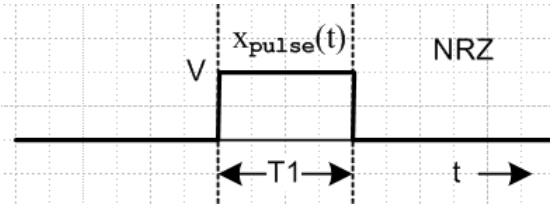
38. Change/Hold line code 1
Example: NRZI line code 10

38. Change/Hold line code

Pulse Shape.

The pulse shape is the same as for unipolar NRZ



$$X_{pulse}(\omega) = (VT_1)\,\mathrm{sinc}(\omega T_1/2)$$

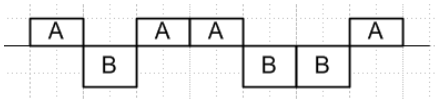
$$\mathcal{P}_{pulse}(\omega) = (1/2\pi)\,V^2 T_1\,\mathrm{sinc}^2(\omega T_1/2) \qquad (36.1)$$

In place of amplitude V, however, we will have A and B as described below.

Coding:

The coding uses two amplitudes A and B. Hold or Change coding means that a 0 is encoded as no change in the pulse amplitude (it remains what it was), whilc a 1 is encoded as a change A↔B. Here is an example starting with an A pulse:

```
data   =  [ 1  0  1  1  0  0  1]
encode =  [ A  B  A  A  B  B  A]
```



Again we shall assume an arbitrary pulse shape and make it be square at the end.

Coefficients $\alpha_{m,n}$ and β:

As with AMI coding, our starting point will be equation (34.10) which we repeat here:

$$\langle |X(\omega)|^2 \rangle = |X_{pulse}(\omega)|^2 \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} \langle y_m y_n \rangle\, e^{i\omega(m-n)T_1} \qquad (36.15)$$

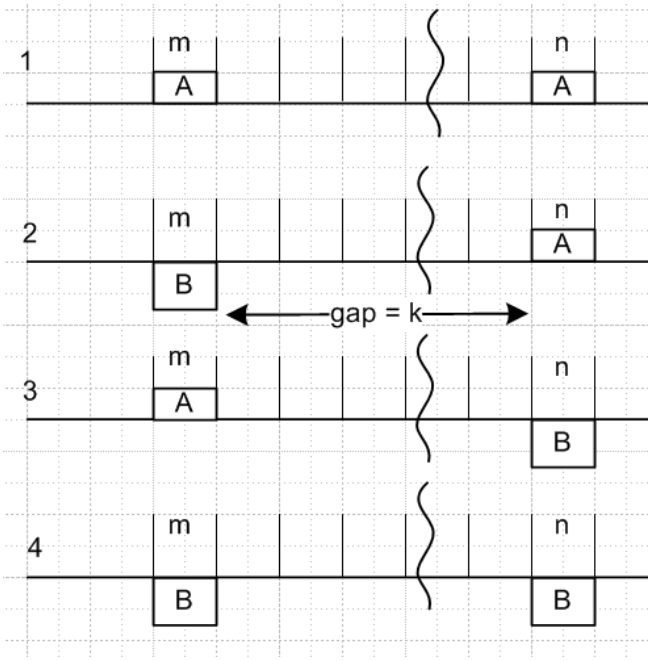
First consider

$$\langle y_n^2 \rangle = [q]A^2 + [(1-q)]\,B^2$$

where q is the probability that slot n is $y_n = A$. In this code, since only change and hold are coded, there is no preference for either amplitude, so q = 1/2 and

$$\langle y_n^2 \rangle = (A^2+B^2)/2 \quad . \tag{38.1}$$

Turning to $\langle y_n y_m \rangle$, consider this picture similar to that used for the AMI case, where the gap is kT_1 units. Here we arbitrarily drawn A > 0 and B < 0 and we draw the pulse as square, