3.3)

Here then my derivation of the final result:

Is there something wrong with using the region 1 King gauge in all regions?

div $\mathbf{A(x)} = -\mu_1\varepsilon_1\, \partial_t\varphi(x) - \mu_1\sigma_1\varphi(x)$ // applies to all of R (1.3.18)

When x is a point in region 2, we still use this equation. We are certainly ALLOWED to do this because you can set div A to any scalar function you want. Consider this other way to write the above

div $\mathbf{A(x)} = -j(\beta_1^2/\omega)\varphi(x)$

As x roams over all three regions, this equation says the same. It is not the King gauge inside the conductors.

Is there something in the step setting E = 0 ?

grad $\varphi = -\mathbf{E} - \partial_t\mathbf{A} \approx -\partial_t\mathbf{A}$

In a really perfect conductor, we really have E = 0 and $\sigma = \infty$ and some finite J there. So I think this really is OK.

Conclusion: Defining the King gauge "my way" does in fact give "my results".

Is there some issue like ξ and ε that changes this somehow, a change in the meaning of the current just as we had a change in the meaning of the surface charge with n_s and n_c ?

What happens in a material with $\mu \neq \mu_0$ anyway? B&B page 136 show that $\mathbf{J}_m$ = curl **M** exists. They say that the magnetic field polarizes magnetic dipoles just as the electric field polarizes electric dipoles in the medium. **M** is analogous to **P**. So **J** = curl **M** is like ρ_{pol} = -div **P**. B&B then show that you get

curl $\mathbf{B} = \mu_0(\mathbf{J}_c + \mathbf{J}_m)$ B&B 5.19

But where is the displacement current??? W are doing magnetostatics so it is not present at this point. Then

curl $\mathbf{B} = \mu_0(\mathbf{J}_c + \mathbf{J}_m) = \mu_0(\mathbf{J}_c + \text{curl } \mathbf{M})$ => curl $(\mathbf{B}-\mu_0\mathbf{M}) = \mu_0\mathbf{J}_c$

Now define $\mu_0\mathbf{H} \equiv \mathbf{B}-\mu_0\mathbf{M}$ so that $\mathbf{B} = \mu_0(\mathbf{H}+\mathbf{M})$. Then $\mu_0\mathbf{H} = \mathbf{B}-\mu_0\mathbf{M}$ so we get

curl $(\mathbf{B}-\mu_0\mathbf{M}) = \mu_0\mathbf{J}_c$ => curl $(\mu_0\mathbf{H}) = \mu_0\mathbf{J}_c$ => curl $\mathbf{H} = \mathbf{J}_c$

So where is μ ?? I guess in analogy with $\mathbf{P} = \chi_e\mathbf{E}$ you say $\mathbf{M} = \chi_m\mathbf{B}$ but that is wrong!!! On page 139 they instead say $\mathbf{M} = \chi_m\mathbf{H}$ which seems a departure from the other case. They claim this is an experimental observation, so OK. Then we get

$\mathbf{B} = \mu_0(\mathbf{H}+\mathbf{M}) = \mu_0(\mathbf{H}+ \chi_m\mathbf{H}) = \mu_0(1+\chi_m)\mathbf{H} = \mu\mathbf{H}$

and there is your μ parameter as in B&B 5.30. That is why $\mathbf{D} = \varepsilon\mathbf{E}$ and $\mathbf{B} = \mu\mathbf{H}$ are sort of backwards, just the way things come out, fine by me. So yes, the effect of M on a problem is reflected in the fact that $\mu \neq \mu_0$. What happens to our curl equation? It is now curl $\mathbf{H} = \mathbf{J}_c$ where you do not see any μ's appearing!! The μ at location **x** is absorbed into the **H** at location x.

So what happens if I do things with H instead of B ? Look back at 1.3.

curl $\mathbf{H} = \partial_t\mathbf{D} + \mathbf{J}$ // Maxwell (1.1.1)

$(1/\mu)$ curl curl $\mathbf{A} = \mu\varepsilon\, \partial_t\mathbf{E} + \mathbf{J}$ // $\mathbf{H} = \mathbf{B}/\mu$, **B** = curl **A** from (1.3.1), and $\mathbf{D} = \varepsilon\mathbf{E}$

grad div$\mathbf{A}$ - $\nabla^2\mathbf{A}$ $= \mu\varepsilon\, \partial_t[-$ grad $\varphi - \partial_t\mathbf{A}] + \mu\mathbf{J}$ // vector identity and $\mathbf{E} = -$ grad $\varphi - \partial_t\mathbf{A}$

$(\nabla^2 - \mu\varepsilon\, \partial_t^2)\, \mathbf{A}$ = grad $[\mu\varepsilon\, \partial_t\varphi$ + div**A**] - $\mu\mathbf{J}$ (1.3.3)

The problem is that we have to use **B** = curl **A**, not **H** = curl **A**.

curl **H** = ∂_t**D** + **J** // Maxwell (1.1.1)

curl (**B**/μ) = ∂_t**D** + **J**

(1/μ) curl (**B**) = ∂_t**D** + **J**

(1/μ) curl (curl **A**) = ∂_t**D** + **J** = ∂_t(ε**E**) + **J** = ε ∂_t**E** + **J**

Then

curl (curl **A**) = με ∂_t**E** + μ**J**

curl (curl **A**) = με ∂_t**E** + μ**J**

grad div**A** - ∇^2**A** = με ∂_t**E** + μ**J** = με ∂_t[- grad φ - ∂_t**A**] + μ**J** // agrees with above

- grad div**A** + ∇^2**A** = με ∂_t[grad φ + ∂_t**A**] - μ**J**

∇^2**A** = grad div**A** + με ∂_t[grad φ + ∂_t**A**] - μ**J**

∇^2**A** = grad div **A** + grad [με ∂_tφ] + με ∂_t^2**A** - μ**J**

∇^2**A**- με ∂_t^2**A** = grad [div **A** + με ∂_tφ] - μ**J**

(∇^2- με ∂_t^2)**A** = grad [div **A** + με ∂_tφ] - μ**J** and this IS (1.3.3), there are no errors here.

So I think (3.3.3) is exactly right. Jackson agrees with me, but is in free space.

$$\nabla^2\Phi + \frac{\partial}{\partial t}(\boldsymbol{\nabla}\cdot\mathbf{A}) = -\rho/\epsilon_0 \qquad (6.10)$$

$$\nabla^2\mathbf{A} - \frac{1}{c^2}\frac{\partial^2\mathbf{A}}{\partial t^2} - \boldsymbol{\nabla}\left(\boldsymbol{\nabla}\cdot\mathbf{A} + \frac{1}{c^2}\frac{\partial\Phi}{\partial t}\right) = -\mu_0\mathbf{J} \qquad (6.11)$$

I have added Jackson references to more equations in this section and I feel pretty solid about (1.3.3). However, Jackson is in vacuum and I am in a medium so not 100% confirmation. Jackson just doesn't do this with a medium present as I have tried to do. But look at B&B p 282. Their (10.62) is the Lorenz gauge but they don't use his name. B&B have my wave equations (1.3.4) and (1.3.5) WITH μ and ε , and μ and ε are also in the gauge condition. So there is more verification.

Conclusion: There is nothing wrong with my starting point equation (1.3.3) where all parameters apply to the region of interest. And then my derivation of (1.3.20) is exactly correct and in μJ, the μ goes with the location of J !!! So maybe that is how you are supposed to interpret his equations.

Is this going to screw up my transmission line equations derivation somehow in Chapter 4 ? Go start with (4.3.1) there and see what happens. You see the μ sitting there in (4.3.1). And then that same μ ends up sitting in (4.3.7) where it is not identified with any "region". I have assumed the same μ for both conductors to get this final result. So in (4.3.7) the μ is for the conductors NOT for the dielectric. This same μ keeps going and sits in (4.4.3). Then it is present in (4.4.8)!!! The external inductance of a wire is a function of μ inside the wire is my reading of (4.4.8). Can I get confirmation of that somewhere? If we look at my appendix C (b) and be careful!

Appendix C work

Appendix C (b). The loop is now in the medium outside the wire so μ is for the dielectric here!! The μ in C.3.1 is the μ of the outside dielectric region for sure. I end up with

$$L_e = \frac{\mu}{8\pi} \ln\frac{R}{a}$$ where μ is for the dielectric, NOT for the conductor.

It is based on energy stored IN the dielectric which has its μ. The inside μ never enters the calculation.

Sad Fact: In (4.4.8) if I follow my derivation, μ should be μ inside the conductor [correct!]. But in my appendix C derivation of (4.4.8), μ comes out being μ in the dielectric. So we have a Major Paradox. and the entire project now (once again) **grinds to a halt**. I will halt this log and work in a separate doc until this paradox is resolved. That is just the way things go/

Status 8:30 PM. Well, the lines building has collapsed yet again.

The first little clue was that the meaning of μ in my A formula seems wrong compared to other people. This occurred to me in bed this morning.

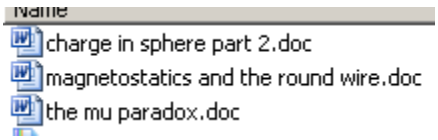
If wrong, then my external inductance calculation is wrong since it seems to contain the conductor μ.

I then decided to do a magnetostatics problem to see if there is maybe a magnetization surface current that I am missing in my calculation. So that was the first stack push.

But then I decided I better write up the electrostatic analog which I had started. This was the second stack push and it ballooned out into a big mess which I now need to clean up. So I will be down at this second level from my real problem of the wrong μ" until I return from Torrey. By then, all momentum will be lost and I will have to start all over again. I thought things were good, but they are not. Something mysterious is going on here.

This is going to take 2 solid weeks to untangle I predict. That is fine, that is what I am here to do.

Three new documents were started but not finished today:



Thurs Nov 7, 2013.

I finished the electrostatic spheres stuff in the AM and popped the stack back up to the magnetostatics paradox doc.

I then finished the magnetostatics problem and luckily resolved the μ_1 versus μ_2 mystery at least at the level of the round wire with a current going through it. I find in particular that outside the wire

$$A_z(r) = -\ (1/2\pi)\, I\, \mu_1 \ln(r) \qquad r > a \qquad \text{outside}$$

and it is μ_1 for the dielectric region that enters this formula! The μ_1 "gets there" through the surface current term in the integration! Wow, that really was complicated. I have to be very careful with all this stuff.

This resolves the issue of which μ appears in the internal and external inductance.

Now I am backing up the stack. Where do I go next??? Let's go to the mu paradox document and show how the paradox is resolved. Well, how do I repair my "conductors" lines section? I have the nice picture. I state the King gauge. Remember that I start with (1.3.3)

$$(\nabla^2 - \mu\varepsilon\, \partial_t^2)\, \mathbf{A} = \text{grad}\,[\mu\varepsilon\, \partial_t \varphi + \text{div}\mathbf{A}\,] - \mu\mathbf{J} \qquad [\,= \text{Jackson (6.11)}\,] \qquad (1.3.3)$$

where the secret is that **J** must include all currents. I will practice in a separate doc

OK, I have done a full edit on Section 1.3 (c) and included the $\mathbf{J}_m$ surface currents everywhere. It did not complicate things too much really. Most importantly, the equations are now correct for arbitrary μ_i !! I then repaired an earlier comment where I said J_m would never be of interest!

Upon return, I will add red comments to the mu paradox doc and then it is done and I am fully popped back up to the top level. In two places I have now promised an Appendix which includes the mag current stuff, and I am thinking now of one appendix that does both the spheres electrostatics problems and this round wire problem. We shall see. Signing off pre Torrey trip. Things are in reasonable shape after this last surface current realization.

Fri Nov 8, 2013.

7 AM and I have a little 2 hour shot here before Smith's trip at 9 and 10:30 departure. I added my red comments to the mu paradox doc, all done with that. Now reading Appendix C: round wire at DC.

C.1 very short, resistance
C.2 surface impedance
C.3
  (a) is very good, compute L_i , did some edits here
  (b) computes L_e , also very good, clean answer even though divergent, etc etc.
C.4

Put this on hold! I see that I have to update Chapter 1 after the "conductors" section to account for surface currents. I will start by rereading my conductors section of yesterday right now. // Everything is OK to the start of section 1.5.

Section 1.5 review in light of changes made to conductors section
(a) reviewed and OK. Off to Torrey with Dave!

Mon Nov 11, 2013.

Back from Torrey. Thought about the problem of how you compute surface current given the volume current a(x,y) in Chapter 4, so will start with this problem.

Pause: what names should I give B and H?

Jackson green:	B = magnetic induction	H = magnetic field
Jackson 3rd Ed	same (also, mag flux dens)	
Bleaneys	B = field or induction	H = mag field
Haus	B = mag flux dens	

I started a new doc "surface currents on non-round conductors". I first wrote up the little formula derivation for K. I then tried to show how you might obtain H from J and thus K from J. But then at 6:30 PM this led to a **paradox**: If J is a constant in the conductor, then H = 0. So now lines comes to yet another full stop while I find the escape hatch for this new problem.

I fixed up this paradox for constant J_z by showing there is a ring source of curl J at r = a. But then when I compute H using this for curl J, intead of getting H = I/2πr, I get some kind of horrible complete elliptic integral thing. So we have now a **new paradox**: fancy solution gives K and E functions, simple solution gives just simple answer.

Possibly related problem: Consider in 2D a disk of radius a which has a uniform linear charge density λ around the perimeter. Consider $\nabla^2\varphi = -\rho$ in 2D and find φ. In 3D we know φ = constant is the only solution. I might try to say that

$$\varphi = \int r dr d\theta\, \lambda\, \delta(r-a)\, 1/R = a\lambda \int d\theta/R \qquad R = r^2 + a^2 - 2ar\cos\theta$$

and this then is a similar integral to my problem.

$$4.^* \qquad \int_0^{\pi} \sqrt{a + b\cos x}\, dx = \int_{-\pi/2}^{\pi/2} \sqrt{a + b\sin x}\, dx = 2\sqrt{a+b}\boldsymbol{E}\left(\sqrt{\frac{2b}{a+b}}\right)$$

$$[a > b]$$

$$5.^* \qquad \int_0^{\pi} \frac{dx}{\sqrt{a \pm b\cos x}} = \int_{-\pi/2}^{\pi/2} \frac{dx}{\sqrt{a \pm b\sin x}} = \frac{2}{a+b}\boldsymbol{K}\left(\sqrt{\frac{2b}{a+b}}\right)$$

$$[a > b]$$

where the E and K are swapped, but you can see that this really is a non-elementary function! Can I find this problem solved somewhere just to get confirmation? Maybe I should do this problem.

Tues Nov 12, 2013.

Spent this entire day on a digression written up in a separate doc about solving the "ring of charge" problem in 3D and 2D. The 2D version will have application in the ongoing surface current question for a uniform-J transmission line conductor.

Weds Nov 13, 2013.

Am now back in doc "surface currents in non-round conductors". // I finally finished the calculation of H from J doing it the hard way. I think now I can continue into Chapter 4 and maybe put this as an appendix. Now 2 PM.

Will now resume Appendix C review.

C.1 DC resistance, OK
C2. DC surface impedance OK
C3. DC inductance
  (a) internal L_i OK
  (b) external L_e OK
C4.
  (a) plan of attack statement

Problem. I get down to this point:

$$\mathbf{A}(\mathbf{x},\omega) = \frac{1}{4\pi} \int [\, \mu_1 \mathbf{J}_m(\mathbf{x}',\omega) + \mu_2 \mathbf{J}_c(\mathbf{x}',\omega)] \frac{1}{R}\, dV' \qquad R = |\mathbf{x} - \mathbf{x}'| \quad . \quad \omega = 0 \qquad (1.5.9)$$

Maybe write this as

$$\mathbf{A}(\mathbf{x},\omega) = \frac{1}{4\pi} \int dx'dy'[\, \mu_1 \mathbf{J}_m(x',y',\omega) + \mu_2 \mathbf{J}_c(x',y',\omega)] \int dx' \frac{1}{R}$$

OK, I have now repaired and adjusted section (b) on the divergence problem, so we are here

C.1 DC resistance, OK
C2. DC surface impedance OK
C3. DC inductance
  (a) internal L_i OK
  (b) external L_e OK
C4.
  (a) plan of attack statement OK
  (b) the divergence problem OK
  (c) avoiding the divergence problem OK

and this then concludes the existing Appendix C. I may want to add another section to show my surface current calculation business??

Now is the time: I think the surface current calculation for the round wire should be section C.5.

Well, now it is 9 PM. I have constructed a long doc which addresses all the surface current issues, and I think it will become a separate Appendix rather than something to be added to Appendix C. Lots of ducks got lined up in a row today, a rare occasion.

**** Add plots of B, H and A_z.

Thurs Nov 14, 2013.

Appendix H and I written, Nov 14, 2013

I have just written Appendix H and I which deal with the 3D and 2D Green's Function stuff in a rather conclusive manner. I need next to go through the main text and refer to these new and improved appendices.

Let's start with Appendix A. The main issue here would be Section A.0, but I don't think it should be cut down, nor should I add extra references to Appendix H and I.

Appendix A is all OK with respect to these new appendices.

What about Appendix C. Is there any interaction between it and H and I? Yes, one tiny place which I glued a little better now with en explicit reference to App I.

I am now going to save out the old Appendix H and install the new App H and App I written today. I don't want multiple docs. Stay integrated please! **DONE**.

Break time at 5:30// and done for the day.

Fri Nov 15, 2013.

Just added 3rd party date to the PC after all these years, tclockex, a thing of beauty. Susan smirked since her Mac does that anyway. yawn.

What appendix material to I now have stacked up ?

1. Surface currents on non-round conductors. This is 14 pages long, so should be a separate appendix. It shows how to compute a surface current given a volume current. Method is indirect: J→H→K. Now H requires knowledge of all of J, so it is a kind of global concept. Is it DC only?

Section 1 is valid for AC and DC.

Section 2 valid AC and DC and I just linked it to Appendix I, excellent.

Section 3 also AC and DC.

Section 4 is DC only and that is noted.

Section 5 is just a test of the general method for uniform J_z which is DC case only.

Section 6 is another uniform J exercise.

OK, now 11:30 and I have gussied up this new Appendix B to get it ready for installation, it is 15 pages. Added some Maple plots for the round wire. I will save off the existing Appendix B for safe-keeping. Then I will install the new Appendix B. **DONE**!

What OTHER appendix material is still outstanding?

* dielectric spheres
* the Jackson dielectric problem in atomic units.

Question: **How were my two big "King Problems" Resolved?**

1. The $1/4\pi\xi$ issue. I resolved this issue in my Section 1.5 (c). Basically, the issue is that the charge density you want in the integral is n_c instead of n_s due to the way the current boundary conditions work. Then everything comes out right. This took me a very long time to get straightened out.

2. The "applied current" issue. Recall that I kept getting a homogeneous wave equation for A, there was no current there to drive A ! In my original document I just invented J_a to have something to put there, like the Jerry Coates Smart Address Strobe. This complex issue was finally resolved in Section 1.3 (c) where I came up with a unified wave equation for all regions at once, and in that way the conductor current was included. The key here was to using the region 1 King gauge in all three regions. I may be the only person in the world who understands this little detail, I suppose it is possible.

Just added the magnetic parallel equations into the Notes of Section 1.1. μ is permeability, fixed that in several spots.

I have been "reviewing" and marking various word docs in the King folder, due diligence, and these due cause changes in lines doc. When they are all reviewed and marked such, I can then I think continue development of lines doc. I think the above * items are the only other "appendix" that I will add, but maybe I will discover something I forget during my review.

Sat Nov 16, 2013.

Boundary Conditions for A_z

I continued reviewing some doc files. I got to the puzzles one and I noticed that I had quoted from the web that

$$\frac{\partial \vec{A_2}}{\partial n} - \frac{\partial \vec{A_1}}{\partial n} = -\mu_o \vec{K}$$

(1) I decided to look into this a bit, and discovered that I have omitted crucial facts from lines doc. A bit set of facts is

" boundary conditions for the potentials φ and **A** at an interface between two media."

I did the fields, but I never did the potentials!

(2) I also realized that I omitted surface currents in my B boundary condition result.

(3) Something is wrong with my K expression, one way I get μ_1 and the other I get μ_0.

So I now have a new pile of tasks to deal with that were not there yesterday. **Phil's First Theorem:** new tasks can suddenly appear on the stack, old tasks only leave the stack when you process them.

Item (3) above is true, I had K_z wrong in App B, and I am now editing a scratch copy of App B to get this all fixed up. Ouch!

Major Edit of Appendix B

B.1 done, now OK

B.2 is also OK, but maybe I should make clear that $J = J_c$ only here!

B.3 is OK

B.4 is OK but seems redundant since I already did this as an example? Leave for now.

I have to stop here because another bug has been detected.

Nov 16 Disaster:

Section 1.3 (c) where I do the King gauge with the conductors picture! I quote (1.3.3) which has a J sitting in it. This is really $\mathbf{J_c}$ and has no $\mathbf{J_m}$ in it since it came from curl $\mathbf{H} = \partial_t \mathbf{D} + \mathbf{J}$ **!!!** I have a *very bad feeling* about this !!! I feel the ground trembling! I will now create a scratch file and try to repair this very important section.

The J_m and μ issue again, the Nov 16 (2013) Disaster

Yes, the tower has collapsed yet again! In my "repair" of Section 1.3 (c) I end up with

$$(\nabla^2 - \mu_1\varepsilon_1 \partial_t^2 - \mu_1\sigma_1)\,\mathbf{A} = -\sum_{i=2}^{N+1} \mu_i \mathbf{J}_i \qquad \text{all of region R} \qquad (1.3.23)$$

I had been making hay by saying "you must include $\mathbf{J_m}$ when computing **A**", but now it seems that you should *not* include $\mathbf{J_m}$ and that means lots of stuff is going to collapse which depended on this idea.

The first item that comes to mind is Appendix B.6 where I start off with (1.5.4)

$$\nabla^2_{2D}\mathbf{A}(\mathbf{x}) = -\mu_1 \mathbf{J_m}(\mathbf{x}) - \mu_2 \mathbf{J_c}(\mathbf{x})\,. \qquad (B.6.1)$$

But this is no longer what the corrected (1.5.4) says!

I have done a scratch edit of Appendix B, and everything now is completely screwed up. My explanation of how A inside and out does the right thing falls completely apart.

Question: Since **B** = curl **A** and since **B** "sees" $\mathbf{J}_m$, I would think that **A** also ought to "see" $\mathbf{J}_m$.

The rescue may be in using the right μ in the right places! In deriving (1.3.3) *suppose* I start off like this:

curl **B** $= \mu_0(\partial_t \mathbf{D} + \mathbf{J}_c + \mathbf{J}_m)$ " **B** sees all currents" $(1.1.9g)_m$

curl curl **A** $= \mu_0(\partial_t \mathbf{D} + \mathbf{J}_c + \mathbf{J}_m)$

grad div**A** - $\nabla^2\mathbf{A} = \mu_0(\partial_t \mathbf{D} + \mathbf{J}_c + \mathbf{J}_m)$

grad div**A** - $\nabla^2\mathbf{A} = \mu_0(\varepsilon\, \partial_t \mathbf{E} + \mathbf{J}_c + \mathbf{J}_m)$

grad div**A** - $\nabla^2\mathbf{A} = \mu_0(\varepsilon\, \partial_t[-\text{ grad } \varphi - \partial_t \mathbf{A}] + \mathbf{J}_c + \mathbf{J}_m)$

grad div**A** - $\nabla^2\mathbf{A} = \mu_0\varepsilon\, \partial_t[-\text{ grad } \varphi - \partial_t \mathbf{A}] + \mu_0\mathbf{J}_c + \mu_0\mathbf{J}_m$

grad div**A** - $\nabla^2\mathbf{A} = -\,\mu_0\varepsilon\, \partial_t \text{grad } \varphi - \mu_0\varepsilon\, \partial_t^2\mathbf{A} + \mu_0\mathbf{J}_c + \mu_0\mathbf{J}_m$

grad div**A** - $\nabla^2\mathbf{A} = -\,\mu_0\varepsilon \text{ grad } \partial_t \varphi - \mu_0\varepsilon\, \partial_t^2\mathbf{A} + \mu_0\mathbf{J}_c + \mu_0\mathbf{J}_m$

-grad div**A** + $\nabla^2\mathbf{A} = +\,\mu_0\varepsilon \text{ grad } \partial_t \varphi + \mu_0\varepsilon\, \partial_t^2\mathbf{A} - \mu_0\mathbf{J}_c - \mu_0\mathbf{J}_m$

$\nabla^2\mathbf{A} - \mu_0\varepsilon\, \partial_t^2\mathbf{A} =$ grad div**A** $+\,\mu_0\varepsilon \text{ grad } \partial_t \varphi - \mu_0\mathbf{J}_c - \mu_0\mathbf{J}_m$

$\nabla^2\mathbf{A} - \mu_0\varepsilon\, \partial_t^2\mathbf{A} = \text{grad [div}\mathbf{A} + \mu_0\varepsilon\, \partial_t \varphi] - \mu_0(\mathbf{J}_c + \mathbf{J}_m)$ (1.3.3)

Now we have to use a gauge with μ_0 sitting in it, with is a new form for the Lorenz gauge

div**A** $+\,\mu_0\varepsilon\, \partial_t \varphi = 0$ // I suppose ε here is ε_1 for the dielectric

Then I get

$(\nabla^2 - \mu_0\varepsilon\, \partial_t^2)\mathbf{A} = -\,\mu_0\mathbf{J}_c - \mu_0\mathbf{J}_m$

and at least this **A** "sees" both conduction and surface current. This is a different gauge that what I had before! Maybe this is the true King gauge?

What happens to the φ equation if I do this gauge?

E = - grad φ - ∂_t**A** // (1.3.1) [= Jackson (6.9)]

div **E** = - div grad φ - ∂_t (div **A**) // take div of both sides

$\nabla^2\varphi + \partial_t[\text{div } \mathbf{A}] = -\rho/\varepsilon$ // div **E** = ρ/ε [= Jackson (6.10)] (1.3.2)

$(\nabla^2 - \mu_0\varepsilon\,\partial_t^2)\varphi = -(1/\varepsilon)\rho$ // apply gauge choice div$\mathbf{A} = -\mu_0\varepsilon\,\partial_t\varphi$.

OK, If I do all this, I end up with

$(\nabla^2 - \mu_0\varepsilon\,\partial_t^2)\varphi = -(1/\varepsilon)\rho$	[= Jackson (6.15)]		(1.3.4)
$(\nabla^2 - \mu_0\varepsilon\,\partial_t^2)\mathbf{A} = -\mu_0(\mathbf{J_c}+\mathbf{J_m})$	[= Jackson (6.16)]		(1.3.5)
div$\mathbf{A} = -\mu_0\varepsilon\,\partial_t\varphi$.	[= Jackson (6.14)]	// Lorenz Gauge	(1.3.6)

Now the Jackson references are only for vacuum we can still claim agreement.

Let's continue in this vein and see where it leads. I jump now to Repair of Section 1_c_3 doc.

STATUS. Basically I have a complete disaster going on here, and I am not sure things are going to recover, though in past disasters I have managed to find a way out. This disaster is so serious, that I need to start a new doc "nov_16_disaster.doc" to try and get a handle on it. Right now it is just spinning completely out of control. In fact, a whole new folder is needed here. I am shutting down this log for a while and will work there.

Sun Nov 17, 2013

I started off working in my new Disaster log, but then digressed to do more changes in Section 1.1 of lines:

- added integral form involving vector potential A
- changed dA to dS for area
- made pictures for Div and Stokes's theorems
- added stuff for K_z^{free} surface current, analogous to the n^{free} stuff
- added two special case items regarding $\partial_n\varphi$ and $\partial_n K_z$
- gave all the mag stuff its own equation numbers

The equation number references are now all wrong, but I will leave them that way for a while, as I try to continue now in the disaster doc. Good news: in the case $\mu_1 = \mu_2 = \mu_0$ I state that

$(\partial_n A_z)_2 - (\partial_n A_z)_1 = \mu_0 K_z$

and finally I have something that reflects my earlier obscure web quote

$$\frac{\partial \vec{A_2}}{\partial n} - \frac{\partial \vec{A_1}}{\partial n} = -\mu_o \vec{K}$$

so finally this has a solid home in lines doc (except for sign!)

Fri Nov 22, 2013

Well, I found the bug after 5 days of work. It was that there are bulk components of J_m that I was ignoring. I think everything is resolved. I tried by gave up on my little "cloying theorem" and won't use it as I update things.

So there is going to be a massive whole-document review and update, for about the 10^{th} time I would guess. I really need to have the early sections clean before going on. So here we go.

Section 1.1.

opening -- OK

(a) I am removing the following text from Note 6:

Just as a polarization surface charge density is induced on the boundary between two dielectrics when $\varepsilon_1 \neq \varepsilon_2$ by the alignment of (or generation of) electric dipoles in one or both media, so also a magnetization surface current density is induced on the boundary between two magnetic materials when $\mu_1 \neq \mu_2$ by the alignment of (or generation of) magnetic dipoles in the medium of one or both media. This subject will come up in Section 1.3 (c) and is studied in Appendix B.

(a) now OK

(b) OK

(c) OK and done. I cleaned up all the equation number references here.

Section 1.2. Very short, all OK. Not changed by my recent disaster.

Section 1.3. Start here early tomorrow.

Sat Nov 23, 2013

Section 1.3 at 6 AM

(a) OK, no changes needed.

(b) OK, a few additions made

(c) I will work on this section in a separate doc since changes will be major. DONE.

OK, this section is cleaner now, no J_m stuff appears, I like it and will install it right now saving out the old section just in case.

Added figure numbers 1.1 to 1.5 for Section 1.1 through 1.3.

Section 1.4 at 7:40 AM. DONE, very quick, some tie in with Appendix A though.

Section 1.5

(a) OK, maybe later I will box up the resulting equations somehow.

(b) OK regarding Helmholtz integrals, I add the word "particular"

I then added a long comment on Stakgold's Dirichlet solution.

(c) OK, after several iterations through previous subsections, this is now done.

(d) OK, finally!!

This just took forever to do! It is now 5:30 PM!

Section 1.6
(a) OK
(b) OK
(c) OK
(d) OK
(e) OK
(f) OK

My Disaster stuff had no effect on 1.6, and it is just fine as is.

FINALLY, this proofing of Chapter 1 is finished, but I have many miles to go.

Chapter 2. I will do a fast reading of this just to make sure all is OK.
intro section: repaired, it now refers to (1.5.32)

Section 2.1 . Just fine, I like it. Did some cleanups using extra info now present in Chapter 1.

Section 2.2
(a) good
(b) good
(c) fine, just summarizing results
(d) OK, plots for coax a little obscure but fine

Section 2.3
(a) OK, formula for round wire surface impedance.
(b) OP for low frequency limit of Z_s
(c) OK
(d) OK, very low level grunt plots for the round wire [maybe goes in title?]

Section 2.4 DONE, a break for all the heavy stuff.

I am now done (once again) with my Chapter 2 review.

I expect some trouble in Chapter 3 having to do with the presence of homo solutions in my "estimates". But I might first try to forge ahead into the 26" think Krell Metal Chapter 4 which has defied all my efforts at nailing down. Also lots of appendix problems, but we are moving ahead now;

Right off the bat I see the same Chapter 4 trouble arising. Where are the homo solutions?? I say nothing about them because I did not think they were present!!! In King's simple opening example, I don't think he mentions a possible homo solution. Oh boy, more big trouble is on the way. I think I can argue that the far away homo solution might be 0, but even that will take some effort. Things are going to slow down again!

Sun Nov 24, 2013

I need to find and prove a theorem which allows me to use only the particular integral in computing parameters of a transmission line. Here are some candidates:

Theorem: In the dielectric of a transmission line, the entire solution is given by the particular Helmholtz integral and there are no homogeneous solutions at all.

Theorem: Maybe the above is valid only of the total current in the line is 0.

Since this is likely to be a big deal, starting a separate probe doc on the subject.

I did start a separate document, but then I felt the need to clarify my round wire experience. This led to what I am right now calling Appendix M (it will get a new letter). I have gathered there details of the Helmholtz Integral for the round wire, and how it needs those homo terms added to meet the BC. This data used to be in Appendix B and I hope now to never have to look at the retired Appendix B ever again. While doing Appendix M, I added a whole section on finding $A_z(r)$ directly from the ODE, something I never did before. So this appendix shows *three different ways* to compute $A_z(r)$ meeting my A_z boundary conditions, which I now have much more confidence in, and the three ways all give the exact same result. I decided to normalize things so that $A_z = K\ln r$ for r>a without any extra constant hanging around. While there in M, I added a little piece on the magnetization, seemed a good place to put it. I am not sure how this appendix hangs together with my other appendices on the round wire. I do feel this appendix will help me in Chapter 4 by giving me a solid simple case that is perfectly well understood.

I realize that King's work always assumes $\mu_1 = \mu_2$ which he calls μ. So basically his work is only valid for both $\mu = \mu_0$, which is a normal situation. People don't use iron wires much. In this case, I did show that the particular integral DOES meet both boundary conditions!! I might have to back off on my effort to maintain μ_1 and μ_2 different when it comes to Chapter 4. Maybe the argument is that when $\mu_1 - \mu_2$, nothing dramatic happens at the boundary r = a and that is why A and slope A are both continuous there. I should firm up that argument. Signing off at 10:10 PM.

Mon Nov 25, 2013

Today I reviewed yesterday's Appendix M [later G] and found it to be "good". I had planned to explain the fine detail about adding a magnetization sheet to match the boundary conditions, I think I can do that now. But I got distracted on a separate problem.

That problem was to compute the Helmholtz integral for the full Helmholtz equation with a prescribed uniform current source. That is to say, the full exact problem with that source for $\omega > 0$. When I first wrote this yesterday, it had this seemingly intractable form,

$$A_z^H(r) = [I\mu_2/(\pi a^2)]\,(j/4)\int_0^a r'\,dr' \int_{-\pi}^{\pi} d\theta'\, H_0^{(1)}(\beta_1\sqrt{r^2+r'^2-2rr'\cos(\theta-\theta')}) \ .$$

I was just commenting on this fancier problem with no intention of actually doing it, but today I amazingly was able to do the double integral! The result is this:

$$A_z^H(r) = [I\mu_2/(\pi a^2)](j/4)2\pi\ (1/\beta_1)$$

$$\{ J_0(\beta_1 r)\,[a\,H_1^{(1)}(\beta_1 a) - r\,H_1^{(1)}(\beta_1 r)\,] + H_0^{(1)}(\beta_1 r)\,rJ_1(\beta_1 r)\,\} \qquad r < a$$

$$A_z^H(r) = [I\mu_2/(\pi a^2)](j/4)2\pi\ (1/\beta_1)\ \{H_0^{(1)}(\beta_1 r)\,aJ_1(\beta_1 a)\,\} \qquad r > a$$

I first had it wrong when I tried to check the r<a small-β_1 limit against my Chapter 2 solution. I had a sign wrong, and that led to finding a whole pile of errors. The corrected result is above. I was then able to show that the small β_1 limit of the result above is this,

$$A_z^H(r) \approx -[I\mu_2/(\pi a^2)](r^2/4) + [I\mu_2/(\pi)](j/2)\,\{(j)\ln(\beta_1 a) + A\} \qquad r < a$$

where A is some weird thing with the Catalan constant or whatever. But the main point is that the non-constant term exactly matches my Chapter 2 result in the same limit of small β_1 where that Chapter 2 problem really does have a uniform current. This then was a major validity test for my computed Helmholtz potential above.

I think next I should finish the Chapter 2 work by computing the fields outside the wires. Then when that is done, I can do a check on the r > a Helmholtz result above. This is the first Helmholtz integral I have ever computed in my life. And a few days ago I computed my first Poisson integral.

I also am wondering about the meaning of this fancy problem with constant current and how that compares to the problem of Chapter 2.

I think today's stuff will help a lot in Chapter 4 since the same stuff and limits are involved.

Tues Nov 26, 2013 // the Appendix D digression began about this time.

Chapter 2, wave on coax comments added, lots of edits, Nov 26, 2013

Time to finish up on the round wire analysis of Ch 2 by adding the outside solution. What I do now is this

2.1 play around inside the round wire after making a set of assumptions. I get the Bessel equation after a while. I am using no-subscript for conductor values. Summary is in (2.1.26) for E and B in terms of simple Bessel functions, although they have that Kelvin phase.

2.2 Here I rewrite E(r) in terms of the Kelvin functions and get into the M and θ versions of these functions which let you plot magnitude. I have good plots and there is the skin effect. Then I write both the E and B field in terms of these functions ber_0 and ber_1 and also I write the ratio. I then get the results out into the time domain. I then do plots for Belden 8281 of these three quantities just listed.

2.3 I am then off on the subject of surface impedance which I see now is the ratio E(a)/B(a). I get this into a ratio first of J's and then of the Kelvin functions. I take the low and high frequency limits. I then plot Z_s versus skin depth, not sure why I do this. It just shows that when the skin depth is small, impedance is high, as you would guess.

2.4 I then have qualitative comments about Z_s for a transmission line. Again, not sure why I do this, it is sort of a side issue. I examine the Z_s of a conductor in a line.

Now my goal is to add section 2.5 which gives a unified treatment of the interior and exterior solution. This has long been missing. I will do this now in a separate doc. // Am battling along, slow going.

Question: Why do I say Lorenz gauge for E and B wave equations (1.5.26). They don't know about gauge. OK, I fixed that up.

Status 6:30 PM. I got the new section roughed in, that is, I have done all the work but it has to be rewritten in a presentable way, it took some doing. I did some code to plot things inside and out, started at them for while, I think it is all there. I guess this wire is radiating and that is the E and B pattern maybe. Don't want to get off into that subject right now. Tomorrow I will try to do a formal writeup of all this stuff, that will probably take another whole day.

Weds Nov 27, 2013

Question: Is there a wave going down my wire in Chapter 2? I say nothing at all about this important question in Chapter 2. In Appendix D I start off with the wave assumption.

$$\mathbf{E}(r,\varphi,z,t) = e^{j(\omega t-\beta_d z)}\,\mathbf{E}(r,\varphi)\ . \qquad \text{(D.1.2)}$$

where now both t and z dependence are shown. But how do I know that β_d = dielectric? Suppose I just assume this at the start

$$\mathbf{E}(r,\varphi,z,t) = e^{j(\omega t-kz)}\,\mathbf{E}(r,\varphi)\ . \qquad \text{(D.1.2)}$$

If I say that k is very small, then it just has little effect and then Chapter 2 is correct because all ∂_z derivatives will be very small. But am I free to make k be small?

What would the correct wire solution look like? I guess I have not done this problem. I suspect the drag of loss in the wire would change k from its dielectric value β_1.

How did Appendix D work when I made this assumption that $k = \beta_1$ right in the starting (D.1.2)?
Section D.1

(a): just PW expansion, no use of β's.

(b) here I assumed β_d in the wave exponent, but I assume β conductor in the wave equation inside the wire.

OK, there must be some reason that k really is the dielectric β_d, but I have not yet found it. There is a wave equation outside the wire that contains β_d so it seems that you would have a different wavelength inside versus outside the wire! We have a wave velocity inside and outside, but inside it is some complex number thing controlled by β and I don't even know what that means! Well let's review that:

We start with this undamped wave equation

$$(\nabla^2 - \mu\varepsilon\,\partial_t^2)\mathbf{E} = \mu\partial_t\mathbf{J} + (1/\varepsilon)\,\text{grad}\,\rho \qquad \text{(1.2.1)}$$

and then when we "absorb" the current using $J = \sigma E$ it becomes the damped equation

$$(\nabla^2 - \mu_2\varepsilon_2\,\partial_t^2 - \mu_2\sigma_2\partial_t)\mathbf{E} = 0 \qquad \text{or} \qquad (\nabla^2 + \beta_2^2)\,\mathbf{E} = 0$$

Since σ_2 is so large, this is basically a decay equation, not a wave equation. What is the solution to this equation in the round wire where we assume $\mathbf{E} = E(r)\hat{\mathbf{z}}$ **?** It is this:

$$E(r,\omega) = E(a)\,[J_0(\beta_2 r) / J_0(\beta_2 a)]$$

Back in the time domain this says

$$\mathbf{E}(\mathbf{x},t) = E_0\, e^{j\omega t}\, \frac{\mathrm{ber}_0[r\sqrt{\omega\mu\sigma}\,] + j\,\mathrm{bei}_0[r\sqrt{\omega\mu\sigma}\,]}{\mathrm{ber}_0[a\sqrt{\omega\mu\sigma}\,] + j\,\mathrm{bei}_0[a\sqrt{\omega\mu\sigma}\,]}\,\hat{\mathbf{z}} \qquad (2.2.14)$$

Where is the "wave" here? Well, consider this 1D side problem:

$$(\partial_x^2 - \alpha\partial_t)\, f(x,t) = 0$$

Assume a wave solution of the form

$$f(x,t) = e^{j(\omega t - kx)}$$

Insert this to get

$$(k^2 + j\omega\alpha) = 0 \qquad \Rightarrow \qquad k = \pm[\,j - 1]/\sqrt{2}\ * \sqrt{\omega\alpha}\ = \text{our usual } \beta \text{ thing}$$

Then here is what the wave looks like

$$f(x,t) = e^{j\omega t} \exp(-(\pm)jx\ [\,j - 1]/\sqrt{2}\ * \sqrt{\omega\alpha}\,)]$$

$$f(x,t) = e^{j\omega t} \exp(-j(\pm)x\ [\,j\,]/\sqrt{2}\ * \sqrt{\omega\alpha}\,) \exp(-j(\pm)x\ [\ -1]/\sqrt{2}\ * \sqrt{\omega\alpha}\,)$$

$$f(x,t) = e^{j\omega t} \exp(+(\pm)x\ /\sqrt{2}\ * \sqrt{\omega\alpha}\,) \exp(jx(\pm)\ /\sqrt{2}\ * \sqrt{\omega\alpha}\,)$$

$$f(x,t) = e^{j\omega t} \exp(\pm x\ /\sqrt{2}\ * \sqrt{\omega\alpha}\,) \exp(\pm jx/\sqrt{2}\ * \sqrt{\omega\alpha}\,)$$

$$f(x,t) = e^{j\omega t} \exp(\pm x/D) \exp(\pm jx/D)$$

What does this say? It says that the wave damps out in distance D during which time the "wave" succeeded in doing $\pi/2$ of phase change. This is what I mean by "it is a damping equation instead of a wave equation".

So inside the wire the solution to the wave equation is basically that skin depth radial damping which happens in 1/4 of a radial wave.

Let's try this again. *Outside* we have

$$(\nabla^2 + \beta_d^2)E(r,\theta,z) = 0$$

and we find a separated solution of the form

$$E(r,\theta,z) = e^{-j\beta dz}\, E(r,\theta)$$

where then

$$(\nabla^2_{2D})E(r,\theta) = 0 \ .$$

and so the residual E is just a Laplace field solution. On the other hand, *inside* we get

$$(\nabla^2 + \beta^2)E(r,\theta,z) = 0$$

If we try a solution of the same form

$$E(r,\theta,z) = e^{-jkz}\, E(r,\theta)$$

we get

$$(\nabla^2_{2D} + \beta^2 - k^2)E(r,\theta) = 0$$

But since β^2 is so large, this roughly says

$$(\nabla^2_{2D} + \beta^2)E(r,\theta) = 0$$

which gives the solution of strong radial decay in from the perimeter of the wire. Now in this case, what determines the constant k ? It seems than any small k will work just fine. If we go to the boundary r = a, we find that

$$E(a,\theta,z) = e^{-j\beta dz}\, E(a,\theta) \qquad \text{// outside}$$
$$E(a,\theta,z) = e^{-jkz}\, E(a,\theta) \qquad \text{// inside}$$

It seems then that $k = \beta_d$.

Now where should I be saying all this?

OK, here is what I did.

(1) added a new section near the start of Chapter 2 which puts Chapter 2 into the wave on wire context.
(2) this same section *replaces* the later inserted digression on the 1D explanation of the skin effect, so I remove that later digression section.
(3) this new section also explains why the wave has $k = \beta_d$ as assumed in Appendix D

I think this is a very major clarification of many things. I will insert right now and then ponder what to do about equation numbering in Chapter 2.

OK, here goes a set of instructions to make room for a new Section 2.1 at the start of Chapter 2.

1. Replace all (2.4 with (2.5 : DONE
2. Replace all (2.3 with (2.4 : DONE and lots of them (globally!)
3. Replace all (2.2 with (2.3 : DONE
3. Replace all (2.1 with (2.2 : DONE

This was a huge change. I will save a copy of this thing before I did all this just in case.

Now change the section headings and I can now number equations in the new Section 2.1 ! It was worth having this major stuff be in its own opening formal section.

Bug: I claim that

If β_d has a small negative imaginary part due to conductivity of the dielectric (see (1.5.1)), the factor $e^{-j\beta_d z}$ says that the wave slowly damps out as it travels down the wire due to dielectric ohmic loss, as it well should.

However, I worked hard to show that β_d has a *positive* imaginary part to make the $H^{(1)}(\beta_d r)$ function decay for large r! That was in Appendix I and somewhere I even drew a picture. I think I will throw out this argument in my Section now 2.6 and have that phase stuff only apply inside the conductor. Then when one writes $\beta^2 = \mu\varepsilon\omega^2 - j\omega\mu\sigma = \omega^2\mu(\varepsilon - j\sigma/\omega)$ the above makes sense. Resolved.

Status at noon: Chapter 2 is fully updated with all these changes and is thus "improved" I think.

Next task: read through all of the rest of Chapter 2 so that the added section 2.6 will "know" what has been said just before!

_____ elided digression that was in Chap 2 _____

Digression on cause of the skin effect. Before continuing, we can show generically how it is that the Helmholtz equation causes skin effect by considering (2.2.12) in one dimension, say x. Then the equation reads $(\partial_x^2 + \beta^2)E_x = 0$ which has the solutions $\exp(\pm j\beta x)$. Since $\beta = (j - 1)\sqrt{\omega\mu\sigma/2}$ these solutions are

$$\exp(\pm j(j - 1)\sqrt{\omega\mu\sigma/2}\, x) = \exp(\mp\sqrt{\omega\mu\sigma/2}\, x)\exp(\mp j\sqrt{\omega\mu\sigma/2}\, x) .$$

If we are interested in $x \geq 0$ with $E_x = 0$ at $x = +\infty$, then we must take the - solution so

$$|E_x(x)| = |E_x(0)|\exp(-\sqrt{\omega\mu\sigma/2}\, x) = |E_x(0)|\exp(-x/\delta) \qquad \delta = \sqrt{2/(\omega\mu\sigma)} .$$

Since $J_x = \sigma E_x$, this means $|J_x(x)| = |J_x(0)|\exp(-x/\delta)$ so the current density decays as $e^{-x/\delta}$ as we move away from x = 0.

Thus it is really a combination of the Helmholtz equation, the complex nature of parameter β^2, and the boundary condition that causes exponential decay of $E_x(x)$ with characteristic distance δ which will appear below as the "skin depth". In the round wire, the reference point will be r = a, and the boundary condition will be that E be finite at r = 0.

STOP! My new section 2.1 just blew a fuse! I end up with $\nabla^2_{2D}\,\mathbf{E}(x,y,\omega) = 0$ outside the wire which is completely wrong! The right equation outside the wire is $(\nabla^2_{2D} + \beta_d^2)\,\mathbf{E}(x,y,\omega) = 0$ (isn't it?).

Sisyphus Paradox of the Day 11_27_13.

I will write down this paradox in a separate document of that title. We are now back in complete shutdown status till and if this can be resolved.

So I wrote this up in "Sisyphus paradox for 11_27.13.doc" to document the paradox. After that, I wrote "rewrite of section 2_5.doc" to try and treat the region 1 part of the round wire problem differently. But that then led to another paradox which is that I get E and B expressions which satisfy one Max curl equation, but violate the other one. So things are really at a full dead stop and maybe drifting backwards. Too bad because I had hoped to get some kind of stability before Tgiving and before December. Things do NOT want to stabilizes in lines doc, that is for damn sure. I have about 500 sticks in the sand and am trying to make sure they are all consistent with each other.

Thurs Nov 28, 2013 Tgiving Lament

Will try to reconcile the 2nd paradox above in the rewrite doc. // now 3:30 PM. Things are in a weak state right now. I had to create a new folder "Meaning of Chapter 2" and a file of that name. This is turning out to be a nasty problem indeed. Right now the calculations of Chapter 2 are just blind math and have no connection to any kind of real wire situation and I hope to remedy that! I developed an approximate combined interior and exterior solution within the Chapter 2 assumption set which violates 2 Maxwell equations, but I went ahead and finished it, correcting Doc 2.5 where I did the exterior incorrectly.

Along the way today I realized that the interior Ch 2 solution determines E(a) and E(b) which I had formerly left as unknown constants. So now the Ch 2 summary box gives exact internal solutions in terms of the current I as a sort of boundary condition. For some reason, the exterior situation has no effect on the interior solution, unlike many boundary value problems. In my Doc 2.5a doc (not real name, see Meaning doc) the exterior is just a sort of "tack on" exterior solution, it is the tail on the dog.

I am concerned that I may have improperly handled "z dependence" in my work with the potentials φ and A_z, I hope not. This relates to 3D versus 2D potential wave equations. It could get very ugly indeed and then most of what I have done for the 2 months is down the loo. When you make a mistake right at the very start, everything downstream is affected. *********

It is time for a walk and then shower and then Tgiving Janet house, [last Sandra Taylor] so I guess this will just have to wait until next time. My hopes of getting this done pre Cod are now lost. It cannot happen, there are too many wrong things in my lines doc, strewn in many sections. That I guess is just the way "research" goes. You have your ups and downs, and lately I have had a slew of all downs with the calendar running out. I have to do the December Duties in many areas all of which take time away from resolving this painful set of issues: MRL stocks, Xmas shop, Xmas cards, Honda emissions, taxes,

contributions, AARP payment, HSA adjustments. Meanwhile, reading, languages, music, piano, general relativity, socialite are all completely shut down. We have a complete saturation of CPU cycles, nothing else can get done until this lines App is finished executing. I could kill it, which is to say I could just give up, but that is not a hand I will play. One problem is that as December drags on, I forget all the details of lines doc and I have to start my review over again for the 14th time.

Fri Nov 29, 2013

Did a lot more inside the "Meaning of Chap 2" doc. I think I have given the Chapter 2 "meaning" by making the round wire be part of a coaxial cable. I did a lot of Appendix D work here and may move it to some other working doc. The m = 0 part of Appendix D is fine, but the tail end where I compute the values of a_m and K_m now seems very wobbly because I cannot justify one of my BC's. So I need to attend to that mystery which is tied in with computing the corresponding Appendix D B fields and then showing that these App D E and B fields satisfy all four Maxwell equations, and if they don't, then why is that? Also I am still looking for an exterior solution for the round wire in the m = 0 case at first, and perhaps later for any m. The stack of tasks is very full and more keep piling on! It is an exponential explosion I fear that will take an infinite amount of time to resolve. But at least we how have "Chapter 2 meaning". Signing off at 8:30 PM.

Sat Nov 29, 2013

Appendix D work, Nov 29, 2013

Today, first for m = 0 and then for m = m, I computed the corresponding Appendix D B fields, and I showed that all four Maxwell equations are satisfied exactly with no assumptions. This was a big deal for me, and I think also helps to verify my Appendix D E-field results in the first place. I also did a lot of algebra check on them today. This was all done with K_m and a_m just left as undetermined constants. This work was done in Actions 1 v2 (for m = 0) and then Actions 2 (for m = m). I was amazed that this all worked.

The next issue is pondering how those K_m and a_m values will get set! For my coaxial cable Chapter 2 situation, we only have m = 0, so in that case I ought to be able to come up with external field expressions! The internal fields by the way are

$$E_z(r,m) = -j\,(\beta'/\beta_d)\,\frac{K_m}{2}\,J_m(x) \qquad x = \beta' r$$

$$E_r(r,m) = a_m\,x^{-1}\,J_m(x) + \frac{K_m}{2}\,J_{m+1}(x)$$

$$jE_\varphi(r,m) = -\,a_m\,x^{-1}\,J_m(x) + \left(\frac{K_m}{2} + \frac{a_m}{m}\right) J_{m+1}(x)$$

$$B_z = (1/\omega)\,\beta'\,\left(\frac{K_0}{2}\right)J_0(x)$$

$$B_r = j\,(1/\omega)\beta_d\,\left(\frac{K_0}{2}\right)J_1(x)$$

$$B_\theta = (1/\omega)\,\beta_d \frac{K_0}{2}\,(1 + \beta'^2/\beta_d^2)\,J_1(x)$$

I am now suspicious of my "arbitrary" $C_{\varphi 0}$ constant in the E_φ equation. I said a step was invalid, but now I think it is not invalid. Even if m = 0, I can insert (D.2.2) into (D.2.1) by replacing a 0 by an expression which is zero, no harm done. So then (D.2.3) is OK for m = 0.

What about the divide by m to get (D.2.15)? That is perhaps dubious, but suppose we jump over to (D.3.3) where I am working directly with the φ Helm equation. If I solve this thing alone, yes I will get that arbitrary $C_{\varphi 0}$ coefficient.

I just made a v2 of the Maple program and replaced the am/m term with 0 AND I multiplied the E_φ function that results by an arbitrary constant q. This adds a factor of q to both the B_z and B_r fields, and the four Maxwell's are still all satisfied. Then what you have in the starting blocks is this

$$jE_\varphi(r,0) = q\,(\frac{K_0}{2})\,J_{m+1}(x)$$

You could set q = 0 or q = 1 or whatever you want, and you get a viable set of E and B. So in that sense, the $C_{\varphi 0}$ coefficients really can be set arbitrarily, I was right about that. So this is another BV issue.

```
collect(expand(Bz),J);
```

$$\frac{1}{2}\frac{q\,Km\,bp\,J(0,bp\,r)}{w}$$

```
collect(expand(Br),J);
```

$$\frac{1}{2}\frac{j\,bd\,q\,Km\,J(1,bp\,r)}{w}$$

```
collect(expand(Bth),J);
```

$$\left(\frac{1}{2}\frac{Km\,bd}{w}+\frac{1}{2}\frac{Km\,bp^2}{w\,bd}\right)J(1,bp\,r)$$

You might expect that a large q would add an azimuthal current flow on the wire which ought to increase the B_z field and you see it does.

I think this issue really is that there is an azimuthal wave you can superpose onto your solution and it will run down the coaxial cable just fine. In fact, in v 3 I set E_z and E_r = 0 and have just my E_φ field with the q multiplier. In this case here are the fields

$$Eth := -\frac{1}{2}j\,q\,Km\,J(1,x)$$

$E_\varphi = -j\,q\,(K_0/2)\,J_0(x)$

$E_r = 0$

$E_z = 0$

```
collect(expand(Bz),J);
```

$$\frac{1}{2}\frac{q\ Km\ bp\ \mathrm{J}(0,\ bp\ r)}{w}$$

```
collect(expand(Br),J);
```

$$\frac{1}{2}\frac{j\ bd\ q\ Km\ \mathrm{J}(1,\ bp\ r)}{w}$$

```
collect(expand(Bth),J);
```

$$0$$

and again all Maxwell's are satisfied. So this is a legal stand-along azimuthal wave you can send right down the coax cable all by itself. This wave really can exist! And in my work I will of course therefore set it to zero and not superpose this complexity on the m = 0 problem!

In v 4 I set $E_\varphi = 0$ and these are the B fields that come out (where Km means K_0)

```
collect(expand(Bz),J);
```

$$0$$

```
collect(expand(Br),J);
```

$$0$$

```
collect(expand(Bth),J);
```

$$\left(\frac{1}{2}\frac{Km\ bd}{w}+\frac{1}{2}\frac{Km\ bp^2}{w\ bd}\right)\mathrm{J}(1,\ bp\ r)$$

.

so no doubt the second term here which dominates gives the Chapter 2 result. Here are the corresponding E fields

```
Ez := -j*(bp/bd)*(Km/2)*J(m,x);
```

$$Ez := -\frac{1}{2}\frac{j\ bp\ Km\ \mathrm{J}(0,\ x)}{bd}$$

```
Er := am*(1/x)*J(m,x) + (Km/2)*J(m+1,x);
```

$$Er := \frac{1}{2}Km\ \mathrm{J}(1,\ x)$$

```
Eth := 0;  # set to 0 to not add in the azimuthal wave superposed problem
```

$$Eth := 0$$

So this gives a nice m = 0 solution similar to Chapter 2, but we do have the E_r field and we do have some tiny additional stuff in the B_θ result. So this would be a nice field set to maybe work up a new subsection either in App D or Chapter 2.

OK, so you then would have

E_z = something
E_r = small something
$E_\varphi = 0$

$B_z = 0$
$B_r = 0$

B_φ = something

How then would you glue on the external problem for this coaxial cable?

(1) B_φ is a tangential field so with no free surface current

$(1/\mu_2)B_{\varphi 2} = (1/\mu_1)B_{\varphi 1}$

(2) E_z is a tangential field so

$E_{z1} = E_{z2}$

(3) The E_r field generates some charge on the surface I can compute. I then know E_{r1}

So there I am in the exterior region where I know E_{z1}, E_{r1} and $B_{\varphi 1}$. All I then have to do is satisfy the homogenous Helm for E and B out there with attention to $r = \infty$ and that should give the exterior solution. I will save this for manana.

So I think I have a solid grip on the m = 0 world. For m > 0 I am still perplexed at how the values of K_m and a_m would be set. These are "wave modes" for a round wire that are not axially symmetric and I imagine that these modes would activate in say a twin lead problem! But it is very unclear to me how that would all work! If I had an operating twin lead line, how would I compute the coefficients?

I am still facing a big mystery question: I am pretty sure we want a constant potential around the periphery of a transmission line conductor, even if it is not a round wire. For the round wire case, that would impose a boundary condition which says "no swirling at the surface", though swirling would occur inside the wire in each mode. I am having trouble justifying such a boundary condition.

Sun Dec 1, 2013

Resolved the issue of why $E_\varphi = 0$ on the surface of a round wire which is part of a trans line. This then enables appendix D's tail end to work right. Then started a full rewrite of that appendix which took all day and I did not get done. Added the B field stuff and the Maxwell equations proof.

Mon Dec 2, 2013

Reviewed and tuned D.1, it is all very good, added a picture. Holding on the opening section though till I am all done.

Reviewed D.2, all the equation numbers were messed up, it is fixed, it is a reasonable section which takes on a complicated problem.

Reviewed D.3, updated internal eq num references, a reasonable section. Main thing is that it reinforces the idea that my solutions don't have errors in them!

Tues Dec 3, 2013

Question: In (D.1.2) can I really take **E**(r,φ) to be real? That would mean it always has a zero time phase shift in the sense of Chapter 1.6, all three components! In Chap 1.6 I said this

$$\mathbf{E}(\mathbf{x},t) = e^{j[\omega_1 t+\varphi(\mathbf{x},\omega_1)]}\, \boldsymbol{e}(\mathbf{x},\omega_1) \;=\; e^{j\omega_1 t}\, e^{j\varphi(\mathbf{x},\omega_1)}\, \boldsymbol{e}(\mathbf{x},\omega_1) \;, \tag{1.6.5}$$

where $\boldsymbol{e}(\mathbf{x},\omega_1)$ was real. Maybe even this is not general enough, because it forces all three components of the **E**(**x**,t) field to have the same phase! But then I say

$$\begin{aligned} \mathbf{e}(\mathbf{x},t) &= \mathrm{Re}\{\, \mathbf{E}(\mathbf{x},t)\} = \cos[\omega_1 t + \varphi(\mathbf{x},\omega_1)]\, \boldsymbol{e}(\mathbf{x},\omega_1) \\ \mathbf{e}'(\mathbf{x},t) &= \mathrm{Im}\{\, \mathbf{E}(\mathbf{x},t)\} = \sin[\omega_1 t + \varphi(\mathbf{x},\omega_1)]\, \boldsymbol{e}(\mathbf{x},\omega_1) \quad . \end{aligned} \tag{1.6.6}$$

and again all three components have the same temporal phase. This now seems wrong to me because one direction might be "resistive" and another direction "capacitative" in some problem, and then you would expect different phases!

OK, I have dealt with this whole issue in "rewrite Section 1_6.doc", see Comments in the new section. I now regard (1.6.5) as just an ansatz form, not a most general form. This also resolves the question in appendix D of whether **E**(r,φ) is real or not. Part of the ansatz is that it is assumed real!

So I may now proceed to Section D.4.

Question returns: Why is that in Appendix D I assume **E**(r,φ) is real, whereas in (2.3.16) and (2.3.17) I obtained things like

$$\mathbf{E}(\mathbf{x},t) \;=\; E_0\; e^{j\omega t}\; \frac{\mathrm{ber}_0[r\sqrt{\omega\mu\sigma}\,] + j\,\mathrm{bei}_0[r\sqrt{\omega\mu\sigma}\,]}{\mathrm{ber}_0[a\sqrt{\omega\mu\sigma}\,] + j\,\mathrm{bei}_0[a\sqrt{\omega\mu\sigma}\,]}\,\hat{\mathbf{z}} \tag{2.3.14}$$

This would seem to conflict with Appendix D's assumption that

$$\mathbf{E}(r,\varphi,z,t) = e^{j(\omega t-\beta_d z)}\, \mathbf{E}(r,\varphi)\;. \tag{D.1.2}$$

where **E**(r,φ) is real! If I were to just set z = 0 in (D.1.2) I get

$$\mathbf{E}(r,\varphi,z,t) = e^{j(\omega t)}\, \mathbf{E}(r,\varphi)\;. \tag{D.1.2}$$

and then **E**(r,φ) is most definitely NOT real! I know that the phase of **E**(r,φ) is going to be a function of r, so that is just plain wrong! So once again I have to repair App D (a). I already did this once and then undid it and now I am doing it again. I now assume that **E**(r,φ) is complex so I cannot wrote out the simple cos and sin series as I did before.

Then what about n(φ)? This question has now ballooned out into yet another Major Issue! I first tried to resolve it quickly here, but that was not possible, so we are now off in "What is the nature of n(φ).doc"

Weds Dec 4, 2013

The n(φ) issue is now resolved and I am now resuming at the start of D.4 where I left off.

At 7 PM I am now through section D.6 where I show the exact fields for the m = 0 case and I obtain a match to Chapter 2 (thank goodness). I decided to throw out (archived) my low ω limit of the field result because this App D is already too long and I don't care about that limit.

I now have to finish off this Appendix with a few extra items. I just hope it doesn't blow up on me again! I doubt the literature contains this exact solution in any easily found place. Probably it was done soon after Maxwell's work in early 1880's.

Thurs Dec 5, 2013

I am going to pause to review my various paradox docs to make sure all is OK.

Since **E**(**x**,ω) is a completely different complex function from **E**(**x**,t), one really should use some notation like $\mathcal{E}$(**x**,ω) or **E**^(**x**,ω), but we trust the reader to make the distinction when the ω argument is present or in the general context of some discussion. -- just some saved text

I did not get far! I have decided to alter Section 1.6 with local ^ notation and to clearly state at the end that I am using overloaded notation. Also, I decided to change Section 1.6 by giving each component a different phase, since that is what will really happen in the round wire.

I can now resume my review of the various working docs. When they all say REVIEWED in their file names, then I can move forward again. // All docs in the App D Work folder are now reviewed and so marked. Nothing in these docs about "outside the wire" fields solutions. It is now noon 12.5.13.

Note: in a capacitor, C and R are related regardless of cross sectional shape. This should be expressed somewhere in lines doc ******* . [It is C and G that are related] I thought it was there, but cannot find it. Recall that there is a generic way to describe this as I have seen in Marriott books. Perhaps Chapter 4 is the place it should be, but I am not there yet! Still laying the foundation, yawn.

As of 5:30 PM I have reviewed all Word docs in the general Transmission Lines folder and in the Appendix B folder. And then at 6:00PM I finished also reviewing the things in "meaning of Ch2". So I am done with my due diligence and it is time to move forward again. Pub is at 7.

Fri Dec 6, 2013

I spent this day trying to find an exterior solution for my round wire in mode m, so to speak. This was done in doc "exterior solution". It caused my E_{φ}(r=a) boundary condition to wobble once again. Spent all day on this, trying to match inside and outside fields at the boundary and all that good stuff. I was not successful, though I tried various methods.

Regarding E_{φ} , I am now confused by a simple question.

Question: Suppose there is a surface current on a metal surface because some surface charge is moving on the surface. Is there a tangential electric field associated with that current? If so, how big is it? If there is no electric field causing this motion, then what is causing the motion of the surface charge?

I sort of know that $J = \sigma E$ in a bulk material, but I don't now how to do it for a surface current. I think that E_z is continuous through the surface, but maybe that is wrong if there is a surface current.

I did a little whiteboard work on this question which involved the velocity v of the surface charge moving in the surface layer. I guess I will someday resume here, but not for a while.

Fri Dec 13, 2013

A lot has happened in the last week, but the $E_\varphi = 0$ boundary condition remains the sticky wicket.

Dec 7 -- did my RLS report, no lines work
Dec 8 -- geometry: played with Maple and my weird parametric equations for an ellipse
Dec 9 -- continued with ellipse thing, had lots of trouble with it
Dec 10-- confusion about ellipse as intersection of surfaces.
Dec 11 -- due diligence review of all this geometry, calculus, surfaces and Maple, cleaned up all OK
Dec 12 -- resumed on the E_φ problem.

Here is my basic problem. If I argue the $E_\varphi = 0$ basic on the quasi-static charge motion argument. then that same argument should cause $E_z = 0$ as well. But $E_z \neq 0$ because it is a continuation of E_z inside the wire at the surface where we know there is some J_z so there must be some E_z. This E_z is thus part of the wave motion driven by a current. As a result, field lines coming in at the wire are not quite perpendicular to the wire in the z direction. This means that the cross sectional mesh of E,B field lines connecting the transmission line conductors is slightly warped out of a z = constant plane.

It seems reasonable then that there could be modes of the transmission line in which E_φ is similarly driven by a current that is an indispensable part of the wave motion. This could be caused by a special apparatus driving the transmission line which forces counter-rotating azimuthal currents on the two conductor surfaces and then this azimuthal current pattern flows down the wire at the dielectric speed of light. Whether such torsional modes exist is unclear, but they would seem to satisfy the Maxwell equations as shown above. One could then superpose such a torsional mode solution onto a conventional transmission line TEM solution, and conversely, one could assume that the usual TEM solution has not such azimuthal wave component and therefore $E_\varphi = 0$ at the round wire surface.

So right now in my "working copy" of Appendix D I am more or less "OK" through the end of D.5, though the opening section needs modification. I have referred the $E_\varphi = 0$ assumption to its own separate D.n section which I will soon write and add. But there are some other sections there right now which I want to peruse first.

Review existing D.6: What about E fields outside the wire?

OK, I just updated this with my latest data and make the point that the solution is intractable. So I think I can leave this section in there, after having updated it.

Review existing D.7. I made a huge mistake right at the start, I archive that incorrect section right here. I think I should just throw this out and not mention potentials at all in this Appendix. Done! The Appendix is way too long even without this.

D.7 What about φ, A and B ?

Inside the conductor, we know that potential φ satisfies (D.1.1), and we know that φ at r=a does not depend on angle φ. [but φ for r < a can depend on angle φ, so this is all wrong] This means that φ is similar to our E_z solution in the m=0 partial wave, and vanishes for all higher partial waves. Thus we write

$$\varphi(r,m) = \delta_{m,0}\ \varphi_0\ J_0(x)/J_0(x_a) \qquad x = \beta' r \qquad \text{(D.7.1)}$$

where φ_0 is the value of the potential on the surface at r=a. Since we know **E**(r,m) from Section 3 (6), we can solve for the vector potential **A** as follows:

$$-j\omega\mathbf{A} = \mathbf{E} + \text{grad}\ \varphi \qquad \text{(D.7.2)}$$

Converted to partial waves, this says

$$-j\omega A_r(r,m) = E_r(r,m) + \delta_{m,0}\ \partial_r\varphi(r,0)$$

$$-j\omega A_\varphi(r,m) = E_\varphi(r,m) - (1/r)\ jm\ \delta_{m,0}\ \varphi(r,0) = E_\varphi(r,m)$$

$$-j\omega A_z(r,m) = E_z(r,m) - j\beta_d\ \delta_{m,0}\ \varphi(r,0) \qquad \text{(D.7.3)}$$

Thus, for m≠0 we have $-j\omega\mathbf{A} = \mathbf{E}$. For m = 0 there are extra pieces as shown for $A_r(r,0)$ and $A_z(r,0)$.

Since **A**(r,m) is known, **A**(r,φ,z) is also known, and then so too is **B** = curl **A**. This curl can also be performed in each partial wave if desired by replacing $\partial_\varphi = -jm$ and $\partial_z = -j\beta_d$ as usual.

Since $-j\omega\mathbf{A} = \mathbf{E}$ in the higher partial waves, we may conclude that the transverse components of **A** are small compared to the longitudinal component, just as is the case for **E**, see (D.3.6). For m=0 we know that $A_\varphi = E_\varphi = 0$, but A_r is a combination of E_r and $\partial_r\ \varphi$ which is *not* small compared to A_z, due to the $\partial_r\varphi$ contribution.

Thus, we arrive at the conclusion that, although A_r is negligible in the dielectric, it cannot be ignored inside the conductor. This explains, incidentally, the problem one encounters with the gauge condition (1.5.5) div**A** = $-j(\beta^2/\omega)\varphi$. Since φ is continuous at the boundary, and β^2 takes a jump of many orders of magnitude (from β_d to β'), something on the left side must change violently. But A_z is also continuous. It is the m=0 A_r inside the conductor that takes up the slack. In fact, taking the difference inside minus outside we conclude that

$$\partial_r A_r\ (r=a-\varepsilon) = -j(\beta'^2/\omega)\varphi_0 \qquad \text{(D.7.4)}$$

from which we can determine φ_0 The potential A_r is discontinuous at r=a.

So now all I have to do is write D.7 where I try to justify the $E_\varphi = 0$ boundary condition. Then maybe I will be done with monster Appendix D.

7PM. I have finally written D.7, it was painful but it is the best I can do. I added some of my mystery questions as a reader exercise. I will now install this into my App D working copy.

Here are some items I am removing from the Appendix D introduction:

2. It is possible to maintain the condition $E_\varphi = 0$ on the wire surface. This condition is consistent with the idea that the wire surface is an electrical equipotential at any constant z.

-- that was my fudge statement since I didn't really know what to say

4. We suggest a method for computing the E fields in the "transmission line limit" of a transmission line consisting of round wires. First, solve the "electrostatics" problem illustrated in Chapter 6. Knowing the potential φ, compute the radial electric field at the surface of the conductors. From this compute the surface charge density n(φ) as a function of azimuth around the wire. Then, as described below, compute the moments N_m (or η_m) of this charge distribution, and use the formulas below to find the electric field.

-- too complicated for my little intro and I only just touch on this subject in Appendix D.

OUCH. While reading the App D intro, I see major screw ups, confusing Helmholtz and wave equations together. I hope this cleans up without a major problem!! Signing off at 8 PM.

Sat Dec 14, 2013

Well, tempest in teapot, I have cleaned up the start of App D. I am removing this text since it has been expanded in D.8 in much detail.

A second assumption is that the potential on the surface of the wire at any z = constant plane is a constant. For the round wire, this cross-section surface is a circle, and perhaps we give it a little depth dz along the conductor. Since the wire surface supports free charge, if the wire surface has some $E_\varphi \neq 0$, this free charge would very quickly adjust itself in such a way as to neutralize E_φ. In (3.1.5) we estimate the time for this to happen for a copper wire to correspond to 10^{19} Hz, so for any practical transmission line the field situation at a point on the wire surface is essentially static relative to this fast time constant, and E_φ must then be 0 on the surface. Since there is no free charge *inside* the wire (see Section 3.1), this argument does not apply below the surface, and in fact we shall find a non-zero E_φ field inside the wire.

One might wonder why this same effect does not also neutralize E_z at the wire surface. In this direction things are different. The whole free surface charge pattern moves down the conductor at the speed of light in the dielectric. Thus, in the z direction the surface charge does move in response to E_z but does not neutralize E_z because new charge moves in where old charge moves out.

A quiet detail of our second assumption is that (1.3.1) says $\mathbf{E} = -\text{grad}\,\varphi - \partial_t \mathbf{A}$ whereas above we have used the fact that $E_\varphi = -\text{grad}\,\varphi$ to argue that the circle is an equipotential. Our main interest is $E_\varphi = 0$ on the surface. To the extent that $A_z >> A_x, A_y$ (which is in fact true), we have $-\partial_t A_\varphi \approx 0$ and then we can say that the circle is an equipotential. The fact that $A_z >> A_x, A_y$ is due to the fact that $J_z >> J_x, J_y$ in a straight round wire, as we shall eventually see in the form $E_z >> E_r$ in what is known as the transmission line limit.

Now in the opening section I am removing this

———

The conclusions one can draw from the analytic solution given below are supportive of the general discussion elsewhere in this monograph:

1. The E_r and E_φ field components are *very small*. In fact, they are smaller than E_z by the factor (a/λ), where a = wire radius, and λ = wavelength of transmission line wave. This fraction (a/λ) always assumed small in any analysis of a transmission line.

2. For a normal TEM wave $E_\varphi = 0$ on the wire surface. This condition is consistent with the idea that the wire surface is an electrical equipotential at any constant z. See Section D.8.

3. We get an explicit formula for the surface impedance. We find that it is non-uniform around the boundary of the wire cross section, and that J_z is non-uniform inside the wire, both radially and azimuthally.

———

At 8 AM I am now finally ready to begin a proofing of the completed Appendix D. This thing has wobbled very many times, I hope it survives this pass.

Lines Doc Review Pass, Dec 14, 2013

Appendix D Review, Dec 14, 2013

opening text:

no equation numbers, did some edits, the main thing is the summary of sections to come. A reader could read this and the skip the whole appendix.

Section D.1

there are 21 equations number correctly.

(a) text all OK. DONE

(b) text and eq refs all OK, DONE. Fig numbers come later. The $\hat{\varphi}$ looks centered in the PDF, test1 !

(c) text and eq refs all OK, DONE

(d) text and eq refs all OK, DONE The Helm comment is a bit sophisticated but good.

time now 9:10 AM. It will be a long slog.

Section D.2 Solutions for the three E_i

I had to repair the two last equation numbers, no big deal

(a) text and eq refs all OK, DONE

(b) text and eq refs all OK, DONE

(c) test and refs OK, DONE. But I really should verify that these solutions solve the Helm equations I claim they do, using Maple! *******

OK, I added a simple full verification at the end of section (c) which now let's me delete the entire section later on concerning the φ Helmholtz equation, making App D a little shorter.

I place the retired section here

———

we will now directly show that our solutions do in fact satisfy the E_φ Helmholtz equation. The E_φ Helmholtz equation (D.1.18) is this, expressed in terms of $x = \beta' r$,

$$[x^2\partial_x^2 + x\partial_x - (m^2+1) + x^2)]\, E_\varphi(r,m) = -2jmE_r(r,m) = 0 \qquad \textit{(D.1.18)} \qquad \text{(D.3.3)}$$

and we found these solutions for E_r and E_φ ,

$$E_r(r,m) = a_m\, x^{-1}\, J_m(x) + \frac{K_m}{2}\, J_{m+1}(x) \ . \qquad \textit{(D.2.11)}$$

$$jE_\varphi(r,m) = -\, a_m\, x^{-1}\, J_m(x) + \left(\frac{K_m}{2} + \frac{a_m}{m}\right) J_{m+1}(x) \qquad x = \beta' r \ . \qquad \textit{(D.2.15)}$$

Treating (D.3.3) as LHS = RHS we then have

$$LHS = [x^2\partial_x^2 + x\partial_x - (m^2+1) + x^2]\, \{-\, a_m\, x^{-1}\, J_m(x) + \left(\frac{K_m}{2} + \frac{a_m}{m}\right) J_{m+1}(x)\, \}$$

$$RHS = 2m\{\, a_m\, x^{-1}\, J_m(x) + \frac{K_m}{2}\, J_{m+1}(x)\} \ . \qquad \text{(D.3.4)}$$

In order to have LHS = RHS, it must be true for arbitrary a_m and K_m . Thus, we want to show that each of the following equations is valid,

$$[x^2\partial_x^2 + x\partial_x - (m^2+1) + x^2]\, \left(\frac{K_m}{2} J_{m+1}(x)\right) = 2m\, \frac{K_m}{2}\, J_{m+1}(x)$$

$$[x^2\partial_x^2 + x\partial_x - (m^2+1) + x^2]\, \{-\, a_m\, x^{-1}\, J_m(x) + \frac{a_m}{m}\, J_{m+1}(x)\, \} = 2m\, a_m\, \{\, x^{-1}\, J_m(x)\, \}$$

which are the same as

$$[x^2\partial_x^2 + x\partial_x - (m^2+1) + x^2]\, (J_{m+1}(x)\,) = 2m\ J_{m+1}(x) \qquad \text{(D.3.5)}$$

$$[x^2\partial_x^2 + x\partial_x - (m^2+1) + x^2]\, \{-\, x^{-1}\, J_m(x) + \frac{1}{m}\, J_{m+1}(x)\, \} = 2m\, \{\, x^{-1}\, J_m(x)\, \} \ . \qquad \text{(D.3.6)}$$

Equation (D.3.5) may be written

$$[x^2\partial_x^2 + x\partial_x - (m^2+1) + x^2 - 2m]\, J_{m+1}(x) = 0$$

or

$$[x^2\partial_x^2 + x\partial_x + x^2 - (m+1)^2]\, J_{m+1}(x) = 0 \ .$$

But this is Bessel's equation for $\nu = m+1$, thus (D.3.5) is valid.

As for (D.3.6), we leave it to trusty Maple :

```
LHS := x^2*diff(f(x),x,x)+ x*diff(f(x),x) - (m^2+1)*f(x) + x^2*f(x);
```

$$LHS := x^2\left(\frac{\partial^2}{\partial x^2}\mathrm{f}(x)\right) + x\left(\frac{\partial}{\partial x}\mathrm{f}(x)\right) - (m^2+1)\,\mathrm{f}(x) + x^2\,\mathrm{f}(x)$$

```
f := x -> -(1/x)*BesselJ(m,x) + (1/m)*BesselJ(m+1,x);
```

$$f := x \to -\frac{\mathrm{BesselJ}(m,x)}{x} + \frac{\mathrm{BesselJ}(m+1,x)}{m}$$

```
LHS := x^2*diff(f(x),x,x)+ x*diff(f(x),x) - (m^2+1)*f(x) + x^2*f(x): simplify(%);
```

$$2\,\frac{m\,\mathrm{BesselJ}(m,x)}{x}$$

Thus (D.3.6) is also valid.

We conclude that the our round wire **E** field solutions satisfy the E_φ Helmholtz equation as well as the other two Helmholtz equations and the div **E** = 0 equation.

Appendix D review continued:

Section D.2 Solutions for the three E_i

I had to repair the two last equation numbers, no big deal
(a) text and eq refs all OK, DONE
(b) text and eq refs all OK, DONE
(c) test and refs OK, DONE including Maple verification now added
(d) test and refs OK, it would be bad to get this BC wrong! Added clarifiers.

Pause. I decided to have Maple verify my "second summary" E field box and it is not verifying!!! Odd that I never thought to do these checks before.

(e) apply BC's: this took a long time, had to fix Z_s , it is done.

Section D.3. The φ Helmholtz DONE, 2 equations.

Section D.4 equations: OK
test: DONE and OK, tiny edits all the time.

Section D.5. equation numbers OK
think simpler Maple code will work here!! No need for unapply methinks.
I updated the code, it is simpler and better

Section D.6 eq nums ok, not many
Checked the m= 0 reduction, all seems right.

Section D.7 fields outside the wire
OK, done and I added a little reader exercise that sounds very hard to do.

Section D.8 (and last) DONE !!!!!!

Let's slap in some Figure numbers. DONE.

I think Appendix D is once more "stable".

Next action: Go through Chapter 2 again and make sure it ties in correctly with Appendix D.
Then install Appendix D and move on. I removed and stored away the old App D from lines just now.

Note: I have been working just on this Appendix D stuff since about Nov 26, which is **19 whole days.** That is really amazing. This involved "the meaning of Chapter 2" and all that stuff. Basically Chapter 2 and Appendix D had no real context, they were sloppy and lousy and hopefully they are now good. If nothing else, things are checked a lot more so that given my assumed assumptions, I know all the results are correct. I had this round wire sort of floating in a dielectric with a partial wave expansion that did not mean much. If it really is in isolation, there are no m ≠ 0 waves! And I had a wave going down the wire with no mention of a wavelength, no "return" path, it was just in very very bad shape and it took me 2.5 weeks of daily labor to get it *into* good shape. Cod is in 5 days, at least I got this App D done pre Cod.

Sun Dec 15, 2013

Reread App D intro only, few edits, it is OK. Now on to Chapter 2 review.

Chapter 2

opening text. I added reference to Appendix D and will delete something in red soon.

Section 2.1. eq nums OK

I like the idea of starting with a general k and then ansatz that k = β_d.
I like both inside and outside mentioned with the linking BC
I like the super fat coax cable context.
I like the 1D skin depth example.

Section 2.2

eq number problem. They are good through 2.2.25, then the last 5 have to be lowered by 2
repairs made

***** Update App D references to Chapter 2

Confusion: In the second E field summary of box (D.2.33) I have factor ($a\beta_d$) which says the E_r and E_φ fields are small relative to E_z in the transmission line limit. But in the summary (D.4.9) it seems that this ratio is instead (β_d/β') which is NOT the transmission line limit, but is instead the assumption that ω is less than some huge value. Neither constant knows about distance a.

OK, I have now completely removed the "transmission line limit" from this entire discussion of Chapter 2 and Appendix D. The only inequality of interest is (β_d/β')<< 1 which is a function of materials and ω.

I resume now on Section 2.2

Section 2.2 all done, this was a BIG section

Section 2.3. Eq nums check: though 17, all OK, DONE.

(a) OK

(b) OK

(c) not OK, repairs needed.

Now OK at 5:10PM, I had to do major stuff at the start, now more like App D.

(d) done and OK, made some good additions.

Section 2.4 on Surface Impedance.

equation numbers: 19 of them, OK.

opening section has a problem, but lets just move on: this is now fixed, move on

(a) OK, did some changes, made it better. Important tie in with Matick!!

(b) OK, low ω limit of Z_s , has connection to Appendix 2, I leave this in red for later check.

(c) OK, more Matick tie in here.

(d) plots. I added real world 12-gauge housewire, think this connect to the real world a bit.

Section 2.5 on transmission lines.

DONE!

Figure numbers: My four-plot set has no number, but I will just leave it that way.

SO, I think Chapter 2 and Appendix D are finally in sync with each other.

What about changing θ to φ in Chapter 2? No! Too many places, not as clear, and I have to change the figures to boot. I think this would detract rather than improve.

There are still some "items in red" in Chapter 2 that need attention, but the main work is done. This chapter is 30 pages long.

I think I will now install Appendix D since if survived my Chapter 2 review. DONE, and we are sitting now at 241 pages. There is an immense amount of work still to go, much of which has already been prepared but I got sidetracked on Appendix D stuff.

Mon Dec 16, 2013

I have three days left pre Cod. I first did a cleanup on my Appendix D folder, all things there are reviewed, I think this world is now stable (ha!). What comes next? My leading red notes say Appendix M is not really useful.

Appendix A I think is still OK, on gauge invariance. I have not wobbled much in this area.

Appendix B is this monster thing on J_m type currents. These are needed for $\mu_1 \neq \mu_2$. I am not sure whether this is worth keeping, but it stays for the moment.

Appendix C. Let's take a quick look at this: DC properties of a round wire

C.1 resistance OK

C.2 surface impedance OK

C.3 DC inductance

(a) internal L, seems OK

(b) external L OK, some red text still.

C.4

(a) I quote a Sec 1 equation with J_m that probably is not there any more.

(b) divergence problem: a bit messy, ends with reader exercise I did somewhere else in lines doc

(c) avoiding the divergence problem, ends with my nice arrows picture.

Comments: App C will need a lot of work, but I need to know what ELSE is in lines doc before I can really rewrite App C. The pieces are orbiting and I cannot remember what is where . But generally I know that App C is about DC stuff only.

Appendix E: Surface charge. Seems good, but can I get verification somewhere? I reviewed above in this log and see no such verification ever attempted, so let's now take a web scan.

Some support from here

http://www.tf.uni-kiel.de/matwis/amat/elmat_en/kap_2/backbone/r2_4_2.html

Fick and Debye are good search terms. Stern layer?

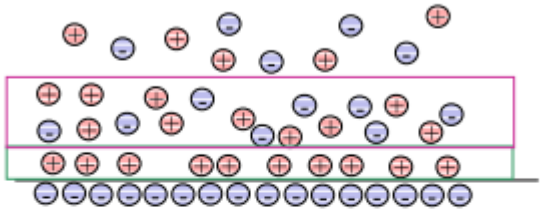
$$n_+(\vec{r}) = \bar{n}, \quad x \leq 0$$
$$= 0, \quad x > 0. \qquad (2.1)$$

For orientation, we remark that a Thomas-Fermi calculation[13,14] leads to an electron density distribution which decreases smoothly from its interior value $\bar{n}$ to zero, over a distance of the order of the Thomas-Fermi screening length [see Fig. 1(a)].

where $v_{xc}[n; \vec{r}] \equiv \frac{\delta E_{xc}[n]}{\delta n(\vec{r})}$. (2.4)

Assuming that the form of $E_{xc}[n]$ and hence of $v_{eff}[n; \vec{r}]$ is known, the solution of the following self-consistency problem gives the exact density distribution of the system of N interacting electrons:

Debye screening physics



Stern layer - ions opposite in charge to surface charge of wall material; effectively immobilized due to strong interactions with wall.

Gouy-Chapman layer - diffuse ions, net same sign as Stern layer, but mobile.

Together, these are called the electric *double layer*.

Debye screening occurs in the diffusive layer.

The potential at the edge of the Stern layer is called the *zeta* potential.

I finally found something in Portis Page 162. He quotes Fick's Law (not numbered) $\mathbf{J} = -D\nabla\rho$ and combines it to get exactly my equation

$$\mathbf{J} = \sigma\mathbf{E} - D \text{ grad } \rho \ . \qquad \text{(E.1)}$$

The electron cloud is called a "bounded plasma". He does not write $\nabla^2\rho = (\sigma/D\varepsilon_0)\,\rho$ but he does get

$$\lambda_D^2 = (D\varepsilon_0/\sigma) \ = 1/k_D^2. \qquad \text{(E.5)}$$

and he calls λ_D the Debye length. This formula E.5 he calls the Debye-Huckel formula. And he finally ends up with (see page 164)

$$\rho(x) = \rho(0)\, e^{-x/\lambda_D} \qquad \text{(E.7)}$$

He then has a little table which shows λ_D for copper as 0.59×10^{-10} m and my calculation was .55, close enough! So Portis is the first source I can recall seeing any of this stuff!! The Debye-Huckel is not too useful to obtain other sources for this same argument. Everyone wants to a solution against a metal, and that is not what I want. I am very thankful to **Portis** and I will give him a reference.

Appendix E is OK: With Portis as my backup, this appendix is now fully "vetted" and I am no longer worried about its accuracy. It makes the point well I think! Time to move on.

Appendix F on waveguides. (I want to get the lesser appendices "out of the way")

F.1 is good, had to fix some Chap 1 equation reference numbers, else OK

F.2 is also good , as is the tie in to Chapter 3.

This is a very concise lecture on "waveguides" . I compare the TE with its cutoff to TEM of the transmission line. I say nothing about TM modes. I am now reminded of how often books want to do waveguides but steer clear of transmission lines.

Appendix F is OK! Do I have backup for this? (F.1.5) is similar to my Chap 2/App D stuff and maybe I should use β' in App F. In Appendix D I was inside the metal, whereas here I am in the dielectric, so things are different. The cutoff expression agrees with green Jackson. I don't think a ref is needed here, since it is such a commonly treated subject.

Appendix A: Another look please! I was hell-bent on avoiding homo sols in the King potential expressions, and I inserted that idea everywhere. OK, I think it is still OK on this issue. I do at least mention the homo solutions and a particular solution.

Appendix H and I: Just want to make sure these are still OK.

Read through H. It states that "homo adder sols are generally not needed if there the source includes everything like source on boundaries". I still wonder about this. In my King application, I need homo sols at the μ_1/μ_2 interface which is a source for J_m but not for J. But in electrostatics, I think it is true. I guess I will leave this with the fudge word "generally".

Read through I: removed a comment that round wire uses $H^{(1)}$, otherwise it is all OK. Not many texts would have appendices like these.

Appendix G is specific to Chapter 4, so I defer on it.

The following appendices are stable and OK and can be ignored for the time being:

A, C, D, E, F, H, I

The following appendices need attention

B	J_m stuff, how does it fit in?
G	make sure OK when you do Chapter 4.
M	something I have in the wings
Q	promised solution of some electrostatic trivial problems.

Let's have a quick run through Chap 1.

1.1 is huge, a summary of all of basic E&M, seems OK

1.2 short and sweet, field wave equations

1.3

(a) OK

(b) OK

(c) long but I think it is done right now.

1.4 on those retarded solutions, not to worry.

1.5

(a) OK

(b) preliminary forms of the King Helmholtz integrals.

(c) OK, it is big and heavy duty, we finally derive those King equations with King quotes.

(d) Here I am building a catalog of equations that I might order from later on.

1.6 OK

Status 12/16/13: I am happy in general with these things as they stand

Appendices:	A, C, D, E, F, H, I
Chapters:	1,2

I will have to worry about

Appendices:	B,G,M,Q, maybe something on the electrical circuit line approach
Chapters	3,4,5,6

So this is my post-Cod task, to follow through on all this stuff. Somewhere I have already written up the situation about $\mu_1 \neq \mu_2$ and the King Helmholtz integral and those homo terms and the surface current as a source of homo terms, but not sure how that will all get presented. I have a long way to go, but think I have a pretty solid platform right now.

Tues Dec 17, 2013

Chapter 3

3.1 OK, added ref to App E.

Ouch. I have failed to give a reason for "no free charge in a dielectric". I thought this was in there somewhere. I do it for a conductor in 3.1. It used to be there somewhere. It used to be in App 1.2 and App 4 in the original, and 1.2 is the "complex ξ" appendix I threw out. The argument there is exactly the same as for the dielectric, just a different time scale. So I can just add this to 3.1.

Weds Dec 18, 2013

Continue on the above in separate docs. At 8 PM I finally ended up with a viable replacement for Section 3.1, and I resume there when I return from the Cod, if I in fact do return.

Thurs Jan 2, 2014

Just reread my "why no free charge rewrite" and think it is good. I just installed it as the replacement Section 3.1 and saved off the previous 3.1 in a separate doc.

OK, I guess now that the document has once again "gone cold", I will do some reading before resuming with Chap 3.

App A, did just a little reading, this thing is really self contained and interacts little with rest of doc.
App B, skip for now, since about surface magnetization.
App C, wondering if I can really ignore the **E•E** energy term?
I had to stop reading because of all the J_m references, not sure what I will be doing here.
App D, just read my little overview, and that is all I will do now.
App E, I kind of like this discussion, why surface charge is so thin.
App F, waveguides. Again, sort of a self-contained topic, so I won't read it now.
App G, doing certain integrals. I might never need these, so don't read this now;
App H, quick read, it is OK
App I, also OK, a bit more complicated in 2D than in 3D!

So I am now "refreshed" as to what these Appendices are about. Next, I will scan the main text. I am not checking equation numbers here!!!

Chapter 1

Section 1.1 Maxwell
(a) OK
(b) OK, on integral forms
(c) OK, on fields at surfaces
Section 1.2 field wave equations -- short and OK
Section 1.3 potential wave equations
(a) OK, very good in fact
(b) OK special rel note
(c) OK, I am happy with things up to this point!
Section 1.4 retarded path not taken. OK

Section 1.5 Wave equations in ω space

(a) transformed wave equations, OK

(b) Helmholtz integrals and Dirichlet comment OK

(c) finally I arrived at the King (23) and (24), it is the best I could do

(d) this is extra data that I never use later: wave equations for fields and pot in Lor gauge

Section 1.6 the complex functions business.

(a) OK

(b) OK (as recently modified)

(c) needs a few small fixes, but lets keep going.

(d) OK and ref to round wire

(e) pitfall OK

(f) OK

Chapter 2

opening material, OK

Section 2.1 implicit wave context, I think this is good

Section 2.2

I now skip the rest of Chapter 2 in this review since it is all self-contained and is re the round wire.

I am now more or less "refreshed" on the appendices and Chapters 1 and 2 of my lines doc, and I can now start into a more serious review of the rest of the doc, starting with Chapter 3 "TL preliminaries".

Chapter 3: I am not checking eq nums on this pass. Looking for larger scale problems.

Section 3.1: why no free charge in die or cond? I just reviewed this earlier today before installing.

Section 3.2: review of App E that surface charge really is on the surface. No eq nums.

Section 3.3 (breaking new ground now). A standalone fine section on loss tangent. OK.

Section 3.4 OK, conversion of current type at a boundary, no big deal.

Section 3.5 Here we go now with those two messy qualitative tables. There will be refs to the round wire appendix, I will want to check the logic flow etc. // But there were no appendix references at all in this tedious section. I might change things so that $J_{\mathbf{r}} = \sigma E_{\mathbf{r}}$ and then "small" $J_{\mathbf{r}}$ yields "very small" $E_{\mathbf{r}}$, but this may conflict with what comes next.

Section 3.6.

[a] notes OK

[b] notes OK

[c] notes OK

Section 3.7: general shape of fields and current in a transmission line

(a) a set of facts, all seem OK, certainly in a qualitative sense.

(b) drawings: cross section and top view.

(c) setting the phases of the currents and fields. I guess OK, not great.

(d) OK.

There are no round wire appendix references of any kind in these sections! I thought there were.

Section 3.8: Preliminaries

We come now to Fact 6 and I am going to have to take some action. This is the subject addressed in the round wire appendix. So finally I have some real work to do here before my Chap 3 review can be completed.

OK, the work is done. I have reviewed my tricky Facts in this section and thing things are OK. This then takes me to the start of Chapter 4. Again, there has been no eq num check for Ch 3.

I am ready to Start into Chap 4 and will attack that tomorrow AM early.

Fri Jan 3, 2014

Section 4.1. right off the bat we have some small problems. I have made changes so that we have the King form with $1/4\pi\xi$ and this required various extra comments. I think I will remove this obscure comment added a while ago

Comment: If we assume that ρ_1 has "zero phase", then in general $\varphi_1(x)$ is going to be complex and will have some non-zero phase. So let's assume ρ_1 is real with this zero phase. Also, at this point conductors can have any 3D shape you want. Also, ρ_1 represents a surface charge in 3D. I think at this point we de-generalize and assume that we have conductors of a transmission line with z = longitudinal

The time has come to digress to Appendix G since that is involved below (4.1.7). I think I corrected this Appendix on 10.31.13 down to a certain point, but let's make sure it is OK. I will quote the GR integral.

OK, as of 11:20 AM I am happy with my edited Section 4.1.

Section 4.2. At 3:30 PM I am having trouble in Appendix G.2 showing that higher terms are order β^2 and higher, where β is small. Time for the walk.

Have started a new doc on this very major malfunction, and will continue there for a while. At least I got a bit of a lead at the end of today's session.

Sat Jan 4, 2014 resuming on small β^2 issue in separate doc
Sun Jan 5, 2014 started rewrite of Chap 4

Mon Jan 6, 2014.

I added a section on the coaxial cable and got the right answers after finding a factor of 2 error I was making.

Chapter 4 and A_z : Chap 5 and Chap 6 work, Jan 6, 2014

Am finally starting on Section 4.6 where A_z enters the picture. I will have to address the μ_1/μ_2 question, but then why wasn't there an $\varepsilon_1/\varepsilon_2$ question for φ? Well, I did the derivations in full detail with summary in box (1.5.23). These Helm integrals must be regarded only as "particular solutions" to which one must in general add homo solutions to meet some BC's. I state that clearly below the box.

So, why didn't I need to worry about those homo solutions in my φ analysis of the 2 conductor line? I said nothing about that!!

I think this is the answer: The purpose of the homo solutions is to meet the boundary conditions. In my V(z) case, the only boundary condition I have seems to be that the potential difference is V(z). There are no parameter discontinuity boundaries within my dielectric region, it is one continuous region, and I have constructed a solution which meets the V(z) boundary condition without any homo terms!

Well let's restate that. I have a Helm integral solution, and it creates some V(z) between the conductors. I then take this resulting V(z) to be my boundary value. What would happen if I were to add in some homo solutions?

What "system" defines the homo solutions? Well, homo means

$$(\nabla^2 + \beta^2)\varphi_{homo}(\mathbf{x}) = 0 \qquad \varphi(\mathbf{x}_1)_{homo} - \varphi(\mathbf{x}_2)_{homo} = 0$$

The difference on the right has to vanish so the homo solution does not alter V(z). But then I have a region completely surrounded by $\varphi = 0$, and probably as with Laplace that forces homo = 0. Somehow this is in the 2D potential world that I will hopefully be clarifying later.

So why should the A_z world be any different? The only difference is that we integrate over the volume of the wires and each wire could have its own μ_i which is different from the dielectric.

So for the moment it seems all that stuff I worried about is irrelevant! But I know that is in fact not the case. Maybe look back at the calculation of things inside and outside a round where one has μ_1 and μ_2 and see if that does not reactivate my concerns on this subject. I think the question was "how does the Helm integral for A_z give the right answer both inside and outside the wire"?

So where are my notes on this subject? "magnetostatics and the round wire". What I found was that if you want a unified A_z expression that works both inside and outside a round wire, one method of solution is to (wrongly one would think) include a J_m surface current in the current driving the equation. I later learned that that J_m term really just creates a homo solution which is then why it is allowed. But this is really a very early doc off 11.24.13. Later I wrote "are there homo solutions" created 11.24.13. I am reminded here that there are A_z and $\partial_n A_z$ BC's to think about.

Maybe I can bypass this problem for now. If I want a single A_z to work inside AND outside a wire, then I have to deal with those two BC's. But if I just want outside, maybe I can ignore it. I am then work with the above argument

$$(\nabla^2 + \beta^2)A_{zhomo}(\mathbf{x}) = 0 \qquad A_z(\mathbf{x}_1)_{homo} - A_z(\mathbf{x}_2)_{homo} = 0$$

Let's try that for now.

Tues Jan 7, 2014.

Have written up the W(z) section yesterday, discovered the K and K_L distinction. Did I realize that distinction before? Nothing in 4.4. But later I am going to claim they are always equal!!! So I had better get on with Section 4.5 to see if that is really true!

I continued along in Chapter 4 and then the famous mu paradox returned in the context of K and K_L. So in fact I cannot just "bypass" this whole issue as I tried to do yesterday. A long struggle now begins at 10AM.

Dealing with the μ problem. So far I have 125 docs related to lines doc! In some of these, I have already delta with "the μ problem". My Appendix M how seems very relevant.

First exercise in M: I show that, even though μ_1 appears in the PDE right side, when you solve things you get μ_2 if you are "on the outside". So this really is a key example to study. The question is: Fine, if I solve the PDE with BC's, I get the right thing. But how do I solve things with Helmholtz integrals?

6 PM. Well, I faced it and I think I have a plan of action. I added a long section in the Ch 4 rewrite about why I have to restrict to $\mu_1 = \mu$ and I will activate Appendix M, perhaps even further enhanced. When this is all done, we end up with $K = K_L$ as a general rule. So I think I have dealt with the main μ issue head on, and my only remaining uncertainty is that I don't see how $K = K_L$ will be true in a symmetric geometry case, but it must somehow work if it is a new general rule! I will do that tomorrow. It took a lot of pain to get over this hump today, and Appendix M was a lifesaver.

Weds Jan 8, 2014.

I successfully verified that $K = K_L$ for symmetric case, it was not obvious but it did work and is I think a good addition. I then made a huge summary box which will go on a separate page.

There is one missing item still: I need a reason why W(z) does not depend on x,y. But I already have it! It is Fact 7.

OK, I keep adding small items to my Chapter 4 rewrite. I think it is very good. I will now do some cosmetic stuff before installing it into lines doc. I don't think anything has been swept under the rug. I hope that no rocks have been left unturned.

Eq nums checked, this one chapter is 34 pages long! Perhaps the most important.

I think rather than proof and install Chapter 4, I should do a rewrite of Chapter 5. I see references in there to my ancient J_a and ρ_a sources, so probably a rewrite is in order. I want to get thru Ch 5 and Ch 6 before doing more with Appendices, including Appendix M. There are *very* many miles to go before I sleep.

Chapter 5. My entire long opening section is no longer relevant. Yes, it was a justification of my "applied" sources which I totally got rid of (thank goodness). I will hold off on this opening section's replacement and forge ahead. // I think this entire Chapter can be greatly simplified now that there is more meat and potatoes in earlier Chapters (since the original writing)

Started a Ch 5 scratch doc, running out of steam at 6 PM.

Thurs Jan 9, 2014.

Plan is to write up some of Chapter 5 before doing the 2D circles problem. I now see connections to Appendix D. Will now reread it and Chap 4.

I just reviewed App D and did a few small edits. There I solve the vector Helmholtz for E and B, and potentials are not mentioned.

I just did a detailed review of the Chapter 4 rewrite and made quite a few edits to get rid of my previous idea that $K = K_L$ only in certain cases. This Chapter I think is pretty good. Now 8:45AM.

10:50AM. I have now written Sections 5.1, 5.2 and 5.3 roughly as they appear in the original lines doc. However, I now think I should have $\rho_t = 0$ and just say that I end up with two Dirichlet problems which are basically the same problem. In original lines doc I maintain ρ_t which I now think is wrong to do inside the dielectric region! So now I will go actually read my original Chap 5 from this point on to see if there is something I am missing. // I read it, there is some thread of reason to it because Matick does do an eigenvalue method. But I think a Dirichlet approach is going to be much better.

Nope! There is more going on here than I thought! I now have to back up and get symbols more consistent.

Section 1.3	μ_1 = dielectric	μ_2 = conductor
Box (1.3.29)	μ = dielectric	μ_i = conductor i
Box below (1.5.2)	μ = dielectric	μ_i = conductor i
Section 1.5.(c)	μ_1 = dielectric	μ_2 = conductor
King box (1.5.23)	ε,μ = dielectric	μ_i = conductor

So far I am pretty consistent through the end of Chapter 1.

Chapter 2: μ,β,ξ = conductor // since about conductors!

Chapter 3:

3.1	σ,ε is used for all materials, dielectric or conductor
3.2	nada
3.3	σ,ε = dielectric
3.4	1 = dielectric 2 = conductor
3.5	μ,σ = conductor
3.6	μ,σ = conductor
3.7	μ,σ = dielectric
3.8	μ,σ,ξ = dielectric

Chapter 4 rewrite entire chapter deals only in dielectric parameters
4.1,2,3,4 μ,σ,ξ,β = dielectric

Appendix C which concerns a wire:
μ = conductor in section (a)
μ = dielectric in section (b)

Appendix D which is similar to Chapter 2:

μ = inside wire = conductor
β = conductor
β_d = dielectric

Appendix E: waveguides

$\beta,\mu,\varepsilon,\xi$ = dielectric

When one material is the main topic, it is the material with μ,β etc

OK, forget that topic for a moment.

New question: I keep reading my two-circles chapter 6 solution. Something is normalizing the solution, but I cannot figure out what it is! I know that the α_i are normalized to 1, so if $\varphi(t)$ is found from

$$\varphi_t(x,y) = \int_{-\infty}^{\infty} dz' \{ \int_{C_1} dx_1' \, dy_1' \, \alpha_1(x_1',y_1') \frac{1}{R_1} - \int_{C_2} dx_2' \, dy_2' \, \alpha_2(x_2',y_2') \frac{1}{R_2} \} \qquad (5.1.2)$$

Then $2\varphi_t$ is NOT also a solution to the problem, although it is a solution to the 2D Helm equation. Somehow the norm on α_i gets through to being a norm on φ_t, but I think I never clarified that fact.

Idea: Suppose we go to a point (x,y) for evaluation which is far away transversely from our conductors. In that case, we get

$$\varphi_t(x,y) = \int_{-\infty}^{\infty} dz' \left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

$$R_1^2 = (x-x_1')^2 + (y-y_1')^2 + (z-z')^2 = s_1^2 + (z-z')^2 \qquad s_1^2 = (x-x_1')^2 + (y-y_1')^2 \qquad (4.2.1)$$
$$R_2^2 = (x-x_2')^2 + (y-y_2')^2 + (z-z')^2 = s_2^2 + (z-z')^2 \qquad s_2^2 = (x-x_2')^2 + (y-y_2') \ .$$

I know how to do this dz' integral from Chapter 4 (4.4.5) and the result is

$\varphi_t(x,y) \rightarrow \ln(s_2^2/s_1^2)$ as $(x,y) \rightarrow$ large transversely from the conductors.

I think this is my missing normalization condition! Now remember that my new K is twice the size of my original lines doc K because I went there with non-squared s in the logs. So I could write

$\varphi_t(x,y) \rightarrow 2 \ln(s_2/s_1)$ as $(x,y) \rightarrow$ large transversely from the conductors.

THEN, when I look at the solution

$f(x,y) = 2 \ln(s_2/s_1)$

I can see that it has the proper behavior for large transverse distance. So there is no scaling flexibility here! This is it. The function 4 $\ln(s_2/s_1)$ will solve the Laplace equation, but it does not satisfy the scaling requirement! This is the missing ingredient!!!

Sat Jan 11, 2014.

I think I have finally stabilized Chapter 5 including a section on lossy transmission lines and a detailed reference to Matick's stripline calculation. If this thing is stable, it remains only to rewrite Chapter 6 on the big example and then I am done with the main body of the text. I will believe that when I see it.

Question: I am confused. I thought in a parallel plate transmission line the E and B fields are more or less uniform, the potentials are linear (as I think H&M say on page 758). So where is Matick getting that sine shape of one of these fields in his analysis? I though such a sine shape was only for a waveguide. Pick up on this question tomorrow.

Sun Jan 12, 2014.

Maybe will do Chap 6 and come back to Question above. I am wondering about my "limiting form" thing in Chap 5. Is it a dipole moment? // Got most of my new Chapter 6 done, first draft, and everything worked right pretty much.

Mon Jan 13, 2014.

First issue: why do I set -K/2 and K/2 as the potentials on the two conductors?

Well this has led to a definite problem! You cannot simply assert -K/2 and K/2 as I did. The circles example shows that in general the potentials are not equal and opposite. I now realize after paging through that Stak never really does a "capacitor problem" except when one conductor is at ∞. So he never has to address this problem, so another source will be needed. I don't recall green Jackson doing anything like this either. I think Smythe deals with this on page 34-38 and it involves that Green's reciprocity theorem. I remember dealing with this a few years ago.

OK, I have untangled this mess, thanks to Smythe, and I have now rewritten a lot of Chapter 5. So time now to review that chapter. I am NOT checking equation references yet.

5.1 Separation of φ equ nums: 11 and in order and positioned , no figures

5.2 Separation of Az equ nums: 11 and in order and positioned , no figures
This section is an exact parallel of the previous section.

5.3 Development of the Transverse Problem
equ nums: 12 and in order and positioned , one Figure 5.1
OK

5.4 The "low-loss" approximation 4 equations, Fig 5.2 only
OK

5.5 The Capacitor Problem equations 17, adjusted, Fig 5.3 only

5.6 What happens if low-loss is not assumed?

STOP! Is my general Stakgold solution form valid for a Helmholtz equation as well as Laplace?
Answer:

(1) It is trivial to generalize the formal derivation of (1.5.11) from Laplace to Helmholtz.

(2) I finally found someone who talks about this and who has my formulas. It is page 78 and 79 of Alber's PDF which I have saved.

So this was a good question, I think I can now continue (whew!!).

5.6 What happens if low-loss is not assumed?
equations only 2, no figures.
OK, a short section with that Matick quote and my general eigenvalue idea.

This concludes my review of Chapter 5. I like it (of course), it is a good shot. I think my gussied up general capacitor problem solution adds some meat to this section. This thing is ready to install.

I guess I am worn a bit at 7:30PM. I want next to review Chapter 6. It needs eq nums etc. Then I hope to do a three-chapter install!

Tues Jan 14, 2014.

I start on Chap 6, but then I had to clarify those center of charge points which I now call x_1 and x_2. I don't think they can be random "nearby points". If they could then you could swap them! This would then change the sign of the $\ln(s_1^2/s_2^2)$ limiting form, which is nonsense. I think they really need to be the center of charge points, but I will not attempt to prove that fact.

Section 6.1. Two equations, no figures, OK

Section 6.2. Five equations, two figures, OK.

Section 6.3. 22 equations OK I added a very solid "reader exercise".

Section 6.4: Summary OK

I am now done with Chap 6 but need to adjust eq nums. DONE.

I would like to work in "strip line" at some earlier point.

I did this as comment 5, the very last item in Chapter 4.

OK, I am now going to save old and install.

What's Next?

Make sure this comment is no longer operative:
Note: Equation numbers for Section 1.1 need massive adjusting globally in this doc.

I spent a long time renovating Chapters 4,5,6 and they are now installed.

New Task: Let's clean up the waveguides thing.

Done. new Appendix F is only 5 pages, I got rid of the irrelevant though amusing interpretation thing. That is something for a waveguides monograph. I just wanted to show that the parallel plates have a TE mode system, and I did that completely now showing that all 4 Maxwell are happy.

Weds Jan 15, 2014.

Did further editing on App F, greatly improved the Figure of the fields, and then installed into lines doc, first saving off the previous App F version. Done with App F, and I think it is good.

Now I am going to deal with the magnetization stuff. My first significant comment about magnetization comes after equation (4.7.6) in my Comments regarding μ. Then next hit is Appendix B. There are also issues in Appendix C. Then nothing else. Recall Appendix M waiting in the wings.

I think there are major wrong things floating around here. First off, recall that App B on mag replaced an earlier App B on the complex dielectric constant which I completely got rid of.

I will just read App B right now and see what I think. I see that in the summary at the start, I am assuming that the mag current is only a surface current, which of course is wrong in general. So maybe this whole Appendix B is toast. Pause on that and let's look instead at Appendix M which I think was written later.

Appendix M. The summary sounds promising.

Section M.1 I am NOT checking eq num references on this reading. (1.5.4) is a correct reference.
Seems OK, I am just setting up for the DC analysis.

Section M.2 is very good. I show how μ_1 and μ_2 appear in the B solutions for a round wire!
I am starting to like this Appendix again.

Section M.3. OK. This section first verifies the $A_z(r)$ found in Section M.2, then it computes J_m everywhere and obtains two bulk values AND a δ surface current. Very good stuff!

Section M.4. Yes I remember. I want to arrive at the same answer using the Helmholtz integral! I like the two methods for a tricky integral. This section is also very good, I always wondered how you got the right result using a Helmholtz integral.

ok to here

Section M.5. This is at least "OK" up to part 3 which I think should be eliminated.
I repaired part 3 and it is now OK. It is an "unfinished" calculation where I did the heavy lifting.

I guess I will include this appendix M in lines doc just because it deals with the very tricky question of μ_1 and μ_2 in the simple round wire solution.

But what then about Appendix B ? And what about red stuff in Appendix C ?

Does Appendix B have anything really to offer? If so, maybe add to M?

Let's first look at App C.
Sections C.1,2,3 are OK, but C4 has some big problems

Critique of Section 4. I am only doing DC so should not be too hard. I see that I edit this adding in the supposed J_m current but now I think that does NOT contribute to A and then B = curlA, so I would leave that out along with all comments. So I might say

1. Compute **A**(x,y) for an arbitrary wire at DC using formula (1.5.9) with $\beta(\omega=0) = 0$:

$$\mathbf{A}(\mathbf{x}) = \frac{1}{4\pi} \int dV' \, [\mu_2 \mathbf{J}_c(\mathbf{x}')] \frac{1}{R} \qquad R = |\mathbf{x} - \mathbf{x}'| \qquad \omega = 0 \qquad (1.5.9)$$

where μ_2 is for the wire. Then I say to compute B = curl A. But what about the homo adder solutions? I am trying to compute A *inside* the wire. I really should quote my region 2 equation (1.3.21) converted to the ω domain since that is using the King gauge of region 1 in region 2, exactly what the above says. Well I guess (1.5.4) also says it.
Will there be adder homo solutions to

$$(\nabla^2 + \beta^2)\mathbf{A} = -\Sigma_{i=2}^{N} \mu_i \mathbf{J}_i \qquad \text{all of region R} \qquad (1.5.4)$$

?? What are the BC's on this A, that is what you have to know. There are no boundaries "inside" the wire, though it does have a surface. When I do this computation for the *round* wire in Section M.4, I get a specific result there called $A_z^H(r)$. I assume this same result is valid inside and out, and I show there MUST be homo adder terms to make things work. So I expect that would be true as well for a non-round wire! So my simple Section C.4 plan with J_m removed does not work! You have to add homo adder solutions before you can continue to "compute B from A".

I could rescue this section by assuming $\mu_1 = \mu_2$ and then the particular solution is the entire solution.

This returns me to the idea that adding J_m actually provides the homo solutions you need! But I never proved that such an idea works. // I gave this some time today, a new little doc, but I am not happy with it and have decided to not even mention the idea in lines doc. App M is OK, but App B will then probably get thrown out since I then have no "interest" in magnetization stuff beyond the good example of App M.

Thurs Jan 16, 2014.

Appendix B, then Appendix C and Holloway, Jan 16, 2014

I tried again on the J_m stuff and maybe this time I got success. I will let my proof "air" for a bit while I now review Appendix B which becomes relevant if the J_m theorem succeeds.

Section B.1

I didn't get far! Right off the bat I find errors and the resulting K_z expression is a little different after corrections are made. I have rewritten B.1 in a scratch doc and now install that in lines doc. There were some equation number changes.

Section B.1 is now rewritten and the new installed, the old saved away.

Done. Now go repair the "proof" doc for this changed statement of K_z. Done, was easy.

Section B.2 Here I formally find H from J, assuming a perfect conductor. Seems OK, very short.

Section B.3. Fine, short, right to the point.

Section B.4 seems superfluous since I already gave it as an example in Section B.1 ??? I leave it for the moment (I repaired the K_z error here). // OK, we need B.4 because it computes H_θ both inside and outside the wire, and I am going to do that using my "general method" in the next section.

Section B.5 This now just fine and "to the point" -- an example of a general formula.

Section B.6. Here I do the round wire "J_m calculation". I think I need to prove my Theorem first.

7 PM. I am quite stunned! As best I can tell, I successfully proved "the J_m theorem" and wrote it up soup to nuts in a new Section B.6. This new section is ready to install!!

I then want Section B.7 to be an application of the J_m theorem for the round wire! I think this will make believers out of my potential readers. This general topic exists right now in the old Section B.6, so I will write up the **new Section B.7** as usual in a separate doc. // Made good progress in this, have a few bugs, will continue tomorrow!

This was a very good day.

Fri Jan 17, 2014.

I fixed Section B.7 and it is now ready to install along with the new B.6. But first, I would like to clean up Appendix C in place.

Holloway, C.L. ; U.S. Dept. of Commerce, Nat. Inst. of Stand. & Technol., Boulder, CO ; Kuester, Edward F.

I finished working on new sections C.3.and C.4, it is all greatly improved, and it is installed. I will now save out and install sections B.6 and B.7. DONE!

Next, I will remove Appendix G since no longer used in Chapter 4, save it off somewhere. DONE

I now have valid appendices A,B,C,D,E,F, hole at G, H,I and still M to add.

Task: Rewrite overview to Appendix B which is now in red! **DONE**

Task: Add Appendix M perhaps as the new Appendix G. Let's in fact do that right now. DONE

I am going to make lots of backups of this lines doc since it has a lot added recently, including jump drive.

I just reviewed a pile of docs and labeled them such. Did jump backup.

Task: Somewhere in need to have the way you get from 3D to 2D. This used to be in Appendix C but I threw it out because not needed there. ********* **DONE** as Appendix J.

Sat Jan 18, 2014.

****** Decide how to spell travelling and be consistent with it (**Done** 6/4, went with single el).
******* Put all Reader Exercises in the same font format. (**Done** 6.4.14)

I tried again to do the rectangular wire numerical integrations. I made some progress and found some errors and redid Section C.4, but I could not do the 232 integrals because some of them crash with recursion errors at the upper endpoint even if you replace 1 by 0.99, so I admitted as much and gave up. This new version C.4 is installed. It was a good try, but it is now 2 PM! It was a costly try.

I just updated the Appendix B overview at the start of that section.

Now I have to face the 3D/2D reduction thing. Maybe I have already done it somewhere.

Chapter 1 states the 3D Helmholtz integral forms in Section 1.5 (b), no 2D stuff. There is 2D for the surface charge in (1.5.13) but that dS' is still over the entire dz' conductor extent.

Chapter 2 does show ∇^2_{2D} for our round wire "wave context" discussion, but there is no nearby use of the Helmholtz integral. Then nothing in the rest of Ch 2.

Chapter 3 nothing.

So yes, it is really with Chapter 4 that we start using the Helmholtz integral for real.

Chapter 4

Section 4.1 and 4.2 start things off.

Section 4.3 starts showing a 2D integration with 1/R propagators.

Section 4.4 then has all 1/R everywhere and we are about to do the dz' integration. I do it, and bank, out come the $\ln(s_{21}^2/s_{11}^2)$ and we are then in the 2D propagator world **for the first time**! I make no mention of this 3D to 2D conversion explicitly, though the reader can see how it is done. I don't mention that ln(s) is the 2D propagator. I did not realize it at the time in fact!

Section 4.5 and 4.6 are examples of twin lead and coax, no ln(s) "theory" there, just crank turning.

Section 4.7 does the μ thing

We go on and the same ln(s) stuff appears.

OK, I ran off the end of Chapter 4. It uses the 2D "reduction" but does not say so.

Chapter 5. Again we come very close here. The anzats separation of charge density ρ leads to what I call the transverse equations involving ∇_{2D}^2. The transverse problems are stated in (5.4.8,9) as PDE's, no Helmholtz integrals. My scaling boundary condition is exactly related to the 3D/2D reduction, and again you see the $\ln(s^2)$ thing appearing.

Below (5.4.4) I have my little 2D/3D review of propagators but not the reduction.

Chapter 6 takes the lns thing as THE total φ_t solution. Done with the main text.

Comment: I can see the need for a whole new and short appendix showing the reduction. It used to be there in Appendix C.

Let's keep searching, however.

App A: Equation (A.1.7) is sort of B = $\int$ curl J but in 3D instead of 2D

App B: Here I just say that when small z dependence, $\nabla_{3D}^2 \rightarrow \nabla_{2D}^2$ which is quite obvious. Once you have the 2D think, the lnR stuff arises directly from Appendix I. I then "jump" in (B.6.13) from 3D to 2D and here I am looking for a place to reference for this step!

App C: This is where I deleted the 2D/3D section since it did not belong here.

App D. A huge monster, nothing on the 2D/3D issue.

App E: Is about thinness of surface charge layer.

App F on waveguides

App G is another monster, on computing A_z for the round wire.

OK, I think my new appendix will be a short one, Appendix J and properly follows H and I which are on the same subject. Title: The 3D/2D Relationship.

DONE. I just sat down and wrote Appendix J and it is installed. It has all the stuff I have been wanting to say about the propagator transitions.

Next up: two more appendices, one on ε electrostatic problems, another on deriving Z_0 in the electronic model of a transmission line. Then comes the big introduction, and then this baby is done!

Network Appendix, Weds Jan 22 2014.

I started into the network appendix and somehow this led me to add two more "internal inductance" calculations to Appendix C. I have written these in separate docs and right now I will install them both.

Now let's return to the network appendix K. ?? Done, this is ready to install!

OK, I will now install Appendix K on network view. This puts us at 299 pages, I will back this up right now.

Next, I wrote up Appendix L about the point charge in dielectric. The Jackson problem is too long and complicated and is not really relevant to "transmission lines". I once thought it would be in terms of the diffraction of B lines coming out of the conductors, but no more. Perhaps it can be a separate document.

Time is 8:15 PM, enough for today.

Thurs Jan 23 2014.

I added a 2D section to Appendix L and will now install Appendix L. Done, now at 314 pages. Time for the introduction.

Did the Overview and Summary it is installed. **DONE**.
Did the Chapter and Appendix Section headings, **DONE**

This has been a long time coming. I will make a PDF just to make sure that mechanism is still working. It was slow on the bookmarks and I think it crashed. Try again. It worked just fine, maybe 4 minutes. So now begins a long round of proofing, done for the first time when everything is present! Lines doc is now 319 pages long. Much work still lies ahead.

Proofing Passes and Releases, Fri Jan 24 2014.

Start the proofing. All equation references are now being verified.

Chapter 1
Section 1.1 eq num seq check: OK fig num seq check: OK
opening text OK, short
(a) notes
0. OK
1. OK, checked all the Jackson references
2. OK

3. OK, checked B&B reference
4. OK, ref to App L is here.
5. OK, added shielding comment
6. OK, checked refs
7. OK, checked refs
8. OK, refers to App E
9. OK, charges only on surfaces.
10. OK

(b) integral forms, OK, seems good.
(c) boundaries, OK, repaired King page reference for ξ boundary stuff!

Section 1.2 OK eq num seq check: OK fig num seq check: OK

Section 1.3 eq num seq check: OK fig num seq check: OK
(a) OK. This is a good careful derivation of the potential wave equations.
(b) OK, this is the relativity thing
(c) OK, this is my Main Act in clarifying King's stuff!

Section 1.4 eq num seq check: OK fig num seq check: no figures
Discovered that FT of the retarded solutions are in fact the Helm integralss.
Added a little FT section at the end, this is MUCH better, now the retarded's "fit in".
Added emphasis on propagators. Also integral operator K and word "kernel".
Even added a little Feynman diagram. OK, enough! Probably no refs to this section.
Yes, this formerly dull section now has some contribution to make! Propagators in title.

Section 1.5 eq num seq check: OK fig num seq check: OK (added #'s)
(a) OK
(b) OK, the Stak stuff is little out of place, but it is particular + homo that I am getting at.
(c) OK, a brutal section, n_s versus n_c, but I have to do it!
(d) OK. This entire Section 1.5 is quite painful, but teaches a lot of stuff.

Section 1.6. q num seq check: OK fig num seq check: none
(a) OK
(b) OK
(c) OK
(d) OK
(e) OK
(f) OK

Comments: This Chapter 1 is in fact an advanced post-graduate course in electrodynamics. Stak is in there, propagators are in there, PDE's are in there, media **P** and **M** are in there, Green's functions are in there. It has the relatively modest title of "Basic Equations". It is 45 pages long. I suppose after doing B&B I could have understood most of this stuff. I will no review my summary of this chapter. // OK. Tomorrow we go to Chap 2 and try to maintain continuity.

Sat Jan 25 2014.

I ran into this comment at the end of Section 2.2. I could not verify it quickly and it seems irrelevant, so I will record it here and then ignore it:

"Question: Somewhere I found Q = I/v_d . Is that correct and does it say something interesting? Since v_d is pretty large, it does seem to confirm that Q is very small. "

Chapter 2

opening text: OK, pretty good

Section 2.1 eq num seq check: OK fig num seq check: none

OK, this was a very good section to add I think, the wire is then in context and skin is explained.

Section 2.2 eq num seq check: OK fig num seq check: 3, all OK

OK, this is the long analysis resulting in box (2.2.30).

Section 2.3 eq num seq check: OK fig num seq check: all OK

(a) OK.
(b) OK.
(c) OK
(d) OK

Section 2.4 eq num seq check: OK fig num seq check:OK

opening text OK
(a) OK, I do a Matick verification of $Z_s(\omega)$.
(b) OK, the low ω limit with connection to Appendix C.
(c) OK.
(d) OK

Section 2.5 eq num seq check: OK fig num seq check: OK

OK

This was 30 dense pages on the round wire topic. It is definitely "monograph level" stuff, not general surface description stuff. It is all OK and "shippable" I think. We move on.

Chapter 3

Section 3.1 eq num seq check: OK fig num seq check: none

OK, I like this section and the Polyanin reference, no figs

Section 3.2 very short, no eq or fig surface charge thickness

OK

Section 3.3 eq OK, first figure of Ch 3 loss tangent

OK

Section 3.4 eq OK, first figure of Ch 3
OK now. This little section required some rewriting with addition of (3.3.8) in prev section.

Section 3.5 eq num seq check: OK fig num seq check: OK
OK, had to repair a bad error re Fig 3.4, and many eq refs were wrong!

Section 3.6 eq num seq check: OK fig num seq check: none
OK, was not SO bad after all.

Section 3.7 eq num seq check: OK fig num seq check: OK
(a) OK
(b) OK
(c) OK
(d) OK

Section 3.8 eq num seq check: OK fig num seq check: none
OK

This item was at the end of Chapter 3, it makes no sense so it gets canned.

" **Reader Exercise:** Reconcile the appearance of Appendix C Fig C.1 with the above proofs of Fact 7. "

My proofing of Chap 3 is complete. There were many bad references that got fixed. Tomorrow I start proofing Chapter 4.

Sun Jan 26 2014.

The above reader exercise has caused trouble, see Repair of Appendix B. // It is now 3PM and my proofing has come to a complete halt because of these troubles.

After much pain, I found a motivating picture in Purcell which shows E not perp to B at the surface of a very low ω "transmission line" (DC), and that forced me to study my simple E•B = 0 "proof" which my own Appendix C.2 image was contradicting. It turns out to be a sort of numerical thing and I think I understand it OK. It is correct at "high frequency" but I don't exactly know how high, I hope to come up with an estimate.

Secondly, I found a derivation of L_i using the flux definition and I think I can maybe do that as alternatives within Appendix C. They are less clear though. This might give a simpler formula for the L_i of that rectangular bar.

Third, I found other people who compute the H field for my bar using different methods. One computes A_z and then H from that. Another adds up lots of tiny square conductors and superposes to get the full bar and he shows my same kind of expressions with ln and arctans. There is probably a magnetic potential method as well (rather than vector potential?, maybe the same). Biot-Savart might provide another method, and I wonder why that formula never appears in my discussions?

I also questioned my formula for computing H directly from current which I use in Appendix C, in terms of whether you need to add homo terms to it. Maybe the answer is no for transverse H which is what I was after.

So many things wobbled today, but nothing completely broke except that E•B thing broke at low frequencies and I have to write that up somewhere.

Also, I want all my "facts" to have reference numbers. So the work plate is filled up once again and I have to do all this before the proofing can resume.

Mon Jan 27 2014.

(1) I added an alternative derivation of my H in terms of curl J formula right after the first one. I did this because other authors are using the A_z method.

(2) I then showed that my H_x and H_y expressions agree exactly with those of Holloway. This took a lot of effort and required hand transcriptions, but we have agreement!

(3) My next task is to read the Holloway paper just to see what they did! // I read this thing, and then sent Kuester an email asking if he could find my factor of two error.

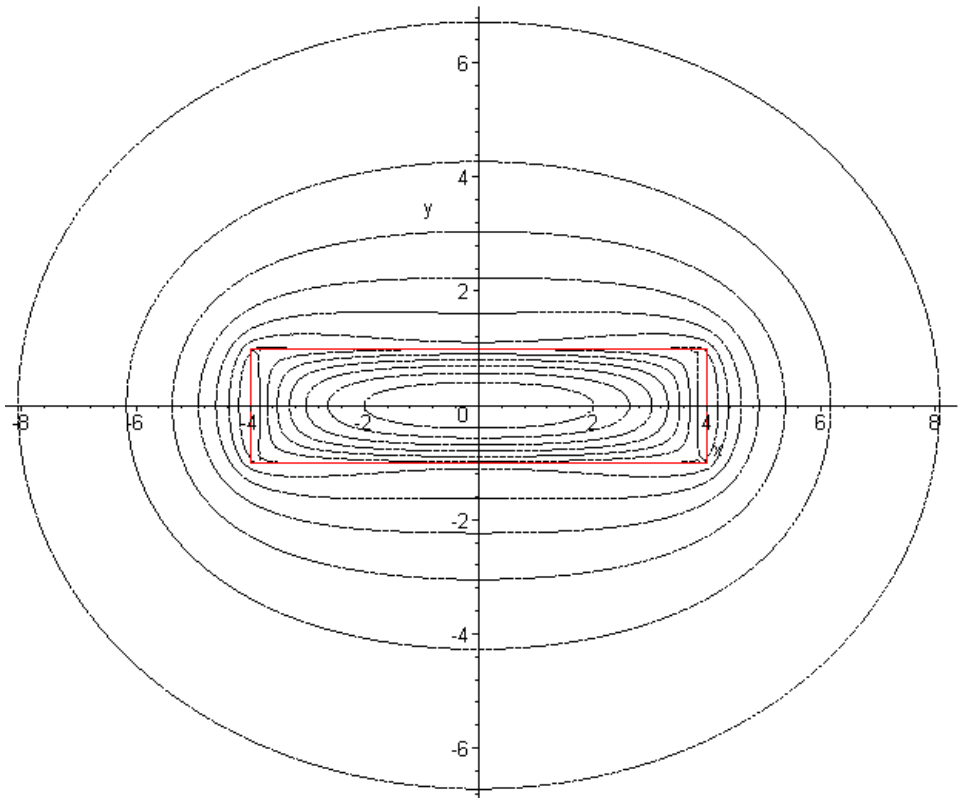
(4) Now I have to deal with the E•B = 0 issue versus frequency. This will probably take a while and I then have to decide where to put it.

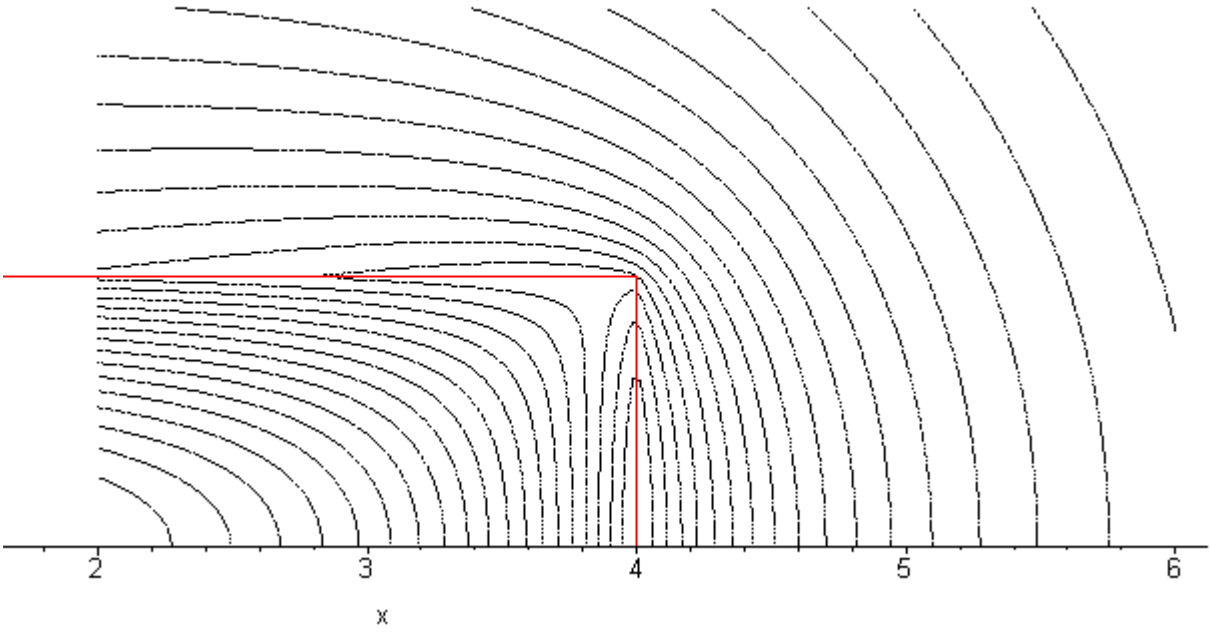
Had a big word crash on a bad sector, lost my Repair of doc, brought back in from backup. Also ran a reboot full disk check,

I added then removed these pictures

Finally, a contour plot showing the H field lines reveals the two little mountain peaks visible in the left of Fig C.3 at the two thin ends of the bar :

```
p3 := contourplot(Hx^2+Hy^2,x= -10..10,y= -10..10, grid = [150,150], color =
black,scaling = constrained):
display(p2,p3);
```





These are lines of constant |**H**|, they are not the "field lines" that I wanted.

Now, on to the **E• B** problem. OK, I did a first cut and got result ω >> 50 to get E perp B. But it is extremely rough (separate doc), and will have to be cleaned up. It is very ball park.

Kuester email, Appendix C work, Tues Jan 28 2014.

(1) I lost a file and then did several more attempts on finding a limit for my **E•B** = 0 validity, but it keeps being a harder problem than I want to attack. I don't really know how to evaluate the "correction terms" and it is all horrible arm-waving in order to get a result. This problem no doubt has a nice solution, but I cannot solve every problem in the EM universe in this one lines doc, so I decided to bail out and just make a generic comment about validity and not being valid at DC. This is now installed ant is 12:30 PM. Time for a bread run, and I am getting sick as well.

(2) Prof. Kuester responded in one day. His explanation at first seemed wrong to me, but then I understood it and it is fascinating. I sent him back an email regurgitating his explanation. I ignored the energy stored in the transverse field component!

(3) Tried to write a Maple program to plot field lines from field equations. After a few hours of fiddling with Maple's inability to handle vector valued functions, I did it manually and got my first ellipse-like look for the rectangular bar H field. Program needs work, but the basics are there. Now 7 PM.

Sun Feb 2 2014.

I am now on Day #6 of a cold. In the last few days I was able to do a little bit. I did get some field lines to plot OK. I worked pretty hard and the a >> b limit of the Kuester thing with some simple models (doc on this subject), but I could not find an easy way to evaluate the transverse contribution. I have given up on some trick way to do the thin strip, but I will do something to highlight what Kuester found.

I will now reread App C through the rectangular bar treatment and make sure all is OK.

C.1 OK
C.2 OK
C.3 OK, but did several edits.
C.4 OK, removed Smedt reference, it is now correct and we are set up for C.5.

I think wrote a new C.5 which studies the Kuester issue as a digressionary topic of interest to the reader, it is only 5 pages so I think OK. Not installed yet. This took all day, it is now 4 PM.

Now let's continue on to C.6. I am looking for external verification for the hollow tube. I find in a Google book,

Self Inductance of a Hollow Tube of Circular Section, Return Neglected. — The *external* inductance is the same as for a solid wire, i.e., equation (13), taking for r the external radius of the tube. The *internal* inductance of the tube, putting r_2 = external radius and r_1 = internal radius, is

$$L_i = 2\mu l \left[\frac{r_1^4}{(r_2^2 - r_1^2)^2} \log_e \frac{r_2}{r_1} - \frac{1}{4} \frac{3r_1^2 - r_2^2}{r_2^2 - r_1^2} \right]. \qquad (14)$$

The term in the square brackets is always less than ¼, i.e., the internal inductance of a hollow tube is always less than the internal inductance of a solid wire; see equation (13a). In the limit, where $r_1 = r_2$ (tube with infinitely thin walls), the *internal* inductance is zero.



where $r_2 = b$ and $r_1 = a$. The above claim is then

$$L_i = 2\mu_i \ell \left[\frac{a^4}{(b^2-a^2)^2} \ln(b/a) - (1/4) \frac{3a^2-b^2}{b^2-a^2} \right]$$ // google book page 827

Pender and Del Mar 1922. I can expand their result as follows

$$L_i = 2\mu_i \ell \frac{1}{(b^2-a^2)^2} \left[a^4 \ln(b/a) - (1/4) \frac{3a^2-b^2}{b^2-a^2} (b^2-a^2)^2 \right]$$

or

$$L_i = 2\mu_i \ell \frac{1}{(b^2-a^2)^2} \left[a^4 \ln(b/a) - (1/4) (3a^2-b^2) (b^2-a^2) \right]$$

or

$$L_i = 2\mu_i \ell \frac{1}{(b^2-a^2)^2} \left[a^4 \ln(b/a) + (1/4) (3a^2-b^2) (a^2-b^2) \right]$$

or

$$L_i = 2\mu_i \ell \frac{1}{(b^2-a^2)^2} \left[a^4 \ln(b/a) + (1/4) (3a^4-4a^2b^2+b^4) \right]$$

or

$$L_i = 2\mu_i \ell \frac{1}{(b^2-a^2)^2} \left[a^4 \ln(b/a) + (3/4)a^4 - a^2b^2 + (1/4)b^4) \right]$$

or

$$L_i = 2\mu_i \ell \frac{1}{(b^2-a^2)^2} \left[(1/4)b^4 + (3/4)a^4 - a^2b^2 + a^4 \ln(b/a) \right]$$

However, my result is this

$$L_i = \mu_i \frac{1}{2\pi} \frac{1}{(b^2-a^2)^2} [(1/4)b^4 + (3/4)a^4 - a^2b^2 + a^4 \ln(b/a)]$$

The book result is 4π larger than my result! But this same book says,

and the "internal" self inductance is

$$L_i = l\frac{\mu}{2}. \qquad (13a)$$

so it has a different meaning for μ ! Their results are all in cgs units! Fine. They at least verify my result then exactly! Maybe I can find a better source?

Status 9 PM. I am now completely done with Appendix C, and today's new C.5 has been installed, figure numbers updated. This has taken a long time for many reasons, only one of which is having a cold.

Mon Feb 3 2014.

Cleaned up the Appendix C files a bit.

Then successfully worked in both the 3D and 2D **Biot-Savart** Laws. This has long been on my list. I also tested the resulting formula for the rectangular wire case and it gives exactly the O&K double integrals for H_x and H_y. This was done in Appendix B and I now have three different methods of computing H from J which I like a lot.

Now I want to continue the general overall proofing. I stopped at the end of Chapter 3 because I ran into that E • B paradox and why these are not perp at low frequencies. I have dealt with that issue, but somehow that brought in Appendix C where the paradox arose, and that led me to redo the section on the thin strip which Kuester showed I did wrong, and then there were other changes in Appendix C.

First, let's do a quick reading of Chapter 3 to "get back up to speed", then I want to dive into Ch 4.

3.1 OK
3.2 OK, but I gave Facts 1,2,3 equation numbers!
3.3 Something is fishy here in my ξ discussion. // Repair has been done, better data added.
3.4 Read this and added Fact numbers.
3.5
3.6 these are the two Table sections, I will not read this stuff again
3.7 Here I have to overhaul all equation numbers to give the Facts numbers.

I need to be careful with cross references here!

Section 3.7 renumbering
(a) done with this, and it now has eq nums through (3.7.8)
(b)
(c) renumbering is in progress
(d) OK and all done. Equation numbering is finished. But xrefs will probably exist.
Section 3.8
This is all OK, and I think our ducks are now all in a row for Chapter 4.

Status: I now have sort of a running start, having taken a quick pass through Chapter 3 which I already gave a detailed review a week or so ago before stopping on Jan 26.

Start Review of Chapter 4.

Section 4.1 eq num seq: OK fig: none
OK

Section 4.2 eq num seq: only 1 equation fig: one
OK

Section 4.3 eq num seq: OK fig: none
OK a little rough on the TL limit business, but the best I could do.

Section 4.4 eq num seq: OK fig: two
OK

Section 4.5 eq num seq: OK figs = OK
OK and excellent.

I think it is good to get these real world famous examples to fit into my complicated King formalism. It was good not to "wait".

Section 4.6 eq num = OK figs = OK
OK and good.

Continue tomorrow with Section 4.7 !

Tues Feb 4 2014.

Continuing my detailed proofing:

Section 4.7 eq num = OK fig = none
OK, and in fact excellent, perhaps some original work here.

Section 4.8 eq num = OK fig = OK
OK, a very short section

Section 4.9 eq num = OK fig = OK
OK, another very short sections

Section 4.10 eq num = OK fig = 4.10 and 4.11
OK

Section 4.11 eq num = OK lots fig = 4.12 and 4.13
OK

We have made it through Chapter 4!! It took months of work to get this Chapter to flow the way it does, with all the required supporting material. No one but me will ever appreciate that fact! This is the logic that King die for the parallel thin wires on a few pages. And this is the logic that I did completely wrong

in my original paper due to having a wrong power series expansion. But the general idea of the development has survived. I sure hope it is right!

Chapter 5: the transverse problem.

Section 5.1 eq num = OK fig = none
OK, everything is done very slowly and carefully here!

Section 5.2 eq num = OK fig = non
OK, parallel to the previous section

Section 5.3 eq num = OK fig = fig 5.1 only
OK

Section 5.4 eq num = OK fig = Fig 5.2 only
(a) OK
(b) OK, I like it.

Section 5.5 eq num = OK fog = Fig 5.3
OK and I think quite impressive. How many people know about this I wonder?

Section 5.6 eq num = OK fig = none
OK, again I like it. It worked out OK, and I will leave it as is!

Chapter 6

Section 6.1 eq num = OK fig = none
OK

Section 6.2 eq num = OK fig = 6.1 and 6.2
OK

Section 6.3 eq num = OK fig = 6.3, 6.4. 6.5
OK

This concludes my Review of Chapter 6 and thus of the entire Main Body!! Today I did the three critical chapters 4,5,6 in a single day so there is some good coherence in the review. I found nothing gapingly out of line. All equation numbers were checked! Total doc is 332 pages.

I guess I am now faced with a final shot through the Appendices. The main body is 172 pages, so the appendices are 332-174 = 158 pages, this will be another long haul of full checking! But lets' stop for the overview:

Overview
OK, did some rearrangement.

Chapter summaries

OK don't forget overall spell check processing somehow!

Appendix A.

Section A.0 eq num = OK fig = none

OK. I added $\varphi(\infty) = 0$ to A.0.1, loosening my original intent, and added "parts integration" !!

Section A.1 eq num = OK fig = none

OK and excellent, adding the parts integration notes is a great assist!

Section A.2 eq num = OK fig = none

OK

Section A.3 eq num = OK fig = none

OK

Section A.4 eq num = OK fig = none

OK

Section A.5 eq num = none fig = none

OK

Section A.6 eq num = OK fig = none

OK, ends with the water wave picture.

This is one Bun Busting appendix I have to say. It is *packed* with a ton of stuff. I guess this will be my last review of it apart from the spell check.

I think it is time for a break!

Appendix B

Overview

OK

Section B.1 eq num = OK Fig B.1,B.2,B.3

Bug! The magnetization picture has problems!!!! OK, I did repairs.

Section B.2 eq num = OK fig = none

(a) OK

(b) OK, the A_z alternative path to B.2.5

(c) OK, I deleted some spurious stuff that did not help.

(d) OK

Section B.3 eq num = OK fig = none

OK, very short

Section B.4 eq num = OK fig = none
OK

Section B.5 eq num = OK fig = B.4
OK, a pretty hairy calculation but it seems to work.

Section B.6. eq num = OK fog = B.5 and B.6
(a) OK, a repeat of my diatribe "regarding μ"
(b)
Statement of theorem OK, but I added a multi-conductor fudge statement.
(1) Preliminaries OK
(2) OK

Bug: If I add up all the (B.6.1) contributions from all the conductors, how do I know that the TOTAL A_z meets the boundary conditions at each conductor? Something is not clear here! I never really thought about this, but it does seem a critical point in my "theorem". I will work on this question tomorrow. I suspect there is going to be trouble here. Stopping at 8 PM.

Weds Feb 5 2014.

In the AM session, I was very lucky to repair the Bug noted above. I then introduced a separate Jm Lemma and Jm theorem. I am quite amazed that things worked out so easily, despite the long equations. So I am once again ready to continue proofing.

But I would like to make my "self consistency statement" somewhere in line doc. // I just added this as new Section 1.5 (e), so it is close to the King Helmholtz derivations.

I don't think there is anything else I want to add, and proofing can now continue. We are at 338 pages and the time is 3:30 PM.

Section 1.5
(e) OK no new equations, no new figures.

Now resume with Appendix B where left off above.

Section B.6. eq num = OK fog = B.5 and B.6
(a) OK
(b) opening comments OK
(1) preliminaries OK equa num = OK fig = B.5
(2) outline OK eq num = OK fig = none
(3) verify B.6.9 OK eq num = OK fig = B.6
(c) OK eq num = ok fig = none

Finally I am done proofing this long and painful Section B.6

Section B.7 eq num = OK figs = B.7 and B.8

opening text OK

(a) the $A_z^{(c)}$ term: OK

(b) the $A_z^{(c)}$ term: OK

(c) verify BC: OK

(d) plots: OK

Hurray!!! I am all done with this monster Appendix B. Time now 5:45 PM.

Appendix C

Section C.1 OK

Section C.2 OK

Section C.3 OK

Section C.4 OK

Section C.5 OK eq num = ok figs = C.6,7,8.9.10.11,12,13,14

Section C.6 eq = OK figs = C.15 and C.16

(a) OK

(b) OK

(c) OK

(d) OK

Appendix C is done, and I am done for the day! I got a lot done today. Tomorrow I will resume on the appendices.

The J_m Theorem in Appendix B, Thurs Feb 6 2014.

I am now curious. Since I have firmly established the J^m theorem, how would that alter Chapter 4 in the case of $\mu_1 \neq \mu_2$? Well, here is what (4.8.1) would look like

$$A_{z12}(\mathbf{x}) = A_{z1}(\mathbf{x}) + A_{z2}(\mathbf{x}) =$$

$$\int_{-\infty}^{\infty} dz'\, i(z') \left\{ \int_{C_1} dx_1'\, dy_1' \frac{\mu_1}{4\pi} b_1(x_1',y_1') \frac{e^{-j\beta R_1}}{R_1} - \int_{C_2} dx_2'\, dy_2' \frac{\mu_2}{4\pi} b_2(x_2',y_2') \frac{e^{-j\beta R_2}}{R_2} \right\}$$

$$R_1^2 = (x-x_1')^2 + (y-y_1')^2 + (z-z')^2 = s_1^2 + (z-z')^2 \qquad s_1^2 = (x-x_1')^2 + (y-y_1')^2 \qquad (4.8.1)$$

$$R_2^2 = (x-x_2')^2 + (y-y_2')^2 + (z-z')^2 = s_2^2 + (z-z')^2 \qquad s_2^2 = (x-x_2')^2 + (y-y_2') \ .$$

where now b_i *include* the effect of surface currents. We would have for example,

$$J_{z1}(x,y,z) + (\mu_0/\mu_1)\, J_{m1} = b_1(x,y)\, i_1(z)$$

to give a redefined $b_1(x,y)$ which would still be normalized. The next equation of interest would be

W(z) (4.10.3)

$$= i(z) \int_{-\infty}^{\infty} dz' \{ \int_{C_1} dx_1' dy_1' \frac{\mu_1}{4\pi} b_1(x_1',y_1')(\frac{1}{R_{11}} - \frac{1}{R_{21}}) - \int_{C_2} dx_2' dy_2' \frac{\mu_2}{4\pi} b_2(x_2',y_2') (\frac{1}{R_{12}} - \frac{1}{R_{22}}) \} .$$

We would still have

$$L_e = \frac{W(z)}{i(z)} = \frac{\mu}{4\pi} K_L \qquad (4.10.8)$$

where K_L is the following dimensionless real number,

$$K_L \equiv \int_{C_1} dx_1' dy_1' \frac{\mu_1}{\mu} b_1(x_1',y_1') \ln(s_{21}^2/s_{11}^2) - \int_{C_2} dx_2' dy_2' \frac{\mu_2}{\mu} b_2(x_2',y_2') \ln(s_{22}^2/s_{12}^2) \qquad .(4.10.9)$$

Let's keep going to see where this leads. Into Section 4.11 now: Box (4.11.1) is the same except for the little ratios shown above in K_L.

Transmission line equations are unaffected. Only K_L is affected! but it stays the same.

The μ problem is fully solved, Feb 6, 2013

A Major Breakthrough today! I have been able to utilize all the work of Appendix B to do a full modification of the Chapter 4 theory to allow for arbitrary magnetic conductors and dielectric! This is quite astounding to me, considering how long I have fretted about this. I will add this as a final section right in Chapter 4. And that little Stakgold thing provided the proof I needed.

Proofing: Did this several times, I am now going to install a brand new Section 4.12. Done. Updated the Chapter 4 overview, and put in a forward reference to this section.

I can now (finally) continue my proofing with Appendix D. Still a long road to Tipperary.

Friday Feb 7 2014.

I did another edit pass on Section 4.12. Now on to Appendix D!

Appendix D

opening text OK, no figs, eq num refs checked.

Section D.1 eq num seq = OK Figs = D.1
opening text: OK
(a) OK
(b) OK
(c) OK
(d) OK all this stuff is very good, a real master's class in analysis.

Section D.2 eq num seq = OK Figs = D.2

(a) OK

(b) OK, Maple is "ever eager" for reader comic relief in the midst of a nightmare.

(c) OK, and very good.

(d) OK, added a few words here and there.

(e) OK -- this was a long haul!

Section D.3 eq num seq = OK Figs = none

OK, this is a truncated section from when I actually solved the φ Helm equation once.

Section D.4 eq num seq = OK Figs = none

OK, computing B for the wire and adding this to the E component solutions

Section D.5

OK, verifying Maxwell's with Maple

Section D.6 eq num seq = one Figs = none

OK, set m = 0 and compare

Section D.7 eq num seq = OK Figs = D.3

Section D.8 eq num = only 2 at end Figs = D,4,5,6

(a) OK. The last "reader exercise" is a bunbuster.

This concludes my proofing of this very long appendix!

I am now going to skip to Appendix G since it is connected with Appendix C and perhaps other appendices I have recently reviewed. I will later come back and fill in.

Appendix G

Opening text OK. The reader might presume this problem has a one line solution.

Section G.1 eq num seq = OK Figs = none

OK, a long setup of the 2D PDE.

Section G.2 eq num seq = OK Figs = none

OK

Section G.3 eq num seq = OK Figs = none

OK after I did a huge repair of a stupid error in computing J_{mz}. Luckily it has no global effect!

Section G.4 eq num seq = OK Figs = none

STOP. I see a huge duplication between here and Appendix B. Something has to be done here! I have now rewritten this solution using the Q integral evaluation done in Appendix B. OK, I continue

Section G.4 eq num seq = OK Figs = none
OK after this rewrite

Section G.5 eq num seq = OK Figs = none
OK, and pretty good I think but I won't ever pursue this path.

This concludes my proofing of Appendix G. I did make some substantial changes. This appendix is a little clumsy in that a lot of it still appears in Appendix B which I wrote much later in time. But I will leave it as it is!

Next stop: Go back to Appendix E and result the proofing review there. Manana,

Sat Feb 8 2014.

Appendix E eq num seq = OK Figs = two
OK, a very short appendix.

Appendix F

Section F.1 eq num seq = none Figs = none
OK

Section F.2 eq num seq = OK Figs =F.1 only
OK I like this little appendix, I verified the fields against some paper somewhere.

Appendix H

Section H.1 eq num seq = OK Figs = none
OK, did a few edits to connect with recently added extra stuff in other sections.

Section H.2 eq num seq = OK Figs = H.1
OK, I think it is reasonably rigorous

Section H.3 eq num seq = OK Figs = none
OK

Appendix I

Section I.1 eq num seq = OK Figs = none

STOP. I think I have a duplication of the wave equation green's function stuff in two places.

Section 1.4. Here I discuss the wave equation in 3D and then the Green's function gets mentioned but I quote Appendix A.7 for the result. So I guess at least I cross reference these two areas.

OK, I have added tie-in references between Section A.7 (my water drop picture) and Appendix I and H. Section 1.4 is also connected to A.7. I now resume on Appendix I

Section I.1 eq num seq = OK Figs = none
OK, did changes both here and in H to make connection to my general Stak Greens (1.5.11) thing

Section I.2 eq num seq = OK Figs = I.1 only
OK

Section I.3 eq num seq = OK Figs = *I.1* only
OK

I think these two appendices are worth their weight in gold bars, but probably no one will ever see them.

Appendix J eq num seq = OK
OK. This is an unusual appendix but I think worth while.

Appendix K eq num seq = OK Figs = three
(a) OK
(b) OK
(c) OK
(d) OK but see below
(e) OK a nice little appendix I think!

Only Appendix L remains!!!

Appendix L
opening comments: OK, I did some editing here

Section L.1 eq num seq = OK, 13 Figs = L.1 and L.2
OK, = I did a lot of fiddling here.

Section L.2 eq num seq = OK Figs = L.3 through L.6
(a) OK
(b) OK
(c) OK // OK, done with the spherical case

Section L.3 eq num = not relevant
OK

Section L.4 eq num = not relevant
(a) OK
(b) OK
(c) OK

Summary and Overview

Overview = OK
Chapter summaries. = OK
Appendix summaries = OK

References = OK

Title page = OK

This conclusions a complete 100% proofing pass of lines doc!

I am now ready for spell checking!

Spellcheck start through end of Chapter 3. This was 109 pages, but it shut down at page 89, so I will now truncate it so I can continue.

Status: spellcheck complete through end of Chapter 3. It can only do about 75 pages in a shot.

Next show will be Ch 4,5,6. DONE, through end of Chapter 6

Next shot will be Appendix A,B,C. DONE!

Next shot will be Appendix D,E,F and G. DONE!

Next shot will be Appendix . DONE

The complete spell check is now done!!

Pagaination, Sun Feb 9 2014.

I did a full review of all non-reviewed doc files. This led me to add a short piece on power lines after the twinlead example of Chapter 4. I was reminded of what a long saga this was, and how many very confusing issues I faced at the start with the King gauge and ξ and all those things!

I am now ready for pagination, but it is noon so break time.

TOC 4.2 pages long! Breaks are fine.

Overviews: header OK, summaries OK.

Chapter 1.
OK thru page 21, the boundary conditions chart is on one page.
problem on page 29.
fixed, all OK thru p 36
good through p 55 which is end of Chapter 1 ! Went pretty well.
I try when possible to get subsections to start on fresh page.

Chapter 2

OK through page 58 for 2.1

OK through page 84 and end of Chapter 2.

Chapter 3

OK through p 91 and 3.5 then starts on a new page.

OK through p 96

OK through p 104

OK through page 108 and end of Chapter 3.

Chapter 4

OK after adjustments through page 114.

OK thru p 117

OK thru p 127. I did not get 4.7 to start on a new page.

OK thru p 133 and 4.11 does start on a new page.

OK thru p 141, that is where the huge summary box goes nicely.

OK thru p 147 and end of Chapter 4

Chapter 5

OK, did not have to do much here.

Chapter 6

OK to page 177 and end of Chap 6, nothing needed, big summary chart box OK.

Appendix A

OK, I had problems with the no-delect hor lines, but all is OK now

Appendix B

OK through page 200

OK all the way, this is a massive huge appendix!!

Appendix C

OK, was not too bad.

Appendix D this is another monster.

OK and done

Appendix E

OK and done

Appendix F

OK and done

Appendix G

OK and done

Appendix H
OK and done

Appendix I
OK and done

Appendix J
OK and done

Appendix K
OK and done

Appendix L
OK and done

References
OK and done

Total is now 341 pages.

Check centering of all Figures: Done.

Am I ready to make a PDF? I entered the title and my name in the Properties.

Making a PDF right now: Done. Failed then took 4.5 min.

Check bookmarks and alignment:

Power Transmission lines did not appear in bookmarks perhaps because not on separate line!
The Magnetization Current didn't show up either, probably for the same reason.
(or because bookmarks only go a few levels???)

I just fixed these two issues in the doc.

How do equations and fonts look in the PDF? My bold subs and supers look just fine.
Integrals are all perfect looking.

Did second pass to fix above problems, there are now 176 bookmarks instead of 174.
The fix is good! It think it is ready, but I will allow a cool down day.

Errata
Page 9: take should be taken in the Appendix D summary! **done**.
Page 15: replace then thumb by the thumb. **done**
Box 1.1.50: "except the last" should be a ref to the equation of interest since I added something to the box. **done**

Created a complete **Visio index**, only one picture is "missing".

Need next to create a **Maple index**, this will be painful!

Maple and Visio indices made, Release PDF, Mon Feb 10 2014.

Did the Maple Index, all is OK.

Did a major file reorg by making a separate folder for each chapter and appendix.
The Maple files are in these folders as appropriate.
The Visio files are all in one folder, since so few and since mixed up.
All PDF files in a separate folder including Kuester.

Comments on Chapter 4.

I went way out of my way to come up with EXPLICIT expressions for V(z) and W(z) in this chapter. I was following both King's plan and my original (though fouled up) plan in the original lines doc. These are certain integrals over the conductors in either 3D or in 2D.

Interesting fact: When it comes right down to deriving the transmission line equations in Section 4.11, I don't know whether these V(z) and W(z) expressions are even used! Their definitions are used, and the definition of surface impedance is used. A key fact however is $W = L_e\ i(z)$ from (4.11.1). I don't know where I would have come up with that equation without having (4.10.4) which is one of those explicit forms where you see that i(z) factors out. I worked pretty hard on this L_e connection because W(z) is such a vague concept. And the $K = K_L$ might have been difficult to obtain. So I guess I am happy with the overall approach of Chapter 4 in terms of explicit expressions.

Quick read of Chap 4.

Bug: I looked through the first 108 pages and the doc and pdf end each page the same way. But starting with page 109 there is a difference which then throws off Chapter 4 ! Why did that happen? I made a separate test1 doc with just the pages in question, but in that test it does things right, whereas in the full doc it does things wrong. I don't see why it did this error! There are no thrown next breaks. I don't really have a fix for this! // But on my next round below problem got fixed !

Another Bug Fixed: I replaced all my bad section breaks with regular page breaks, you can search on next page breaks with ^b. This was probably OK, but now the number of sections is correct.

OK, lets fix all errata through this point and do another run. Done, and bug above is repaired.

Resume quick read of Chap 4.

Pagination bug. 4.4 starts on a last line, I failed to notice this. I have to repaginate Section 4 now.
I will now do another cycle and see if the previous bug comes back. Result: both bugs fixed, so I can now continue.

Result quick read of Chap 4: OK, I read a little bit, things seem OK, I cannot proof the whole thing. The bookmarks look OK.

I think this thing is ready to go out into the world!

Errata: Below (B.6.16)' should have s- instead of x-. I fixed it in the doc so it will be fixed next cycle.

Note: I never mentioned why we can ignore the B field in the Lorentz force law. I guess I ever think about any "forces" in lines doc. I guess no need to add a comment.

OK, now 4:30, I have been doing random reading in Chap 1, fixed a few things, I will now do a cycle to repair all errata so far found: **done**. I paged through all pages in pdf to make sure no blanks, all OK. This is ready to roll, but first a walk to Smiths.

Am back. Created a **release folder** and I have updated my local site, seems to be OK. But I have several other things to update, so I will address them as needed.

OK, lines doc is fully released and spider pushed and done. I will start an errata file in my little folder. I also released Maple, Stackel and a single-file version of tensor doc, pushed all on Google and Bing, there is no where else to push really.

2/12/14. While reviewing my coax cable doc, I ran into a few things that should be added to lines doc.

First of all, recall from

$$q(z) = q(0)\, e^{-jk_\varphi z} \qquad \Rightarrow \qquad q(z,t) = q(0)\, e^{j(\omega t - k_\varphi z)} \tag{5.1.11}$$

and the later finding that

$$k_\varphi^2 = k_A^2 \equiv k^2 = -zy = -(R+j\omega L)(G+j\omega C) \tag{5.3.4}$$

$$k = \sqrt{-zy} = j\sqrt{zy} = j\sqrt{(R+j\omega L)(G+j\omega C)} = j(A+jB)$$

I never make the connection with attenuation.

$$e^{-jkz} = e^{-jj[A+jB]z} = e^{+Az}\, e^{jBz}$$

****

Comparison of (5.3.3) with (5.3.2) shows that

$$k_\varphi^2 = k_A^2 \equiv k^2 = -zy \tag{5.3.4}$$

which fulfills the expectation earlier that we should have $k_\varphi = k_A$. With the assumed longitudinal behavior as given in

$$q(z) = q(0)\, e^{-jk_\varphi z} \quad \Rightarrow \quad q(z,t) = q(0)\, e^{j(\omega t - k_\varphi z)} \qquad (5.1.11)$$

$$i(z) = i(0)\, e^{-jk_A z} \quad \Rightarrow \quad i(z,t) = i(0)\, e^{j(\omega t - k_A z)} \qquad (5.2.11)$$

the appropriate root for k is then

$$k = -j\sqrt{\mathbf{zy}}$$

so that all quantities like q(z), i(z) and fields have this longitudinal behavior for a wave traveling in the +z direction,

$$F(z) = F(0)\, e^{-jkz}$$
$$= F(0) \exp[\, -\sqrt{\mathbf{zy}}\, z]$$
$$= F(0) \exp[\, -\sqrt{(R+j\omega L)(G+j\omega C)}\, z]$$

For example, at ω = 0 we get F(0) exp[$-\sqrt{RG}\, z$] which exhibits the expected attenuation decay over distance. More generally,

$$F(z) = F(0) \exp[\, - \mathrm{Re}(\sqrt{\mathbf{zy}}\,)z]\ \exp[\, - j\mathrm{Im}(\sqrt{\mathbf{zy}}\,)z\,] \ = \ F(0)\, e^{-az}\ \exp^{-jbz}$$

so that the per-distance attenuation factor is given by

$$a \equiv \mathrm{Re}(\sqrt{\mathbf{zy}}\,) = \mathrm{Re}[\sqrt{(R+j\omega L)(G+j\omega C)}\,] \qquad \text{attenuation per length}$$
$$b = \mathrm{Im}(\sqrt{\mathbf{zy}}\,) = \mathrm{Im}[\sqrt{(R+j\omega L)(G+j\omega C)}\,] \qquad \text{phase}$$

I have made changes now below equation (5.3.4), so this forces me to renumber equations (5.3.5) through (5.3.11). Are there cross references to these equations apart from the local section?

Equations

(5.3.5) through (5.3.11) all got bumped up by 2.

OK, I fixed all cross references to these equation numbers, and I remade the TOC and changed date to Feb 12.

I then repaginated the rest of Chapter 5 after where changes start. The purpose of all this was to get a statement of attenuation somewhere in my document!

Question: Suppose you have G = 0 and you are at DC. Then $a = \sqrt{RG} = 0$. How can this be? you would get a loss in R still, no? Well in this limit, $Z_0 = \sqrt{R/G}$ and if G = 0, then $Z_0 = \infty$ and no current flows in the line, so no loss, fine!

Another Release Feb 12, 2014

The Feb 12 release occurred right here!

The $Z_S(\theta)$ issued realised, Feb 15, 2014

While casually reading the intro summaries, a question occurred to me. How can R and L_i be the real and imaginary part of Z_s (sum 1 and 2) if Z_s varies around the periphery of each conductor? Is it possible that E_z is constant around the conductor surface? That cannot possibly be true for conductors which have inactive regions!!!

So let's start with (4.11.2) and see how this happened. This equation pair is general and clearly valid. Then with the A_z-only assumption (4.11.3) pair must also be valid. My intension here is that **x** is an arbitrary point in the dielectric. Then (4.11.4) is just a more precise rewrite of (4.11.3).

Now going to (4.11.5) I do the $\mathbf{x}_1$ and $\mathbf{x}_2$ subtraction trick. I then insert V(z) and W(z) as shown, and at this point I have made the assumption that both of these depend only on z. This gives (4.11.7) where I am hazy about the function arguments! If I write this out I would say

$$E_{z12}(\mathbf{x}_1) - E_{z12}(\mathbf{x}_2) = -\partial_z V(z) - j\omega W(z)$$
$$\partial_z W(z) = -j(\beta^2/\omega)\, V(z) \quad . \qquad (4.11.7)$$

Right here, it seems that the difference $E_{z12}(\mathbf{x}_1) - E_{z12}(\mathbf{x}_2)$ MUST be a function only of z, but I cannot assume that for the separate contributions. I have no comment on this but probably should.

Now we come to (4.11.8) which should probably say

$$E_{z1}(\mathbf{x}_1) = Z_{s1}(\mathbf{x}_1)\; i_1(z) \qquad E_{z2}(\mathbf{x}_2) = Z_{s2}(\mathbf{x}_2)\; i_2(z). \qquad (4.11.8)$$

so at this point both Z and E could vary azimuthally around a round conductor, say. For example, due to the form shown, if $E_{z1}(\mathbf{x}_1)$ is small at some azimuth, then $Z_{s1}(\mathbf{x}_1)$ is also small at that azimuth. Now let's maintain this notation and write (4.11.9):

$$[Z_{s1}(\mathbf{x}_1) + Z_{s2}(\mathbf{x}_2)]\, i(z) = -\partial_z V(z) - j\omega W(z)$$
$$\partial_z W(z) = -j(\beta^2/\omega)\, V(z)\,. \qquad (4.11.9)$$

Now we are forced to the conclusion that

$$[Z_{s1}(\mathbf{x}_1) + Z_{s2}(\mathbf{x}_2)] = f(z)$$

which let me write as

$$Z_{s1}(x_1, y_1, z) + Z_{s21}(x_2, y_2, z) = f(z)$$

How can this be true? Write again this way for r,θ,z a cyl coord sys for the #1 doc

$$Z_{s1}(\theta_1, z) + Z_{s211}(\theta_2, z) = f(z)$$

This really implies that $Z_{s1}(\theta_1, z)$ is independent of θ_1 and that MUST be wrong!

But maybe not. Consider again,

$$E_z(\mathbf{x}) = -\partial_z\varphi(\mathbf{x}) - j\omega A_z(\mathbf{x})$$

Now for our wave solution things go like this,

$$q(z,t) = q(0)\, e^{j(\omega t - k_\varphi z)}$$

and this applies to φ and A_z separately, so the above says

$$E_z(\mathbf{x}) = +jk_\varphi\varphi(\mathbf{x}) - j\omega A_z(\mathbf{x})$$

but then write them all with the same z behavior and you get

$$E_z(x,y) = +jk_\varphi\varphi(x,y) - j\omega A_z(x,y)$$

NOW, let x,y = a,φ be on surface of the wire. Then,

$$E_z(\varphi) = +jk_\varphi\varphi(\varphi) - j\omega A_z(\varphi)$$

Since φ and A_z are EACH constant around the surface, so must be $E_z(\varphi)$!!! So way back on the quiet inactive perimeter of two closely spaced fat wires, this must work out!

I certainly could check this for the Chapter 6 exact solution!!! I guess this will be in a new doc, so I am back into lines doc again! If $E_z(\varphi)$ is really constant, then it seems J(z) must be constant at the surface, and that goes against all my intuition! I could look at the m = 1 partial wave perhaps. But just by its nature, this must have cosφ dependence.

I think I am in serious trouble here! Maybe all of King is only for widely spaced wires???

This Achilles Heel Sisyphus issue just won't go away!!!

Here is another equation of interest:

$$\partial_z A_{z12}(\mathbf{x}) = -j\,(\beta^2/\omega)\,\varphi_{12}(\mathbf{x})$$

I do the subtract thing to get (4.11.7)

$$\partial_z W(z) = -j\,(\beta^2/\omega)\,V(z) \quad . \qquad (4.11.7)$$

which I could then write as

$$+jk_A\, W(z) = -j\,(\beta^2/\omega)\,V(z)$$

and this directly relates the two main functions of the game!

I want to see all these things for my exact solution of Chapter 6, so to do that now.

Making another pass through Chapter 4, examining assumptions.

- assumption of separation of variables such as (4.1.2)
- assumption of balanced line as in (4.1.4)
- transmission line limit same as small β as in Section 4.3
- assumption *(3.8.10)* that φ is constant at a given z.
- assumption that transverse components A_x and A_y can be neglected so that $\mathbf{A} = A_z\hat{\mathbf{z}}$. (4..7.1)
- assumption about μ
- time dependence is $e^{j\omega t}$

It is with this long list of assumptions that we enter Section 4.11. Notice that "low loss" has NOT been assumed at this point, we have K and K_L separate. Everything we know at this point I think appears in box (4.11.1). There are 6 equations in that box. Note that i(z) and q(z) do appear. Also NOT assumed is the wave dependence on z.

With the above listed assumptions, King gauge, (4.11.2) is undeniable.

The first line of (4.11.3) is nothing new, while the second line is new and uses the assumption that we can ignore A_x and A_y AND their derivatives. So a big assumption then going into (4.11.3).

Then (4.11.4) is nothing but a rewrite.

Then (4.11.5) is the evaluate and subtract thing for selected $\mathbf{x}_1$ and $\mathbf{x}_2$ points.

Then (4.11.7) I would write this way:

$$E_{z12}(\mathbf{x}_1) - E_{z12}(\mathbf{x}_2) = -\partial_z V(z) - j\omega W(z)$$
$$\partial_z W(z) = -j\,(\beta^2/\omega)\,V(z) \quad . \tag{4.11.7}$$

Then

$$E_{z1}(\mathbf{x}_1) = Z_{s1}(\mathbf{x}_1)\ i_1(z) \qquad E_{z2}(\mathbf{x}_2) = Z_{s2}(\mathbf{x}_2)\ i_2(z). \tag{4.11.8}$$

so at this point both Z and E could vary azimuthally around a round conductor, say. For example, due to the form shown, if $E_{z1}(\mathbf{x}_1)$ is small at some azimuth, then $Z_{s1}(\mathbf{x}_1)$ is also small at that azimuth. Now let's maintain this notation and write (4.11.9):

$$[Z_{s1}(\mathbf{x}_1) + Z_{s2}(\mathbf{x}_2)]\ i(z) = -\partial_z V(z) - j\omega W(z)$$
$$\partial_z W(z) = -j\,(\beta^2/\omega)\,V(z)\ . \tag{4.11.9}$$

Our set of assumptions above has then led us to this conclusion:

$[Z_{s1}(\mathbf{x}_1) + Z_{s2}(\mathbf{x}_2)]$ = value for any $\mathbf{x}_1$ and any $\mathbf{x}_2$ in the same z plane.

In other words, the claim is that

$[Z_{s1}(\mathbf{x}_1) + Z_{s2}(\mathbf{x}_2)] = f(z)$

This is not really a claim, it is a fact resulting from all our work above including the assumptions made.

But I think we can obtain more. We can keep $\mathbf{x_2}$ fixed and let $\mathbf{x_1}$ vary to some new $\mathbf{x_1}'$. Then we have

$$[Z_{s1}(\mathbf{x_1}') + Z_{s2}(\mathbf{x_2})] = f(z)$$

Subtract to get

$$Z_{s1}(\mathbf{x_1}) = Z_{s1}(\mathbf{x_1}')$$

but this in turn implies that, since the above is true for all points on the conductor perimeter.

$$Z_{s1}(\mathbf{x_1}) = f_1(z)$$

The same then is true for the other, so we have

$$Z_{s2}(\mathbf{x_2}) = f_2(z)$$

and these are stronger claims than just for the sum. Now go back to

$$E_{z1}(\mathbf{x_1}) = Z_{s1}(\mathbf{x_1})\ i_1(z) \qquad E_{z2}(\mathbf{x_2}) = Z_{s2}(\mathbf{x_2})\ i_2(z). \qquad (4.11.8)$$

These then read

$$E_{z1}(\mathbf{x_1}) = f_1(z)\ i_1(z) \qquad E_{z2}(\mathbf{x_2}) = f_2(z)\ i_2(z). \qquad (4.11.8)$$

and we then conclude that

$$E_{z1}(\mathbf{x_1}) = E_{z1}(z) \qquad E_{z2}(\mathbf{x_2}) = E_{z2}(z)$$

This is a very dramatic result. We know from box (1.1.50) that E_z is continuous at the surface. This tells us that

$$J_z(\mathbf{x_1}) = J_z(z)$$

The current "just below the surface" is constant around the entire conductor! This seems extremely strange to me. It makes no comments about currents deeper down in the conductor.

This conclusion is extremely problematic for me. It says for example that all higher partial wave E_z fields must vanish, which is nonsense.

Exercise #1 For Chapter 6, I could in theory compute the moments η_m from the charge distribution, and from that I could in theory compute E_z along the surface of one of the conductors. Here is my formula from (D.2.33) for E_z :

$$E_z(r,m) = (1/4)\ \eta_m\ I\ R_{dc}\ (a\beta')\ [\frac{J_m(x)}{J_{m+1}(x_a)} - \frac{J_m(x)}{J_{m-1}(x_a)}]$$

Setting r = a then gives

$$E_z(a,m) = (1/4)\,\eta_m\, I\, R_{dc}\, (a\beta')\,[\frac{J_m(x_a)}{J_{m+1}(x_a)} - \frac{J_m(x_a)}{J_{m-1}(x_a)}] \qquad x_a = \beta' a \qquad \beta'^2 = \beta^2 - \beta_d^2$$

Note that,

$$[\frac{J_m(x_a)}{J_{m+1}(x_a)} - \frac{J_m(x_a)}{J_{m-1}(x_a)}] = J_m(x_a)\,[\frac{1}{J_{m+1}(x_a)} - \frac{1}{J_{m-1}(x_a)}] = J_m(x_a)\,\frac{J_{m-1}(x_a) - J_{m+1}(x_a)}{J_{m-1}(x_a)\,J_{m+1}(x_a)}$$

$$= J_m(x_a)\,\frac{J'_m(x_a)}{J_{m-1}(x_a)\,J_{m+1}(x_a)}$$

so this is not identically zero. E_z is "small" because R_{dc} is very small.

Well, I already did this, and here is the result:

$$Z_s(\varphi) = (1/I) \sum_{m=-\infty}^{\infty} E_z(a,m)\, e^{jm\varphi} \qquad \text{// (D.1.3a)}$$

$$= (1/4)\, R_{dc} \sum_{m=-\infty}^{\infty} \eta_m\, [\frac{x_a J_m(x_a)}{J_{m+1}(x_a)} - \frac{x_a J_m(x_a)}{J_{m-1}(x_a)}]\, e^{jm\varphi} \qquad \text{// (D.2.33)}$$

where, (D.2.35)

$$\eta_m = N_m/N_0 = \frac{\omega a}{\beta_d I} \int_{-\pi}^{\pi} d\varphi\, n(\varphi)\, e^{-jm\varphi} \qquad \text{// (D.1.5b) and (D.2.31)}$$

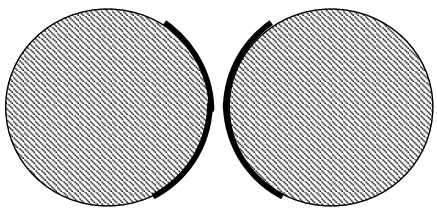
So this will give for sure a non-uniform $Z_s(\varphi)$ around the wire. This is a calculation I really could do using the Chapter 6 solutions since they determine surface charge $n(\varphi)$.

Back up Again. Here are some steps:

$\mathbf{E} = -\text{grad}\,\varphi - j\omega\mathbf{A}$
$E_z(\mathbf{x}) = -\partial_z\varphi(\mathbf{x}) - j\omega A_z(\mathbf{x})$
$E_{z12}(\mathbf{x}) = -\partial_z\varphi_{12}(\mathbf{x}) - j\omega A_{z12}(\mathbf{x})$
$E_{z12}(\mathbf{x}_1) - E_{z12}(\mathbf{x}_2) = -\partial_z V(z) - j\omega W(z)$

I can ignore the 2nd equation in each pair, my problem is with the 1st equation of each pair!

Idea #1. I think several of my "mysteries" are tied together. For example, consider this situation,



and exaggerate it every more by putting the conductors VERY close together so there is only a tiny active area.

Wrote Bipolar Doc, Feb 25, 2014

After being sidetracked on **bipolar doc** for 10 days (that is now released, 64 pages!), I now return to the problem described above, 11:30AM. At least now I can compute Z(θ) explicitly maybe for this two cylinders case, and that might help things.

After fiddling for a while, I see that I have Big Problems with many related issues, and that my lines doc in some sense is corrupted, so **I pulled it** from the index file so it is no longer visible on the site. I probably have another month (ha!) of labor to do the required repairs, and I think they will be substantial. The alternatives are to have a corrupt document on line, or to give up on it, and I don't like either of those alternatives.

[So OK, what exactly were these Big Problems?]

Mar 6, 2014 [fixed some unrelated bugs here]

Major Repairs are still in progress, but I found some simple **errors** that I want to repair right now so I can forget about them. These are **in Appendix D**, and may affect Chapter 2. I will have to repaginate Appendix D of course after doing these repairs. They concern the m = 0 limit of the fields, I have three different errors -- three items are 0 which I did not show as 0. I have fixed this, and adjusted my comment in Chapter 2 related to Appendix D since now there is only one small component E_r and $E_\varphi = 0$. φ θ Φ

I just went ahead and replaced φ by θ in Appendix D. I then had to find other places where this change is needed, I probably did not find them all. This is an improvement for two reasons:

- I use φ for scalar potential, so better to use θ for polar angle
- I use θ in Chapter 2, good to use same angle in Appendix D
- I use θ in bipolar doc.
- I like θ better for 2D thinking, Stak uses it as well, etc.

Appendix M written, Mar 7, 2014 **[** why $A_t << A_z$; this was installed on May 7, 2014]

Just **wrote new Appendix M** to explain why A_t is small in a transmission line. It was much more than just a few lines, about 20 equations, so that is why I broke it out as a new Appendix. It is all just qualitative. I am still hard pressed on this question:

$$\mathbf{E}_t = -\nabla_t\varphi - j\omega\mathbf{A}_t$$

I have argued that $\mathbf{A}_t$ is small in some sense, but why does this mean $\omega\mathbf{A}_t << \nabla_t\varphi$? I have no real estimate of the size of A_t except maybe $A_z = 10^3\, A_t$.

OK, I have now written up an argument for why $\mathbf{E_t} = -\nabla_t\varphi$ at any ω and therefore why φ = constant on the conductor surfaces. This really is an underpinning girder of my whole effort. The argument right now is in Assemble the Facts doc. Before installing anywhere, I have many other matters to clean up, but this was an important one! I think next will be the Z_s issue in Chapter 4 which I have been battling to get to.

First look at the ω→0 limit of the theory, Lines Overhaul, Mar 10, 2014

At this point, I decided to test my Appendix D fields by studying them in **the limit ω → 0.** I expected for example to find that the currents in the two-cylinder problem conductors would become constant in this limit. There should be a uniform J_z which is something I had always assumed without question at DC. But I was surprised when the limits of the Appendix D fields did NOT give this result, and this set off a whole new multi-week round of pain. My calculation of the field limits was done here

Very Low Frequency Limit of the Appendix D fields.doc

I continued with lots of notes in this lines edit log related to this low ω subject, but right now I am moving them to a new document

Low frequency limit of My Theory.doc

which is a little more general I think, Lots of paradoxes encountered, a trip to Marriott, books downloaded, and it is still in progress on March 12.

Radial Hall Effect and Appendix N, March 28, 2014

The low ω limit theory as above is still in force, and is still different, as expected. from the DC two wires uniform J_z situation. I have now done the "**radial Hall effect**" which confirms the uniform J_z in a round wire while showing how a radial E field can exist without a radial current! This involves the "**Magnetic Version of Ohm's Law**." I show that uniform J_z continues in magnetostatics despite another wire being nearby making a B field with possible gradient. There is no magnetostatic proximity effect! I have gone through the 1900 classical **Drude** conduction model. I think regular Ohm's Law is still OK at the B field intensities encountered in transmission lines, so Appendix D survives as does most of lines doc. I accept now that the King constant A_z on surface analysis requires being in the strong skin effect limit. So a lot has happened since Mar 10. What I want to do next is settle the business of Z_s and the "active perimeter" so that Chapter 4 can be "rescued" and made meaningful for other than wide spaced thin conductors. So that will start today.

March 30, 2014.

I decided to write up the **Radial Hall Effect** as a separate item. I did this as doc **Appendix N** which (so far) is 21 pages long. I may break this out as a stand-alone document because I think it might have some general interest, but not sure of that.

I would like to add to this section my conclusions about a different situation which is the effect of an external **B** field which has a gradient. This is the idea that there is no DC proximity effect. I might be able

to stick this at the very end of App N. I will have to reconstruct my arguments for this tomorrow. I think it is an important point to make and support.

Eddy Currents and Appendix P, April 7, 2014.

I spend a week learning about **eddy currents** and doing a few calculations with a **thin round plate**. I think this argues qualitatively for what happens inside the wire of a transmission line, but the calculation is too hard to do. I will try now to address the connection between eddy current stuff and transmission line stuff in a separate doc.

April 30, 2014.

Back from a Cape Cod trip, have to get the flywheel turning again.

Read doc about E_z field inside and outside a round wire for very small ω, seems OK, red comments.

Reading now **Appendix P on Eddy currents and Proximity Effect.** opening section = good, but then things are in a state of disrepair, so I start again on Version 2 of Appendix P, incorporating better text from Connection between Eddy and Lines doc.

I then wrote up the simple circular plate example as Section P.2.

May 5, 2014.

Finished my *third version* of Appendix P on eddy currents. I wanted to push down this pathway just a bit (29 pages worth) to get the basic eddy current idea stabilized.

Today I will start with one more **proofing of Appendix P,** then I will install it!

Section P.1 OK, fig and eq nums OK
Section P.2 OK, fig and eq nums OK
Section P.3 this is a very long section with 33 equations!
opening section OK, figs and eq nums OK
subsection (a) OK, figs and eq nums OK
subsection (b) OK, figs and eq nums OK
subsection (c) OK, figs and eq nums OK
Section P.4 has 16 equations, fig and eq nums OK
Section P.5 has 6 equations, fig and eq nums OK
Section P.6 has 0 equations, fig and eq nums OK
Section P.7 has 0 equations, fig and eq nums OK
Section P.8 has 0 equations, fig and eq nums OK
Section P.9 has 0 equations, fig and eq nums OK

OK, it took all morning, but I am happy with Appendix P and this last proofing did find plenty of errors that are now fixed. This is ready to install. // Installation complete at 3:45 PM, by which time I also reviewed all the docs in the Eddy folder.

May 6, 2014.

I created a Maple and Visio index for Appendix P, and I did a fast proofing if this appendix directly in Lines doc, found and fixed a few more things. This appendix is now DONE!

Next, I want to review and then install Appendix N on the radial hall effect.

Today I will do a **proofing of Appendix N,** then I will install it!

Section N.1 very good.
Section N.2 again very good. Much more detail than any book gives. Eq and fig OK
Section N.3 OK, eq and fig OK.
Section N.4 OK, eq and fig OK. Magnetic Ohm's Law
Section N.5 OK, eq and fig OK. Redo Hall Effect.
Section N.6 OK, eq and fig OK. Multiple carrier types.
Section N.7 OK, eq and fig OK. Multiple carrier types.

Installing right now: it is DONE. I then started reviewing docs in my Radial Hall folder and this led to my adding another Section N.8. I finished reviewing almost all the docs and will continue tomorrow. Then I will get on to Appendix M and get it installed as well.

May 7, 2014.

I finished reviewing all docs in the Hall folder, ran into no new problems. So on to Appendix M. I just read the Appendix M. Happily it is only 6 pages. I think it is OK, though it is highly technical. I give two reasons why the transverse A is smaller than A_z and quote a factor of 10^{-4} for the ratio! I added a set of references, but I have hold off fulfilling my η_m capacitance reference for a while, so that one item stays in red text. This is then ready to install: DONE.

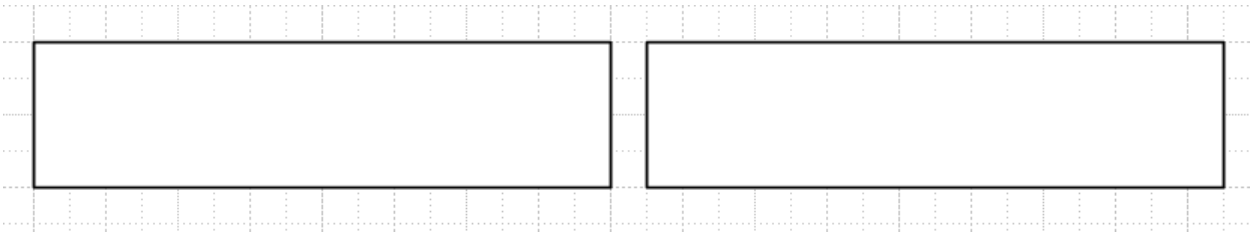
For the first time in a long time, everything I have is installed. There exists no Appendix O just because I didn't like the letter O, looks too much like 0.

Project Status. All appendices are now in place. I can now "pop the stack" to get back to the various problems that I was concerned with in the **"lines overhaul Feb 2014"** folder. Notice that it took me 3 full months to deal with the distractions of (1) small A_t; (2) Hall Effect; (3) Eddy Currents and Proximity Effect. These subjects were all triggered by my considering the $\omega = 0$ limit of my theory which gave me an unexpected result and kept me wondering about a DC proximity effect! So again, I have very many miles to go before I sleep. A related topic is that Chapter 4 has to be redone so it only applies in the skin effect regime where A_z and W can be constant on the conductor surfaces.

The quasi-static subject is treated in Assemble The Facts.doc. In that document, I still have the following problem: I want to argue that φ = constant on a conductor cross section up to 1000 GHz or some such. But in this document, I keep writing $A_z \approx (\beta_d/\omega)\,\varphi$ which is problematical since I want φ to be constant on a conductor surface, but I know that at low ω quantity A_z is NOT constant, so how can this equation be true at low ω? Perhaps this is a good place to start.

I have been reviewing docs in the "overhaul" folder. In "the current asym issue" section 5, I see this situation:

Suppose you have conductors that look like this in your transmission line,



Even if you are in the very strong skin-effect regime, there is a big problem with the King approach. We know that J_z will be strong near the gap and weak elsewhere, hence the same for E_z. Since φ = constant on the boundary, this means from $E_z = +j\,\beta_d\,\varphi - j\omega A_z$ that A_z varies violently as you go around the perimeter of either conductor above. [but even though E_z varies violently around the boundary, it is always small, and we always have $+j\,\beta_d\,\varphi \approx j\omega A_z$ so in fact A_z does NOT vary violently on the border. This is the subject of Paradox #1 which I reviewed on May 8] Thus, you don't even come close to having A_z = constant on the surface of the conductor, but this is the basis of my Chapter 4 King development. This skin effect by itself does not recue Chapter 4, and I think even now that this is a big problem. [but I think this is resolved by the above red comments. At low ω away from the skin regime, A_z really does vary violently, as seen in my plot of the two cylinder A_z and in that regime King theory does not apply]

May 8, 2014.

Wrote up my resolution of Paradox #1 and Paradox #2 in a new document. I think this is now all OK.

May 9, 2014.

I photographed and then wrote up everything in my whiteboard picture. Reviewed some docs for a second time in the overhaul area. I think I am ready to start rewriting Chapter 3. Perhaps sections 3.1 through 3.6 are OK still, I will have to review them now. But then 3.7 is where the important new stuff will go.

Section 3.1 OK, and I have added at the end a comment on the exception for radial Hall effect.
Section 3.2 OK. Added closing remark on Debye Surface Currents and why they are neglected.
Section 3.3 OK, on Loss tangent, did not add anything.
Section 3.4 OK, though I don't think I use anything from this section anywhere.
Sections 3.5 and 3.6 OK, I recommended reader skip Explanations in both sections!

We are now up to Section 3.7 and we shall now start to make changes and additions. I will construct a new Section 3.7 in a Separate document for now. As I start doing this, I see that yes, here is where I have to do a complete rewrite to talk about the E and B fields in the dielectric. This is going to require some heavy lifting and a clear statement of assumptions. I don't feel like starting this at 6:30 PM so will put it on hold till tomorrow.

May 10, 2014.

I have now started into the new Section 3.7. To get φ = constant, I made use of my fancy set of steps in Assemble the Facts.doc. It does seem ODD that I get φ = 0 at ω = 0, but then I have to skip the low ω range and get up to strong or extreme skin effect to get φ = 0 again. Is this fact not true for "low frequencies" ? We are talking $\mathbf{E_t} = -\nabla_t\varphi - j\omega\mathbf{A_t}$ and I am trying to make $- j\omega\mathbf{A_t}$ go away on the conductor surface. It obviously "goes away" at ω = 0, but for ω > 0 I need some proof that it goes away!

5:10PM. I have made some progress writing a new Section 3.7, I to do some repairs and define E_θ carefully and distinguish E_θ from $\mathbf{E_t}$. I think what I have so far is OK.

By 6:25 PM I have also rewritten Section 3.8 and this then concludes the rewrite of Chapter 3. It was not horribly major, but I had to renumber a lot of equations and filter out wrong statements.

Tomorrow I guess I will start into Chapter 4, ouch!

May 11, 2014.

I reviewed Section 7.8 from yesterday, seems OK. Starting to construct a rewritten Chapter 4.

4.1 no change

4.2 no change

4.3 no change on transmission line limit idea

4.4 Pay attention now! No changes above (4.4.8), K gets defined. Capacitance C and G.

But then I start quoting results from later sections, so I will put that all in red for now and move on then to the next section.

4.5 example of twinlead. Computes K for this case. It seems all OK except for a few red lines.

4.6 similar example of coax cable, some danger items at the end made red!

4.7 this then is the first section concerning A_z . I think this is all OK, some minor issues I ignore.

4.8 is also OK, doing A_z from both conductors additively

4.9 is also OK, doing TL limit on messy integral form

4.10. First mention of A_z = constant, so add caveats, use blue. Just a few changes made here to restrict to small δ regime. In this section K_L appears for the first time. Otherwise all seems OK.

4.11 Classic TL equations, this is the Big Enchilada that is going to need lots of work!! Changes above this are mostly minor but still necessary. I think I am OK through (4.11.7). I think (4.11.8) is also OK, and we have some very small surface impedances Z_{si}. This is where I am going to have to do a lot of editing!

Comment on (4.11.9). Yes, the LHS varies over the perimeter and the right side does not, so this is a contradiction. This contradiction also exists back in (4.11.3).

OK, I just went back to Chapter 3.7 and 3.8 and *weakened* all my claims even in the extreme skin effect regime! I am now claiming that φ ≈ constant and A_z ≈ constant even in the extreme regime. This will then give me some wiggle room in Chapter 4.

OK, I did some major acrobatics, and things are now rescued up to (4.11.10).

1:45 PM. I have indeed done some heavy lifting and I think my new threading is good, things are very much better now. I am through the end of Section 4.11, had to upshift many equation numbers by 4, and

later I will have to repair external references to Section 4.11 !!! ********** [On 6/4/14 I verified all reference to section 4.11.* from outside that section, made a few fixes. **Done**.]

5:30 PM. Have read all red text in this new Chapter 4 and I think it is good! My confidence level is high now, I have rectified the main reason I pulled this doc from the web = that Z_s was screwed up.

I will now save the existing lines doc as of this date, and install the new Chapter 4 along with the new Sections 3.7 and 3.8. I have to keep moving forward!

Installation of both is DONE. I will repair only cross references before Chapter 5. // But I did not find any such cross references. So then I did all the ones in Chap 5 and Appendices. Done.

I think the next step is to review Chapter 5 since things may be closely tied to Chapter 4. I don't want to find new problems way later, want them right now.

OK, I scanned through Chapter 5. It is very technical but it is about "the transverse problem" and has some small mention of lossy lines.

Chapter 6: done, nothing needed changing here once I updated a few 4.11 equation numbers.

Right now, this is the end of lines doc and where the appendices begin.

Summary section needs updating. And I want to add Chapter 7 I guess on the current asymmetry situation.

May 12, 2014.

I tried again in a separate doc to extend my proof that φ = constant to low ω values, but I did not succeed. My existing proof is pretty complicated I now realized, and I added a little picture of the steps.

I have now started on Section 6.5 to do the proximity effect for the two cylinder transmission line. I got the n(θ) and η_m calculations reviewed, now I am having trouble finding where my best notes are on what comes next. I will list sources here as I find them:

overhaul folder:
Computation of Az for two cylinders case REVIEWED.doc has most of the stuff I need.

It is now 6:45 PM and have made much progress. I plotted that proximity effect J_z stuff and it all looks very good. I tied in with bipolar doc pretty well. I think plotted J_z around the edges and it looks just like n(θ) !

The next notes I need concern how J_z is connected with n(θ). Found some notes in "starting over 3_14" in low ω folder. But this is not my most recent source on this! It is a note added in "Bull By the Horns", found it!

I wrote up next a little section showing $J_z(a,\theta) = (v_d /a) (1/2 + a/\delta) (1/a) n(\theta)$ and stop there for today.

More Chapter 3 changes , May 13, 2014.

I added sections (d) and (e) in which I compute two different ways the relationship between $J_z(a,\theta)$ and $n(\theta)$. I think this really clinches the connection, though both of course rely on my charge pumping boundary condition. That condition underpins this entire document and has been challenged many times but has never been shot down. I really do hope it is OK.

So I now have to say something about the proximity effect and low frequencies, it cannot be avoided. But first I will proof what I have for Section 6.5.

(a) OK, did some edits
(b) OK, did some edits again
(c) OK, did some edits again
(d) OK, did some edits again
(e) OK, did some edits again

Now some comments on low ω.

1. In Section 3.7 I was unable to show that $\varphi \approx$ constant on surfaces at low ω, only at $\omega = 0$. But I just did some more work on this, and added comments to Section 3.7 that I think $\varphi \sim$ constant (in scale) in the low frequency range and so the theory might be correct at least "in scale".

It still remains to add low frequency comments to the end of Section 6.5. // I have now added such a section and it is 4:45 PM. I think that is all I have to say on this subject!

Installation of 6.5 is now complete, I have no more known stuff to add other than overview updates. The doc is now a whopping 428 pages long!

I am now going to plot my own versions of the Smith curves I quoted in Appendix P. The symbol connection is 2C = b and wires of radius a. But his plots are for current in same direction. He has

$C/a = 1, 2, 5$ and ∞

$b/(2a) = 1,2,5,\infty$ $\quad\quad$ $C = b/2$

$b/a = 2,4,10,\infty$

Can I solve for the ξ_1 values? I know from below Fig 6,14 that

$a/b = 1/(2\text{ch}(\xi))$

$b/a = 2\text{ch}\xi = 2,4,10\ \infty$

$\text{ch}\xi = 1,2,5,\infty$

Maple tells me

$$\xi = 0, 1.32, 2.29$$

Note that $\xi = 0$ means the two cylinders are just touching! In my world, that would mean $n(\theta)$ was infinitely peaked??

STOP. I see how that Smith is doing currents in the same direction and my model has nothing to say about that. I did add a final section addressing this subject.

All NEW writing is now done (I hope!). I will now do some more doc reviewing to see if there is something that I have done wrong or which has been omitted.

May 14, 2014.

I added the App M conclusion as a separate Fact in 3.7 and am reproofing that section. $B_{\mathbf{r}} \neq 0$

Bug: I make a comment in 3.8 about waveguides where there is reflection from the walls but I removed this portion of Appendix F. Maybe I should restore it for this reason.

Idea: Use Appendix O to show how to plot magnetic field lines. Not sure if this is not somewhere else. Then I could refer to that from Section 3.7 counter example.

Bug: [resolved] having qualms about my voltmeter voltage comment(s)! I read one PDF on the subject. If $A_{\mathbf{z}}$ is present, then you have to consider the B flux passing through the loop of the meter leads because this will show up on the meter. So your reading will vary with how the leads are arranged! This is not something i want to get into, so I am right now going to remove my reference to this subject or at least adjust it.

Old Section Removed:

Fact 5: The potential $\varphi(x)$ can be identified with the transverse "voltmeter voltage" . (3.8.7)

Proof: This is not immediately obvious. The thing one measures as "voltmeter voltage" is the line integral of the electric field between two points. If $\mathbf{E} = -\nabla\varphi$, one can identify φ with this voltmeter voltage, but according to Eq. (1.3.1), we have an extra term to worry about,

$$\mathbf{E} = -\nabla\varphi - \partial\mathbf{A}/\partial t \, . \tag{3.8.8}$$

However, according to Fact 4 of (3.8.5), the transverse components of $\mathbf{A}$ are negligible, so

$$\mathbf{E}_{\mathbf{t}} = -\nabla_{\mathbf{t}}\,\varphi \qquad \text{where} \quad \nabla_{\mathbf{t}} \equiv \hat{\mathbf{x}}\,\partial/\partial x + \hat{\mathbf{y}}\,\partial/\partial y \quad . \tag{3.8.9}$$

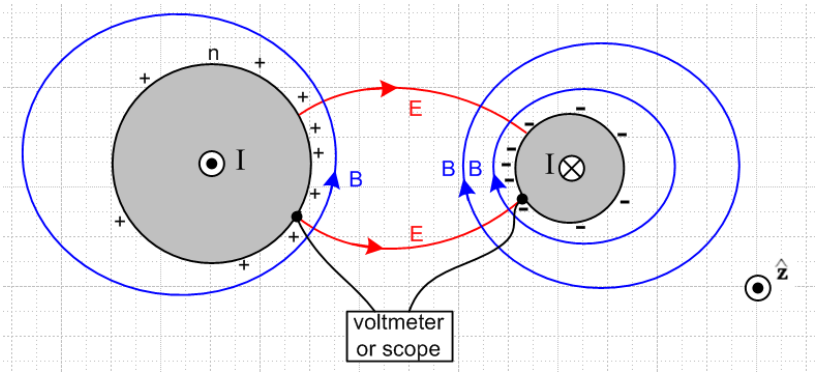
At least from (3.7.4) we know this is valid in the extreme skin effect regime. If one line-integrates $\mathbf{E}_t$ from one conductor to the other (keeping z fixed), one gets $\varphi_1 - \varphi_2$ which is a voltage that a voltmeter would measure.

Comment: In contrast with Fact 5, consider two adjacent circular rings on a round wire surface separated by dz in the extreme skin effect regime. The rings have V(z) and V(z+dz) so there is a constant dV between the rings going around the perimeter. But J_z and E_z vary dramatically around the perimeter if the conductor spacing is close (see Section 6.5). Thus, the voltmeter voltage between the two rings varies dramatically around the perimeter, although dV = constant. Thus, potential φ(x) cannot be identified with the longitudinal "voltmeter voltage". The issue is that $E_z = -j\beta_d\varphi - j\omega A_z$. If we imagine that φ = V(z) = constant around the perimeter, it is the fact that $A_z \approx$ constant that allows E_z to vary on the perimeter. Since the two terms on the RHS are large, a small variation in A_z allows a dramatic variation in E_z.

Replacement Section Added:

Fact 5: The potential φ(x) can be identified with the transverse "voltmeter voltage" . (3.8.7)

In the transverse direction (z = constant), and in the extreme/strong skin depth regime, we know from (3.8.5) that $\mathbf{E}_t = -\nabla_t\varphi - j\omega\mathbf{A}_t \approx -\nabla_t\varphi$ because $\mathbf{A}_t$ is very small. In the drawing below there is no difference then between the line integral of the electric field between the two black dots, and the potential difference $\varphi_1-\varphi_2$ between these same points. Since there is no B field perpendicular to the plane of paper, there is no time-varying magnetic flux through any loop containing the probe wires of our "planar" voltmeter, so there is no "EMF" induced in these leads to confuse the meter reading, and the meter directly reads $V = \varphi_1-\varphi_2$. If in the drawing we were to move the right black dot attachment point to a point on the left conductor in some other z plane, the meter leads then do enclose B field flux *and* $-j\omega A_z$ comes into play, and it is then less clear what the meter is reading.



I had to fix up Fig 3.6.b, support is in Az lines1.mws. Numbers were wrong I think. Result is still just fine.

So I guess I am happy with this. I avoid saying that voltmeter reads line integral of E now because I don't know if that is true. I just leave things hazy in the non-transverse case.

Status 5:10 PM. I have just concluded a "final review" of all docs in the overhaul folder. Many little details came to light, and this is now resting in peace. I have other folders to look at, however.

I am quite happy with the status of the Eddy Currents folder.

The time has come now to review the nasty "low frequency" folder. I expect some flack.

Question: The cpbc assumes no conductivity outside the round wire. How would such conductivity affect the results of Appendix D ? I bet $n(\theta)$ would change to $n_c(\theta)$ and all that stuff, as in the main body text somewhere. This is the old ε and ξ issue and I don't think I want to bring it up at this late date!!

As I fiddle with the low freq docs, I am back to the reflection idea for how to do the $\omega = 0$ limit, I might be on to something here, am at least optimistic. I will write up this reflection analysis tomorrow to get to the DC limit with no asymmetry!

May 15, 2014.

Spent all day reviewing low freq folder docs, all done. Had some items I wanted to fix, but I lost them when the edit log went hard read-only! I presume I will be reminded again when I see it.

May 15, 2014.

Spent all day reviewing low freq folder docs, all done. Had some items I wanted to fix, but I lost them when the edit log went hard read-only! I presume I will be reminded again when I see it.

May 16, 2014.

Pondered the asymmetry mystery pretty hard for most of the day and once again I could not make it go away. I think wrote up the "reflection scenario" and I think it does make asymmetry go away and I will add this somewhere.

May 17, 2014.

Softened my comments in lines doc that $\varphi \neq$ constant a low frequencies because I now want my theory to be used down to low ω. This is aided by the averaging idea of Section 4.11 to make up for $A_z \neq$ constant on the surfaces. I am now back to $\varphi =$ constant as the Rock of Gibraltar at all ω.

Action items: ********** ALL DONE

- do a specific calculation of resistance effect due to asymmetry (**Decided against this**, but added a comment below Fig 6.12 telling the reader HOW to do such a calculation using results from Appendices P and D)
- do a computation for a typical monster audio cable that is properly terminated (**Decided against this**, see "lamp cord.... doc". It just does not work very well)

but added a comment in Chap 6 about how you would do it using my App P formula.

- write up how to plot B field lines somewhere. **DONE**

Appendix D Update. I want to get f_m and g_m and h_m in there and get the symmetries and limits all stated somewhere so I don't clutter the main doc with that stuff.

D.2 (e)	done, f_m first introduced here in summary box (D.2.33), OK thru end of D.2
D.3	no change
D.4	no change
D.5	no change
D.6	no change
D.7	no change
D.8	no change

So I will just start a new Section D.9 with the limits I want

While playing with the high-ω limit, I found a mistake in my M_ν and θ_ν limits! In and around (2.4.15) I think $\delta/16 \rightarrow \delta/4$ but I remember seeing the $\delta/16$ from somewhere! Yes, where I saw it was in my 1991 document where I made the same mistake quoting A&S, I just checked. Matick takes limits of the ber functions directly so never deals with this.

Completed my repair of Section 2, corrected numbers in red. I like the $\delta << 4a$ better since the limit now applies when δ is larger than before with $\delta << 16a$.

Wrote Appendix D.9 on the large ω limits of the E fields.

Started Appendix D.10 on small ω limits.

May 18, 2014.

I discovered much simpler forms for g_m and h_m today, so I have to revamp some of the existing Appendix D to incorporate these things. DONE, was not too much to do, one Maple change.

Did an overhaul of yesterdays Setion D.8 which is now on symmetry and large ω limits, and I get some now and powerful results that will help later in Section 6.5.

Next step is to do a corresponding low ω section D.9 based on yesterday's start. DONE, and I am pondering its conclusions right now. // OK, it is done, and I want to get these things installed right now!

Installation complete, we now have Sections D.9 and D.10 on high and low ω limits of Appendix D. Everything you ever wanted to know.

May 19, 2014.

I reviewed D.9 and D.10 and did various edits, in particular, giving results for general n(θ) not just even. Now I want to edit Section 6.5 in light of my new D.9 and D.10.

Section 6.5

(a) OK, no changes needed

(b) shortened to use *(D.9.4a)* and other edits, now OK

(c) this took me a long time, but it is now updated, a section was removed.

Finally I am ready to face up to my Proximity Effect section 6.5 (e).

A System Wide Disaster Has Struck Once Again time is 5/19/14 2PM

I thought I was on a fast track to completion, but once again some VERY major support beams have collapsed and large sections of lines doc are now threatened. Not all of it, but maybe 1/4th of it or less. All the various Achilles Heels of lines doc seem to have come together and they are all trying to tell me that something big is wrong. Here is a short list:

1) the charge pump boundary condition is once again in doubt. Now seems that if that current moves down the surface (in effect) at v_d, then you would have $J_r = 0$ at the surface, I showed this in my most recent Debye doc. But combined with $J_\theta = 0$ at the surface this kills off the entire Appendix D E-field solution. This is directly related to my favorite Debye surface current issue. And then what happens to a_m and K_m in Appendix D?

2) The $E_\theta = 0$ surface condition is also in doubt, maybe there are azimuthal currents. I was unable ever to argue them away, despite D.8 on this subject with lots of arm-waving. So now BOTH boundary conditions are at risk, and these of course are the underpinning of all Appendix-B related materials.

3) The DC current asymmetry continues to be disturbing, I just think it is wrong even though the current is small in the wire.

4) I am unable to do my Reader Exercise about where the surface charge comes from.

Perhaps Chapters 1 and 2 are OK. Hard to say about Chapters 3 and 4. Many appendices are OK. Chapter 5 is probably OK on transverse problem. Chapter 6 is OK up to I guess section 6.5. Appendix D of course is a problem, and perhaps this makes its way into some other appendices, I am not sure.

I think I need to do some desktop cleanup. This disaster may cost 6 months, I have no idea. I need to do backups, Torrey is coming, the fast track is back to the slow track again. I have the books, I have the web, I have all my work, I'm sure it will get solved, but nothing fast is going to happen, so time to "do other things" as well as this stuff.

Comment: Chapter 4 has provided I think the complete exterior solution, so I know about the E fields in the dielectric just from the capacitor deal, and I then know n(θ) exactly. The problem is when you ask what happens INSIDE the conductors. Off hand things seem completely decoupled inside versus outside.

May 21, 2014.

I am trying to get back on the horse.

I just found a misleading statement below (D.2.2)

$$\beta_d^2 = \omega^2 \mu_d \xi_d \qquad \beta^2 \approx -j\omega\mu\sigma \qquad \Rightarrow \qquad \left|\frac{\beta^2}{\beta_d^2}\right| \approx \frac{\mu}{\mu_d}\,\frac{\sigma}{\omega\varepsilon_d}.$$

In scale, μ and μ_d are about the same, so

$$\left|\frac{\beta^2}{\beta_d^2}\right| \approx \frac{\sigma}{\omega\varepsilon_d} = \frac{5.81 \times 10^7}{2\pi f\, 8.85 \times 10^{-12}} \approx \frac{10^{18}}{f(\text{Hz})} = \frac{10^9}{f(\text{GHz})}$$

$$\left|\frac{\beta}{\beta_d}\right| \approx \frac{3\times 10^4}{\sqrt{f(\text{GHz})}}$$

For f = 100 GHz we then find that $|\beta/\beta_d| \approx 3000$, so for f < 100 GHz, $|\beta/\beta_d| > 3000$.

OK, I now have a little Section D.9-NEW which addresses the nasty subject of Debye surface currents and ONCE AGAIN, the charge pump boundary condition is rescued. I guess I had this informally figured out before several times, but now it is formalized in lines doc! I think I *back in the saddle again*. Have to review, renumber App D sections, review a lot of stuff in App D.

Thu May 22, 2014.

Will try for a few hours today pre Torrey. I proofed my new Section D.9 and it seems OK, no major problems, just small edits.

At this point, I started working on this question:

More Appendix D work, Mon June 2, 2014.

Torrey and subsequent maintenance cost 8 lost days for work.

Resuming today in my doc about how to generalize the cpbc, it is " Extending the cpbc" . I think I brought that discussion to a conclusion and will add it at the end of some section. Now, "new text" is that last thing I wrote pre Torrey which was about the cpbc, so I am now going to review that section.

Review of Section D.9 on the CPBC:

(a) OK after lots of edits
(b) OK, no edits needed
(c) OK, where n(θ) comes from.

I will now tack on a new section (d) . This took a long time, but I have a cut at it, it seems good.

Next, in order to get figure numbers right, I have to go edit the existing Section D.8. Since this is another delicate subject, I defer until tomorrow since now 7:30 PM.

Tues June 3, 2014.

I have read existing D.8 and I am going to remove the user exercise and store it below right here: my reasons are as follows. First, in item 2 I show a wrong plot! On a round conductor, at a given time the charge will be positive all around the conductor, which is not what I show! I would have to remake this little picture which would take a long time. Second, I now address this subject directly in a later section of this appendix which I will soon add. Third, I would like to see a the plots that (3) mentions, but I should do them, not the reader! Item (1) is still interesting but perhaps not so relevant.

****

Exercise for the Reader

(1) Show using **F** = m**a** and **F** = q**E** that a classical electron inside a transmission line conductor traverses a tiny elliptical path and thus never really goes anywhere. That path is traversed once per period T= 2π/ω. Mathematically, show that this amounts to proving that the three equations

$$x = A\cos(\omega t - a)$$
$$y = B\cos(\omega t - b)$$
$$z = C\cos(\omega t - c) \qquad \text{(D.8.1)}$$

are parametric equations for an ellipse with some orientation in 3D space. This goes-nowhere aspect of the electron is similar to what happens with a droplet of water in an ocean wave. (Hint: first show that the first two equations describe an ellipse in the xy plane and that the semi-major axes in general are *not* A and B .)

(2) When a TEM wave travels down a transmission line with a round conductor, the electric field "raises" a surface charge density on that conductor as it passes by. Exactly where does this surface charge come from? Is the charge density (though not individual charges) just sliding down the line in the z direction at the dielectric light velocity, and that is where it comes from -- the surface charge moves in the z direction, and there is then a z-directed surface current? Or does this charge get pumped off the other side of the conductor through the interior by the radial field E_r ? Or does the charge get driven around the cross section surface of the conductor by an E_θ field which we have proposed vanishes? Here is a simplified drawing showing how the phased elliptical motions of individual electrons might answer these questions:

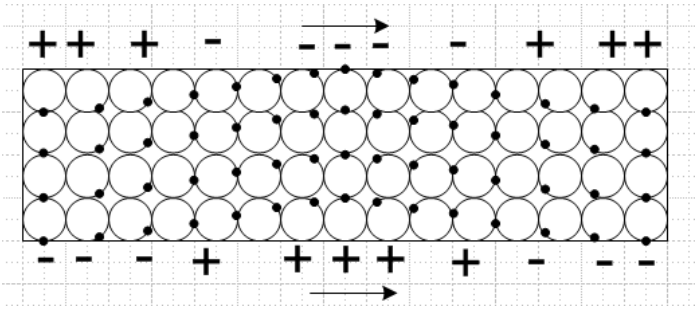


Fig D.6

(3) Use Maple or other software to make a cross-sectional 2D "field plot" like Fig C.2 of current flow in a round wire for a given partial wave m. A starting point (for z = 0) might be

$$\mathbf{E}_{\mathtt{trans}}(r,\theta,t) = \cos(-\omega t + m\theta + \arg[E_{\theta}(r)]\,)\,|E_{\theta}|\;\hat{\boldsymbol{\theta}} + \cos(-\omega t + m\theta + \arg[E_{r}(r)]\,)\,|E_{r}|\;\hat{\mathbf{r}} \qquad (D.8.2)$$

where $\hat{\boldsymbol{\theta}} = -\sin\theta\,\hat{\mathbf{x}} + \cos\theta\,\hat{\mathbf{y}}$ and $\hat{\mathbf{r}} = \cos\theta\,\hat{\mathbf{x}} + \sin\theta\,\hat{\mathbf{y}}$. Make a series of plots at sequential t values to obtain a weather pattern for the E field components (and thus the currents), and see if this helps answer question (2) above. Try making a 3D field plot adding in the $\hat{\mathbf{z}}$ field component.

****

OK, I can now do figure numbering for my new section D.9 in new text.doc, first is Fig D.6. So this new text now has Fig D.6 and D.7. Now before installing this new D.9, I have to adjust the existing D.10 to be D.11, and then D.9 to be D.10. Be careful!

Last section done. Now change D.9 to D.10: Done.

Now install new text as the new Section D.9. Update TOC and save with today's date.

Next, update Fig numbers in Sections D.9,D.10 and D.11. Done, only one more picture./

Maybe add a symbols list such as φ = scalar potential θ = cylindrical az, and so on. **DONE**

Review of D.9

(a) OK
(b) OK
(c) I added back my electron elliptical path Exercise.
(d) OK

This section D.9 is now finalized!

Review of Section D.10: DONE, did a small edit or two.

Review of Section D.11:

(a) OK
(b) OK
(c) OK

Finally I think Appendix D is in a Final Shape with all the pieces in place. I updated the opening little summary. Might not have time to do more until return from Colorado.

Weds June 4, 2014.

I just added a huge symbol index at the document start, as suggested above. Checked spelling in separate doc.

OK, I hunkered down and wrote Appendix O showing 3 ways to plot field lines! This was suggested earlier in this log as something that would be good to do. There are other suggestions pending! What happened to my explanation of a transmission line shorted by a bar? Did I ever obtain a symmetric current distribution for that case using reflections? I forgot how that all ended!

Time for Colorado. Backing up. On return, proof Appendix O and then install it.
Have to redo the introduction summaries and who knows what else.

Thurs June 5, 2014.

I had a little pre-Colorado time so reviewed the low-ω asymmetry issue a bit, looking mainly at my most recently created docs on this subject in the low ω folder. I think this is how it is going to play out.

1. The CPBC says roughly that J_r(below surface) = jωn(θ). This certainly does say that $J_r \to 0$ in the low ω limit, while n(θ) stays constant in this limit, so that is an encouraging start.

2. The "div E argument" is presented now starting with (6.5.14) in lines doc. The key lines are these, where we are evaluating div E = 0 just below the surface:

$$\partial_r (r E_r(r,\theta)) + r \partial_z E_z(r,\theta) \approx 0 \qquad \text{// near r = a [} E_\theta \text{ is ignored for usual reason]}$$

$$\partial_r (r E_r(r,\theta)) - j\beta_d r E_z(r,\theta) \approx 0 \qquad \text{// using } \partial_z \to -j\beta_d \text{, see (D.1.16)}$$

$$E_z(r,\theta) \approx (1/j\beta_d)(1/r)\,\partial_r (r E_r(r,\theta)) \quad . \qquad \text{// near r = a} \qquad (6.5.15)$$

Here I have made the "single wave assumption" in doing $\partial_z \to -j\beta_d$. The last line then reads

$$j\omega E_z(r,\theta)/v_d \approx (1/r)\,\partial_r (r E_r(r,\theta)) = (1/r)(1/\sigma)\,\partial_r (r J_r(r,\theta))$$

But roughly the RHS according to the cpbc is on the order of $J_r(r,\theta) \sim j\omega n(\theta)$ and then we get

$$j\omega E_z(r,\theta)/v_d \sim (1/r)(1/\sigma)\, j\omega n(\theta)$$

and the problem is that the two ω factors then cancel and we end up with $E_z(r,\theta)$ not vanishing and tracking the shape of n(θ). This is the problem I have to somehow overcome as $\omega \to 0$.

3. Suppose I could argue *somehow* that in the "two wave assumption" we can set $\partial_z = 0$ instead of this being $-j\beta_d$. Then the div E condition simply says

$$\partial_r (r J_r(r,\theta)) \approx 0 \qquad \text{// what the div E = 0 condition says if } \partial_z = 0$$
$$J_r(\text{below surface}) = j\omega n(\theta) \qquad \text{// cpbc}$$

Then as $\omega \to 0$, although the n(θ) stays finite, our div E condition :
(1) is consistent with the cpbc which says $J_r \to 0$
(2) no longer makes any connection between J_z and J_r

(3) therefore, we get no conclusion regarding J_z in the $\omega \to 0$ limit from the div E = 0 condition.

This would then break the argument which says J_z tracks n(θ) as ω→0, and this is what I want to see. I have some dim evidence of this $\partial_z = 0$ idea in my "reflection review" doc. Perhaps the loss theory could give this result (an alternative to reflection idea).

4. What does the "loss theory" have to say? This is presented in lines App D.11 where we find

$$\beta_d = (\omega - j\omega_c)/v_d \qquad \text{where} \quad \omega_c = (v_d^2/2)\,(R_{dc}C) \tag{D.11.2}$$

Then for $\omega << \omega_c$ we just have

$$\beta_d \approx (-j\omega_c)/v_d = \text{constant}$$

In this case, the connection between n(θ) is broken for $\omega << \omega_c$!!! I guess I never noticed this fact before. The steps above are then

$\partial_r (r\,E_r(r,\theta)) + r\,\partial_z E_z(r,\theta) \approx 0$ // near r = a [E_θ is ignored for usual reason]

$\partial_r (r\,E_r(r,\theta)) - j\beta_d\, r\,E_z(r,\theta) \approx 0$ // using $\partial_z \to -j\beta_d$, see (D.1.16)

$E_z(r,\theta) \approx (1/j\beta_d)\,(1/r)\,\partial_r (r\,E_r(r,\theta))$. // near r = a

$\beta_d E_z(r,\theta) \approx (1/r)\,\partial_r (r\,E_r(r,\theta)) = (1/r)(1/\sigma)\,\partial_r (r\,J_r(r,\theta)) \sim (1/r)(1/\sigma)\,j\omega n(\theta)$

where now β_d = a constant. Then we get the interesting result that $E_z(r,\theta) \to 0$ as ω→0.. But perhaps a constant part of E_z escapes this somewhat vague fate. We want the DC part of E_z to somehow remain!

So this "loss approach" is just a new idea, maybe it doesn't solve the problem, but there is hope. This is perhaps a good place to start next time. Maybe use low ω expressions for E_r with this lossy β_d in mind.

Mon June 9, 2014.

Am back from CO, Janet is moving, just delivered Crown burgers. Reread the last part above. Let's go back to the limit of D.11 and ask what happens if we include "loss":

Small ω limit of the E field solutions : $R_{dc} = \dfrac{1}{\sigma\pi a^2}$ (D.11.17)

$E_z(r,m) = (1/4)\,\eta_m\, I\, R_{dc}\, (a\beta')\, f_m$ $\quad f_m = (r/a)^m\,(m+1)\,(2/\beta' a)$ $\quad f_0 = 4/(a\beta')$

$E_r(r,m) = (j/4)\,\eta_m\, I\, R_{dc}\, (a\beta_d)\, g_m$ $\quad g_m = (r/a)^{m+1} - (r/a)^{m-1}$ $\quad g_0 = 2\,(r/a)$

$E_\theta(r,m) = (1/4)\,\eta_m\, I\, R_{dc}\, (a\beta_d)\, h_m$ $\quad h_m = (r/a)^{m+1} + (r/a)^{m-1}$ $\quad h_0 = 0$

where $-\beta_d^2 = -(j\omega_c)^2/v_d^2 = (\omega_c/v_d)^2$ = constant and $\beta' \approx (\omega_c/v_d)$ = constant. Write out'

$$E_z(r,m) = (1/4)\,\eta_m\, I\, R_{dc}\, (a\beta')\, f_m$$

$$= (1/4)\,\eta_m\, I\, R_{dc}\, (a\beta')\, (r/a)^m\, (m+1)\, (2/\beta' a)$$

$$= (1/4)\,\eta_m\, I\, R_{dc}\, (r/a)^m\, (m+1)\, (2)$$

So "loss theory" does NOT resolve my long-standing problem, since here we get moments for $m \neq 0$.

Conclusion: only the reflection theory has a chance of explaining this anomaly. The loss theory does not do it. So I need to examine the "two wave assumption" now in more detail.

My "play-through" of Appendix D for two waves appears in "reflection scenario.doc".

What does it "mean" to have $n(\theta)$'s with each wave going opposite directions? I guess there will be a standing wave pattern. But how do we make this pattern appear with only one conductor being pondered? If we short the end, maybe $n(\theta) = 0$ there! That would mean

$$n(\theta,z) = e^{j(\omega t-\beta_d z)}\, n_R(\theta) + e^{j(\omega t+\beta_d z)}\, n_L(\theta)$$

$$n(\theta,L) = e^{j(\omega t-\beta_d L)}\, n_R(\theta) + e^{j(\omega t+\beta_d L)}\, n_L(\theta) = 0$$

Tues June 9, 2014.

What happens when I take the Real Part of my round wire Appendix D solution? Do I get cos, and can this be made to vanish at the end of a finite line? Well for low ω I have already done this in (D.10.4a)

$$E_z(r,\theta) = (1/4)\, I\, R_{dc}\, (a\beta')\, [\, f_0 + 2\, \Sigma_{m=1}^{\infty}\, f_m\, \eta_m\, \cos(m\theta)\,]$$

$$E_z(r,\theta,z,t) = (1/4)\, I\, R_{dc}\, (a\beta')\, [\, f_0 + 2\, \Sigma_{m=1}^{\infty}\, f_m\, \eta_m\, \cos(m\theta)\,]\, e^{j(\omega t-\beta_d z)}$$

$$\text{Re}\, E_z(r,\theta,z,t) = I\, R_{dc}\, \{\, 1 + \Sigma_{m=1}^{\infty}\, \eta_m\, (r/a)^m\, (m+1)\, \cos(m\theta)\, \}\, \cos(\omega t-\beta_d z)$$

So the answer is: the result is a traveling wave, not a standing wave, so NO you cannot force it to vanish at some distance $z = L$. And as usual we have our $m \neq 0$ contributions.

Question: What is the low ω solution including losses? I know that

Small ω limit of the E field solutions : $$R_{dc} = \frac{1}{\sigma \pi a^2} \qquad \text{(D.11.17)}$$

$E_z(r,m) = (1/4)\,\eta_m\, I\, R_{dc}\ (a\beta')\, f_m$ $\qquad f_m = (r/a)^m\,(m+1)\,(2/\beta' a)$ $\qquad f_0 = 4/(a\beta')$

$E_r(r,m) = (j/4)\,\eta_m\, I\, R_{dc}\ (a\beta_d)\, g_m$ $\qquad g_m = (r/a)^{m+1} + (r/a)^{m-1}$ $\qquad g_0 = 2\,(r/a)$

$E_\theta(r,m) = (1/4)\,\eta_m\, I\, R_{dc}\ (a\beta_d)\, h_m$ $\qquad h_m = (r/a)^{m+1} - (r/a)^{m-1}$ $\qquad h_0 = 0$

where for small ω we have

$\beta' = (\omega_c/v_d)$ $\qquad \beta_d = (-j\omega_c)/v_d$ = "all loss and no wave" = $-j\,(\omega_c/v_d)$

Then the above says:

$E_z(r,m) = (1/2)\,\eta_m\, I\, R_{dc}\ (r/a)^m\,(m+1)$ $\qquad m = 1,2,3...$

$E_r(r,m) = (j/4)\,\eta_m\, I\, R_{dc}\ [-ja\,(\omega_c/v_d)\,]\,[(r/a)^{m+1} + (r/a)^{m-1}]$ $\qquad m = 1,2,3...$

$= (1/4)\,\eta_m\, I\, R_{dc}\ [a\,(\omega_c/v_d)\,]\,[(r/a)^{m+1} + (r/a)^{m-1}]$

$E_\theta(r,m) = (1/4)\,\eta_m\, I\, R_{dc}\ [-ja\,(\omega_c/v_d)\,]\,[(r/a)^{m+1} - (r/a)^{m-1}]$ $\qquad m = 1,2,3...$

Now, recall the boundary conditions,

$E_r(r=a,m) = (j\omega/\sigma)\, N_m = (j\omega/\sigma)\,\eta_m\, N_0$ (D.2.26)

$E_\theta(r=a,m) = 0$ (D.2.27)

But with r = a our low-ω solutions read

$E_z(a,m) = (1/2)\,\eta_m\, I\, R_{dc}\ (m+1)$ $\qquad m = 1,2,3...$

$E_r(a,m) = (1/4)\,\eta_m\, I\, R_{dc}\ [a\,(\omega_c/v_d)\,][\,2\,]$ $\qquad m = 1,2,3...$

$E_\theta(a,m) = (1/4)\,\eta_m\, I\, R_{dc}\ [-ja\,(\omega_c/v_d)\,]\,[0]$ $\qquad m = 1,2,3...$

Now the E_θ BC is correct, but what about the E_r one ?? To be correct, I have to show that

$(j\omega/\sigma)\,\eta_m\, N_0 = (1/2)\,\eta_m\, I\, R_{dc}\ [a\,(\omega_c/v_d)\,]$

or

$(j\omega/\sigma)\, N_0 = (1/2)\, I\, R_{dc}\ [a\,(\omega_c/v_d)\,]$

But recall

$$N_0 = (\beta_d/2\pi\omega a)\, I \ . \qquad \text{(D.2.31)}$$

$$R_{dc} = \frac{1}{\sigma\pi a^2} \qquad \text{(D.2.29)}$$

So then I have to show that

$$(j\omega/\sigma)\,(\beta_d/2\pi\omega a)\, I \ = \ (1/2)\, I \frac{1}{\sigma\pi a^2}\ [a\,(\omega_c/v_d)\,]$$

or

$$(j)\,(\beta_d) \ = \ [\,(\omega_c/v_d)\,]$$

which is correct. So I have now verified that the low ω limits do still meet the two BC's, and in doing this I fixed a sign error! Always good to do checks.

How about the large ω limit case? I see $E_\theta = 0$ at once. and I see

$$E_r(r,m) \ = (j/4)\,\eta_m\, I\, R_{dc}\ (a\beta_d)\, 2 \sqrt{\frac{a}{r}}\ e^{(1+j)(r-a)/\delta}$$

so that

$$E_r(a,m) \ = (j/4)\,\eta_m\, I\, R_{dc}\ (a\beta_d)\, 2$$

I then have to show that

$$(j/4)\,\eta_m\, I\, R_{dc}\ (a\beta_d)\, 2 = (j\omega/\sigma)\,\eta_m\, N_0$$

or

$$(1/4) \frac{1}{\pi a^2}\ \ (a)\, 2 = \ \ (1/2\pi a)$$

and this too is correct!

Now back to the low ω solution with losses:

$$E_z(r,m) \ = (1/2)\,\eta_m\, I\, R_{dc}\ \ (r/a)^m\,(m+1) \qquad m \ = 1,2,3...$$

$$E_r(r,m) \ \ = (1/4)\,\eta_m\, I\, R_{dc}\ [a\,(\omega_c/v_d)\,]\,[(r/a)^{m+1} + \ (r/a)^{m-1}] \qquad m \ = 1,2,3...$$

$$E_\theta(r,m) = (1/4)\,\eta_m\, I\, R_{dc}\ \ [-ja\,(\omega_c/v_d)\,]\,[(r/a)^{m+1} - (r/a)^{m-1}] \qquad m \ = 1,2,3...$$

The E_i are non-zero in each partial wave, so in particular for E_z we have "asymmetry". I am just reaffirming what I already know.

Conclusions:

1. For a well-conducting non-ferrous round wire which is part of a 2-conductor transmission line carrying a traveling wave of the form $e^{j(\omega t-\beta_d z)}$ through a vacuum dielectric, the internal E fields are completely determined by the relative moments η_m of the surface charge distribution $n(\theta)$ as obtained from an electrostatic calculation based on the shape of the line cross section. Parameters in the E field expressions are:

ω	angular frequency of the monochromatic wave
a	radius of the wire
β_d	wavenumber of the dielectric wave
β	wavenumber inside the conductor
β'	$\beta'^2 = \beta^2 - \beta_d^2$
σ	conductivity of the round wire

where

$\beta_d = (\omega - j\omega_c)/v_d$ $\quad \omega_c = (v_d^2/2)(R_{dc}C)$ $\quad v_d = c$ = the speed of light

R_{dc} = resistance per unit length, total of both conductors

C = capacitance per unit length of the two conductors

$\beta = e^{j3\pi/4}(\sqrt{2}/\delta)$ $\quad \delta \equiv \sqrt{2/\omega\mu_0\sigma}$

2. At all frequencies, including the limit $\omega \to 0$ (where $Z_0 \to \infty$), the current distribution J_z in the wire is non-uniform, and is determined from $J_z = \sigma E_z$. The current is non-uniform because the amplitudes of the partial-wave fields $E_z(r,m)$ for $m \neq 0$ do not in general vanish -- see for example (D.11.18). The one exception occurs if the round wire is the center conductor of a coaxial cable (see Chapter 2).

3. These conclusions apply to an infinite transmission line, or to a truncated transmission line which is properly terminated by $Z_t = Z_0$ where Z_0 is given by (4.4.12) with G = 0 (since vacuum dielectric). The conclusions do not apply to a truncated transmission line which is terminated with some other impedance, such as $Z_t = 0$.

Fact: I don't understand how to treat this problem in terms of a reflection. I think the reflection details are determined by what goes on *outside* the wire. My futile attempts suggest that the waves going in each direction will have asymmetric J_z and then so would the superposed total standing wave . But in retrospect, since I assume some kind of bad termination such as $Z_t = 0$, the theory doesn't really apply to either wave. I will now desist from worrying about this problem.

Review Starting at Section 6.5.

(a) OK, small edits made
(b) OK
(c) OK, I think the plots will be a "big hit" :)
(d) OK
(e) OK, I installed my summary and conclusion stated above !
(f) OK

How about an audio example. Lamp cord? Where would I get parameters?? I will just measure things and assume $\varepsilon = 2.3$ for the rubber? // I tried to work up this example, took a few hours. I get 100 ohms so huge mismatch, my stuff does not apply, web says not really a transmission line for audio due to load and source impedance. People use little networks at the load sometimes, it is a big mess and my stuff just is not applicable, so I have decided NOT to include this. See " lamp cord audio transmission line.doc".

One other thing: is it possible to plot my round wire solution somehow? I just think that would be a huge job. You would want to do it in r,θ,z space, it would depend on the η_m so you would use the Ch 6 example. I have already plotted just E_z in the proximity section, and that in itself was complicated just for magnitude. And recall the complex plots of the simple case of Chapter 2! So I will NOT do this!

So once again I am sort of "done" with lines doc in terms of new material.

Start another proofing cycle, Tues June 10, 2014.

I am going to start wrapping up efforts, I hope. Maybe I will read appendices one at a time and update each one's overview.

Appendix P on Eddy Currents.

Opening text: very good
Section P.1. Very good, I like the approach, hides perturbation smallness details.
Section P.2. The simple round plate example, I like it.
Section P.3 Round plate with gradient B field, opening text
(a) stream function and Poisson equation, all set up. Just fine.
(b) restate in cyl coordinates, OK, very short
(c) the solution and graph, all OK. Added a good reader exercise.
Section P.4 Plot shows how skin effect arises from eddy current in round wire! I like it.
Section P.5. Effect of external B field on quiet wire, very good, pieces of a puzzle being assembled.
Section P.6. Shows how uniform external B field can create asym J_z in w round wire
Section P.7 Summary of examples is just fine.
Section P.8. Finally we get to prox and skin effect in a *transmission line*.
Section P.9. Reference to the Smith paper, finally I get external sources into the soup.
Section P.10. Resistance increase effect.

OK, this was an excellent appendix IMHO and is ready to be published. I verified all doc internal references. I now must write a summary of this appendix!

Appendix P discusses the eddy current interpretation of the skin and proximity effects. A perturbation expansion is developed and for small ω the first term of this expansion is used to compute the eddy currents in some simple cases. A thin round plate is treated analytically for a uniform then for a non-uniform external B field. Then a series of qualitative examples leads to an explanation of the skin and proximity effects in a transmission line as well as in generic parallel wires with same or oppositely directed currents. It is shown why there is current crowding, and why such wires attract or repel.

Appendix O (I will review this, then install it, then write a summary).

(a) statement of the problem with example, fine
(b) brute force method and its drawbacks
(c) theory and detailed sample for the ODE case
(d) demonstration of the analytic method for two thing wires, very good.

OK, I am done with Appendix O, time now for a summary.

Appendix O reviews three methods for generating 2D field line plots. The first method is brute force tracking iteration, while the second method makes use of Maple's ability to numerically solve a pair of coupled differential equations. The third analytic method works in some cases. Examples of each method are presented.

OK, Appendix O and its summary have been installed into lines doc, we are at 464 pages. 7 PM.

Weds June 11, 2014.

I plan to continue through the higher appendices.

Appendix N.
Section N.1 is excellent.
Section N.2 on basic Hall effect, excellent
Section N.3 cyclotron frequency just fine
Section N.4 on magnetic Ohm's law, very good. This is a good appendix so far.
Section N.5 better Hall solution
Section N.6 multiple carrier types and how then Hall R_H can be either sign, fine.
Section N.7 radial Hall effect, is very small in all aspects. Very good writeup IMHO.
Section N.8 mag Ohm law for arbitrary B, fancier math, simple conclusions

OK, this appendix is just fine and it needs a summary.

Appendix N describes some subtle aspects of current flow in the presence of magnetic fields. The regular Hall effect is treated, the notion of "magnetic Ohm's law" is derived, and the Hall effect is reconsidered in light of this law. After dealing with multiple carrier types and magnetoresistance, we show that in a static round wire carrying a current I, the longitudinal current density J_z is uniform, and there exists a "radial Hall effect" inside the wire. There is a small radial electric field E_r and a small free charge density ρ inside the wire which is balanced by a small surface charge on the wire surface. The cyclotron frequency ω_c plays a major role in this discussion.

Next:

Appendix M Problems right away here, I have to adjust to include my loss model at low ω, ouch! Am editing stuff in. Pondering ω_c for a power line!

$$\omega_c = (v_d^2/2)\,(R_{dc}C) \;=\; (c^2/2)\,(R_{dc}C)$$

I show that K = 17.5 for a certain example and $Z_0 = 524\Omega$ below (4.5.13).

R = .02Ω/thousand feet = .02 * 10^{-3} Ω /ft * (39/36) feet/m = .06 * 10^{-3} Ω/m = .6 x 10^{-4} Ω/m

For both lines then

R_{dc} = 1.2 x 10^{-4} Ω/m

Meanwhile C = 4πε/K = 4π x 8.85 x 10^{-12} / 17.5 = 6.35 x 10^{-12} F

Then

```
evalf(4*Pi*8.85/17.5);
```

6.354993141

```
c := 3e8;
```

$c := .3\ 10^{9}$

```
Rdc := 1.2e-4;
```

$Rdc := .00012$

```
C := 6.35e-12;
```

$C := .635\ 10^{-11}$

```
omegac := (c^2/2)*Rdc*C;
```

$omegac := 34.29000000$

```
fc := evalf(omegac/(2*Pi));
```

$fc := 5.457422997$

So for a power transmission line, f_c = 5 Hz! So I cannot just say "on the order of several KHz". Repairs are well underway now.

Appendix M Comments. This appendix is much rockier than App P or O or N. I wrote it pretty long ago, and have now updated it to account for the f_c issue. // I have reread it a few times, it is "OK" and I will leave it as is. It now needs a summary.

Appendix M shows qualitatively that, in the King gauge, the vector potential transverse components $\mathbf{A}_t$ are much smaller than the longitudinal component A_z for all frequencies of transmission line interest.

I now have a summary for each appendix. But I want to continue reviewing them!

Appendix L.

opening text OK

L.1 point charge inside a hollow shell, all OK.

L.2

(a) OK, point charge in cavity

(b) OK, point charge in ball

(c) point charge in infinite medium

L.3 the 2D version of L.1

L.4 the 2D version of L.2

The purpose of my inserting this appendix is stated in the opening text -- just something to exercise **P** and ρ_{pol}. The existing summary is just fine.

I see my inconsistency in Appendix Section notation, but think I will leave it as is!

Question: What happened to the "telegrapher's equation" in my lines doc?

Appendix K.

(a) statement of the network model, very clear I think
(b) calculation of Z_0 is very clean, I like it, all OK
(c) here I come up with the same Z_0 . This repeats (4.11.16) but I like it redone anyway.
(d) STOP, and resume Fri 13, carrying this below

I am suddenly back to my Achilles Heel / Sisyphus problem again and I started a new doc to work on it yet again, for about the 25th time.

The reflection issue, Fri June 13, 2014.

Well I took another stab at using the **reflection** they in order to "get to" the problem of a shorted transmission line version of Appendix D. I did manage to obtain standing wave forms for various quantities, but the current asymmetry did not go away! When you take the limit $\omega \to 0$ on the Appendix D path, you do not arrive at the place you arrive for the actual shorted-bar problem.

So once again I give up on this, and I am now claiming that the entire theory is not valid near $\omega = 0$ so the limit is just not meaningful.

App D.11. I strengthened my comments on this subject just now. The loss model is not valid at very low ω, the whole theory is wobbly there for various reasons. Now I need to make Chapter 6 sound good too, but first I want to resume and finish with Appendix K.

Appendix K.

(a) statement of the network model, very clear I think
(b) calculation of Z_0 is very clean, I like it, all OK
(c) here I come up with the same Z_0 . This repeats (4.11.16) but I like it redone anyway.
(d) did some repairs here ("not too close"), lots of interesting facts I think here.
(e) OK

Now read the summary: it is find. Done with Appendix K.

I will now do Appendix H,I,J in that order and be done with them.

Appendix H

H.1 good introduction and discussion of significances
H.2 OK

H.3 OK

Appendix I

I.1

I.2

I.3 all sections very good, where else would you ever find such stuff???

Appendix J.

This is a very "advanced" appendix, reviewing examples of 3D to 2D transitions which occurred in the main text. It will probably not be appreciated by anyone, but it clarified things for me.

Next up is Appendix G.

opening text	OK
Section G.1	a long "setup" of the problem as a 2D PDE
Section G.2	reads well, I like it, flows fine
Section G.3	2nd method plus examples of magnetization, all just fine.
Section G.4	the Helm integral method, not too bad, 3 ways to get same result!
Section G.5	comments only about doing an actual Helm integral (vs Poisson) OK

Summary: OK

Up next is Appendix F on waveguides.

Section F.1. Adjusted slightly for current knowledge of E perp B. An intro.

Section F.2. More adjusts. Does the parallel plate waveguide. Very good.

Summary: adjusted to say TEM goes to very low ω instead of to DC.

Up next is **Appendix E** on surface charge thickness.

Problems with dimensions and equations!!!

From (E.1) I know that dim(D) = m^2/sec.

From (E.5) we get

dim(RHS) = ($D\varepsilon_0/\sigma$) = m^2/sec * F/m* ohm-m = m^2/sec * F ohm = m^2/sec * sec = m^2 OK

I have no reference for my D expression.

http://en.wikipedia.org/wiki/Diffusion claims that

D = μkT

but this seems totally wrong because dim(μ) = dim(v/E) = (m/sec * m/volt) = m^2/(volt-sec)

OK, I did a full referencing of everything in Appendix E, it is much better. Found 1991 notes on the subject!

Summary: OK!

This then brings us to Appendices A,B,C,D which I save for another day.

Sat June 14, 2014.

I will skip Appendix D for the moment.

Appendix C: DC properties of a wire.

C.1 totally trivial, OK. Still, had lots of bad things and did a rewrite!
C.2 OK, did lots of edits. Notation is similar now to previous section. Refs to App P.
C.3 Inductance of wires, this is a fascinating section, complexity is building in this appendix.
C.4 treats the rectangular wire, reader will be amazed at how hard it is to do.
C.5 the thin flat wire and Kuester and my mag field plots. I should tell Kuester about this section.
C.6 hollow pipe L_i with verification

Summary:

Next comes **Appendix B.**

Overview: a long agenda for this appendix! Includes the J_m theorem.
Section B.1. This is a tough section for me! I am trying to get an expression for K_z
Section B.2
(a) my first formula for **H** in terms of **J** which is (B.2.5) or (B.2.6)
(b) rederivation of this same result using potential A_z as intermediary
(c) claim that the H_t integral shown needs no homo adder solutions.
(d) derivation of Biot-Savart first in 3D, then in 2D.
Section B.3 General method (no examples) of computing K_z surface current for arb wire
Section B.4 Example: compute K_z and J_m for round wire with uniform J_z
Section B.5 Repeat round wire example using messy B3 method with (B.2.6).
Section B.6 The fancy King modification for $\mu_1 \neq \mu_2$.
(a) general discussion -- repeats stuff from the main text, overview
(b) the J_m Lemma just stated with important comments.
(1) preliminaries. Quote Stak results as you approach a surface.
(2) J_m Lemma proof outline, is very clear
(3) actual proof is pretty straightforward, though complicated.
(c) the J_m Theorem, statement and proof. Similar proof to the J_m lemma.
Section B.7 apply the J_m Lemma to a round wire as an example!
(a) (b) (c) all OK, we check all results
(d) OK with simple plots

This is one very hairy appendix B! Stak's fanciest stuff is brought to bear on this problem. I had forgotten what a great "victory" this was for me.

Summary: very good!!

This leaves now only Appendix A and Appendix D.

Appendix A

A.0 intro fine

(a) Coulomb's law for point and distribution
(b) Green's fucntion
(c) uniqueness of our solution
(d) proof of two theorems, parts integration and parts.

A.1

(a) OK
(b)
(c) OK
(d) OK

A.2

A.3

A.4 all OK

A.5 connection to E&M and history of "gauge" and current usage.

A.6 QED and the Lor gauge, very good I think, mind blowing for a newbie (motivating?)

A.7 a little catch 22 problem solved

Comments OK

I did not really change anything significant here, this appendix A has long been stable. Few things changed.

Overview: OK

This finally brings us to the monstrous Appendix D.

Appendix D

opening comments and overview. Both are just fine.

D.1

(a) the traveling wave ansatz, convention comments
(b) partial waves all OK, picture OK
(c) OK, vector Lap notes
Helm comments OK

D.2 Solutions

(a) for E_z OK
(b) for E_r OK, first appearance of a_m and K_m
(c) first summary and a detailed Maple verification!
(d) the CPBC, all OK
(e) get coefficients from the BC's, second summary E_i + "observations"
Maple verification

D.3 What about the E_θ equation?
D.4 Getting the B fields from a Max curl equation all OK
D.5 Max verify the B fields
D.6 State m=0 fields and compare to Chap 2, OK
D.7 Outside the round wire?
D.8 About $E_\theta = 0$.
(a) the quasi static argument
(b) the ansatz argument -- This discussion is still OK, can leave it as is!
D.9 About the CPBC. opening text OK
(a) Debye surf current. OK
(b) why you can ignore Debye surface currents in the CPBC
(c) where does n(θ) "come from" and ellipse reader exercise
(d) he CPBC modified for a conducting dielectric
D.10 high ω
(a) $f_m = f_{-m}$ symmetries and expressions for E_i as sums
(b) f_m etc at high ω. Observations all OK.
D.11 low ω
(a) loss or no loss, we have β'a << 1 so x<< 1 so small ω limit is what we are doing
(b) the loss model and two examples of f_c computations
(c) done! OK, this leads to future comments in Section 6 on prox effect at low ω.

Summary: I added stuff to the existing summary.

Review Status: ALL appendices are now stable. The next step is to review the Chapters and to write more in Chapter 6 on the low ω limit. Time Sat 6:35 PM.

Sun June 15, 2014.

Rather than get burned out on Chapter 1 and 2, I will start instead with Chapter 3 today and work toward Chapter 6 and my final comments on the low ω problem.

Chapter 3

3.1 very good, I like the math approach here, and final comment on Radial Hall.
3.2 surface charge thickness, I fixed up the comment on Debye Surface Current!
3.3 loss tangent, a pretty good discussion I think.
3.4 improved this current conservation thru patch idea, into term "charge pumping".
3.5 improved def of local cyl coord sys, read all details, generally OK
3.6 scanned it all, saw nothing obviously wrong in light of recent learning
3.7
(a) $E_\theta = 0$ at surface, OK
(b) transverse $A_t << A_z$ quoted from App M, cleaned up a bit, now OK
(c) the issue of conditions on φ = constant around conductor boundary at z = const
(d) lots of good facts (all OK) and the "counterexample" for ω = 0 with pix.
(e) the E perp B business, already cleaned up
(f) some field pictures and my obscure comments about z direction contraction and curl eqs

(g) more field pictures.

In this section I am now going to remove a part I never liked, here it is:

****

(10) We have glossed over the fact that the E and B fields track each other in magnitude. For example, they are both maximal at the same longitudinal position z_Q. B is maximum there because J_z is maximum, but it is not quite clear why E is maximal at the same point. We know this alignment occurs in a plane wave, but a transmission line TEM mode is not *just* a plane wave. Various arguments can be ginned up for the alignment of the E and B maximums. One simple argument involves the green cylindrical Gaussian box drawn inside the lower conductor, and we reverse the discussion above. Note that this box lies entirely inside the conductor and so does not enclose any surface charge. Since there can be no charge inside a conductor, this box has $Q_{enclosed} = 0$. Thus, the total current flowing into this box must be zero. Since the J_z current flows into both ends of this box (black arrows), the J_r current has to flow out on the cylinder's curved surface. By considering shorter green boxes one can show that J_r is maximal at z_P (as drawn). Thus J_{disp} is maximum at z_P which means $\partial_t E$ must be maximum there, which means E = 0 at z_P which means E has its maximum in alignment with the maximum of B.

****

I replace this with the following much simpler text:

(10) We have glossed over the fact that the E and B fields track each other in magnitude. The Maxwell equation curl **E** = -jω**B** requires that E and B vanish at the same place ($z = z_P$) and therefore are also maximum at the same place ($z = z_Q$).

I now continue the review from above

(e) the E perp B business, already cleaned up
(f) some field pictures and my obscure comments about z direction contraction and curl eqs
(g) more field pictures, item (10) improved.
(h) arguments that $J_r << J_z$. Added command that App D verifies this conclusion!

3.8 TL preliminaries, I now call this section a "review" of the preliminaries.

Comments: I am reminded of the heavy rewriting I had to do on Chapter 3! I think it is now much better than it was long ago in terms of accuracy, but it has suffered in terms of coherence. I am reluctant to throw things out that I worked so hard on. The reader will be able to tell there was much editing. But it does say all the things I want to say, in one place or another in this chapter. In particular, I have a lot of caveats now about the low frequency range where things are hazy.

Chapter 4

4.1	very good
4.2	very good
4.3	OK, lots of arm-waving about small β and the4 TL limit
4.4	K appears, jump-ahead summary of TL "properties"
4.5	twin lead example. OK up to power TL. All is good in this section.

4.6 coax example, and comments, all just fine
4.7 now we start on the A_z world. Added a good phase Note. Comments on μ. All OK.
4.8 short, analog of an earlier φ section
4.9 jump a lot of steps, then result is analog of 4.3.10, I had the wrong eq # !
4.10 compute W(z), relate to L_e, now have K and K_L , some fancy moves here.
4.11

Pause. I don't like my averages involving Z_s, there must be a better way to do this which brings in the active distance p for each conductor.

Averaging Repairs, Monday June 16.

I have done this Z_s in "averaging repair.doc" and this is now installed in lines doc and I managed not to juggle later equation numbers. So we continue the above, starting over with 4.11

Chapter 4

4.11 OK, finally after a whole day spent on this section, various improvements.
4.12 very good, this took a very long time for me to get figured out (when I did it)

Summary: OK! Added one sentence on my averaging stuff. I am now ready for Chapter 5.

Chapter 5

5.1 Derive the transverse equations for φ
5.2 Mirror image section, get those equations for A_z
5.3
(a) OK, showing $k_\varphi = k_A$ and $\sqrt{zy}$ and a loss model with attenuation, and final trans Helm eq's
(b) the scale BC that $\varphi \rightarrow \ln(s_2^2/s_1^2)$
5.4
(a) OK
(b) revisit the scaling BC, all OK
5.5 The Capacitor Problem

Bug. Need to fix up "linear charge density" n and symbols there. Done

5.5 The Capacitor Problem
long first section is OK
second restatement section also OK. Changed all *n* back to n.
5.6 losses? I claim some ev problem, then refer to Matick who DOES indeed have an ev problem.

OK, enough of Chapter 5. I tried to be very general with Section 5.5, something one does not see done very often. I am just not that interested in the loss problem, and the Matick LONG section shows that it is not an easy subject.

Summary: OK as is

Chapter 6.

6.1 OK
6.2 Apollonian circles
6.3 OK to above (6.3.1), and OK to the end, added note to reader exercise.
6.4 Summary
6.5

opening text, OK
(a) changed focal distance from *a* to d to be consistent with earlier chapter 6 usage!
(b) OK, just fine, quotes results from Appendix D
(c) idea that $J_z(r,\theta)$ tracks $n(\theta)$, all OK
(d) OK, showing that J_z tracks $n(\theta)$
(e) I added a lot here, I think it says what I want it to say.
(f) OK

Summary: OK, added a bit.

Added my final reader exercise, and am now looking for King's Ref 40 on that Z_s modification formula.

7. "Wave Propagation over Parallel Wires: The Proximity Effect," by J. R. Carson, *Philosophical Magazine*, April, 1921, page 632.

I can log in to Marriott still as Jim, but they only carry 2003 forward, so I would have to go over there.

"Wave Propagation over Parallel Wires: The Proximity effect", *Philosophical Magazine*, volume IXLI, June 1921, pages 607–633.

Realization: I need to get some confirmation somewhere on my $n(\theta)$ solution for two cylinders [I never got this confirmation, could not find anything]. This is now extremely important, and an error here would be disastrous for my lines doc. I did this in bipolar, but I never found confirmation anywhere. I don't know how to find verification. My formula does give center of charge at the focal point, that is probably a fairly severe test. // But lots of web work turned up nothing, I don't want to get further into this. My center of charge calculation sort of confirms $n(\theta)$ is correct.
[I never got confirmation of $n(\theta)$ from any external source.]

Tuesday June 17.

Added a section on the telegrapher's equations, just the time domain versions of what I already had. Added comment on telegraph and telephone impedance, learned that a single line was used over ground plane (hard to find that out!). Phone cable outside is 600 ohms. Twinlead 300 ohms, and so on.

Now reviewing continues.

Chapter 2: I will skim this only, since it has been reviewed very many times already.

opening text: OK
2.1 It is long, but says what I want to get said and so is OK. Wave context, Helmholts.

I changed the title to add Helmholtz.

2.2 I derive a summary box filled with equations. All OK.

2.3 Study of the solution

(a) Kelvin functions, all OK

(b) plots of |E| showing skin depth, lots of detail, I guess that is OK

(c) physical fields corresponding, good to do this every once in a while!

(d) plots of mag and phase of E and B.

2.4 Surface impedance

opening text defines Z_s , though not very well.

(a) general Z_s formula with Matick verification

(b) low ω limit of Z_s and interpretation

(c) high ω limit and more Matick verification

(d) plots of Z_s .Not same as E(r) plots! These are vs ω. Too much detail!

2.5 Surface impedance for a transmission line.

holding here for a moment. Why don't I compute Z_s in chapter 6 for cylinders?

From my reader exercise end of Ch 6, it would seem that

$$E_z(a,\theta) = (-j\omega/\sigma)\,(\beta/\beta_d)(1/a)\,(q/2\pi)\Big[\,1 + 2\sum_{m=1}^{\infty}(-1)^m\, e^{-m\xi_2}\cos(m\theta)\,\Big]\ .$$

$$Z_s(\theta) = E_z(a,\theta)/I = -(j\omega/\sigma)\,(\beta/\beta_d)(1/a)\,(q/2\pi I)\Big[\,1 + 2\sum_{m=1}^{\infty}(-1)^m\, e^{-m\xi_2}\cos(m\theta)\,\Big]\ .$$

$$Z_s = \langle Z_s(\theta)\rangle = (1/2\pi)\int_0^{2\pi} Z_s(\theta)\,d\theta = -(j\omega/\sigma)\,(\beta/\beta_d)(1/a)\,(q/2\pi)\,(1/I)$$

What should I make of this claim? Something seems amiss here! First do a dim check

$$\dim(\omega/\sigma * 1/a * q/I) = \sec^{-1}\ \text{ohm-m}\ \ m^{-1}\ \text{Cou/m}\ \ \text{sec/Cou} = \text{ohm/m}\quad \text{OK}$$

How are I and q related?

$$i(z) = q(z)\,v = I \qquad (4.11.19a)$$

Then

$$Z_s = \langle Z_s(\theta)\rangle = (1/2\pi)\int_0^{2\pi} Z_s(\theta)\,d\theta = -(j\omega/\sigma)\,(\beta/\beta_d)(1/a)\,(q/2\pi)\,(1/qv)$$

$$= -(j\omega/\sigma)\,(\beta/\beta_d)(1/a)\,(1/2\pi)\,(1/v_d)$$

Now use,

$$\beta = (j-1)/\delta \qquad \beta_d = \omega/v_d$$

to get

$$Z_s = -(j\omega/\sigma)\,(\beta/v_d\beta_d)(1/a)\,(1/2\pi) = -(j\omega/\sigma)\,(\beta/\omega)(1/a)\,(1/2\pi)$$

$$= -(j/\sigma)\,(\beta)(1/a)\,(1/2\pi) = -(j/\sigma)\,(\beta/a)\,(1/2\pi) = -(j\beta/2\pi a\sigma)$$

$$= -(j/2\pi a\sigma)\,(j-1)/\delta$$

$$= (j/2\pi a\sigma)\,(-j+1)/\delta$$

$$= (1/2\pi a\sigma)\,(1+j)/\delta = \frac{1}{2\pi a\sigma\delta}(1+j)$$

This agrees with (2.4.16) !

Something is wrong with this Z_s business. I just computed $<Z_s>$ for a round wire in my two-cylinder line and found that it is **exactly** the same as Z_s in Chapter 2 for high ω. This is MAJOR problem now, I have to stop. King says Z_s needs the correction factor he comes up with, I say no correction factor is needed since I already account for the proximity effect.

OK, I am now done adding stuff to Chapter 6. I don't have the King references and I am not that interested, so I will just let it go.

It remains now only to proof Chapter 1. Time is already 5 PM.

I just did a proofing of all the symbols and made a few changes there. (repairs!)

Chapter 1

1.1 Maxwell and other equations
- (a) notes on same, made changes, they are very good notes.
- (b) integral forms
- (c) boundary relations. All tough stuff, I had to clean up a few errors!

1.2 E and B field wave equations, very brief!!

1.3 Potential wave equations
- (a) wave equations in the Lorenz gauge
- (b) relativity comments
- (c) potential wave equations in two gauges with conductors present OK

1.4 Retarded's -- a very good section IMHO!

1.5 Wave equations in the ω domain
- (a) I use the FT without yet defining it, but I guess OK
- (b) Helmholtz integrals
- (c) getting the final King equations, n_c and n_s , fancy stuff my friend
- (d) Lorenz gauge field and potential wave equations (a catalog I guess)
- (e) self consistency. Good stuff to say, it stays. I claim a complete solution to fat twin lead.

1.6 Complex functions
- (a) the notion of extending solutions to complex solutions and picking real or imag as physical

(b) general forms and phases
(c) the FT with hat notation
(d) advance warning of complex functions to appear in Chapter 2
(e) pitfall
(f) overloaded

DONE! Overview: OK

Introduction: OK

References: OK, some small changes

Status 9 PM June 17. I am done with my content view. What remains is
spell check in sections
pagination before have 474 pages
cool down
release and push the spiders

Weds June 18.

Spell check, try 100 pages at a time.

start - 108 found 5 spelling errors and fixed them in this chunk.
This is perhaps the oldest chunk so I expected only a few problems.

108-200 found only 2 spelling errors, this takes into the start of Chapter 6

200-300 found 4 items, but at D.2.20 spell check gave up so start there in next batch.
that was page 298 so it almost made it!

297-384 found 1 error, then it stopped at (I.2.7) which is page 371, so resume there

370-474 no errors found in this last chunk, probably because I checked each appendix
before I installed it.

Spell check is done, time now 10AM.

Headers:
no header on TOC
Overview and Summary starts where it should.
Chap 1 starts OK
Chap 2 starts OK
Chap 3 starts OK
Chap 4 starts OK
Chap 5 starts OK
Chap 6 starts OK

Appendix A starts OK
Appendix B starts OK
Appendix C starts OK
Appendix D starts OK
Appendix E starts OK
Appendix F starts OK
Appendix G starts OK
Appendix H starts OK
Appendix I starts OK
Appendix J starts OK
Appendix K starts OK
Appendix L needs a header: Point and Line Charges in Dielectrics, fixed.
Appendix M needs a header: Why A_t is small, fixed.
Appendix N needs a header: Magnetic Ohm's Law and the Radial Hall Effect, fixed
Appendix O needs a header: Plotting Field Lines, fixed
Appendix P needs a header: Eddy Currents and the Proximity Effect, fixed
References: Starts OK
DONE!

Did new TOC and full dated save.

Pagination:

TOC: add one blank line to fix orphan Appendix N, have to do this each time!
Overview: very good how it ends up. The symbols ends with only 4 on the last page. But I will probably be adding more over time, so leave that way rather than deleting 4.

I scanned entire doc adding new things to symbol list, will hold it at 5 pages. Done.

Chapter 1: starts page 16
16 through 27 OK
28 thru 32 OK
33 thru 42 OK
42 thru 60 OK end of Chap 1, page 60
this chapter worked out quite well, it is ready for prime time

Chapter 2: starts page 61
61 thru 89 OK
did not change much, probably OK from last time, no big problems

Chapter 3: starts page 90
90 thru 96 OK
97 thru 121 OK not much changed

Chapter 4: starts page 122
122 thru 165 OK this chapter went pretty fast despite new stuff

Chapter 5: starts page 166
166 thru 185 OK went very fast

Chapter 6: starts page 186
186 thru 196 OK
197 thru 214 OK went fast

Appendix A: starts p 215
215 thru 227 OK

Appendix B: starts p 228
228 thru 259 OK

Appendix C: starts p260
260 thru 281 OK

Appendix D: starts p282
282 thru 326 OK
331 thru 338 OK
This was the huge appendix, I think it is paginated OK now.

Bug: dimensions in D.9.4 look wrong! Fixed!

Appendix E: starts p339
339 thru 342 OK, went fast no changes

Appendix F: starts p343
343 thru 347 OK, short

Appendix G: starts p348
348 thru 358 OK, just a bit rough

Appendix H: starts p359
359 thru 363 OK

Appendix I: starts p364
364 thru 371 OK

Appendix J: starts p371
371 thru 377 OK

Appendix K: starts p378
378 thru 383 OK

Appendix L: starts p384
378 thru 397 OK

Appendix M: starts p398
398 thru 403 OK

Appendix N: starts p404
404 thru 424 OK
425 thru 427 OK, and done!

Appendix O: starts p428
428 to 436 OK

Appendix P: starts p437
437 to 439 OK
440 to 455 OK
456 to 465 OK

References: starts p 466
466 to 468 OK

Made a new TOC with adjust, set date to June 18, 2014 with no time.

Quick review of picture centering: fixed up quite a few, think I left an F hanging but can't find it.

OK, let's take a first shot at a PDF export! It ran for 8 minutes and failed

Close Word down and try again. Took 8 minutes with success!!!

Check bookmarks against TOC: the TOC is fine, nothing missing, a few small errata collected.

Look for blank pages: 468 pages, no blank pages, it all looks good !!!!

Fixed my 3 small bugs but did not remake PDF yet. I know I will find more things in my general review session. But I know the PDF export works! File size PDF is 6.2 MB, largest yet.

Thurs June 19.

Spent this entire day re-pondering the "reflection scenario" and was able to hack my way deeper into this jungle. I want to know why it fails to do what I want? For a while did some DC + AC work, but decided that could not be justified. The question remains: how do you solve the pair of shorted at the end round wires?

Fri June 20.

Realized yesterday that $N_0 = (1/2\pi)\ q/a$ and want to somehow get this fact stated. I think $q(z) = q\ e^{-j\beta dz}$ and I have never really used the symbol q before. Maybe $N_0 = (1/2\pi)\ q(0)/a$ where $q(z) = q(0)\ e^{-j\beta dz}$. I

have a similar confusion with symbol I. I think i(z) = i(0) $e^{-j\beta dz}$ and maybe i(0) = I. This is all very hazy in my lines doc. Keep track of sections that get chanced!

Chapter 4 introduces q(z) in (4.1.2) and (4.1.4). I even found this:

$$q(z) = q(0)\, e^{-j\beta z} \qquad // \; q(z,t) = q(0,0)\, e^{j(\omega t - \beta z)} \tag{4.3.8}$$

Chapter 4 introduces i(z) in (4.7.3) and (4.7.5), but I failed to state the above equation for i(z). // Just added the missing equation in (4.9.2).

Now how is I introduced? There is no I in Chapter 4, nor in Chapter 5. There is a q in (6.5.2) just in reference to a capacitor, no TL.

I is first quoted in (6.5.10) taken from App D. So I think App D is where I first appears. It first appears in (D.2.31) as an integral of J_z. I think I can identify I = i(0).

Yes, In appendix D there is no statement about $e^{j(\omega t - \beta z)}$ other than for E and no other parameters are mentioned other than fields UNTIL (D.2.31).

Edit made: I added this line on page 285, stealing the next equation number.

$$N_0 = (1/2\pi a)\, q(0) \tag{D.1.8}$$

I want to state this right where N_m is defined! Repaginate App D!! Now having add this, go down to (D.2.31).

OK, I now know about I = i(0) and $N_0 = (1/2\pi a)\, q(0)$ so maybe add a comment in the glossary. DONE.

Need to repaginate App D and Chap 4. DONE

Did more pondering of the Sisyphus low ω paradox in reflection scenario 2 doc, at the session end got some dim ideas that I can pick up next time.

Sat June 21, 2014

I wrote up my little DC ladder resistance problem and quietly added it to the end of Appendix K. I put my solution on a new page so reader might not spot it right away. I thought this was a problem worth writing up.

I then rewrote my low frequency proximity effect in the following manner:

(1) I showed that various aspects of my theory are invalid for low ω
(2) I went ahead anyway and did the low ω plots which are wrong.

I just installed this new Section 6.5 (e) and section 6 needs to be repaginated DONE

It remains to clean up Section D.12 on low ω limits. // DONE and ain't purdy once again, but I let it lie.

Repaginate Appendix D:

OK thru p 341 painful but it is done.

Repaginate Chapter 4:

122
thru 126 OK
thru 135 OK
thru 143 OK
thru 160 OK

DONE with Chapter 4.

Repaginate Chapter 6:
thru 195 OK
thru 215 OK
Done.

I just reread the intro section including glossary, more fine edits.

Pushed out a new PDF.
Scanned and noticed:

BUG: My two loss models seem to disagree:

Appendix D loss model
The (5.3.6) loss model.

I will need to resolve this.

I now think the Appendix D thing is wrong because V and I are complex (at least one is complex) and I did not take that into account and it wrecks my nice little derivation. So I ought to stick to the known good result.

Do I have any external verification of my attenuation formula? Not in King.

Matick page 27 has this:

$$\gamma^2 = (R+j\omega L)(G+j\omega C)$$

$$\partial_z^2 v_z - \gamma^2 v_z = 0$$

So the connection is

$\gamma^2 = zy = -k^2$

so yes, there is some support! In fact 100% support. How about another reference of support. HM has this on page 46.

To obtain an expression for the voltage alone, (3) is substituted into the derivative of (4).

$$\frac{d^2\hat{V}}{dz^2} - (j\omega L + R)(j\omega C + G)\hat{V} = 0 \tag{5}$$

With the voltage found from this equation, the current follows from (4).

$$\hat{I} = \frac{-1}{R + j\omega L}\frac{d\hat{V}}{dz} \tag{6}$$

Albeit complex, the coefficient in (5) is constant, so it is again appropriate to look for exponential solutions. Using the convention established in Sec. 14.5, we look for solutions $\exp(-jkz)$. Substitution into (5) then shows that

$$k^2 = -(j\omega L + R)(j\omega C + G) \tag{7}$$

So as to be clear in distinguishing the two roots of this dispersion equation, we *define* β as having a positive real part and write the roots as

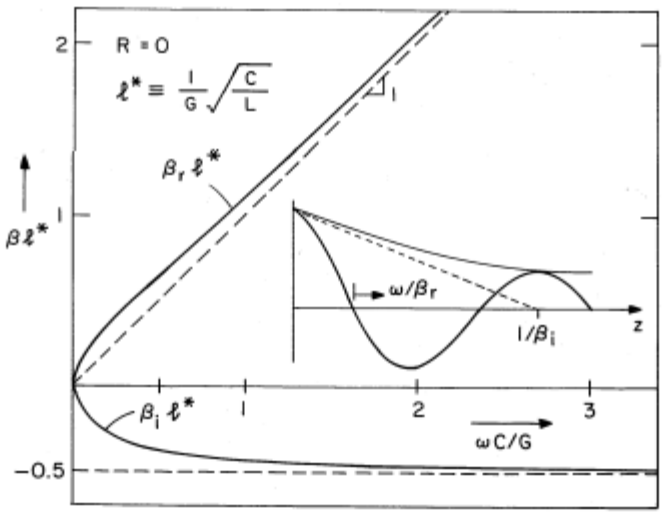


Fig. 14.7.2 Roots of (7) as functions of normalized ω. The real and imaginary parts, respectively, of the complex wave number β relate to the phase velocity and rate of decay of the wave, as shown.

$$\boxed{k = \pm\beta; \qquad \beta \equiv \sqrt{(\omega^2 LC - RG) - j\omega(RC + LG)}; \qquad \text{Re}\,\beta > 0} \tag{8}$$

These roots, $k = k_r + jk_i$, are pictured as a function of frequency in Fig. 14.7.2. From (7), k^2 is in the lower half-plane. It follows that the value of k having a positive real part (defined as β) has a negative imaginary part.

These definitions take on physical significance when the solutions to (5) are written as

$$\hat{V} = \hat{V}_+ e^{-j\beta z} + \hat{V}_- e^{j\beta z} \tag{9}$$

because it is then clear that we have defined β so that V_+ represents a wave with points of constant phase propagating in the $+z$ direction. Note that because β_i is negative, this wave decays in the $+z$ direction, as shown in Fig. 14.7.2. Similarly, $\hat{V}_-$ is the complex amplitude at $z = 0$ of a wave that decays in the $-z$ direction and has phases propagating in the $-z$ direction.[10]

So OK, I have plenty of support and I should comment in lines doc. I guess I had just forgotten that I had this loss formula, and that is going to require lots of rewriting!

Meanwhile, for very small ω we seem to get my β vanishing after all. Yes, this is going to take a LOT of rewriting in several places in lines doc. Glad I caught this problem.

Sun June 22, 2014

Spent this day doing two things re the loss model.

1. I computed the real and imaginary part of

$$\beta_d = k = -j\sqrt{zy} \qquad = -j\sqrt{(R+j\omega L)(G+j\omega C)}$$

which is the longitudinal model's estimate of what β_d should really be.

2. I compared this β_d with the one I derived in Appendix D.11. At first I thought the models were totally different, but then I showed they were pretty close and in fact agreed over a certain high ω range.

3. I learned about the formula ∂_z(IV) = such and so, as seen in HM, and understood that IV really is the "power flow" down the line.

4. In the Phil model for β_d I assume that power flows at some rate v, but it turns out that at low ω this is an unknown. I can compute this first as the phase velocity of the model 1 shown above, but that did not make our two theories exactly match. I think the resolution is that the rate at which power actually flows is the group velocity, and maybe that would make the theories match.

5. I decided to go ahead and use the above expression as the basis for my loss models and not worry about why my simple model was inaccurate. It was in fact OK for small losses.

6. Since my low ω work depends on β_d at low ω, I think it is better to use expression 1 above since it is more accurate I think.

Loss Model, Mon June 23, 2014

Rewrite Appendix K on the network model, so it now derives both Z_0 *and* all the transmission line equations directly from the model, enhancing the motivation that the model is CORRECT. That point was perhaps lost in my first rendition. I also improved the derivation of Z_0 and incorporated my ladder reader exercise.

Comment: The symbols in Chapter 2 are consistent with Appendix D. In both appendices we are only concerned with the INSIDE of the wire.

Full document scan to make β_d and related symbols all consistent!

Chapter 1 ? We are certainly OK up to Section 3.1 (c), where σ could apply to either conductor or to the dielectric. Then in section (c) I use the 1 and 2 notation

But then in (1.3.29) I START using ω,ε σ for in the dielectric! I am going to fix that right now.=
OK now through (1.3.30)
OK now through (1.3.35)
OK up to the start of Section 1.4
Section 1.4 on retarded stands on its own, I leave off the d subscripts
Section 1.5
OK thru 1.5.1, added convention comments.
OK thru start of section 1.5 (b)
OK thru start of section 1.5 (c)
OK thru (1.5.17)
OK thru start of Section 1.5(d)
OK thru start of Section 1.5(e)

Section 1.6 OK

$e^{-j\beta_d R}$

$\frac{e^{-j\beta_d R}}{R}$ $e^{-j\beta_d R}$ $\frac{e^{-j\beta_d R_1}}{R_1}$ $\frac{e^{-j\beta_d R_2}}{R_2}$ $e^{-j\beta_d R_1}$ $\frac{1}{4\pi\xi_d}$ $\frac{e^{-j\beta_d R_2}}{R_2}$ $\frac{\mu_d}{4\pi}$

Chapter 3?

3.1 Here unprimed symbols are used for both cases, but it is OK
3.2 no symbols used
3.3 Here unprimed are used for the dielectric! I may fix this
3.4 Here I use symbols 1 and 2, I think it is OK
3.5 In table explanations, I use unprimed for inside the conductor, but fixes needed

OK, I am going to make the change starting with 3.3.

Section 3.3 DONE
Section 3.4 I leave this with 1 and 2 for the time being
Section 3.5 Explanation of tables: unprimed for inside metal, so OK as is. Rest is OK
Section 3.6 Did some fixes for leakage stuff, all done
Section 3.7 OK thru (a) and (b).
Section 3.7 OK thru (d)
OK thru end of Section 3.7

Section 3.8

Now ready to start into notation change for Chapter 4.

4.1 done
4.2 done
4.3 done
4.4 done
4.5 done
4.6 done
4.7 done
4.8 done
4.9 done
4.10 done
4.11 done
4.12 holding; done finally!!!

Appendix B ?

B.1 uses 1-2 notation throughout
B.2 OK, no real use of anything
B.3 OK
B.4 OK

all the rest is now fixed up, nothing major.

Chapter 5 is next! Time for a bread and granola run. 2:40 PM.

5.1 done
5.2 done
5.3 done
5.4
(a) done
(b) done
5.5 done
5.6 done
done with Chapter 5.

Chapter 6

OK through end of 6.4
OK up to low ω proximity, HOLD

Appendix C OK
Appendix D of course OK
Appendix E OK
Appendix F done
Appendix G is all in 1-2 notation
Appendix H and I: OK as is
Appendix J, made a few fixes, now OK
Appendix K, NEW section not installed yet, done
Appendix L: OK
Appendix M: OK
Appendix N: all OK since all inside "a metal or semi"
Appendix O: plot field lines OK as is
Appendix P: μ and ε are inside the DUT, all OK

This concludes my Full Document review so that now β_d is indicated in all the right places. It took a very long time!

I am now ready to tackle my "loss model" stuff. There will be many places that get edited.

Section 5.3 (a). Here I do mention the loss stuff, but I am in the middle of doing the transverse equations and this seems a bad place to interrupt things. I did change some things here, removing some extra stuff, so have to repaginate all of Section 5. Equation numbers did not get shifted at all.

Fact: Notice that we really have $\mathbf{z} = Z_s + j\omega L_e$ and L_i is somehow inside Z_s.

Fact: Down at (5.3.9) I could write

$$(\beta_d^2 - k^2) = j\omega Z_s 4\pi\xi_d / K = \frac{j\omega Z_s 4\pi\xi_d}{K} = j\omega Z_s C'$$

$$= j\omega Z_s(\xi_d/\varepsilon_d) C = j\omega (1/\varepsilon_d) [\varepsilon_d + \sigma_d/j\omega] Z_s C = [j\omega + \sigma_d/\varepsilon_d] Z_s C \quad (5.3.9)$$

Does this add anything? First, generally σ_d is small for a dielectric. so $(\beta_d^2 - k^2) \approx j\omega Z_s C$. For **low ω,** we think that Z_s = constant, as we found for the round wire

$$Z_s(\omega) = \frac{1}{\sigma\pi a^2} + j\omega \frac{\mu}{8\pi} = R_s + j\omega L_s$$

so for low ω perhaps

$$(\beta_d^2 - k^2) = j\omega C [\frac{1}{\sigma\pi a^2} + j\omega \frac{\mu}{8\pi}]$$

which gets very small as ω gets small. [this is the reverse of what I thought, but you really have to do this test differently as shown in (5.4.1) where I show that $k \approx \beta_d$ for $(\delta/a) << K/\sqrt{2}$.

On the other hand, for large ω we get for the round wire

$$Z_s(\omega) \approx \frac{1}{2\pi a} \sqrt{\frac{\mu_c}{2\sigma_c}} (1+j) \sqrt{\omega} \quad . \quad (4.11.35)$$

and then

$$(\beta^2 - k^2) = j\omega C \frac{1}{2\pi a} \sqrt{\frac{\mu_c}{2\sigma_c}} (1+j) \sqrt{\omega} = \text{constant} * \omega^{3/2}$$

so at very high ω we expect $(\beta^2 - k^2)$ to be large, again the reverse of what I thought. But perhaps the largeness of σ_c tames this fact for frequencies of interest.

Comment: I have now tentatively updated section 5.4 which is one of my low-loss sections. I am not happy with my results for Belden cable! This will have to be repaired, but I think I will be replacing all this with a much better loss model ! Maybe ignoring L_i was the wrong thing to do! I will be back here for sure. Section 5.6 seems OK as it is, the eigenvalue thing.

The next loss encounter in in Section 6.5 (e) with prox effect at low ω. I need to just hold off on that until I get the true loss model installed somewhere.

The next stop finally is Appendix D.11. I think this is where I will start tomorrow, I am worn down. I spent all day updating 450 pages with the right β_d symbols!

First Appendix Q written, Tues June 24, 2014

Wrote yet another appendix: Appendix Q details information about the important β'_d function! I have to have this information in order to approach the loss questions.

For high ω

$$\beta_d' = \omega\sqrt{LC} \; - j\,\frac{RC+GL}{2\sqrt{LC}} \quad = \omega/v_d - j\,\kappa$$

$$\beta'^2 = \beta^2 - \beta'^2_d = -j\omega\mu\sigma - (\omega/v_d - j\,\kappa)^2$$

$$= -j\omega\mu\sigma - (\omega/v_d)^2 + 2j\,\kappa\,(\omega/v_d) + \kappa^2$$

$$= -(\omega/v_d)^2 - j\omega\mu\sigma + 2j\,\kappa\,(\omega/v_d) + \kappa^2$$

In any event, we see that for large ω, β'^2 is large in abs value and so our f_m limits are correct. The question is: can we ignore $(\omega/v_d)^2$ relative to $j\omega\mu\sigma$? I bet yes. The κ correction does not even enter.

For low ω and G = 0:

$$\beta_d' = \sqrt{\omega RC/2}\;(1-j) = \sqrt{\omega RC}\;e^{-j\pi/2} \qquad |\beta'_d|^2 = \omega RC$$

$$\beta^2 = -j\omega\mu\sigma = \omega\mu\sigma\, e^{-j\pi}$$

Now you would argue that at low ω,

$$\left|\frac{\beta'_d}{\beta}\right| = \sqrt{\omega RC}\;/\sqrt{\omega\mu\sigma} = \sqrt{RC/\mu\sigma}$$

Now let's go to the twin lead and say (R is total of both wires)

$$R = 2/(\sigma\pi a^2)$$

$$C = 4\pi\varepsilon_d/K$$

Then

$$\left|\frac{\beta'_d}{\beta}\right|^2 = \frac{RC}{\mu\sigma} = \frac{2C4\pi\varepsilon_d}{\mu\sigma\,\sigma\pi a^2 K} = \frac{8\varepsilon_d}{\mu_d\sigma^2 a^2 K} = 8\,\frac{\varepsilon_d}{\mu_d}\,\frac{1}{K}\,\frac{1}{a^2\sigma^2} = \frac{8}{K}\,\frac{1}{Z_d^2}\,\frac{1}{a^2\sigma^2}$$

$$\left|\frac{\beta'_d}{\beta}\right| = \sqrt{8/K} * \frac{1}{a\sigma Z_d}$$

Both factors are dimensionless. Let's just try this directly for Belden 8281

$$\left|\frac{\beta'_d}{\beta}\right|^2 = \frac{RC}{\mu\sigma} = \frac{36 * 68 * 10^{-12}}{4\pi \text{ x } 10^{-7} * 5.81 \text{ x } 10^{7}} = \frac{36 * 68 * 10^{-12}}{4\pi * 5.81} = 0.33 \text{ x } 10^{-10}$$

$$\left|\frac{\beta'_d}{\beta}\right| = 0.6 \times 10^{-5}$$

Then I claim that for low ω we have

$$\beta'^2 = \beta^2 - \beta'^2_d \approx \beta^2 = -j\omega\mu\sigma = -j\omega\ 73$$

Then as $\omega \rightarrow 0$, we then get $\beta' \rightarrow 0$ and this then gives the limits I show in my Appendix.

and then at low ω we get.

$$\left|\frac{\beta_d}{\beta}\right| \rightarrow \infty$$

and then

$$\beta'^2 \approx \beta_d'^2 = \omega RC\, e^{-j\pi} = -j\,\omega RC$$

which is a SMALL parameter in this limit. But things are now different from my original App D.11. I still go ahead with my small x limits of things like f_m. I end up then with

Small ω limit of the E field solutions : $$R_{dc} = \frac{1}{\sigma\pi a^2} \qquad \text{(D.11.17)}$$

$E_z(r,m) = (1/4)\,\eta_m\, I\, R_{dc}\, (a\beta')\, f_m$ $\qquad f_m = (r/a)^m\,(m+1)\,(2/\beta' a)$ $\qquad f_0 = 4/(a\beta')$

$E_r(r,m) = (j/4)\,\eta_m\, I\, R_{dc}\, (a\beta'_d)\, g_m$ $\qquad g_m = (r/a)^{m+1} + (r/a)^{m-1}$ $\qquad g_0 = 2\,(r/a)$

$E_\theta(r,m) = (1/4)\,\eta_m\, I\, R_{dc}\, (a\beta'_d)\, h_m$ $\qquad h_m = (r/a)^{m+1} - (r/a)^{m-1}$ $\qquad h_0 = 0$

We then have]

$$E_z(r,m) = (1/4)\,\eta_m\, I\, R_{dc}\, (a\beta')\, f_m = (1/4)\,\eta_m\, I\, R_{dc}\, (a\beta')\,(r/a)^m\,(m+1)\,(2/\beta' a)$$

$$= (1/2)\,\eta_m\, I\, R_{dc}\,(r/a)^m\,(m+1) \qquad m > 0$$

and of course nothing happens to our original paradox. What is a little new here is that now both the other fields go away even for finite I :

$$E_r(r,m) = (j/4)\,\eta_m\, I\, R_{dc}\, (a\beta'_d)\, g_m = (j/4)\,\eta_m\, I\, R_{dc}\, (a\beta'_d)\,[(r/a)^{m+1} + (r/a)^{m-1}]$$

$$= (j/4)\,\eta_m\, I\, R_{dc}\ (a\sqrt{\omega RC}\ e^{-j\pi/2}\,[(r/a)^{m+1} + (r/a)^{m-1}] \rightarrow 0 \text{ as } \omega \rightarrow 0$$

I saved old Section D.11 and I have now been editing it a bit.

Idea 153,465,767:

Recall that for the two-cylinder situation we have

$$J_z(r,\theta) = \sigma E_z(r,\theta) = (I/\pi a^2)(\beta a/4)\,[\ f_0(r) + 2\,\Sigma_{m=1}^{\infty}(-1)^m e^{-m|\xi_1|}\, f_m(r)\cos(m\theta)\ ]$$

where

$$f_m(r) \equiv \left[\frac{J_m(x)}{J_{m+1}(x_a)} - \frac{J_m(x)}{J_{m-1}(x_a)}\right] \qquad x = \beta' r \qquad x_a = \beta' a$$

$$\beta'^2(\omega) = \beta^2(\omega) - \beta_d'^2(\omega)$$

$$\beta^2(\omega) = \mu\varepsilon\omega^2 - j\omega\mu\sigma$$

For sure we have $\beta^2(\omega) \rightarrow 0$ at low enough ω, I see no way to change that fact. Then we basically have

$$\beta'^2(0) = -\beta_d'^2(0)$$

In my network model, I find that $\beta_d'(0) = 0$ since $\sqrt{\omega RC/2} \rightarrow 0$. This then leads to $\beta' \rightarrow 0$ and then the small x limit has to apply and then we get our asymmetry. But suppose we have $\beta_d'(0) = A$, just some constant. Then we have

$$\beta'^2(0) = -\beta_d'^2(0) = -A^2$$

$$\beta'(0) = jA$$

Then the low frequency model is this:

$$J_z(r,\theta) = \sigma E_z(r,\theta) = (I/\pi a^2)(\beta a/4)\,[\ f_0(r) + 2\,\Sigma_{m=1}^{\infty}(-1)^m e^{-m|\xi_1|}\, f_m(r)\cos(m\theta)\ ]$$

$$f_m(r) \equiv \left[\frac{J_m(x)}{J_{m+1}(x_a)} - \frac{J_m(x)}{J_{m-1}(x_a)}\right] \qquad x = jrA \qquad x_a = jaA)$$

where x is neither close to 0 nor close to ∞ in magnitude. I am pretending A = real, but it could also be comples. In this case, what does $f_m(r)$ look like?? Terms do oscillate I suppose. But what really matters is the integral?

Conclusion of this idea: In the correct theory, all elements of the current sum should vanish for m > 0. No matter *what* constant A I use, $f_m(r) \neq 0$ and so the result is wrong!

Comment: Whatever β'_d might be, I know that Appendix D is finding an exact solution to Maxwell's equations that satisfies my two boundary conditions. If those boundary conditions are correct, then the solution MUST BE the one and only correct solution in the wire. There are only three possibilities for the function $\beta'_d(\omega)$ at $\omega = 0$, whatever the "true" $\beta'_d(\omega)$ might be: 0, constant, ∞. For each case, I know that the solution is WRONG! I have shown this, because in each of these cases, you get some $E_z(r,m)$ for $m > 0$ and that has to be wrong according to the eddy current theory.

A Candidate Explanation: At low ω, we get that radial Hall effect where $J_r = 0$ and $E_r \neq 0$ at $r = a$. I have not incorporated this into Appendix D. Basically the idea is that you have to use magnetic Ohm's law instead of regular Ohm's law. That is really the only way I see out of this puzzle of asymmetry for very low ω. (other than the existing escape hatch).

Plan for tomorrow: try to incorporate magnetic Ohm's law somehow into Appendix D. 6:30 PM.

Thurs June 26, 2014

Maybe I missed a log day above. Today I continued writing stuff into my " altering the CPBC for radial Hall.doc" and I sadly concluded that the radial Hall effect does not fix the J_z asymmetry paradox. One more item I can cross off the list.

But I continued writing in that doc, looking at random details. I was able to get rid of I in the E solutions to show that things explictly all vanish as $\omega \rightarrow 0$. I then have q as a constant instead of I or V. I then looked carefully at the $\omega \rightarrow 0$ limits using Appendix Q limits and found various results. I ended up in that doc with a certain Paradox B which is rather mysterious:

Paradox B. Consider a line with $G > 0$. We know that as $\omega \rightarrow 0$, we will have $Z_0 = \sqrt{R/G}$ and therefore some current $I = V/Z_0 = V\sqrt{G/R}$ will flow. The decay distance is $L_{decay} = 1/\alpha = 1/\sqrt{RG}$ which could be very long. The paradox B is that the field equations above say $\mathbf{E} = 0$ at DC. Then Ohm's law says you cannot have a current flowing. Maybe this is a hint as to my general problem.

I am in the process of pondering Paradox B. But first, I decided to go through Appendix D live in lines doc and make edits concerning the general nature of parameter β_d and how it is NOT just ω/v_d, In doing this, I had to make more comments at the very start of App D, and I see now that there are quite a few different ansatz's going on here!! I am trying the make sure this appendix is "clean" and that I don't sneak in a $\beta_d = \omega/v_d$ somewhere. Anywhere I claim that $\beta' \approx \beta$, I have now to qualify with "low loss" or something like that. I got down to (D.9.23) and will continue on this tomorrow. I will finish this task, then return to Paradox B above.

Fri June 27, 2014

I resolved Paradox B and for the first time I have a static problem with asymmetry J_z and I really believe it for the first time. There are no eddy currents. It is the limit $\omega \rightarrow 0$ of the problem with $G \neq 0$ which I will get written up soon.

I now have a mess with β_d and β_d' floating around. I have decided (did this a long time ago once) to replace β_d in Appendix D by symbol k. It took work to make this change (separate doc) and I am right now going through the doc to make sure this is all OK.

I did repairs through D.10 and it all seems OK. Fortunately I never used k for any purpose of significance, so this change is tolerated. I commented in all the low-loss special cases noted.

But what about Chapter 5? It works perfectly! I already called it k there, and this is the same k as now in Appendix D.

I have now a new version of Appendix Q with k in place of β_d' .

Much Maple code has to be edited to fit into this new "k scheme", Appendix D and Q and surely elsewhere. ********** [I think this has all been done as of 7/29/14]

Tried adding another term to Appendix Q result. I should do this entire appendix just in Maple!

Sat June 28, 2014

Rewrote Appendix Q so that

(1) it now has only Maple derivations which allows it to be 100% verifiable by the reader.

(2) each limit now has an extra term, just in case this is needed.

This rewrite took all day, from about 9 AM to 4:30 PM.

I am going to **install** this Appendix Q right now so I can be completely done with it. **DONE**.

Next, even though it is incomplete, I am going to save the existing Appendix D with β_d and I am going to **install** my new Appendix D with k and lots of new remarks. **DONE**

Next I will ponder The high and low ω ending sections of Appendix D, editing in place.

Well, first I had to update the section on adding dielectric conductivity. I now have all the basic forms as stated in "altering the CPBC" and I also obtained a strange result which says the current increases by the square root of the factor that I thought it would increase by! I am not sure this is right, but I leave it for now.

I am now ready to start into section D.10. Appendix D is fully updated before that point.

Sun June 29, 2014

Did edits on Section D.9 to clean up from yesterday. Basically, all three equations maintain their exact same form when written in terms of current I. This was my original observation which I lost and then today recovered. Then I don't have to write these equations in all the other forms (like involving N_0 or q), but I keep that stuff for the moment in blue.

I then went through D.10 to get the fields for large ω. Did a few edits here. Have added variable name β_{d0} to my glossary to make the meaning of β_d perfectly clear, it has been fuzzy.

Now finally we come to the critical section D.11.I will rewrite this completely in a separate doc.

Well, I went a ways into that and realized that I can never get a uniform J_z no matter what happens, so it is not going to solve all my problems. I have a few new questions:

Question: Is Chapter 4 valid for a conducting dielectric?

Well, we have to go back much further than Chapter 4. In Section 1.5 (c) I am talking about n_s and n_c and *all the time* I am assuming that $\xi_1 \neq \varepsilon_1$ for the dielectric, so I AM assuming *all the time* that it conducts. But I do assume in that section that $\sigma_1 << \sigma_2$, see for example (1.4.15). This is what leads me to the conclusion there that $n_c(\mathbf{x},\omega) = (\xi_1/\varepsilon_1)\, n_s(\mathbf{x},\omega)$. It assumes $\sigma_1 << \sigma_2$, but that does not mean the dielectric cannot still conduct a significant amount! I make a similar assumption above (D.9.21).

Put the above answer on hold, because we now have another more important question. I call it the Way Back assumption and it is now the subject of a separate doc, so we close out here for now. ******* [this way back is DONE.]

Mon June 30, 2014

Need to repair **summations** such as in (D.10.4), first see how looks in PDF. *********

Reread current Section D.10 and it is OK.

Question: where is my Belden cable data? It was in the loss model of Appendix D.11. Found it in App D folder as "old Section D".

What is K for Belden? I keep wanting this number. Recall that

$C = 4\pi\varepsilon_d/K \qquad \varepsilon_d = 2.3\varepsilon_0$ for PE

$K = 4\pi\varepsilon_d / C$

```
> K := 4*Pi*ed/C;
```

$$K := 4\,\frac{\pi\, ed}{C}$$

```
> ed := 2.3*e0;
```

$$ed := 2.3\, e0$$

```
> e0 := 8.8541877e-12;
```

$$e0 := .88541877\, 10^{-11}$$

```
> C := 69e-12;
```

$$C := .69\, 10^{-10}$$

```
> evalf(K);
```

$$3.708833471$$

So let's use K = 3.7.

I have now as of 4 PM finished my Section D.11 rewrite and am ready to install it. I then need to finish the Appendix K rewrite which I started and then put on hold.

It is now 6 PM, I am going to install the new Section D.11. DONE.

Next, I see some left over mess from where I added the (ξ/ε) stuff in D.9. Clean up DONE.

Status: for the first time in a long time, Appendix D is stabilized including discussions of high and low ω limits of things.

Next task: want to clean up the end of Appendix K on network model. We are OK through section (c), so start with (d).

But I first added $Z_s(\theta)$ to Section D.10 which was interesting. Did the same for Section D.11.

Done with Section K (d), on to (e).

Done with Appendix K rewrite, I am ready to install. DONE!

I think that completes work for today.

Ongoing section reviews, cycling around, Tues July 1, 2014

Let's dive into Chap 6 again. All is well up to Prox Effect Section 6.5 so that is where I start.

Section 6.5 (a) is just fine.
Section 6.5 (b) -- lots of editing, no change in eq numbers, OK.
Section 6.5 (c) is OK, has all the plots.
Section 6.5 (d): OK, did a small fix
Section 6.5 (e): This is where work will be needed!

I will do a fresh Section 6.5 (e): right now in a separate doc. It is done, short and sweet with reference to Section D.11 for details. We continue

Section 6.5 (e): updated and done, no change in eq nums
Section 6.5 (f): OK, but opn a whole different subject
Section 6.5 (g): OK

So after a long battle, I have a new Chapter 6.

Next, I want to review all comments about the Belden cable. Right away I get to problems in section 5.3 (a) concerning lossiness estimates. This digressed into problems with my (1.5.1) equations which I have now repaired. I now have to scan the entire lines doc and fix all refs to these (1.5.1) equations. DONE.

That took a long time, perhaps 15 references to some form of (1.5.1). We now have (1.5.1a,b,c,d)! Data was missing.

I can now return to (5.3.8) where things get hazy. I think (5.3.8) is 100% correct,

$$k^2 = -\mathbf{zy} = -[Z_s + j\omega\frac{\mu_d}{4\pi} K]\, j\omega\, 4\pi\xi_d/K$$

$$= -Z_s\, j\omega\, 4\pi\xi_d/K + \omega^2\mu_d\xi_d$$

$$= -\, j\omega\, Z_s\, 4\pi\xi_d/K + \beta_d^2 \,. \qquad \text{// see (1.5.1a)} \qquad (5.3.8)$$

This really is β_d^2 here, and the same β_d^2 appears in the transverse equations. This all makes complete sense:

$$[\,\nabla_t^2 + (\beta_d^2 - k^2)]\,\varphi_t(x,y) = 0 \qquad \varphi_t(C_1) = K_1 \quad \varphi_t(C_2) = K_2 \quad K_1 - K_2 = K \qquad (5.3.10)$$

$$[\,\nabla_t^2 + (\beta^2 - k^2)]\,\mathbf{E} = 0 \qquad \text{// in appendix D}$$

Question: In the first equation above, what do I know about $(\beta_d^2 - k^2)$??

1) at high ω, I think $k \rightarrow \beta_{d0}$ or something close, so maybe it is small at high ω.
2) at low ω is is also small because $(\beta_d^2 - k^2) \approx j\omega Z_s C$ and at low ω, $Z_s = R_{dc}$.

That is encouraging to have this difference be small at both high and low ω.

Specifically, at large ω I have shown in App Q that

$$k \rightarrow \beta_{d0} - j\frac{(RC + GL)}{2\sqrt{LC}} = (\omega/v_d) - j\, v_d \frac{(RC + GL)}{2}$$

where the first term is large and the second is small. I also know

$$\beta_d^2 = \omega^2\mu_d(\varepsilon_d - j\sigma_d/\omega) \rightarrow \beta_{d0}^2$$

So then for large ω

$$(k^2 - \beta_d^2) = (k-\beta_d)(k+\beta_d) \approx (k-\beta_{d0})\, 2\beta_{d0} \qquad \text{// wrong because k not} \approx \beta_d$$

$$= [-\, j\frac{(RC + GL)}{2\sqrt{LC}}]\quad 2\beta_{d0} = [-\, j\frac{(RC + GL)}{\sqrt{LC}}]\quad (\omega/v_d)$$

$$= [-\, j\,(RC + GL)]\ \omega$$

so this is linear in ω, but with a probably small coefficient.

STOP. In a Helmholtz equation like this one, which has a smooth simple solution I think, the Helm parameter is "small" when it is small compared to D^2 ! It is not a dimensionless parameter! So I am really interesting in know when this is true:

$$| \beta_d^2 - k^2 | \varphi_t << \partial_x^2 \varphi_t(x,y) \approx (1/D)^2 \varphi_t(x,y)$$

If this condition were true, then we would have our Laplace equation in effect.

$$| \beta_d^2 - k^2 | << (1/D)^2$$

$$RC\omega << D^2$$

$$\omega << D^2/RC$$

For Belden coax, $RC = 36 \times 68 \times 10^{-12} \approx .36 \times 68 \times 10^{-10} \approx 24 \times 10^{-10} \sim 2 \times 10^{-9}$ sec/m^2

D = the gap = perhaps larger radius = 3 mm = 3e-3 m

Then we get

$\omega << (3e-3)^2/(2e-9) = 9e-6 * (1/2)e9 = e-5 * e9 = e4 = 10{,}000$ Hz.

So we don't last long ! But my approx was for large ω and this result is low ω!

STOP for today, here is where it is left:

" I end up with certain transverse equations for φ_t and A_{zt} which have the form

$$[\nabla_t^2 + (\beta_d^2 - k^2)] \varphi_t(x,y) = 0 \quad \varphi_t(C_1) = K_1 \quad \varphi_t(C_2) = K_2 \quad K_1 - K_2 = K \qquad (5.3.10)$$

I want to argue that $(\beta_d^2 - k^2) \approx 0$ so these become Laplace equations, and then you can reduce the TL problem to "the capacitor problem". But this is just arm-waving BS without support. I have been claiming the model is good at high ω, so I would like to see $(\beta_d^2 - k^2) \approx 0$ at high ω so my capacitor approach is still reasonable. But the calcs above don't seem to work right to make that true. The good news is that I think I know exactly what k(ω) is, especially for high ω ".

Basically I am tired.

Weds July 2, 2014

Went off into a separate math / pde/ Helmholtz world and studied up on the nature of Helm solutions for various values of Helm parameter k^2 and learned a lot doing this. Realized that this has the potential to cause a skin effect in the dielectric region ! Did this in 1D and then in 2D and did lots of plots and got a

very solid idea of what happens. Significant Imk removes all oscillation effects and you get basically skin effect results.

So now I want to start over on my examination of the transverse equations as examples of such Helm equations! No need to panic here as I think I did yesterday.

$$[\nabla_t^2 + (\beta_d^2 - k^2)]\,\varphi_t(x,y) = 0 \qquad \varphi_t(C_1) = K_1 \quad \varphi_t(C_2) = K_2 \quad K_1 - K_2 = K \qquad (5.3.10)$$

$$[\nabla_t^2 + (\beta_d^2 - k^2)]\,A_{zt}(x,y) = 0 \qquad A_{zt}(C_1) = W_1 \quad A_{zt}(C_2) = W_2 \quad W_1 - W_2 = K \qquad (5.3.11)$$

First, let's do large ω. I know from App Q that

$$\text{Large } \omega: \quad \text{Re}(k) = \omega\sqrt{LC} + \frac{(RC-LG)^2}{8\omega(LC)^{3/2}} \qquad // \sqrt{LC} = 1/v_d \text{ and } \omega\sqrt{LC} = \omega/v_d = \beta_{d0}$$

$$\text{Im}(k) = -\frac{(RC+GL)}{2\sqrt{LC}} + \frac{(RC-GL)^2\,(RC+GL)}{16\omega^2\,(LC)^{5/2}} \qquad \omega >> (R/L),(G/C) \qquad (Q.5)$$

And I know that β_d is the true complex β_d so

$$\beta_d^2 = \mu_d\varepsilon_d\omega^2 - j\omega\mu_d\sigma_d = \omega^2\mu_d(\varepsilon_d - j\sigma_d/\omega) = \omega^2\mu_d\xi_d \qquad \xi_d \equiv \varepsilon_d - j\sigma_d/\omega \ . \qquad (1.5.1a)$$

But just to make things simple, lets assume a non-conducting dielectric [but later I added this back in in red] . Then

$$\beta_d^2 = \mu_d\varepsilon_d\omega^2 \qquad // \text{ still true with } G\neq 0 \text{ at high } \omega \text{ since}$$

$$\text{Large } \omega: \quad \text{Re}(k) = \omega\sqrt{LC} + \frac{(RC-LG)^2}{8\omega(LC)^{3/2}} \qquad // \sqrt{LC} = 1/v_d \text{ and } \omega\sqrt{LC} = \omega/v_d = \beta_{d0}$$

$$\text{Im}(k) = -\frac{(RC+GL)}{2\sqrt{LC}} + \frac{(RC)^2\,(RC)}{16\omega^2\,(LC)^{5/2}} \quad \omega >> (R/L),(G/C) \qquad (Q.5)$$

Write the above all using v_d

$$\text{Re}(k) = \omega/v_d + v_d^3(RC-GL)^2/8\omega$$
$$\text{Im}(k) = -(1/2)(RC+GL)v_d + (RC)^3\,v_d^5/(16\omega^2)$$

Now let's drop terms $1/\omega$ and $1/\omega^2$ to get

$$\text{Re}(k) = \omega/v_d$$
$$\text{Im}(k) = -(1/2)\,(RC+GL)v_d$$

Then

$k = \omega/v_d - j(1/2)\,(RC+GL)v_d$ // agrees with yesterday

[From here on, just make the replacment RC → (RC+GL)]

$k^2 = [(\omega/v_d) - j(1/2)(RC)v_d]^2 = (\omega/v_d)^2 - (1/2)^2(RC)^2v_d^2 - j(RC)v_d(\omega/v_d)$

$= (\omega/v_d)^2 - (1/2)^2(RC)^2v_d^2 - j(RC)\omega$

$= (\omega/v_d)^2 - j(RC)\omega - (1/2)^2(RC)^2v_d^2$ // sorted by powers of ω

Then

$(\beta_d^2-k^2) = \mu_d\varepsilon_d\omega^2 - (\omega/v_d)^2 + j(RC)\omega + (1/2)^2(RC)^2v_d^2$

$= j(RC)\omega + (1/2)^2(RC)^2v_d^2$

$= RC[\, j\omega + 1/4\,(RC)\, v_d^2\,]$

$= (RC+GL)\,[\, j\omega + 1/4\,(RC+GL)\, v_d^2\,]$

Maybe it would be good to check the relative sizes of terms for Belden.

R = 36
C = 68e-12
v_d = 3e8

$1/4\,(RC)\, v_d^2 = 0.55e8 \approx (1/2) \times 10^8$

```
R := 36;

C := 68e-12;

vd := 3e8;

(1/4)*R*C*vd*vd;
```

$R := 36$

$C := .68\ 10^{-10}$

$vd := .3\ 10^{9}$

$.5508000000\ 10^{8}$

$f = 2\pi\omega = (1/3) \times 10^9 = 1/3$ GHz

So this Helm parameter increases linearly with ω and at large ω is entirely imaginary.

This is the point at which the two terms become equal in $(\beta_d^2-k^2)$. So we roughly have

$(\beta_d^2-k^2) = RC[\, j\omega + 10^8\,]$

If we had R = 0 (perfect conductor) we would claim this was 0 and Laplace applied.

The the question is: is this small in some relevant sense? $(RC) = (1/4) \times 10^{-8}$. So:

$$(\beta_d^2 - k^2) = (1/4) \times 10^{-8} [\, j\omega + 10^8 \,]$$

$$= (1/4) \times 10^{-8}\, j\omega + 1/4$$

At say 30 MHz you might argue that

$$\kappa^2 \equiv (\beta_d^2 - k^2) \approx (1/4)\ m^{-2}$$

In my plots, setting k = 0 or k = 1 were all the same.

For this Belden cable I claim maybe $D = a_2 = 3$ mm. So I expect very little alteration from the Laplace pattern when κ is small, or

$$\kappa < 1/D$$

$$1/\kappa > D$$

So $D = 3 \times 10^{-3}$

$$1/D = 333\ m^{-1}$$

So if $\kappa << 333\ m^{-1}$, I expect very little disturbance from Laplace!
But in my example $\kappa = 1/2\ m^{-1}$. So I expect no oscillatory activity.

Now eventually κ gets large. We have above

$$\kappa^2 = (1/4) \times 10^{-8}\, j\omega + 1/4$$

Trouble occurs then when

$$\kappa \sim 333$$

$$\kappa^2 \sim 110889$$

$$(1/4) \times 10^{-8}\, j\omega + 1/4 \approx 110889$$

$j\omega = 500{,}000\ e8 = 50000\ GHz\omega$.

OK, this is great! I will stop and see what tomorrow brings.

Thurs July 3, 2014

I added G back in in red above, don't think makes any difference. But I shouild compute G for Belden example. I did this somewhere recently.

Where is a good place to install my Belden example in full detail? All in one place? Has to be after 4.11 somewhere. I think at the very end of 4.11. So where does my source data come from?? I have no files with "belden" in the name! It is called 8281.pdf.

I did this, and then realized I need to expand Z_0 the way I did k, so another section on Appendix Q, and the thing is a bit of a mess, but I think I have the right answer.

Fri July 4, 2014

(1) I spent lots of hours doing the real and imaginary part for $Z_0(\omega)$ with Maple support. But there were anomalies with Maple on certain complex signs.

(2) I then found a completely new and much simpler way to compute the real and imaginary parts of Z_0. However, this new method gives results which DO NOT AGREE with the previous method which I was quite sure was right.

So it is now 2:30 PM and I am blocked until this matter can be resolved. This new method could also be used for k as well as Z_0. This implies a complete rewrite of Appendix Q?

I had a simple math error as usual. **Appendix Q now has two separate pieces**, with simple equation numbering. All installed. Updated Refs to App Q. Repaired headers, new doc date, added App Q summary. So now I am ready to continue with that Belden stuff which I think is App Q. The hold up was that I needed to know the function $\mathrm{Re}(Z_0(\omega)$ so I could plot things for the 8281 cable. I still think App R will be a valuable addition. Now 8:30PM and shutting down. There is at least one other loose end hanging around, "the way back" thing.

Sat July 5, 2014

Wrote up Appendix R on Belden, thought it was pretty good, but....

Appendix R written, coax enters lines doc, Sun July 6, 2014

When doing the decay loss stuff for Belden, after much flailing I found that I made FIVE errors:

(1) presentation method is very bad, in retrospect
(2) I used the DC resistance R instead of the true $R(\omega)$ in my various R,L,C,G expressions. This was causing much smaller attenuation than reality
(3) I ignored the tinning correction which I see from old coax notes can be significant.
(4) my a_2 radius also needs a correction as discussed in those coax notes.
(5) I used tanL = .0002 but it should be .0005, see those same notes.

So I guess I will just start over on Appendix R. I need separate models for the inductance of the center wire and for the shield.

I did start over, and I wrote **Belden v3.** This is a shorter version of Appendix R. I use here a different model for L_i where both sheath and center wire are represented by a sheath and I only consider skin effect frequencies. I now find that my attentuation values are 3X too low instead of 10X too low, and the shape of the att curve seems right comparing to my Excel. The mystery is this: I did all this in my 1991 Coax document which I now am looking at. That document gets the attenuations *exactly right*, whereas my Belden v3 is way too low on the attenuation values. It could be the tinning factor thing, but I threw that in and it does not make much scaling difference. So now I have to detangle this mess.

Higher Level View.

Appendix R has now opened the entire Coax Document can of worms, something I was not planning to get involved with. I could omit Appendix R, but then my Belden connection is very weak. I have no test at all of my basic computations.

But once this can is opened, I am looking at another month or two of solid work to restabilize things!! That means I cannot finish lines doc before Cape Cod, the second time this has happened! So that goal is now unattainable. The end date then moves out to perhaps end of September but then German visitor and it is out to end of October. We are then getting onto a full year or more on lines doc! Sisyphus then wins yet another round!

So again, I have two distinct problems
(1) I cannot get any inductance value as high as the one quoted by Belden
(2) my attentuation is 300% too low.

I also have various other "loose ends" to deal with.

By the way, this is page 187 of the edit log!!! That tells you something!

7.14.14. Had a little time on my last day so am poking around a bit. I need to check to see whether the notation Z_0 is used only for the high ω impedance of a line, or for the ω dependent impedance. I may have done this wrong everywhere! ********* [no, I had it right, wiki and Matik eg]

I am looking now at my coax cable notes. Fig 1.3 there shows a plot of L_i starting off at 50 nH and then after that it drops off. In those notes, chapter 1 page 9, I show L_e = 377.2 nH. So the most you could ever get for total inductance would be this plus 50 nH, which is then 377.2+ 50 = 427.2 nH. This is in fact pretty close to the modern value for L, so maybe it is the DC L that they spec out, not the high ω value which things are very small.

OK, I have solved the inductance mystery! I think I forgot to add the shield and internal contributions, AND their quote then agrees exactly with my detailed DC calculations to 0.1% error. I have been rewriting Belden v3 and am now reverting to *some* inserting Maple calcs as I go.

I am now looking at the AC situation and I would like to verify this equation which appears in my coaxial cable document,

The tinning correction then gives equation 2.4 (3) which is the same as above with t(f) added.

Continuing with my 1991 paper, we get to Section 2.5 and I claim that

atten(dB/100m) = 869α

This agrees with my new MWS which says

```
dB := 868.5*a;
```

So my current a is the same as the paper's α. This is the POWER dB in both 1991 and 2014 worlds, no question about that. And both α and a are the voltage decay factors.

I have now verified my 1991 equation (18) for α(ω), and I have updated the mws code with various changes that mimic the 1991 work. Things are better now I think. Beldon v3.doc is getting edited along the way here.

I am still a factor of 3 too low in scale for my a = -Im(k) plot, using the updated R,L,C,G values. But what is new is that I agree with equation (18). Now my 1991 only claims to be good at high ω, and my 2014 should make the same claim even though I use Im(k). I threw in tinning and I still have a problem Houston with the scale of the dB.

Status: I have now verified many equations from coax doc including Section 2.5 (3) for α, which supposedly gives the 30 dB type values shown in Fig 3.1.1 ! So my next step will be to reproduce that plot using my 1991 equation (3) and see if the plot is really correct! If it is, then I will continue to debug.

Today's summary:

(1) I was able to reproduce Belden's DC inductance value, finally.
(2) I improved Belden v3.doc regarding high ω equations
(3) I derived various 1991 equations (see separate doc) for the first time.

But the factor of 3 problem still remains and needs to be debugged.

Resume on Sat July 26, 2014 after return from Cape Cod.

Read thru my little "checking 1991" doc, and read through last entry above. Maybe I can *find* the Excel spreadsheet which appears as Fig 3.1.2 and which gives the plot of 3.1.1 which shows the 30 dB. The equations don't appear in Fig 3.1.2 so I need the XLS. // I cannot find this little XLS, even under a different extension, it is not in either of the 1991 coax folders, too bad, so that path is not available. It is the Model column that is of course of interest.

OK, it is now 6 PM and I have *finally* made belden v3.mws generate reasonable attenuation values. I was also able to reproduce that exact Model values which appear in the 1991 paper -- that is in "coax 1991 spreadsheet.mws". So I guess I can finally start moving forward again. It turns out that the tinning correction is not all that signficant. Maybe I should be plotting R for the inner and outer conductors or something like that.

Things are in a sloppy state right now, but at least I got the attentuation to come in OK. Tomorrow I will try to do some cleanup. Stopping at 6:45 PM.

Sunday July 27, 2014.

I am going through Belden v3 doc, converting it to a new version of Appendix R. This took all day, and as of about 9 PM I think I have it ready for a final edit tomorrow. I also looked through my 1991 binders for coax doc and lines doc. This little Appendix R is the only coax doc work I ever intend to publish.

Monday July 28, 2014.

Did a full proofing of the new Appendix R on Belden cable, I think it is pretty good in fact. Did lots of small edits along the way. // Then cleaned up the mws file used for Appendix R.

Bug noted: In the plot of Re[$Z_0(f)$] versus f, if I raise the high end to 1e10 or higher, the left part of the plot is a straight line, but when the endpoint is 1e9, the left part is curved. Also, the place where the straight line ends varies with the right endpoint! This seems wrong to me.

Example: if right endpoint is 1e10, the straight segment ends around 1e7.
Example: if right endpoint is 1e11, the straight segment ends around 1e8.
Example: if right endpoint is 1e12, the straight segment ends around 1e9.

It probably is just something about log plots that I don't understand at the moment.
// Yes, it was just a **numpoints artifact**. I need to recheck all plots now.

Found this helpful statement in my little Belden pdf thing

> Traditionally, cable manufacturers have specified this value as typical or nominal. In some cases, the value had a tolerance. In the case of video cable, a typical value was 75 ± 3 ohms. Therefore, the characteristic value is between the value of 72 and 78 ohms or about ± 4%. Some precision video cables, such as Belden 8281, made with a solid conductor and solid polyethylene dielectric were specified as ± 1.5 ohms, or ± 2%.

and this fits very well with my model.

I added van der burgt as a reference and commented on his noise stuff. Gives me another reference at the end of the list with a nice PDF link.

So I spent another day on this appendix, I think it is ready to be installed and a summary added.

Will now do final proofing.

Intro OK
(a),(b),(c) OK
(d),(e) OK
(f), (g) OK

(h), (i) OK

Looks good, my edit rate is dropping off now.
Final check on eq numbers and figure numbers and alignment.
Spelling check OK.

Overview:

Appendix R applies the theory developed in this document to a case study: Belden 8281 coaxial cable.

I am now ready to install.

// Installation complete, we are now exactly 500 pages ! Amazing.

I just read the overview, chapter and appendix summaries, symbols.

Confirmed with Matick and wiki that I am using the symbol Z_0 correctly, it is a function of ω.

Tues July 29, 2014.

Scan back through this log looking for loose ends:

I wanted to work in my little electronics style loss formul, but that got supplanted by just using the function k(ω) which generates the attenutation coefficient.

I now want to proof the section of lines doc where k(ω) is first discussed.

Section 4.11 review
- opening OK
- (a) OK
- (b) OK, still don't have k but I have made small corrective edits!
- (c) OK, proof that $K = K_L$
- (d) OK, example of $K = K_L$
- (e) summary box, I added L_i
- (f) telegraph

Well, OK, did some good edits, but that is not where k(ω) appears. But it was a good section to review!

Chapter 5: Some red text right at the start! I will proof this chapter a bit then I think I can delete the red text which concerns notation for things like μ and ε subscripts.

Chapter 5
- 5.1
- 5.2 These are copy and paste sections, and I use ξ_d and β_d notation everywhere.
- 5.3
  - (a) more red text I have to deal with, subject is transverse equations.

(b) scaling BC digression which I skip for right now to stay forcussed
5.4 on low loss.
(a) removed some red text posted for removal, about notation. Did lots of edits to clean this section up, it had some bad problems noted in red.
(b) more on scaling condition.

I then go on to do the capacitor problem. I skip now to

5.6 What if low-loss not assumed?

STOP, I am confused. I write this in (5.3.6)

$$k^2 = -\mathbf{zy} = -j\omega Z_s 4\pi\xi_d/K + \beta_d^2 \qquad jk = a + jb = \sqrt{\mathbf{zy}} = \sqrt{(R+j\omega L)(G+j\omega C)}$$

which says

$$(\beta_d^2 - k^2) = \frac{j\omega Z_s 4\pi\xi_d}{K}$$

I then work two different ways when dealing with losses. The way done locally in this chapter is that I think directly about the form Z_s takes for high ω and for low ω and show what "low loss" means in these two limiting worlds. But this is all equivalent to taking limits of k(ω) which is more the approach of Appendix Q and R.

One main idea: anywhere I have a formula for K, I obtain that formula by doing "the capacitor problem". But that is a Laplace problem, and so I have already at that point assumed that I can ignore the Helmholtz term, and that is what I mean by low-loss. So basically all my work is in the low-loss regime. This of course allows for losses, as we saw in 8281 attenuation. But if loss is large enough, meaning Z_s is large enough, then the capacitor problem method fails, and then you are in the eigenvalue problem regime.

I added some text at the start of Section 5.6 which I think is useful.

The Way Back problem. I think this is written up somewhere but not installed. // Yes, there is a doc on this subject in the Lines Doc folder top level. // It is done, and I got to use the same two examples, so cross this long delayed item off the list!

Energy Conservation and Power Loss Stuff. I just wedged this in as Section 5.3 (c), soon after the quantity k first makes its appearance. That is why I have placed this oddball section in Chapter 5 which perhaps will seem odd to a reader, but I got it worked in.

Lines doc is now 504 pages. I think it is done, but I now have to go through a phase of "reviewing documents" to make sure there are no gotchas. I am aware of no new stuff that I want to put in.

Starting another proofing cycle, Weds July 30, 2014.

Reviewed doc files, cleaned up file storage so there is just one top level lines doc file which is in place in the physics world. This consumed the morning.

On June 23 I did a massive full document proofing. So what stuff has been edited since then?

Chapter 5.4 **DONE**
D.9 and D.10 and D.11 **DONE**
Appendix Q was written **DONE**
end of Appendix K on network model, did a rewrite in fact **DONE**
Chapter 6.5 (e) (f) (g) **DONE**
Appendix R on Belden **DONE**
chap 1 on way back thing **DONE**
overview and appendix summaries **DONE**
Chapter 5.3 thru 5.6 **DONE**
energy conservation section in 5.3 **DONE**

So I will now undertake proofing starting with the appendices, then DONE them above.

Appendix K: Bug! In what sense are the two circuits "electrically identical" ? OK, I got happy about this again and added a little comment.

(a) OK
(b) OK
(c) OK
(d) OK
(e) OK
(f) OK

Appendix D. I won't review the whole thing, just part

Section D.11 Low frequency limits of the round wire E fields are presented, including losses.???
I deleted the losses phrase since I no longer have a loss section here. Loss is implicit in the k(ω) formula.

opening text OK
D.1

(a) OK
(b) scanned only, OK at end in particular

OK, now onto the main stuff.

D.9 OK, I browsed through this, heavy going, not much new.

D.10 OK, did a browsing only.

D.11 This is the key section where I may have problems.

(a) is very good, something I added concerning the meaning of k and validity
(b),(c),(d) all OK

There is a LOT going on in this little section, and I think for the analytic work *and* the words are good. I fess up to "the anamoly" that J_z is non-uniform at $\omega = 0$ in the model, but not in reality. I would rather make this problem explicit rather than bury it somewhere, and this was the place to bring it out.

This concludes my partial proofing of Appendix D.
And I have done the same for all other chunks marked DONE in red above.

The time has come for pagination! It is about 7 PM 7/30/14. With 504 pages, this will be a major effort, since I probably fiddled in many sections so I really have to do the whole thing again!

I will just get started.

Check upper right corner header labels: DONE, found that App D had lost its header, all fixed.

TOC: this works out fine, no adjustments needed.

Overview and Summary: OK, no changes made

Chapter 1: OK thru p 64 I did maybe 10 pagination changes here due to added stuff.
Went thru this again, I like it, finalized!

Chapter 2: OK thru p 81. Got rid of wrong word "stripline" and used parallel plate line. Done Ch 2.

will continue this tomorrow.

Thurs July 31, 2014.

Pagination:

Chapter 3: OK thru p 125 -- no changes made

Chapter 4: OK thru p 164 -- made about 6 changes, material was added here!~

Chapter 5: OK thru p 191 -- made maybe 6 changes here, stuff was added!

Chapter 6: OK thru p 217 -- better alignment with about 4 changes

Appendix A: no changes needed, just looked at this in print preview

Appendix B: no changes needed, just looked at this in print preview

Appendix C: no changes needed, just looked at this in print preview

Appendix D: OK thru p 342 -- very painful, lots of changes.

Appendix E: no changes needed

Appendix F: no changes needed

Appendix G: no changes needed, just looked at this in print preview

Appendix H: no changes needed, just looked at this in print preview

Appendix I: no changes needed, just looked at this in print preview

Appendix J: no changes needed, just looked at this in print preview

Appendix K: made some changes since this was edited.

Appendix L: no changes needed, just looked at this in print preview

Appendix M: no changes needed, just looked at this in print preview

Appendix N: no changes needed, just looked at this in print preview

Appendix O: no changes needed, just looked at this in print preview

Appendix P: no changes needed, just looked at this in print preview

Appendix Q: no changes needed, just looked at this in print preview

Appendix R: adjusted as needed, did some edits as well.

I did some edits in the referenced, and verified all links!

What's next? I need to update the Visio and Maple index! Maybe think about sum notation and cosmetics like that.

Maple Index update: Done and very painful.

Second Major Release, Fri Aug 1, 2014.

In morning session updated the Visio index, all done.

Created a PDF, first show failed, second OK. This is 500 pages, the largest PDF I have ever made. Size is a modest 6.4 MB.

Check bookmarks:

Second Summary of fields in D is missing as bookmark, not a big deal I think. I will leave as is, it is because heading is not on a separate line.

extra spaces on App K headings, now fixed.

Scan for blank pages: no blank pages, scanned all 500 pages fast.

Check alignment of section headers:

Header for Cha6 6 should say cylindrical instead of circular. Fixed. Else all OK

Proof OV and Sum in PDF at 122% :

Overview is Just Fine.
Summaries fine.
Read through symbols but started glazing in the greeks so stopped.

Scan Appendix R (since new): done, fixed a few tiny cosmetics.
Scan Appendix P on eddy currents. Read some, it seems fine, started to glaze again.

As I scan, the typesetting looks fine. Subs and supers are find even though bold. Single line sums are fine as well. Integral endpoints are OK.

Where is it that I use full size summation symbols?? There just are not many such sums. The first full bore sums occur in App D where m is the partial wave index. I conclude that the sums there are just fine, the bold supers and subs are just fine, I like it. They are easy to read when bolded, but that does not make them particularly annoying in the PDF IMHO.

I have made many tiny fixes and will do a new PDF soon. I think I want to ascend to my why took so long doc and work there a bit.

New PDF was made on 8.2.14, I perused it a bit, seems OK. Then at 4:15 PM I released it to my local website and updated the index.html file. It comes up OK locally.

I think I need to do another release of bipolar doc at this time, so go to that edit log. Done.

I then did Filezilla and pushed all out to Xmission and checked that things work.

I then did google analytics (see separate doc) and confirmed that my analytics snippet is in there OK. I deleted the rimrockinteractive account since long gone. Seems to work OK but not interested right now.

Aug 12, 2014. I think I successfully constructed a reflection scenario solution and it too exhibitst the same J_z asymmetry at DC, so this little mystery remains alive and well. In doing this in the last week or so, I generated various files which are now stored in the low frequency limit folder and can be easily found there by sorting by creation date. The PDF release has not been withdrawn. I have a few small errata in an errata file for when I decide to redo it.

Aug 20, 2014. While rewriting App M to remove reference to my old ω_c loss model of old Sec D.11, I noticed a bug in Chap 4. That bug is that I assume there the form $e^{-j\beta_d z}$ as z-dependence of things rather than the more general form e^{-jkz} which allows for losses. Here is the situation moved here from the App M repair doc:

Ouch, I claim that $\mathbf{J}_{t,i}(x,y,z) = e^{-j\beta_d z}\,\mathbf{J}_{t,i}(x,y)$ with β_d there instead of k. Did I do that back in Chapter 4? I am now looking thru Ch 4. The $e^{-j\beta_d z}$ gets into the discussion thru (1.5.9), yes. I then do the TL limit

idea to get (4.3.7). But then bang, I say $q(z) = q(0)\, e^{-j\beta_d z}$ so everything is suddenly limited to the lossless theory! I am claiming that β_d is very small as a general rule, based on long λ idea.

So now I need some kind of repair back in Section 4.3. Can I argue that k is also small? At this point in Ch 4, there has been no mention of k, but that will appear with the TL equations. I will find that

$$jk = a + jb = \sqrt{\mathbf{zy}} = \sqrt{(R+j\omega L)(G+j\omega C)}$$

whereas at high ω we get

$$jk = j\beta_d = j\omega\sqrt{LC} \qquad \text{or} \qquad k = \beta_d = \omega\sqrt{LC} = \omega/v_d$$

Now maybe I can argue that, when losses are included, we replace β_d by k, but $|k| < |\beta_d|$ and so the entire discussion is still valid if we replace β_d by k. So I would want to show that

$$\beta_d \geq |k|$$

I know from (Q.1) that

$$a \equiv [(R^2+\omega^2L^2)(G^2+\omega^2C^2)]^{1/4} = |k|$$

so I would have to show that

$$\omega\sqrt{LC} \geq [(R^2+\omega^2L^2)(G^2+\omega^2C^2)]^{1/4}$$

or raising both sides to the 4th power,

$$\omega^4 L^2C^2 \geq (R^2+\omega^2L^2)(G^2+\omega^2C^2)$$

or that

$$\omega^4 L^2C^2 \geq \omega^4 L^2C^2 + \omega^2(L^2 G^2 + R^2C^2) + R^2 G^2$$

[for very large ω, these are roughly equal and so $\beta_d \approx |k|$ at that point]

or that

$$0 \geq \omega^2(L^2 G^2 + R^2C^2) + R^2 G^2$$

and obviously this is not going to be true.

Perhaps I would have to just require this:

$$|k|\, D << 1$$

in order to be in the TL limit! This condition would then require that

$$[(R^2+\omega^2L^2)(G^2+\omega^2C^2)]^{1/4}\, D << 1$$

and this just puts an UPPER limit on ω for which our manipulations of Chapter 4 are justified. In Chapter 4 we require instead that

$$\beta_d D << 1$$

or

$$\omega \sqrt{LC}\, D << 1$$

It is then a similar but different condition on the largest value of ω that can be accepted.

OK, I am going to add new text at the very end of Section 4.3, which allows for new equation numbers, and will require repagination of Ch 4.

Done. The new text I think is quite reasonable.

Are there other places I need to fix this $e^{-j\beta_d z}$ versus e^{-jkz} situation? I can search for $e^{-j\beta}$ to locate occurrences of $e^{-j\beta_d z}$. Did this, and the only other fix needed is in the A_z analogous section. So I think I am done with this set of edits.

Elisabeth Voight visit happened right here, Aug 22- Aug 30 in effect, I now resume Sat 8/30

I recall that I was working on the Appendix Q limits for the case that the four parameters are NOT constants in ω. This problem was discovered while I was rewriting App M in a doc of that name. I then started "App Q revisited" on 8/21/14 so I will go read that now. // This led me to start that doc over under name App Q rewrite v2.doc and I did a day of work inside that doc. I think I obtained the high ω and low ω limits for k(ω), and they are indeed different in some cases from the limits in the original App Q. Stopping now at 5:30 PM

Appendix Q Rewrite, Sept 3 2014

Update Sept 3, 2014. After much battle, I have a version of Appendix Q that I think is OK, and I am going to proof it right here.

Appendix Q rewritten:

- opening text OK
- Q.1 the model OK eq num OK fig num OK
- Q.2 sep of k = Re + Im. No need to check in detail, one eq num and no figs. Same as old App Q.
- Q.3 k for large ω. OK eq num OK no fig
- Q.4 k form small ω
  - $\omega_d > 0$ case: OK eq num OK thru Q.4.6
  - $\omega_d = 0$ case: OK rest OK
- Q.5 sep of Z_0 = Re + Im. OK one eq num, one fig num, OK

Q.6 Z_0 for large ω OK eq nums OK, no figs

Q.7 Z_0 for small ω

$\omega_d > 0$ case: OK

$\omega_d = 0$ case: OK

All done, so I will now do some general cleanup and will hold off on installation of this new App Q.

All done, and now I am popping the stack back to my Appendix M rewrite project. Made a little progress there, signing off 7 PM.

Update Sept 5, 2014

I have been working on the first part of Appendix M, and have already done several rewrites of that section. While doing this, I found an App Q goof in the for Belden, $\omega_d = 10^{-4}$ and not 113, so now I have to go back once again to App Q and see what implications this has. App M is then on hold.

The problem is that in App Q I get an expansion in (ω/ω_d) for small ω, but this does not seem very useful if you learn that $\omega_d = 10^{-4}$. So I somehow have to rethink the low ω expansion of k(ω).

Update Sept 9, 2014.

I have been working more on Appendix Q, adding sections about "general appearance". I just ran into a discrepancy with numbers (.20 vs .27) and I found that I have used the wrong $\tan_L$ in Appendix Q! The Appendix says I used .0005 but the code shows .0002. So I am now going to fix this problem, then I can return to Appendix Q. [there I quote some results from Appendix R !] BUT, after going through everything, I think I must have changed .0005 to .0002 much later since nothing seems to change between the updated belden3.mws and lines doc App R. So in fact no edits needed at all!

So I still have my little discrepancy. But I fixed it, fine.

I now have Section Q.9 sitting in separate doc temp1.

Actions:

(1) install the new Section Q.9 from temp1 into the current separate Appendix Q. **DONE**

(2) Update lines doc refs to Appendix Q **DONE**.

(3) Save off the old Appendix Q from lines doc (which treated R,C,L,G as constants). **DONE**

(4) Install the new Appendix Q. **DONE**.

(5) Verify that the section headers are still OK. **DONE** (they were OK)

I think finally I can return to continuing my update of Appendix M. But I now see that is dependent on the low-ω forms for the E fields, and that in turn is given in Appendix D.11. BUT, there I use the old Appendix Q results which are wrong, so:

Repair Section D.11 (separate doc) Done, was simpler than I thought, all installed.

Just found a fixed a bug in (D.11.11) and its applications. The new equation reads,

$$\frac{E_z(r,\theta)}{E_z(r,0)} = \frac{1 + \Sigma_{m=1}^{\infty} (r/a)^m (m+1)\, \eta_m \cos(m\theta)}{1 + \Sigma_{m=1}^{\infty} (r/a)^m (m+1)\, \eta_m} \qquad (D.11.11)$$

but the conclusion that it is not-unform is not altered! I reread part (a) of D.11 and it is still OK, I explain why we should expect problems at low ω

Now once again back to Appendix M. I think I have finally finished my edit on this (in " Appendix M rewrite done Aug 19, 2014 version 2.doc"). Had to change equation numbers a lot. Will now correct any eq num references in the main lines doc to this appendix: DONE, only a single reference!

Equation nums are good. Only two figures. Ready to install, but save old App M first. **DONE**.

Are there any references to the old Appendix Q in lines doc? Yes, we have some issues!

I have to go repair section D.10 (b) which refers to Appendix Q. Done. I have now handled all the lines doc references to Appendix Q.

Hopefully, lines doc is now stable from the point of view of Appendix Q and Appendix M.

I guess I will then go back to my curl E paradox business and see where that takes me. At some point I need to clean up the mws files for Q and maybe M.

Write new Chapter 7, Sept 20, 2014

I have been writing Chapter 7, a new addition to lines doc, which faces up to the various anomalies. One of those is what I call "the curl E problem", which is really that certain B_i magnetic field components diverge when $\omega \to 0$. In order to show this, I have to do lots of work. I realized that I ought to do that work directly in Appendix D by cleaning up my statement of the E and B fields. Here is my new compact form for this summary:

Summary of E and B fields inside a round wire (D.4.*)

$$E_z(r,m) = (1/4)\, \eta_m\, I\, R_{dc}\, (a\beta')\, f_m \qquad x = \beta' r \qquad x_a = \beta' a \qquad \beta'^2 = \beta^2 - k^2$$
$$E_r(r,m) = (j/4)\, \eta_m\, I\, R_{dc}\, (ak)\, g_m$$
$$E_\theta(r,m) = (1/4)\, \eta_m\, I\, R_{dc}\, (ak)\, h_m$$

$$B_z(r,m) = (j/4)\, (a/\omega)\, \eta_m\, I\, R_{dc}\, (k\, \beta'\, e_m)$$
$$B_r(r,m) = -(1/4)\, (a/\omega)\, \eta_m\, I\, R_{dc}\, (\, r^{-1} m\, \beta'\, f_m + k^2\, h_m\,)$$
$$B_\theta(r,m) = (j/4)\, (a/\omega)\, \eta_m\, I\, R_{dc}\, (\, k^2\, g_m - \beta'^2 f_m\, [\, (m/x) - J_{m+1}(x)/J_m(x)]\,)$$

$$e_m = \left[\frac{J_m(x)}{J_{m+1}(x_a)} + \frac{J_m(x)}{J_{m-1}(x_a)}\right] \qquad g_m = \left[\frac{J_{m+1}(x)}{J_{m+1}(x_a)} + \frac{J_{m-1}(x)}{J_{m-1}(x_a)}\right] \qquad R_{dc} = \frac{1}{\sigma \pi a^2}$$

$$f_m = \left[\frac{J_m(x)}{J_{m+1}(x_a)} - \frac{J_m(x)}{J_{m-1}(x_a)}\right] \qquad h_m = \left[\frac{J_{m+1}(x)}{J_{m+1}(x_a)} - \frac{J_{m-1}(x)}{J_{m-1}(x_a)}\right]$$

Now when I want to show that B fields diverge as $\omega \to 0$, I can simply use these B field expressions which saves a lot of Chapter 7 work. I included a full verification.

The upshot is that I have rewrites now of sections D.4, D.5 and D.6 (all sitting in the same document). I want to install this new stuff, but want to spell check first and deal with the impact on global equation numbers!!! So don't do this too fast please!

I might want to update D.10 and D.11 now to include B component limits!

Appendix D work, Sept 21, 2014 Lots of editing in D.4, D.5 and D.11

I proofed and added and checked equation numbers in the replacement sections D.4, D.5 and D.6. Also did spell check. I now want to adjust all references to equations in these sections throughout lines doc. I will do that in place. // That was not hard to do. Next, I will copy off those 3 sections to an archive file. All done, Appendix D and lines doc is now fully updated for this set of changes.

Idea: Given the large ω E fields in (D.10.13), why don't I use $-j\omega B = \text{curl } E$ to get the corresponding B fields! Here is how that would go: Start with the E field results,

Large ω limits of the E field solutions : $R_{dc} = \dfrac{1}{\sigma\pi a^2}$ (D.10.13)

$$E_z(r,m) = -(j/2)\,\eta_m\, I\, R_{dc}\, (a\beta)\sqrt{\frac{a}{r}}\, e^{(1+j)(r-a)/\delta} \qquad x = \beta r$$

$$E_r(r,m) = (j/2)\,\eta_m\, I\, R_{dc}\, (a\beta_d)\sqrt{\frac{a}{r}}\, e^{(1+j)(r-a)/\delta} \qquad x_a = \beta a$$

$$E_\theta(r,m) = 0$$

Then apply,

$$B_r(r,m) = (j/\omega)\,[\text{curl } E]_r = (j/\omega)\,[r^{-1}jmE_z + jkE_\theta]$$

$$B_\theta(r,m) = (j/\omega)\,[\text{curl } E]_\theta = (j/\omega)[-jkE_r - \partial_r E_z]$$

$$B_z(r,m) = (j/\omega)\,[\text{curl } E]_z = (j/\omega)\,[r^{-1}\partial_r(rE_\theta) - r^{-1}jmE_r]\,. \qquad \text{(D.4.7)}$$

I enter the B_i expressions into Maple

```
restart; alias(I=I,j=sqrt(-1),J=BesselJ):

Br := (j/w)*(j*m*Ez/r + j*bd*Eth);
```

$$Br := \frac{j\left(\frac{j\,m\,Ez}{r} + j\,bd\,Eth\right)}{w}$$

```
Bth := (j/w)*(-j*bd*Er - Diff(Ez,r));
```

$$Bth := \frac{j\left(-j\,bd\,Er - \left(\frac{\partial}{\partial r} Ez\right)\right)}{w}$$

```
Bz := (j/w)*((1/r)*Diff(r*Eth,r) - (1/r)*j*m*Er),
```

$$Bz := \frac{j\left(\frac{\frac{\partial}{\partial r} r\,Eth}{r} - \frac{j\,m\,Er}{r}\right)}{w}$$

I enter the E_i into Maple from the box above, leaving off the factor (j/2) η_m I R_{dc} (a)

```
Ez := -b* sqrt(a/r)*exp((1+j)*(r-a)/d);
```

$$Ez := -b\sqrt{\frac{a}{r}}\,\mathbf{e}^{\left(\frac{(1+j)(r-a)}{d}\right)}$$

```
Er := +bd* sqrt(a/r)*exp((1+j)*(r-a)/d);
```

$$Er := bd\sqrt{\frac{a}{r}}\,\mathbf{e}^{\left(\frac{(1+j)(r-a)}{d}\right)}$$

```
Eth := 0;
```

$$Eth := 0$$

.

and I have Maple compute things

```
Bz;value(Bz);
```

$$\frac{j\left(\frac{\frac{\partial}{\partial r}0}{r}-\frac{j\,m\,bd\sqrt{\frac{a}{r}}\,\mathbf{e}^{\left(\frac{(1+j)(r-a)}{d}\right)}}{r}\right)}{w}$$

$$\frac{m\,bd\sqrt{\frac{a}{r}}\,\mathbf{e}^{\left(\frac{(1+j)(r-a)}{d}\right)}}{w\,r}$$

```
Br;value(Br);
```

$$\frac{m\,b\sqrt{\frac{a}{r}}\,\mathbf{e}^{\left(\frac{(1+j)(r-a)}{d}\right)}}{w\,r}$$

$$\frac{m\,b\sqrt{\frac{a}{r}}\,\mathbf{e}^{\left(\frac{(1+j)(r-a)}{d}\right)}}{w\,r}$$

```
Bth;value(Bth): simplify(%);
```

$$\frac{j\left(-j\,bd^2\sqrt{\frac{a}{r}}\,\mathbf{e}^{\left(\frac{(1+j)(r-a)}{d}\right)}-\left(\frac{\partial}{\partial r}\left(-b\sqrt{\frac{a}{r}}\,\mathbf{e}^{\left(\frac{(1+j)(r-a)}{d}\right)}\right)\right)\right)}{w}$$

$$\frac{1}{2}\,\frac{\mathbf{e}^{\left(\frac{(1+j)(r-a)}{d}\right)}\,a\,(2\,bd^2\,r\,d-j\,b\,d+2\,j\,b\,r-2\,b\,r)}{w\,r\,d\sqrt{a\,r}}$$

The grouping in the last result is this:

$2\beta_d^2\, r\, \delta - j\beta\delta + 2j\beta r - 2\beta r$

$= r(2\beta_d^2\, \delta - j\beta\delta/r + 2j\beta - 2\beta)$

$= r(2\beta_d^2\, \delta + \beta\,[- j\delta/r + 2j - 2]\,)$

$= r\,\beta_d\,(2\beta_d\delta + (\beta/\beta_d)\,[- j\delta/r + 2j - 2]\,)$

I just have to leave all these terms even though $(\beta/\beta_d) >> 1$. Well suppose $(\beta/\beta_d) = 1000$. Then have

$= r\,\beta_d\,(2\beta_d\delta + 1000[- j\delta/r + 2j - 2]\,)$

Not worth more work. So we end up with

$$B_z = (1/\omega)\, m\beta_d/r * \sqrt{\frac{a}{r}}\; e^{(1+j)(r-a)/\delta}$$

$$B_r = (1/\omega)\, m\beta/r * \sqrt{\frac{a}{r}}\; e^{(1+j)(r-a)/\delta}$$

$$B_\theta = (1/\omega)\, \beta/r * \sqrt{\frac{a}{r}}\; e^{(1+j)(r-a)/\delta} \;*\; (\; \beta_d r(\beta_d/\beta) - j/2 + jr/\delta - r/\delta \;)$$

or

$$B_\theta = (1/\omega)\, \beta/r * \sqrt{\frac{a}{r}}\; e^{(1+j)(r-a)/\delta} \;*\; [\; (\beta_d r)(\beta_d/\beta) - j/2 + (r/\delta)\,(j-1) \;]$$

Now suppose I argue that we can set $r \approx a$, since for $r < a$, the expo kills things off anyway. Then

$$(\; \beta_d r(\beta_d/\beta) - j/2 + jr/\delta - r/\delta \;) \approx (\; (\beta_d a)(\beta_d/\beta) - j/2 + ja/\delta - a/\delta \;)$$

Now maybe $\beta_d a$ is small due to the transmission line limit, and (β_d/β) is also $<< 1$, and finally we can set a/δ = large, so then

$$\approx (a/\delta)(j-1)$$

Then we would have

$$B_z(r,m) = (j/2)\, \eta_m\, I\, R_{dc}\; (1/\omega)\, m\beta_d \left(\frac{a}{r}\right)^{3/2} e^{(1+j)(r-a)/\delta}$$

$$B_r(r,m) = (j/2)\, \eta_m\, I\, R_{dc}\; (1/\omega)\, m\beta \left(\frac{a}{r}\right)^{3/2} e^{(1+j)(r-a)/\delta}$$

$$B_\theta(r,m) \approx (j/2)\, \eta_m\, I\, R_{dc}\; (1/\omega)\; \beta \left(\frac{a}{r}\right)^{3/2} e^{(1+j)(r-a)/\delta}\; (a/\delta)(j-1)$$

The last one exact is

$$B_\theta(r,m) \approx (j/2)\, \eta_m\, I\, R_{dc}\; (1/\omega)\; \beta \left(\frac{a}{r}\right)^{3/2} e^{(1+j)(r-a)/\delta}\; [\; (\beta_d r)(\beta_d/\beta) - j/2 + (r/\delta)\,(j-1) \;]$$

In the TLL we have $(\beta_d r) << 1$ and we always have $(\beta_d/\beta) << 1$ so simplify to

$$B_\theta(r,m) \approx (j/2)\, \eta_m\, I\, R_{dc}\; (1/\omega)\; \beta \left(\frac{a}{r}\right)^{3/2} e^{(1+j)(r-a)/\delta}\; [\; - j/2 + (r/\delta)\,(j-1) \;]$$

Due to the expo decay, we can replace r by a in the last factor, making little difference. Then

$[- j/2 + (r/\delta)(j-1)\ ] = [- j/2 + (a/\delta)(j-1)\ ] \approx (a/\delta)(j-1)$

This just says we have skin effect for all the components, and that only B_θ exists for m = 0.

Here is how I will load this into lines doc:

Reader Exercise. Use -jω**B** = curl **E** in the form (D.4.7), and (D.10.13) for **E**, to obtain the following expressions for the partial wave magnetic fields inside a round wire at large ω:

$$B_z(r,m) = (j/2)\,\eta_m\, I\, R_{dc}\ (1/\omega)\, m\beta_d\, (\frac{a}{r})^{3/2}\ e^{(1+j)(r-a)/\delta}$$

$$B_r(r,m) = (j/2)\,\eta_m\, I\, R_{dc}\, (1/\omega)\, m\beta\ (\frac{a}{r})^{3/2}\ e^{(1+j)(r-a)/\delta}$$

$$B_\theta(r,m) = (j/2)\,\eta_m\, I\, R_{dc}\ (1/\omega)\ \ \beta\ (\frac{a}{r})^{3/2}\ e^{(1+j)(r-a)/\delta}\ \ [\,(\beta_d r)(\beta_d/\beta) - j/2 + (r/\delta)(j-1)\,]\,.$$

In the transmission line limit $|(\beta_d r)| << 1$ and from comments below (D.2.2) $|(\beta_d/\beta)| << 1$, so the last bracket simplifies to $[- j/2 + (r/\delta)(j-1)\ ]$. Since the exponential decays quickly in r, we could set $r \approx a$ in this bracket and make little difference to get $[- j/2 + (a/\delta)(j-1)\ ]$. But $(a/\delta) >> 1$ more or less in the large ω limit, so then the bracket is $\approx [\ (a/\delta)(j-1)\ ]$ Observations:

• As expected, the B field components have the same skin effect exponential decay as the E field components.

• The B_z and B_r components vanish for m = 0 but the B_θ component does not. Why is this so?
[Hint: Look at (D.4.6)]

• B_θ is larger than B_r by roughly (a/δ), and B_r is larger than B_z by the factor $|(\beta/\beta_d)| >> 1$.

I just added this to lines doc at the very end of Section D.10. I might as well get this result into the doc, but I didn't want to give all the detail. It is archived above and in "B for large omega.mws".

NEXT: **I better do something now about (D.11)** , at least read through it, in light of Chapter 7 now in production. I already have this

$$\begin{aligned} E_z(r,m) &= (1/2)\,\eta_m\, I\, R_{dc}\ (r/a)^{|m|}\ (|m|+1) \\ E_r(r,m) &= (j/4)\,\eta_m\, I\, R_{dc}\ (ak)\ [(r/a)^{|m|+1} + (r/a)^{|m|-1}] \\ E_\theta(r,m) &= (1/4)\,\eta_m\, I\, R_{dc}\ (ak)\ [(r/a)^{|m|+1} - (r/a)^{|m|-1}] \end{aligned} \qquad \text{(D.11.7)}$$

$$\begin{aligned} E_z(r,0) &= I\, R_{dc} \\ E_r(r,0) &= (j/2)\, I\, R_{dc}\ (ak)\ (r/a) \\ E_\theta(r,0) &= 0 \end{aligned} \qquad \text{// low } \omega \text{ E fields}$$

Seems I could repeat the above exercise to obtain the corresponding B fields, and they will then show the problem as ω→ 0. But I have to do it separately for m = 0 and m > 0. We have

$$B_r(r,m) = (j/\omega)\,[\text{curl } E]_r = (j/\omega)\,[r^{-1}jmE_z + jkE_\theta]$$

$$B_\theta(r,m) = (j/\omega)\,[\text{curl } E]_\theta = (j/\omega)[-jkE_r - \partial_r E_z]$$

$$B_z(r,m) = (j/\omega)\,[\text{curl } E]_z = (j/\omega)\,[r^{-1}\partial_r(rE_\theta) - r^{-1}jmE_r]\ . \qquad \text{(D.4.7)}$$

I want to make this replacement for I

$$I = CV(\omega/k) \qquad \text{// from Chapter 7}$$

Then we get

$$\begin{aligned} E_z(r,m) &= (1/2)\,\eta_m\,CV(\omega/k)\;R_{dc}\;(r/a)^{|m|}\;(|m|+1) \\ E_r(r,m) &= (j/4)\,\eta_m\,CV(\omega/k)\;R_{dc}\;(ak)\;[(r/a)^{|m|+1} + (r/a)^{|m|-1}] \\ E_\theta(r,m) &= (1/4)\,\eta_m\,CV(\omega/k)\;R_{dc}\;(ak)\;[(r/a)^{|m|+1} - (r/a)^{|m|-1}] \end{aligned} \qquad \text{(D.11.7)}$$

$$\begin{aligned} E_z(r,0) &= CV(\omega/k)\;R_{dc} \\ E_r(r,0) &= (j/2)\,CV(\omega/k)\,R_{dc}\;(ak)\;(r/a) \\ E_\theta(r,0) &= 0 \end{aligned} \qquad \text{// low } \omega \text{ E fields}$$

or

$$\begin{aligned} E_z(r,m) &= (1/2)\,\eta_m\,CV(\omega/k)\;R_{dc}\;(r/a)^{|m|}\;(|m|+1) \\ E_r(r,m) &= (j/4)\,\eta_m\,CV(\omega)\;\;\;R_{dc}\;(a)\;[(r/a)^{|m|+1} + (r/a)^{|m|-1}] \\ E_\theta(r,m) &= (1/4)\,\eta_m\,CV(\omega)\;\;\;R_{dc}\;(a)\;[(r/a)^{|m|+1} - (r/a)^{|m|-1}] \end{aligned} \qquad \text{(D.11.7)}$$

$$\begin{aligned} E_z(r,0) &= CV(\omega/k)\;R_{dc} \\ E_r(r,0) &= (j/2)\,CV(\omega)\,R_{dc}\;(a)\;(r/a) \\ E_\theta(r,0) &= 0 \end{aligned} \qquad \text{// low } \omega \text{ E fields}$$

Now note the common factor $\eta_m\,CV\,R_{dc}$. Removing this factor, we have

$$\dim(\eta_m\,CV\,R_{dc}) = \text{cou/m} * \text{ohm/m} = \text{cou} * \text{ohm/m}^2$$

$$\begin{aligned} E_z(r,m) &= (1/2)(\omega/k)\;(r/a)^{|m|}\;(|m|+1) \\ E_r(r,m) &= (j/4)\;(\omega a)\;[(r/a)^{|m|+1} + (r/a)^{|m|-1}] \\ E_\theta(r,m) &= (1/4)\;(\omega a)\;[(r/a)^{|m|+1} - (r/a)^{|m|-1}] \end{aligned} \qquad \text{(D.11.7)}$$

$$\begin{aligned} E_z(r,0) &= (\omega/k) \\ E_r(r,0) &= (j/2)\;(\omega r) \\ E_\theta(r,0) &= 0 \end{aligned} \qquad \text{// low } \omega \text{ E fields}$$

dim(η_m CV R_{dc})dim(ω/k) = cou*ohm/m^2 * sec^{-1}m = amp*ohm/m = volt/m OK

I will do the m > 0 case first in a new mws. Here is the Maple stuff. Assume m > 0.

```
# compute B for small omega

restart; alias(I=I,j=sqrt(-1),J=BesselJ):
```

Enter the Bi expressions

```
Br := (j/omega)*((j*m/r)*Ez + j*k*Eth);
```

$$Br := \frac{j\left(\frac{j\,m\,Ez}{r} + j\,k\,Eth\right)}{\omega}$$

```
Bth := (j/omega)*(-j*k*Er - Diff(Ez,r));
```

$$Bth := \frac{j\left(-j\,k\,Er - \left(\frac{\partial}{\partial r} Ez\right)\right)}{\omega}$$

```
Bz := (j/omega)*(1/r)*( Diff(r*Eth,r) - j*m*Er);
```

$$Bz := \frac{j\left(\left(\frac{\partial}{\partial r} r\,Eth\right) - j\,m\,Er\right)}{\omega\,r}$$

Enter the Ei expressions for m > 0

```
Ez := (1/2)*(omega/k)*(r/a)^m*(m+1);
```

$$Ez := \frac{1}{2}\frac{\omega\left(\frac{r}{a}\right)^m (m+1)}{k}$$

```
Er := (j/4)*(omega*a)*( (r/a)^(m+1) + (r/a)^(m-1));
```

$$Er := \frac{1}{4} j\,\omega\,a\left(\left(\frac{r}{a}\right)^{(m+1)} + \left(\frac{r}{a}\right)^{(m-1)}\right)$$

```
Eth := (1/4)*(omega*a)*( (r/a)^(m+1) - (r/a)^(m-1));
```

$$Eth := \frac{1}{4}\omega\,a\left(\left(\frac{r}{a}\right)^{(m+1)} - \left(\frac{r}{a}\right)^{(m-1)}\right)$$

Here then are the resulting B_i field components:

```
Br: simplify(%);
```

$$\frac{1}{4}\frac{\left(\frac{r}{a}\right)^m (-2m^2 - 2m - k^2 r^2 + k^2 a^2)}{rk}$$

```
value(Bth): simplify(%);
```

$$\frac{1}{4}\frac{j\left(\frac{r}{a}\right)^m (k^2 r^2 + k^2 a^2 - 2m^2 - 2m)}{rk}$$

```
value(Bz): simplify(%);
```

$$\frac{1}{2} j \left(\frac{r}{a}\right)^m (m+1)$$

Does this agree with my earlier hand calcs in "the curl E problem? What the above shows is that both fields B_r and B_θ go as 1/k for small k, and if $k \sim \sqrt{\omega}$, then both these fields blow up ! On the other hand, the B_z field is finite. This agrees with the first column of my little table in "the curl E problem".

Write the above out as

$B_r = (1/4)\ (r/a)^m\ (a/r)a^{-1}(1/k)[\ -2m(m+1) + k^2(a^2-r^2)]$

$B_\theta = (j/4)\ (r/a)^m\ \ (a/r)a^{-1}(1/k)\ [\ -2m(m+1) + k^2(r^2+a^2)]$

$B_z = (j/2)\ (r/a)^m\ (m+1)$

Rewrite as

$B_r = (1/4)\ (r/a)^{m-1}\ a^{-1}(1/k)[\ -2m(m+1) + k^2(a^2-r^2)]$

$B_\theta = (j/4)\ (r/a)^{m-1}a^{-1}\ (1/k)\ [\ -2m(m+1) + k^2(r^2+a^2)]$

$B_z = (j/2)\ (r/a)^m\ (m+1)$

Now take limit as k→ 0 to get

$B_r = (1/4)\ (r/a)^{m-1}\ a^{-1}(1/k)[\ -2m(m+1)]$ = 1/k

$B_\theta = (j/4)\ (r/a)^{m-1}a^{-1}\ (1/k)\ [\ -2m(m+1)]$ = 1/k

$B_z = (j/2)\ (r/a)^m\ (m+1)$ = no ω dependence

Now repeat this all for m = 0 in lower part of the Maple program

```
Ez := (omega/k);
```

$$Ez := \frac{\omega}{k}$$

```
Er := (j/2)*omega*r;
```

$$Er := \frac{1}{2} j\, \omega\, r$$

```
Eth := 0;
```

$$Eth := 0$$

.

Then we find

```
Br: simplify(%);
```

$$0$$

```
value(Bth): simplify(%);
```

$$\frac{1}{2} j\, k\, r$$

```
value(Bz): simplify(%);
```

$$0$$

None of these blows up and in fact all three → 0 and this agrees with rest of my table: which I now quote

	m > 0	m = 0
[curl **E**(r,m,z)]$_r$	$B_r \rightarrow \infty$	$B_r \rightarrow 0$
[curl **E**(r,m,z)]$_\theta$	$B_\theta \rightarrow \infty$	$B_\theta \rightarrow 0$
[curl **E**(r,m,z)]$_z$	$B_z \rightarrow$ finite	$B_z \rightarrow 0$

So where should I display this work? First, summarize the results right here:

$B_r = (1/4)\ (r/a)^{m-1}\ a^{-1}(1/k)[\ -2m(m+1) + k^2(a^2-r^2)]$
$B_\theta = (j/4)\ (r/a)^{m-1} a^{-1}\ (1/k)\ [\ -2m(m+1) + k^2(r^2+a^2)]$
$B_z = (j/2)\ (r/a)^m\ (m+1)$

$B_r = 0$
$B_\theta = (j/2)kr$
$B_z = 0$

Now add back the omitted factors

$B_r = (1/4)\ \eta_m\ CV\ R_{dc}\ (r/a)^{m-1}\ a^{-1}(1/k)[\ -2m(m+1) + k^2(a^2-r^2)]$
$B_\theta = (j/4)\ \eta_m\ CV\ R_{dc}\ (r/a)^{m-1} a^{-1}\ (1/k)\ [\ -2m(m+1) + k^2(r^2+a^2)]$
$B_z = (j/2)\ \eta_m\ CV\ R_{dc}\ (r/a)^m\ (m+1)$

$B_r = 0$

$B_\theta = (j/2)\, CV\, R_{dc}\, kr$
$B_z = 0$

Dimension check:

$\dim(CV\, R_{dc} a^{-1}/k) = \text{Coul/m} * \text{ohm/m} = \text{Coul} * \text{ohm/m}^2 = \text{amp-sec-ohm/m}^2 = \text{volt-sec/m}^2 = \text{OK}$

Only k's appear, no ω's. I like this form better than anything I found before. Then I can do

$k = \sqrt{R_{dc2} C}\; e^{-j\pi/4} \sqrt{\omega}$ for G = 0

$k = -j \sqrt{R_{dc2} C \omega_d} = -j \sqrt{R_{dc2} G_{dc}}$ for G > 0

where R_{dc2} is the total tarnsmission line DC resistance per length (both conductors), while R_{dc} above is for just the round wire conductor. We can then write things for the two cases:

For G =0 :

$B_r(r,m) = (1/4)\, \eta_m\, CV\, R_{dc}\, (r/a)^{m-1}\, a^{-1} [\, -2m(m+1)] * 1/[\sqrt{R_{dc2} C}\; e^{-j\pi/4} \sqrt{\omega}\,]$
$B_\theta(r,m) = (j/4)\, \eta_m\, CV\, R_{dc}\, (r/a)^{m-1} a^{-1} ([\, -2m(m+1)] * 1/[\sqrt{R_{dc2} C}\; e^{-j\pi/4} \sqrt{\omega}\,]$
$B_z(r,m) = (j/2)\, \eta_m\, CV\, R_{dc}\, (r/a)^m\, (m+1)$

$B_r(r,0) = 0$
$B_\theta(r,0) = 0$
$B_z(r,0) = 0$

Here we see explicitly the first two fields blowing up as $1/\sqrt{\omega}$ where we have the vacuum dielectric.

Digression: I think I have a bug below (D.9.22). I show that going to G>0 results in this change

$N_m \rightarrow (\xi_d/\varepsilon_d)\, N_m$ everywhere

Remember that in Appendix D quantity k is an arbitrary fixed constant and I won't set it to k(ω) until we are all done. So we should then have

$I = 2\pi a N_0 \omega/k \quad \rightarrow \quad 2\pi a[(\xi_d/\varepsilon_d) N_0]\omega/k$

due to the change of G = 0 to G > 0. So assume the case G > 0 and we get this result on the right

$I = 2\pi a[(\xi_d/\varepsilon_d) N_0]\omega/k$ $\qquad N_0$ = what it was before = $\langle n(\theta) \rangle = q/(2\pi a) = CV/(2\pi a)$

I shown in "First Paradox..." that

$I = (\omega/k)\, CV \qquad G = 0$

$I = (\omega/k)\, C' V \qquad G > 0 \qquad C' = (\xi_d/\varepsilon_d)C$

so this is the same conclusion. Go repair Appendix D right now! I archive the wrong stuff right here in blue:

$$I = 2\pi a N_0(\omega/k) \;\rightarrow\; I' = 2\pi a N_0(\omega/k')\,(\xi_d/\varepsilon_d)\,.$$

The current appears to grow larger due to the new factor (ξ_d/ε_d), but one must realize that the wavenumber k also changes to k' when the dielectric conduction is turned on. Using the model of Chapter 4, we have

$$k = -j\sqrt{(R+j\omega L)(j\omega C)} \;\rightarrow\; k' = -j\sqrt{(R+j\omega L)(G+j\omega C)}\,.$$

Therefore the new current may be written in terms of the old current,

$$I' = I\,(\xi_d/\varepsilon_d)\,(k/k') = I\,(\xi_d/\varepsilon_d)\sqrt{\frac{j\omega C}{G+j\omega C}}\,.$$

For $\omega >> G/C$, I' is larger than I by the full factor (ξ_d/ε_d).

Edit is done, end of digression.

Back to our results above which were

$$B_r = (1/4)\,\eta_m\, CV\, R_{dc}\,(r/a)^{m-1}\, a^{-1}(1/k)[\,-2m(m+1) + k^2(a^2-r^2)]$$
$$B_\theta = (j/4)\,\eta_m\, CV\, R_{dc}\,(r/a)^{m-1} a^{-1}\,(1/k)\,[\,-2m(m+1) + k^2(r^2+a^2)]$$
$$B_z = (j/2)\,\eta_m\, CV\, R_{dc}\,(r/a)^m\,(m+1)$$

$$B_r = 0$$
$$B_\theta = (j/2)\, CV\, R_{dc}\, kr$$
$$B_z = 0$$

Since these are all linear in the E_i, we know that we add a factor (ξ_d/ε_d) to these results to account for the change from G = 0 to G > 0. But

$$(\xi_d/\varepsilon_d) = (\varepsilon_d - j\sigma_d/\omega)/\varepsilon_d$$

and as $\omega \rightarrow 0$ we get

$$(\xi_d/\varepsilon_d) \;\rightarrow\; -j(\sigma_d/\varepsilon_d)\,(1/\omega) = -j(G_{dc}/C)\,(1/\omega)$$

Thus we end up with these results for G > 0 :

$B_r = -\,j(G_{dc})\,(1/\omega)\,(1/4)\,\eta_m\,V\,R_{dc}\,(r/a)^{m-1}\,a^{-1}(1/k)[\,-2m(m+1) + k^2(a^2-r^2)]$
$B_\theta = -\,j(G_{dc})\,(1/\omega)\,(j/4)\,\eta_m\,V\,R_{dc}\,(r/a)^{m-1}a^{-1}\,(1/k)\,[\,-2m(m+1) + k^2(r^2+a^2)]$
$B_z = -\,j(G_{dc})\,(1/\omega)\,(j/2)\,\eta_m\,V\,R_{dc}\,(r/a)^m\,(m+1)$

$B_r = 0$
$B_\theta = -\,j(G_{dc})\,(1/\omega)\,(j/2)\,V\,R_{dc}\,kr$
$B_z = 0$

But in this case we have

$k \rightarrow -j\sqrt{R_{dc2}G_{dc}}$ as $\omega \rightarrow 0$ //which we assume is very small

so then

$B_r = -\,j(G_{dc})\,(1/\omega)\,(1/4)\,\eta_m\,V\,R_{dc}\,(r/a)^{m-1}\,a^{-1}\,[\,-2m(m+1)]\,/\,[-j\sqrt{R_{dc2}G_{dc}}\,]$
$B_\theta = -\,j(G_{dc})\,(1/\omega)\,(j/4)\,\eta_m\,V\,R_{dc}\,(r/a)^{m-1}a^{-1}\,[\,-2m(m+1)]\,/\,[-j\sqrt{R_{dc2}G_{dc}}\,]$
$B_z = -\,j(G_{dc})\,(1/\omega)\,(j/2)\,\eta_m\,V\,R_{dc}\,(r/a)^m\,(m+1)$

$B_r = 0$
$B_\theta = -\,j(G_{dc})\,(1/\omega)\,(j/2)\,V\,R_{dc}\,r\,[-j\sqrt{R_{dc2}G_{dc}}\,]$
$B_z = 0$

Now we find that ALL the B_i fields blow up as $1/\omega$!! So we obtain this anomaly for both cases G = 0 and G > 0, although the divergence power is different in the two cases! This is the first time I have gotten this result. I am ready now to get this into Chapter 7. Rewrite the above in simplier form

$B_r = \sqrt{G_{dc}/R_{dc2}}\;(1/\omega)\,(1/4)\,\eta_m\,V\,R_{dc}\,(r/a)^{m-1}\,a^{-1}\,[\,-2m(m+1)]$
$B_\theta = \sqrt{G_{dc}/R_{dc2}}\;(1/\omega)\,(j/4)\,\eta_m\,V\,R_{dc}\,(r/a)^{m-1}a^{-1}\,[\,-2m(m+1)]$
$B_z = G_{dc}\,(1/\omega)\,(1/2)\,\eta_m\,V\,R_{dc}\,(r/a)^m\,(m+1)$

$B_r = 0$
$B_\theta = -\sqrt{G_{dc}/R_{dc2}}\;(1/\omega)\,(j/2)\,V\,R_{dc}\,r$
$B_z = 0$

How about a dimension check!

$\dim(\sqrt{G_{dc}/R_{dc2}}\,) = [\text{mho/m // ohm/m}\,]^{1/2} = [\text{mho/m * m/ohm}\,]^{1/2} = \text{mho}$

$\dim(\sqrt{G_{dc}/R_{dc2}}\;(1/\omega)\,V\,R_{dc}\;a^{-1}) = \text{mho*sec*volt*ohm/m*(1/m)}$

$= \text{sec*volt*1/m*(1/m)} = \text{volt-sec/m}^2 = \text{OK}$

$\dim(G_{dc}\,(1/\omega)\,V\,R_{dc}) = \text{mho/m* sec*volt*ohm/m} = 1/\text{m* sec*volt*1/m} = \text{OK}$

Write them yet again

$$B_r = -(1/2)\,\eta_m\, V\, R_{dc}\,\sqrt{G_{dc}/R_{dc2}}\;(1/\omega)\,(r/a)^{m-1}\,a^{-1}\,m(m+1)$$
$$B_\theta = -\,(j/2)\,\eta_m\, V\, R_{dc}\,\sqrt{G_{dc}/R_{dc2}}\;(1/\omega)\,(r/a)^{m-1}a^{-1}\;m(m+1)$$
$$B_z = \;(1/2)\,\eta_m\, V\, R_{dc}\;G_{dc}\,(1/\omega)\,(r/a)^{m}\,(m+1)$$

$$B_r = 0$$
$$B_\theta = -\,(j/2)\,V\,R_{dc}\,r\,\sqrt{G_{dc}/R_{dc2}}\;(1/\omega)$$
$$B_z = 0$$

OK, I have now added all the above stuff to Chapter 7, so done here with that subject.

More Section 4 work, 9/23/14.

Today I rearranged Section 4.11 and made it be Section 4.12 and I added a new Section 4.11 and move the μ section down to be 4.13. I then adjusted all equation references from the main doc to this new stuff, but I may have missed a few. I then started "reviewing" and storing desktop docs. My original 4.11 was not in logical order concerning various things, and this was confusing me while writing Appendix S.

Issue. I realized the L_e is not entirely real, but in many places I treat it as if it were, such as in Appendix R on the Belden cable, and such as in my big summary box which is now (D.12.24). I will try to resolve this issue quickly right here in line.

My symbol L_e first appears in (4.4.11) but that is a forward reference to "(4.10.8) with (4.12.20", so I skip this for the moment. Then in (4.4.17) I again treat L_e as if it were realm forward reference to (4.12.24) box. In Section 4.5 I continue to refer to it as real.

Finally I get to the point in (4.10.7) where I actually define L_e and show it is $L_e = \dfrac{W(z)}{i(z)} = \dfrac{\mu_d}{4\pi}\,K_L$ and I comment that it is complex instead of real. (now made red).

I then enter Section 4.11 which does not mention L_e.

I then enter Section 4.12 where I first quote the earlier claim that $L_e = \dfrac{W(z)}{i(z)} = \dfrac{\mu_d}{4\pi}\,K$. I mention L_e in the averaging discussion. Several more references, then it appears in my transmission line equation pair! I then get to

$$\mathbf{y} = j\beta_d^2/(\omega L_e) \qquad = G + j\omega C = j\omega C' . \qquad \text{// } \mathbf{y} \text{ and G are mhos/m} \qquad (4.12.16)$$

I thought yesterday and L_e had to be real in order to get $G \neq 0$ but I now see that is wrong. Rather

$$j\beta_d^2/(\omega L_e) = j\,[\omega^2\mu_d\xi_d]/(\omega L_e) = j\,\omega\mu_d\xi_d]/L_e = j\,\omega\mu_d(\varepsilon_d - j\sigma_d/\omega)]/L_e$$

$= j\,\omega\mu_d\varepsilon_d/L_e - [\, j\,\omega\mu_d\, j\sigma_d/\omega\,]/L_e$

$= j\,\omega\mu_d\varepsilon_d/L_e + \mu_d\,\sigma_d/L_e$

Then if L_e is real, we still get this thing having real and imaginary parts, and moreover

$G = \mu_d\,\sigma_d/L_e \qquad j\omega C = j\,\omega\mu_d\varepsilon_d/L_e \qquad \Rightarrow \qquad C = \mu_d\varepsilon_d/L_e$

Is this anything new? The right equation says

$C\,L_e = \mu_d\varepsilon_d$ // which I already have covered in (4.12.19)

and then we get

$G = \mu_d\,\sigma_d/L_e = \mu_d\,\sigma_d\,[\,C/\,\mu_d\varepsilon_d] = C(\sigma_d/\varepsilon_d)$

and I have this one covered in (4.11.15).

Conclusion: I really want L_e to be real, so I need K_L to be real. Of course later $K = K_L$ makes it real. So I will go make some edits to fix this up. // I did this right where the K_L integral is written out in (4.10.9). I will now rescan the doc and undo any changes I earlier made regarding L_e being complex! Done.

OK, thank goodness this issue is resolved and K_L and L_e are real. They might become a bit complex in the Appendix S detail, but I won't worry about that right now.

Next: fix italic equation numbers in the big summary box everywhere it appears. I will make them red one at a time as I do this.

Fix italic eq nums in box (4.12.24): Done, and there were many errors.
Where is this box in part repeated? First place is below (K.7) so I will fix that now. Done with that one. I think that is the only other place. So now turn these italics black again in both places.

I am sure there are still lots of bad cross references, though I tried to catch them all with full scans, but obviously I missed lots of the italic ones I just fixed above.

Now to through and look for red text showing unresolved items. // doing this and am now at page 222 where there is something strange below (6.5.28). I will resume here tomorrow.

9.24.14.

I continue on p 222, there is a sign error of some sort. Fig 6.8 shows charge +q sitting on C_1 which is on the left of the cross section view. n_1 is then positive as in 6.5.1. Then q is positive in 6.5.2. Let's look at E_z in 6.5.28. Where is this E_z coming from? It must be approx result 6.5.19. I can then do that here

$Z_s \equiv \langle Z_s(\theta)\rangle = \langle E_z(a,\theta)\rangle/I = \{\,(-j\omega/\sigma)\,(\beta/k)\,n(\theta)\,\}/I$

Maybe (6.5.13) is a better reference, but it is really from App D I am quoting this E_z. But the sign is as shown above from either source. I quote E_z again below the fat twinlead picture. Suddenly I am talking about "the right conductor" which has charge -q. In most stuff here, E_z's sign is determined by the $n(\theta)$ sign, so I could be in either conductor. True I guess in (6.5.19). Just above 6.5.22 I specify the right conductor. I that explains the sign. Done with that red text, time to look for more. // No more red.

Now let's edit Appendix S for the new Ch 4 equation numbers and see where it now leads. All numbers are OK thru (S.10). // I am now OK to below (S.28) after statement of the modified TL equations.

I have now reworked appendix S and we surprised to end up with exactly $K = K_L$! It may not be perfect, but I will leave it as is and let someone else do battle with subtleties.

I want to install Appendix S so first

spell check	OK
eq num sequence	OK
no figures	

I just installed Appendix S, and will now adjust the headings. Done.
Added a little appendix summary. Done.

I am now ready to resume in Chapter 7 where I left off. // Finished this off. I blame the low ω problems on the fact that the e^{-jkz} ansatz is invalid for low ω, and a few other vague things. I have to bring this saga to an end, and I think I have faced this low ω issue.

I now want to install Chapter 7.

spell check	OK	
add equation numbers:	OK	
sequence eq num	OK	and right adjust all

I think I had better proof this entire Chapter 7 now prior to installation.

Chapter 7

opening paragraph OK

7.1 = OK, a reasonable summary of Appendix D and the meaning of k

7.2 = OK, the J_z asym is noted, and even superposition does not stop it.

7.3 = OK, I think this is an OK proof, though it has a little approx in it.

7.4 = OK, addressing the $B = \infty$ problems with the theory at $\omega = 0$

7.5 = OK, I place the blame in a certain place, invoking Appendix S.

I am now ready to install Chapter 7 for the first time. // Install complete and heading added.
We are now at 567 pages, truly mind boggling for this little tiny 1991 paper. There were a lof of details that needed being dealt with.

Next task: I have dealt with the low ω problems already at several places in lines doc, and I need now to consolidate these comments and not keep repeating them.

In Chapter 2 I take low ω limit of things. Is this reasonable to do? It means a coaxial transmission line at low ω. I have again assumed e^{-jkz} and I have just set $k = \beta_d$ mindlessly.

I do the low freuency limit of $Z_s(\omega)$ and I get the right answer even though I am using the high frequency value $k = \beta_d$. Why does that work out right? Well I am doing the surface impance Z_s, not the characteristic impedance Z_0. In Chapter 2 I assume $k = \beta_d$ but then I assume $\beta >> \beta_d$ so β_d goes completely away in Chatper 2 . Thus, neither k nor β_d appears in any conclusion of Chapter 2. Perhaps I should think of the round wire as a perfect conductor, $\sigma = \infty$, and then I guess we are OK down to DC.

Let's not get bogged down on this question, and save the k question for later on. The poor reader is already struggling with Ch 2 as is. So I add no qualifications or changes to Ch 2.

Chapter 3 probably has some small ω issues, but I am constantly saying "strong skin effect" so probably nothing misleading in this Chapter.

Ch 4 I have just finished messing with, so I guess OK.

I think it is Chapter 6 starting at Section 6.5 that I want to review. Things seem OK down to the start of Section 6.5 (e). But I am sent off to Section D.11 (a) first so let's go there.

Section D.11 (a) This gives a summary of the low ω problem, and my original guess that there are "correction terms" in the 2nd order TL equations turns out to be correct, as per T(z) in App S and Ch 7. I was just guessing when I wrote that. There is some redundancy, but I think I will leave it exactly as is, since it gives a concise summary, and it never hurts to repeat things that are hard to comprehend. I did insert a reference to Chapter7, however,

Section D.11 (b) Doing β' etc for low ω, nothing here to change

Section D.11 (c) I just get low arg for f_m etc, nothing to add.

Section D.11 (d) gives the low ω E fields, even though I state earlier they may be wrong. OK as is. I mention the anomaly.

And so ends D.11, so I won't make any changes. I added another Chapter 7 reference.

Now back to Section 6.5 (e). I repeat a lot of Chap 7, but again I want to leave it as is. I give the full θ dependent ratios here for J_z non-uniformity.

Section 6.5 (f) and (g) = OK as is.

So I think I am done with this task.

Summary for Chapter 7 ******** done.

Status: I think this brings to an end a very long and painful round of changes for lines doc. All the pieces are once again assembled into a single document. I am not aware of any glaring problems apart from those I have already addressed. The e^{-jkz} ansatz takes most of the blame.

I will go off and review any docs I find lying around and try to update the indices. At some point I have to face the huge pagination problem, but that is all just mechanical stuff. The main thing is that I think the theory is now OK.

10.3.14

The doc has not changed much. I have as usual been pondering the low ω situation, I just keep doing this over and over again, perhaps I am on the 15th iteration now. I just can't get happy. As this endless Sisyphus task continues, I think I want to make a change in lines Section 1.6 (e) . It has this little section,

(e) A Pitfall to Avoid

Notice that

$$\mathbf{E}(\mathbf{x},t) = \mathbf{e}(\mathbf{x},t) + j\,\mathbf{e}'(\mathbf{x},t) \quad \Rightarrow$$
$$\mathbf{E}\hat{}(\mathbf{x},\omega) = \int_{-\infty}^{\infty} dt\, \mathbf{E}(\mathbf{x},t)\, e^{-j\omega t} = \int_{-\infty}^{\infty} dt\, [\mathbf{e}(\mathbf{x},t) + j\,\mathbf{e}'(\mathbf{x},t)]\, e^{-j\omega t}$$

$$= \mathbf{e}\hat{}(\mathbf{x},\omega) + j\,\mathbf{e}'\hat{}(\mathbf{x},\omega)\,. \qquad (1.6.17)$$

Whereas **e(x,t)** and **e'(x,t)** are the real and imaginary parts of **E**(**x**,t), the functions **e**^(**x**,ω) and **e'**^(**x**,ω) are *not* the real and imaginary parts of **E**^(**x**,ω) since in general **e**^(**x**,ω) and **e'**^(**x**,ω) are both complex functions. In this document we shall never deal with transforms of the type **e**^(**x**,ω) or **e'**^ (**x**,ω).

But nowhere in 567 pages have I ever encountered this "pitfall". It is just a curiosity really. I an thinking of replacing the above section with this

****

(e) The Line Strength

In the discussion above we have already defined many kinds of electric fields:

$E_i(\mathbf{x},t)$	general complex electric field (component i)	(1.6.17)
$e_i(\mathbf{x},t)$	Re[$E_i(\mathbf{x},t)$] = candidate physical field	
$e'_i(\mathbf{x},t)$	Im[$E_i(\mathbf{x},t)$] = candidate physical field	
$E\hat{}_i(\mathbf{x},\omega)$	Fourier Integral Transform of $E_i(\mathbf{x},t)$	
$E_i(\mathbf{x},\omega)$	magnitude of a monochrome field with frequency ω	
$\varphi_i(\mathbf{x},\omega)$	phase of a monochrome field with frequency ω	

$\mathcal{E}_i(\mathbf{x},\omega)$ line strength of a monochromatic field with frequency ω

The last item is new. It has been added to make the above list complete, and we define it right here. Recall the form of the Fourier Transform of a monochrome field given in (1.6.1),

$$\hat{E}_i(\mathbf{x},\omega) = [E_i(\mathbf{x},\omega_1)\, e^{j\varphi_i(\mathbf{x},\omega_1)}]\, 2\pi\delta(\omega-\omega_1) \qquad (1.6.10)$$

The factor which multiplies $2\pi\delta(\omega-\omega_1)$ we shall refer to as the **line strength** of the monochromatic electric field component, and we shall use this notation,

$$\mathcal{E}_i(\mathbf{x}, \omega_1) \equiv [E_i(\mathbf{x},\omega_1)\, e^{j\varphi_i(\mathbf{x},\omega_1)}] \qquad // E_i(\mathbf{x},\omega_1) = |\, \mathcal{E}_i(\mathbf{x}, \omega_1)\,| \qquad (1.6.18)$$

and then

$$\hat{E}_i(\mathbf{x},\omega) = \mathcal{E}_i(\mathbf{x}, \omega_1)\, 2\pi\delta(\omega-\omega_1)\ . \qquad \mathcal{E}_i(\mathbf{x}, \omega_1) = \text{line strength} \qquad (1.6.19)$$

Since we shall normally refer to a monochrome frequency as ω (rather than ω_1) with dependence $e^{j\omega t}$, we might rewrite the last three equations as

$$\hat{E}_i(\mathbf{x},\omega') = [E_i(\mathbf{x},\omega)\, e^{j\varphi_i(\mathbf{x},\omega)}]\, 2\pi\delta(\omega'-\omega) \qquad (1.6.20)$$

$$\mathcal{E}_i(\mathbf{x},\omega) \equiv [E_i(\mathbf{x},\omega)\, e^{j\varphi_i(\mathbf{x},\omega)}] \qquad // E_i(\mathbf{x},\omega) = |\, \mathcal{E}_i(\mathbf{x}, \omega)\,| \qquad (1.6.21)$$

$$\hat{E}_i(\mathbf{x},\omega') = \mathcal{E}_i(\mathbf{x},\omega)\, 2\pi\delta(\omega'-\omega) \qquad \mathcal{E}_i(\mathbf{x},\omega_1) = \text{line strength} \qquad (1.6.22)$$

(f) Overloaded Notation and Maxwell's Equations in ω space

A rigorous textbook probably should be careful about which of the above many field versions are the subject of any particular discussion. To the reader's possible dismay, we shall generally (but not always) refer to all these electric fields as E_i and shall depend on the reader to decipher which kind of field is implied in a given situation. The reason for this decision is that having a large number of notations for electric fields (and for magnetic fields, and various other derived quantities such as potential V and current i and current density J_i) adds a level of visual font complexity to equations which are already complex enough to begin with. It is a tradeoff between precision and font clutter.

In particular, earlier in this section we have carefully denoted the Fourier Transform of f(t) as f^(ω) which is a notation used by Stakgold and others (though Stakgold has our (1.6.8) phases negated as in his equation (5.32)). In the rest of this document, however, we represent the Fourier Transform of f(t) as f(ω) to avoid a proliferation of hat ^ symbols. Since the functions f(t) and f(ω) are completely different functions, the symbol f is "overloaded" (in the sense of overloaded variable names in computer languages) and we trust the reader to understand that f(ω) always means f^(ω). It is the presence of the argument ω that cues the reader to this fact. This overloaded notation has already been used in Section 1.5 and we continue it below. Similarly, a generic field $E_i(\omega)$ may refer to the full Fourier transform $\hat{E}_i$, or

it may refer to the line strength $\mathcal{E}_i$ if monochromatic fields are being used. A field magnitude will always be properly indicated as a magnitude. The physical fields make only rare appearances.

In the Maxwell and related equations which include the ∂_t operator, if the fields are expanded onto their Fourier transformed components using (1.6.8b), then using the rule (1.6.9) one may instantly write the frequency-domain version of these equations, just as in the example of Section 1.5. For example,

$$\text{curl } \mathbf{H}(\mathbf{x},\omega) = j\omega\mathbf{D}(\mathbf{x},\omega) + \mathbf{J}(\mathbf{x},\omega) \tag{1.6.23}$$

$$\text{curl } \mathbf{E}(\mathbf{x},\omega) = -j\omega\mathbf{B}(\mathbf{x},\omega) \tag{1.6.24}$$

$$\text{div } \mathbf{J}(\mathbf{x},\omega) = -j\omega\rho(\mathbf{x},\omega) \quad . \tag{1.6.25}$$

Other equations in the Section 1.1 list have the same form but in terms of the frequency-domain functions. For example,

$$\mathbf{J}(\mathbf{x},\omega) = \sigma(\mathbf{x})\ \mathbf{E}(\mathbf{x},\omega) \tag{1.6.26}$$

where we momentarily allow $\sigma(\mathbf{x})$ to have spatial dependence but not time dependence. All these ω dependent fields can be regarded either as full Fourier transforms, or as the line strengths corresponding to those transforms, where the $2\pi\delta$ functions cancel on the two sides of the equation.

****

Now what about equation numbers?

1.6.14 has no references
1.6.15 has no references
1.6.16 has no references
1.6.17 has no references

So I will just renumber as shown above.
Any references to section (f) on overloading will still be valid.

Saved the old sections and then did an install out of separate doc for spell check, all done.

10.5.14

I spent much time working in doc "low freq discussion 9_25", spinning things around and around as usual. Added some headings. Decided there is still some unexplained stuff, but I am done with my lines doc and will itnore that extra stuff. I reread all of Chapter 7 and felt it was OK. I then started into D.11 again and found a bug!

Bug. I get to (D.11.8) and all is OK. Since I use "I", I guess OK for G = 0 and G > 0. These I factors cancel in the ratio shown. I then start my Anomaly section. I guess it is OK for both G = 0 and G > 0, but the fact that the ratio is not 1 is only a surprise in the G = 0 case!

My possible bug has to do with these two equations,

$$I = V/Z_0 \approx V\sqrt{G/R} \qquad k \approx -j\sqrt{RG} \qquad G > 0 \qquad \text{(D.11.12)}$$

$$I = V/Z_0 \approx V\sqrt{j\omega C/R} \qquad k \approx \sqrt{RC}\,\omega^{1/2}\,e^{-j\pi/4} \qquad G = 0 \qquad \text{(D.11.13)}$$

Is this consistent with my usual I ratio in these two cases : ?

$$V\sqrt{G/R} = (\xi_2/\varepsilon_2)\,V\sqrt{j\omega C/R}$$

I claim in (7.4.6) that

$$(\xi_d/\varepsilon_d) = \rightarrow (\varepsilon_d - j\sigma_d/\omega)/\varepsilon_d \rightarrow -j(\sigma_d/\varepsilon_d)\,(1/\omega) = (G_{dc}/C)\,(1/j\omega) \qquad \text{as } \omega\rightarrow 0 \qquad \text{(7.4.6)}$$

Thus, the following equation has to be true:

$$\sqrt{G/R} = (\xi_2/\varepsilon_2)\sqrt{j\omega C/R} = (G/C)\,(1/j\omega)\sqrt{j\omega C/R}$$

This does not look promising. Square both sides

$$G/R = G^2/C^2\ (-1/\omega^2)\,(j\omega C/R)$$

$$G = G^2/C\ (-1/\omega^2)\,(j\omega)$$

$$1 = G/C\ (-j/\omega)$$

$j\omega C = G$? dim LHS = sec^{-1} far/m dim RHS = mho/m = OK

This is not true, so I really do have a bug. // In Paradox of the Day I have resolved this but, and I have to find a way to clarify all this stuff in Appendix D and lines doc in general! Signing off at 9 PM.

10.6.14

I just found four stale references in lines doc to (4.11.34). This box is now (4.12.24). I thought I dealt with these cross referenced earlier, but I guess not. So go fix all places: DONE.

I have written a new ending for Section D.9 (d), and a new Section D.11 (d) and I would like to install both right now after saving out the old stuff. The new stuff is in "rewrite of Section D.9).

Both installs are done. Now at 574 pages.

Defer fixing cross references to these sections. ********** **DONE** on 10/7

Go Review Section 6.5:

(a) is OK

(b) things start out OK. But then I quote equations that no longer exist!

This led me to another round of fixes for D.9, D.10 and D.11 directly in lines doc. I suspect I am not done, but at least things are in reasonable shape now at 8 PM, shutting down. I guess I will need to review this stuff tomorrow once again and fix all references and then do 6.5 and other stuff.

10.7.14.

Reread Section D.9 (d), tail end, I think it is good.

Reread Section D.10 and it is fine. The reader exercise on B is a little weak, since no support.

Reread Section D.11; part (a) is excellent, a good summary. (b) is very clear. (c) also very clear.
OK, this entire D.11 is just fine.

So yesterday I beat these three sections into shape, and today I get to move on to Section 6.5 and Chapter 7, then I need to review all cross references into D.9→D.11.

Section 6.5 (a) is very good, leans on Bipolar doc, I like it a lot, hope reader will too.

First change will occur just after (6.5.0). Trouble with constants:

$$(1/4)\,\mathcal{B}\,(\omega a)\;(\beta'/k) = (1/4)\,(\xi_d/\varepsilon_d)\,CV\,R_{dc}\,(\omega a)\;(\beta'/k)$$

$$= (1/4)\,(\xi_d/\varepsilon_d)\,CV\,(1/\pi a^2\sigma)\,(\omega a)\;(\beta'/k)$$

$$= (1/4)\,CV\,(1/\pi a^2\sigma)\,(\omega a)\;(\beta/\beta_{d0}) \qquad \text{// since large } \omega \text{ assumed}$$

$$= (1/4)\,CV\,(1/\pi a^2\sigma)\,(\omega/\beta_{d0})\;(\beta a/4) \qquad \text{// since large } \omega \text{ assumed}$$

$\beta^2/\beta_{d0}^2 = -j\omega\mu\sigma * \nu_d^2/\omega^2$ = nothing useful

$$E_z(r,\theta) = (1/4)\,\mathcal{B}\,(\omega a)\;(\beta'/k)\,[\,f_0(r) + 2\,\Sigma_{m=1}^{\infty}\,f_m(r)\,\eta_m\,\cos(m\theta)\,]\;. \qquad \textit{(D.10.4a)}$$

Now average this over θ to get

$$< E_z(r,\theta) > = (1/4)\,\mathcal{B}\,(\omega a)\;(\beta'/k)\,f_0(r)$$

and then

$$E_z(r,\theta) = < E_z(r,\theta) >_\theta\,[\,1 + 2\,\Sigma_{m=1}^{\infty}\,[f_m(r)/f_0(r)]\,\eta_m\,\cos(m\theta)\,]$$

$$J_z(r,\theta) = < J_z(r,\theta) >_\theta\,[\,1 + 2\,\Sigma_{m=1}^{\infty}\,[f_m(r)/f_0(r)]\,\eta_m\,\cos(m\theta)\,]$$

$$J_z(r,\theta) = J_{zav}(r,\omega)\,[\,1 + 2\,\Sigma_{m=1}^{\infty}\,[f_m(r)/f_0(r)]\,\eta_m\,\cos(m\theta)\,]$$

This is not useful! Start over

$$E_z(r,\theta) = (1/4)\,\mathcal{B}\,(\omega a)\,(\beta'/k)\,[\,f_0(r) + 2\,\Sigma_{m=1}^{\infty}\,f_m(r)\,\eta_m\,\cos(m\theta)\,]\ . \qquad (D.10.4a)$$

$$E_z(r,\theta) = F(\omega)\,[\,f_0(r) + 2\,\Sigma_{m=1}^{\infty}\,f_m(r)\,\eta_m\,\cos(m\theta)\,]\ . \qquad (D.10.4a)$$

$$F(\omega) = (1/4)\,\mathcal{B}\,(\omega a)\,(\beta'/k) = (1/4)\,(\xi_d/\varepsilon_d)\,CV\,R_{dc}\,(\omega a)\,(\beta'/k)$$

I will then need to rewrite the Maple code! It is in file plot prox effect 1 and I copy that and make it #2.

First, save off the old Section 6.5 (b) as it was (do from backup).

I have rewritten Section 6.5 (c) using my new constant F(ω). I think much better, had to redo the plots, the new Maple file is plot prox effect 2.

Section 6.5 (d) is just fine, shows that E_z tracks n(θ). I keep hammering on this.

Section 6.5 (e). This is where I want to focus now. // OK, fixed some references and made some small changes. It is done

Section 6.5 (f) is OK, concerning computing p.

Section 6.5 (g) is OK, concerning computing p.

OK, what now remains is Chapter 7 (once again), and doing cross reference checks as noted above.

Chapter 7

opening text OK

7.1 (a) OK (b) OK (c) OK (d) updated and now OK

7.2 OK after I updated the superposition part a bit

7.3 I don't think my elsewhere changes affect this little 2D analysis one iota, no changes

7.4 The Inifinite B field issue. I will edit up a new version of this in a scratch doc file. OK, I think the rewrite is complete. I will now check it then install it. Done, and I will later discard temp1.doc.

7.5 What is the cause of the trouble? OK

So Chapter 7 is now updated and seems good.

This I think completes this last round of fixeds: D,9, D.10, D.11, 6.5 and then Ch 7.

Search references to D.10:

two refs in App D re Z_s

Bug? I have this small ω expression for $E_z(r,\theta)$,

$$E_z(r,\theta) = e^{j/4}\, V\, R_{dc} \sqrt{\omega}\ \sqrt{C/R_{dc2}}\ \left[\ 1 + \sum_{m=1}^{\infty} \eta_m\ (r/a)^m\ (m+1)\cos(m\theta)\ \right] = (1/\sigma)\, J_z(r,\theta)\ .\quad (D.11.11)$$

$$J_z(r,\theta) = \sigma\, e^{j/4}\, V\, R_{dc} \sqrt{\omega}\ \sqrt{C/R_{dc2}}\ \left[\ 1 + \sum_{m=1}^{\infty} \eta_m\ (r/a)^m\ (m+1)\cos(m\theta)\ \right]$$

What is the implied value of I as integral of J_z ? The sum gives no contribution, so

$$I = \left[\ \sigma\, e^{j/4}\, V\, R_{dc} \sqrt{\omega}\ \sqrt{C/R_{dc2}}\ \right] * \pi a^2 = \left[e^{j/4}\, V \sqrt{\omega}\ \sqrt{C/R_{dc2}}\ \right]$$

so we can then write

$$J_z(r,\theta) = I\, R_{dc}\left[\ 1 + \sum_{m=1}^{\infty} \eta_m\ (r/a)^m\ (m+1)\cos(m\theta)\ \right]$$

I really should have this simple form! OK, I fixed this up in D.11, now let's start again on cross references.

Search on D.9 references made from Sections outside D.9: OK

Search on D.10 references made from Sections outside D.10: OK

Search on D.11 references made from Sections outside D.11: OK

The above took quite a while, I think I have everything now.

Now sitting at 575 pages, not sure what comes next. What I usually do at this point is "doc reviews" which then remind me of something yet undone.

Lines is stable again after many more changes, reviewing docs, 10.8.14.

Spent this entire day "reviewing" lots of docs in various folders, especially the two "low freq" folders. This did result in some changes in lines doc, such as a new little piece in Appendix M. I am reminded how I have suffered with respect to my low ω anomalies for the last 6 months! A half a year! I turned over many stones in that time. I think I am done with that topic and Chapter 7 has the last word.

Hopefully only production work lies ahead, perhaps some more overview section stuff about my doc and why it is so long. Although something could come up (it always does for Sisyphus), perhaps I am on the final lap. Massive pagination problems of course. Appendix Q is too long, needs explanation of why.

The Maple and Visio indices will need much updating! Also other meta files in top level folder, such as "why did this take so long? ".

10.9.14.

Updated the Maple index, took a long time, mostly due to messy Appendix Q. All done.
Updated the Visio index, no page numbers here so faster, a few new things.

Repairs inside Appendix Q: I noticed to items left undone.

Item 1: I was quoting details of what k(ω) looks like at moderatly small ω, as an equation, but this seems not really relevant, so I deleted the equations.

Item 2: What symbol am I using for the sign involved in the Z_0 world?

Things start with Section Q.6 on the real and imag parts of Z_0. Here I clearly use S, not σ. I had this right in the text but wrong in (Q.6.1) so I just fixed this equation box.

Now comes Q.7. Below (Q.7.1) I have my first σ symbol appearing in the Maple code, so I will go fix that right now. " App Q rewrite / Q2 hi omega Z0 version 3.mws". Fixes all done.

What about Q.8? Same repair needed here. All done, a different mws file fixed.

What about Q.9? Repairs done here too.

All done with these Appendix Q repairs.

I think all that remains is proofing and pagination, two monstrous tasks. Now 2 PM.

Proofing Pass 10/9/14 through 10/19/14, 11 solid days

Paginate Opening Sections.

TOC is OK, nothing critical here, don't really want to edit this thing.

Overview and Summary and Symbols, non-critical. All is run together here.

Chapter 1: ok thru 66 done Ch 1

Proofing:

opening OK
1.1 ME
(a) notes on ME
0 OK
1 OK
2 OK
3 OK
4 OK
5 OK
6 OK
7 OK
8 OK

9 OK I will omit radial Hall

(b) integral forms of ME etc OK and I think very good

(c) BUG found concerning (1.1.45) ! Repaired.

BUG found: two equations (1.1.49), ouch!

Equation number repair.

Replace any reference to (1.1.49) meaning n_{free} by (1.1.49) , ie, let stand. **OK**

Replace any reference to (1.1.49) meaning B = B by (1.1.50) **OK**

Replace any reference to (1.1.50) by (1.1.51) **OK**

Replace any reference to (1.1.51) by (1.1.52) **OK**

I have finished Section 1.1 then in this review.

10.10.14.

I found some small problems in my section on boundary behavior of fields and corrected them. This added text and I will have to repaginate Ch 1 again. I redid Section 1.2 and it comes out fine. Then 1.2 starts on a new page perfectly.

Today I seem to like having page breaks to get things starting on a fresh page, at least for major sections like 1.3, but even for some minor ones. By starting relativity on a new page which is (b), we get (c) also so starting. I only have to check now up to page 44 since 1.4 starts on a new page.

I will now resume proofing starting at (1.1.42) more or less.

Finished proofing 1.1, all OK. Ends in the King BC quote.

Section 1.2 proofed and OK.

Section 1.3

(a) proofed and OK

(b) proofed and I think very good.

(c) proofed and fine. This was a hard-fought section of long ago! It has survived.

Section 1.4 Fascinating even as I read it yet again. Feynman connection. There will some reader somewhere who will appreciate this I think.

Section 1.5

(a) Going to ω space, all is well, proofing complete.

(b) the Helmholtz Integral solutions and comments, I like it, proofing complete.

(c) very good, getting the King equations was very hard work, 40 pages.

(d) grab bag of stuff I won't ever need, just for completeness. All Lorenz Gauge.

(e) a good didactic comment on self-consistency, proofing complete.

Section 1.6

(a) OK, proof complete, complex fields

(b) monochrome time, proofing complete, all fine.

(c) motivation for Fourier, and statement of Fourier: proofing OK

(d) very short, OK (an old holdover), proof OK

(e) line strength is an add on, OK, proofing complete

(f) proofing done, and of Chapter 1, all is well so far.

Rechecked eq num sequence for all of Ch 1, it is OK.
Rechecked pagination, all OK.
The pag/proof process is now complete for pages 1-67 out of 577.

Chapter 2

opening text, very good, proofing done

2.1 A lot of background here, travel wave anzatz with $k = \beta_d$. Should I say "lossless" line, or "ignores the resistive loss in the conductors". I added a qualitifier that we are assuming "low loss" TL.

2.2 Start got pushed down, too bad. I have reviewed this many times, it is all OK, and so is the comment relating to App D. So proofing complete.

2.3 Study of solutions

(a) OK, Kelvin functions, proofing done.

(b) More than anyone ever wants to know! Proofing OK.

(c) This is the only place I ever write physical fields. I guess round wire is simples place to do it. It is OK, proofing complete.

(d) added last equ number, note large ω for E in terms of δ as appears much later. Proof OK.

// pagination OK thru page 86

2.4

Glazing now, it is 6 PM, time for a break. Am only at page 86 of 577. // Did a half run.

2.4 Surface impedance Z_s

(a) Proofing done.

(b) Proofing done, all OK

(c) fine, proofing done.

(d) OK

2.5 General TL impedance. A short section, all OK, proofing complete.

// pagination OK thru page 96

I am done for today. Tomorrow I hope to flow smoothly through Chapters 3,4 and 5. These are the key chapters in my presentation really, and they are all directly connected.

10.11.14.

Chapter 3:

3.1 why no free charge. Proofing complete, I did make one change. I like this section.

3.2 very good, and proofing complete.

3.3 About σ_{eff}, proofing done.

3.4 This section is screwed up! I am going to do a rewrite.

I did a complete rewrite, and had to alter equation numbers. I will now globally adjust all equation numbers in lines doc which refer to section 3.4: there are NONE!!! (just a didactic section I guess).

So I will now install this new section 3.4, spell check already done, eq num seq OK. DONE.

// pagination OK thru page 104

Question: Is Section 3.4 taking into account the σ_{eff} effect which increases G etc ?
Answer: If ε_1 goes slightly complex in Section 3.4, then we really should be regarding σ_1 as σ_{eff} and I have indeed failed to do that !!!! So yet another rewrite of Section 3.4 is now required!

Second rewrite is complete and is now installed.
// pagination OK thru page 104

Resume proofing:

3.5 Reg 1 OK; Reg 2 OK; Reg 3 OK (finally!), proofing complete.

3.6 [a] OK; [b] OK after edits; [c] OK after edits

These two tables and their descriptions are an endless pain in the butt. Each time I proof them, things get changed. But I guess on each pass the descriptions of large and small etc are getting better.
// pagination OK thru page 110

3.7 This is a monster section, I doubt I will finish it today!
(a) Fact 0: $E_\theta = 0$, proofing OK
(b) Fact 1: A_t is small, proofing OK, error fixed.
(c) Fact 2: Fancy proof that φ = constant, inclu map, Proof OK.
(d) Facts 3,4 and 5 about B fields lines and A_z constant, and counterexample. Proofing OK.
(e) Field line observations. Very good, proofing complete.
(f) cross section and top view of E and B fields: elaborate; proofing OK
(g) the fancy picture and a good description, proofing OK
(h) to show $J_r << J_z$, I think is is OK, another Gauss box. Proofing OK.
// pagination OK thru page 127, only one not-nice partial white space.

**** Maybe add back part of App F about waveguide reflections! (DONE!)Then refer to that from 2nd paragraph of 3.8. Or find something in a text. I kind of liked my method, let's restore it.

3.8 Yes, it is summary of Facts. Proofing all OK.
// pagination OK thru page 130

So, I have finally made it through proofing Chapter 3, now 7PM Oct 11 Sat.

BUG: Below Fig 3.10 equation should be (3.8.8) and not (3.8.10).

I make these two changes so will have to change external regs the same way:

(3.8.10) → (3.8.8)
(3.8.11) → (3.8.9) both done!

Status: Ready to start proofing Chapter 4 and onward!

10.12.14.

Chapter 4

4.1 Very good, a slow and careful start, proofing done.

4.2 OK, added a comment explaining why x_1' is shown on the surface; proofing complete.

4.3 OK included added section on losses, proofing pending one red reference item.

4.4 OK and very good in fact, did various clarifying edits, proofing complete. Very close reading.

4.5 number error in (4.5.8) K fixed, all fine, proofing complete.

4.6 coax example, small edits, proofing complete. Removing we's a bit.

4.7 BUG below (4.7.7): Why do I say there is no free surface current on a TL conductor? Later I say that there is in fact a Debye Surface current which is caused by the motion of the "free" surface charge. When I wrote Section 4.7, I was probably unaware of the Debye current. This could be a major problem!

Ouch ouch ouch! Time to digress! I start with

$$A_{z1}(x,y,z) = \frac{\mu_1}{4\pi} \int_{-\infty}^{\infty} dz'\, i(z') \int_{C_1} dx'\, dy'\, b_1(x',y') \frac{e^{-j\beta_d R}}{R} \quad . \tag{4.7.6}$$

I claim that there is no "magnetic boundary", so this function and its derivatives are continuous though the conductor boundary. King I think says this as well. But if there is a Debye surface current, then the first derivative is NOT continuous. Both facts cannot be true!! Yeouch!

Decision: In order to maintain continuity in my prooofing, I am going to ignore this problem right now. I will only be concerned if $\partial_n A_z$ shows up in the main line dicussion, and if it does I will red-line it. So let's just continue for now.

4.7 Things are fine down to the Comments Regarding μ section. I put that whole section now in tentative red and move past it. At start of 4.8 I state that all the μ's are the same. But of course I still have the question of why no homo adder sols must be added to the Helm solution. Let it go for now.

So 4.7 proofing is complete with red caveat sections.

4.8 Very short, proofing complete.

4.9 OK, proofing done.

4.10 OK, fix eq num, proofing done.

4.11 OK, proofing done.

4.12 The TL equations.

opening text, OK

(a) OK, proofing complete

(b) averaging repair and TL equations, proofing done

(c) the $K = K_L$ example with wide twin lead, proofing done.

(d) OK, checked all refs, found many wrong and fixed, proofing done.

(e) telegraph, proof complete.

4.13 *Defer* till after clearing up the surface current problem.

Bug found: there is no Section 4.12 (c) ! So I need to relabel,

4.12 (d) → 4.12 (c)
4.12 (e) → 4.12 (d)
4.12 (f) → 4.12 (e) no cross references to fix!

OK, I have now rewritten the Section " Comments regarding μ " in a way that gets rid of the Debye free surface charge (claiming it can be neglected) and which is more parallel in development between potentials φ and A_{z1}. Equation numbers after (4.7.6) got renumbered! I saved off the old section first, which had numbers (4.7.7) thru (4.1.10). Only 1 external ref had to be adjusted, and I would have gotten to it anyway since it is downstream.

I have now completed my proofing of (4.7), and thus things are proofed through 4.13.

The plan: tomorrow proof 4.13, and if that goes OK, I can then check all Ch 4 equation sequences, and then do pagination starting where I left off at page 130 which was end of Ch 3. Then Ch 4 will be finished. Still trying to maintain presentation logic flow, so don't stop off for App B etc right now!

10.13.14.

4.13 This is in fact not such a complicated section, and it all seems good. I added a comment that not only Z_0 but also k changes as the perm knob is rotated. So proofing complete! I removed my suggestion that the reader skip this section. The hard work is really off in Appendix B.

Now: check ALL equation number sequences in Chapter 4. DONE! No errors.

Now paginate starting at page 130.

Plan: I will run 4.1,4.2,4.3,4.4 without section page breaks since all about φ and V.
Then each of the two examples 4.5 and 4.6 starts on its own new page.
I will run 4.7,4.8,4.9,10 together since all about A_z and W.
All of the above ends well on page 160.

OK through STOP, pause on page 136 for red text item.
OK through 137.
Page break so 4.4 starts on a new page, will ponder that, leave in place for now.

OK through 137. Very good thru 142, causing 4.5 to start nicely on new page.
Good thru 148, starting 2nd example on own page. Ok thru 152, start 4.7 on new page.
Maybe keep all the V(z) related ones in sequence with no page breaks.

Rescan again up to start of 4.6. OK to 153. Thru 160 again is good. Again thru 160.
Good thru 163, a good ending there.

Now start 4.12 on page 163. OK thru 169. OK thru 175.

Start 4.13 on new page. Good thru 180.

Done with Chapter 4 !!!! It was a whopping 50 pages, took a long time to deal with.

Chapter 5

into I hold red until later
5.1 proofing done
5.2 proofing done
5.3
(a) proofing done, I keep fixing references all the time! But things look good with the transverse 2D differential equation systems obtained here.
(b) proofing done, the scale condition on φ_t
(c) proofing done, added russian phrase
5.4
(a) low loss discussion, proofing done
(b) dipole interp, very good, proofing done.
5.5 The capacitor problem. Proofing complete, a rather long section.
But I am showing "how you compute K".
5.6 proofing done. This "lossy" section is lousy, but I refer to Matick for more.

Done proofing Chapter 5. It showed how you reduce to the transverse problem for a low-loss transmission line and then how you can compute the number K which is the key to everything.

Check all eq nums for Ch 5: DONE.

Paginate ch 5: ok thru 202. all DONE!

Chapter 6

6.1 proofing done and fine.
6.2 proofing done, I like it.
6.3 proofing done, I like it again.
6.4 proofing dome.
6.5 intro OK proofing done
(a) proofing done, fine.
(b) prox effect, proofing done
(c) the famous plots, proofing done, all good
(d) RESUME HERE MANANA!

10.14.14 Tues

(d) proofing done, I added some clarifications like large ω assumed
(e) proofing done, we accept the bad ω = 0 prediction of J_z asymmetry.
(f) more meat and potatos for the reader, proofing complete, compared with King
(g) proofing complete, very short section.

Full eq num eq check for Ch 6: Bug found, summary box should be 6.4.1. It has no refs so easy fix.

DONE!

Paginate Ch 6: ok thru 229 DONE with Ch 6

Chapter 7

7.1

(a) proofing complete

(b) proofing complete

(c) proofing complete

(d) proofing complete

7.2 first sign of trouble

7.3 proof J_z uniform at DC BUG found!!! There are possible A_{r0} and $A_{\theta 0}$ coefficients. But luckily this change does not affect the overall outcome since these too are killed off by the BC's. After making changes, I proofed it again, and so proofing complete!

7.4 proofing complete, the infinite B fields.

7.5 proofing complete.

Full eq num eq check for Ch 7: DONE
Paginate Chapter 7: thru p 248 OK DONE!

Now that I have proofed Chapters 1 through 7, let's look at the overview of these chapters!

Chapter Overviews: proofing done. Also the opening overview section proofing done. But not the Appendix summaries.

It remains now to proof all the appendices. These account for 577-249 = 328 pages, more than half the document. Most of these have been stable since the last proofing episode. Still, I will at least look at each one.

Appendix A: This certainly is a long and complicated appendix, bringing in many rather advanced topics. I guess I just wanted to show that it could really be done this way. I read the entire thing today, checked some of the references, made a few edits, and I will leave it at that. Really the conclusions here have no bearing on the main body of lines doc, so I am not too worried about something being wrong.

pagination: ok thru 261, all seems OK.

Appendix B: This is an area where I have perhaps fiddled things, so a full check is warranted. It relates to the mag surface current stuff. I will look for gaping errors and bad references.

Overview: Come back and verify the outline when done ******** DONE and OK.

B.1 A long section, I had to redo Fig B.2 to make its relation to B1 clearer, added a Debye caveat. This is a very tricky section, but I think I do end up with the correct equations. Proofing complete.

B.2

(a) get H in terms of J. proof complete

(b) BUG! Unclear how arrive at (B.2.7). I set $\beta = 0$, but why?

I must be assuming ω = 0, but I never say this! In (a) it is assumed because I assume no z dependence of H in (B.2.4) which leads to Laplace theory. If there were z dependence, what would it be? I would have to assume general k, and then I get β' floating around.

This is ballooning out now into a Major Snag, something is amiss in Denmark. So off we go into a separate doc "problems in Appendix B". Closing out here for a while.

10.15.14 Weds

I am now doing a rewrite of Appendix B.2 in a scratch doc. I am able to use 3D instead of 2D formulas for things so far, so things are more general. I think confusions have been cleared up. Rather amazingly, it happens that the first equation number in section (c) is unchanged after this rewrite of (a) and (b).

B.2

(a) done
(b) done
(c) done
(d) done, the 3D and 2D Biot-Savart Laws

I will hold off on installing my new section (B.2) and try to continue proofing. I am sort of updating all the sections now in scratch.

B.2
B.3
B.4
B.5

B.6 I will try to do in place.

(a) editing done, proofing complete
(b) the Lemma
intro proof OK
Comments need work ******* Done and OK.
(1) Preliminaries. Proofing complete.
(2) proofing complete
(3) proofing complete
(c) the Theorem: it is OK, proofing complete! $\frac{e^{-j\beta_d R}}{R}$ $e^{-j\beta_d R}$

B.7. Proofing complete.

I will now install my new Sections B.2 thru B.5, first saving out the old one from a backup lines doc. That install is now done.

Pagination of Appendix B. OK thru 299 DONE with B!!
Final eq number check: DONE

Look at the Summaries now of App A and App B. Done.

Appendix C:

C.1 proof complete
C.2 proof complete
C.3 proof complete
C.4 very excellent section on the rect wire, proof complete (all the time small fixes)
C.5 very good on the thin strip, proofing complete
C.6 proof complete,

End of App C.
Eq Num seq check: OK
Paginate App C: thru 318 done. Not as perfect as one hopes but OK.

This brings me now at 7 PM to Meg Appendix D. I will try to get started a bit tonight.

Summary: proofing complete!

Appendix D

D.1
(a) proofing complete
(b) proofing complete
(c) proofing complete
(d)
1. complete
2. complete
3. complete
4. complete

D.2
(a) complete
(b) complete
(c) complete
(d) complete
(e) complete

D.3 complete

D.4 compute B fields proofing complete

D.5 proofing complete

D.6 proofing complete

D.7 proofing complete

D.8

opening text proofing complete
(a) proofing complete
(b) proofing complete

D.9 to be continued

10.16.14 Weds

D.9 opening OK
(a) Debye: proofing complete
(b) show can ignore: proofing complete
(c) where n ? proofing complete
(d) long section , proofing complete, I think it is good and convincing.
I guess I will keep all the intermediate boxes.

D.10 opening OK
(a) proofing complete
(b) hi ω limits proofing complete

D.11
(a) proofing complete
(b) proofing complete
(c) proofing complete
(d) proofing complete

Check all eq num sequences: all OK
pagainate: OK through 384, and reviewed it all, it is just fine.
And so I am done with the Monster Appendix D.

Appendix E: proofing complete.
eq num OK pagination OK thru 388

Appendix F.
F.1 Proofing complete
F.2 Proofing complete
eq num OK
pagaination OK thru 393

I am now going to reinstall my little piece about the waveguide reflections. Where is this located? OK, in the right place. Added it and will now proof it.

F.3 proofing complete
eq num OK

Appendix F is now done!

Appendix G:

intro material: proofing complete
G.1 proofing complete
G.2 very good, proofing complete
G.3 OK, proofing complete
G.4 OK, demonstration of homo terms needed, proofing complete
G.5 OK, proofing complete, I added a reader exercise.

Eq num seq check: OK
Pagainate: OK through 405.

Appendix H and I. I just got rid of the phrase "Poisson propagator" in favor of "Laplace propagator".

I quickly prooved Appendix H and I since I know they have not really changed. Did pagination adjuistments, they are both regarded now as proof complete and paginated.

Appendix J. Proof complete, pagination OK, eq seq OK.

Appendix K:

(a) proofing complete
(b) proofing complete
(c) proofing complete
(d) proofing complete
(e) proofing complete
(f) proofing complete

I have never liked that last sections much, but I am trying to explain to a lay reader what those parameters like R and L *mean* in terms of physics. I leave things as they are.

Eq num seq: OK
pagination: OK

Appendix L:

opening text proof complete
L.1 proofing complete, more interesting than I thought, exercise Ch1 equations
L.2 proofing complete
L.3 proofing complete
L.4 proofing complete

Eq num seq: OK
Pagination: OK thru 446 (we are getting there....)

Appendix M: Proofing complete, it went fast. Added one line of text.
pagination: OK thru 454. all OK

Appendix N. This better wait for tomorrow, I have done too much already today.

10.17.14 Fri

Update summaries before continuing on to Appendix N. All are OK. Small changes

Appendix N

N.1 proofing complete, it reads pretty well, no equation checks really.

N.2 Snag on the what happens when q→-q ! Had to do some rewriting here, but it is done and much improved. This is a very good section, I like it even now, proofing complete.

N.3 About particle physics use of cyclotron frequency, proofing complete.

N.4 added a matrix tensor form at the end, proofing complete

N.5 proofing complete, made a few changes.

N.6 proofing complete, multiple carrier types, magnetoresistance

N.7 radial Hall effect, proofing complete. I like it, perhaps original work?

N.9 more edits, but proofing now complete

eq num seq check: OK, after doing some fixes

pagination: OK thru 478

It is now already 4:30 PM, I spent the entire day on Appendix N and some MRL eye stuff as requested by MWL.

Appendix O

opening text proof complete

(a) proofing complete

(b) very good, proofing complete

(c) very good, proofing complete

(d) very good, proofing complete

A short appendix.

eq num seq chk: OK

pagination: good through 487. Update app summaries: fine

Appendix P

P.1 the iterative idea, proofing complete

P.2 proofing complete, added a paragraph.

I am getting rid of this last reader exericse at the end of P.2 :

Reader Exercise: The EMF due to Faraday induction drives $\mathbf{J}_{\mathtt{eddy}}$ in a tangential direction as Fig P.4 shows. Each conduction electron appears to maintain its radius from the disk center. Interpret this behavior in terms of the Lorentz force acting on the electron. Is there a "radial Hall effect" present in this problem? (see Appendix N)

P.3

opening text, proofing complete

(a) proofing complete, the stream function idea

(b) proofing complete

(c) proofing complete, and I like the exercise.
P.4 proofing complete
P.5 proofing complete
P.6 proofing complete, I am fading a bit with all these pictures.
P.7 proofing complete
P.8 pretty good, proofing complete
P.9 proofing complete
P.10 proofing complete

eq num seq chk: OK Fig seq check:

pagination: OK through page 515

SNAG: I don't like the arrows and tails in Fig P.18. I don't understand them, things seem backwards, should be able to correlated with Fig P.17 some how, see visio eddy.vsd page 1, continue on this tomorrow. This final figure is supposed to be my grand finale of Appendix P and it is screwed up.

10.18.14 Sat

I redid the final pictures in Appendix P, things are much better now.

pagination: start with p 506. OK through 519 (finally, 12:30 PM Sat)

Appendix Q
opening text, proofing complete
Q.1 proofing complete, all about the model and how good it might be. Many eqnum fixes.
Q.2 proofing compelete
Q.3 proofing complete (large ω of k)
Q.4 proofing complete (small ω of k)
Q.5 plots of Rek and Imk for Belden cable, proofing complete
Q.6 re and im for Z_0, proofing complete
Q.7 proofing complete (large ω for Z_0)
Q.8 proofing complete (small ω for Z_0)
Q.9 plots of ReZ_0 and ImZ_0 for Belden cable, proofing complete

I added various things in this proofing pass, some eq nums were wrong or even omitted. Added the Belden data. Added a little TOC at the start as a guide.

eq num seq: OK
fig num seq: OK
pagination: OK through 559 // now 5:15 PM Sat 10.18.14

Appendix R
(a) proofing complete
(b) proofing complete
(c) proofing complete

(d) proofing complete
(e) proofing complete
(f) proofing complete
(g) proofing complete
(h) proofing complete
(i) proofing complete

This is a good "workman's appendix" on the Belden cable, I think.
A flavor different from the more mathematical sections of lines doc.

eq num seq: OK
fig num seq: OK
pagination: OK through 575

Appendix S (the last one!!!!!)
proofing complete, only one long section

eq num chk: OK
pagination: done through 580

Look now at appendix **summaries** again.
Appendix summaryies: all OK
Symbols: read through it and check things. DONE!

References: done.

I read the intro a few times, I cannot think of anything else that needs doing here!!!!!!!

Just for fun, let's try for a PDF! First shot failed. Second shot succeeded.

10.19.14 Sun

Release Oct 19, 2014

I am going to do it today, but first there are more checks to be done.

- Verify Section headings in the PDF: all OK

- Verify spacing in the bookmarks, look for missing sections:
*** Second Summary of E fields bookmark is missing, maybe OK. Other than that, everything is fine, nothing missing, alignments all good. I will NOT change this.
*** Well, I guess I should change to Chapter Summaries without Adding second phrase, based on bookmarks. **Edit done.**

- Check pagination, look for blank pages or other large gaps: it all looks fine.

• Quality of graphics in PDF viewer: looks good in Xchange., typesetting is good.

• How does it look in Adobe viewer XI ? They have some export to Word pane on the right that I cannot get rid of. Click Tools, OK. Graphics still ratty in Acrobat! Integral endpoints and sums look fine.
Same look fine in Xchange, which I see is a much faster viewer!

• Do regular and PDF links work? I will now check all the links in References,

), www.ecadigitallibrary.com/pdf/IWCS08/14_2.pdf . says website disabled

This thing has moved to here:

http://iwcs.omnibooksonline.com/data/papers/2008/14_2.pdf

Edit done.

All other References links work fine.

OK, let's look at the errata doc which seems to have some errata. All have already been handled, put bar for new release.

I now want to deal with the white board picture that shows the low ω mystery in a nice way. It is already photographed, so where did I write it up? DONE.

Update Maple index page numbers to get within ±1. done.

Update lines history doc. done.

I am ready to make a new PDF with all the latest few changes. // Done and looks good, Oct 19 date.

I **released both Lines and Maple on Oct 19, 2014,** then pushed Google and Bing, no problems with that. Tested downloads, all OK. My ranking is very low on simple searches, no one would ever find my stuff without a lot of work I am afraid. I might work on that soon. Right now, I just wanted to get this thing done.

Oct 20, 2014. Like Columbo last night, I did think of "one more thing" and it is this:

Recall the derivation of the following equation:

$$(\nabla^2 - \mu_1\varepsilon_1 \partial_t^2 - \mu_1\sigma_1\partial_t) \mathbf{A} = - \mu_2\mathbf{J}_2 \quad . \qquad \text{// region 2} \qquad (1.3.20)$$

which is the same as

$$(\nabla^2 + \beta_1^2)\mathbf{A}(\mathbf{x},\omega) = - \mu_2\mathbf{J}_2(\mathbf{x},\omega)$$

which is for "region 2" which is the insides of a conductor, where β_1^2 is for the dielectric. This particular equation has a qualifier on it which I talk about in the paragraph below (1.3.36). The condition means that the equation is not valid below a certain ω value, which was 15 KHz for the Belden 8281.

Now do I actually use this equation in my "theory" ? Well, this is part of the Region R application of this differential equation, and the Helmholtz King integral is this

$$\mathbf{A}(\mathbf{x},\omega) = \frac{1}{4\pi} \sum_i \int \mu_i \mathbf{J}_i(\mathbf{x}',\omega) \frac{e^{-j\beta_d R}}{R} dV' \qquad R = |\mathbf{x} - \mathbf{x}'| \quad . \tag{1.5.9}$$

where the integral is over all the conductors. So yes, I DO make use that region 2 assumption and I assume it of course in all the conductors. The equation above (1.5.9) is of course the basis of the W(z) portion of Chapter 4 and 5 from which I derive those TL equations!

So maybe I should add a comment on this quietly into Chapter 7. I have plenty of room on the bottom of page 249 so I would not be altering any pagination. This would come after "there are various other hints of trouble".

Another possible source of our low-ω anomalies goes way back to Chapter 1 where, in our derivation of the King gauge potential wave equation (1.3.20) inside the conductors (like "region 2"), we dropped a certain term based on σ_2 being large in a conductor. Dropping this term is the same as assuming that the operating frequency f is larger than the amount shown in (1.3.38), which for the Belden 8281 cable requires that f be larger than 15KHz. Although this is a small frequency compared to the usual RF range carried by such a cable, it is considerably larger than "DC". We had to drop this σ_2 term in order to obtain (1.3.20) which in the ω domain becomes (1.5.4) $(\nabla^2 + \beta_d^2)\mathbf{A} = -\sum_i \mu_i \mathbf{J}_i$ where the sum is over currents in all conductors. This PDE has the Helmholtz integral solution (1.5.9) which forms the *basis* of the W(z) portion of Chapter 4 starting in Section 4.7 which eventually led to the transmission line equations (4.12.17). Thus, we really should be adding the condition (1.3.38) to our analysis if we wish to avoid still more "correction terms" in the transmission line equations, and this would then discourage us from trying to take the $\omega \rightarrow 0$ limit.

OK, I have now inserted this above large paragraph into page 249 of lines doc after a spell check and careful equation numbers check. This does not alter any pagination by the way (although it would not matter if it did since this is the end of a section). I will now make a new Oct 20 PDF.

I want all the evidence I can muster to explain away my ω = 0 horrible problems! Now I have three instead of just two arguments.

I made a new release area for this 10/20/14 release, and then put it out on the web, all done.

10.24.14. Test question: The J_m Lemma makes an interesting claim, but since it doesn't compute J_m, how does that proof demonstrate the claim? It takes a lot of work to compute J_m as examples have shown.

Answer: In the proof, I claim that J_m is characterized by $K_z = -\left(\frac{\mu_2}{\mu_0} - \frac{\mu_1}{\mu_0}\right) H_\theta$, so J_m is "known" to the extent that H_θ is known at the surface on which J_m lies (and its K_z alter ego). Things then all boil down to showing that $-\mu_1 H_\theta(s) = \partial_n A_z(s+)$ where A_z is the "conduction" or uncorrected A_z, and H_θ got in there from J_m as shown above. But then the above is easy to show from B = curl A and from assuming the skin effect limit so H is tangential. OK, so although we don't know J_m in detail, we know it in terms of H_θ and we know that in terms of B = curl A where A is $A^{(c)}$. So I think it is all OK. Perhaps this is a novel proof.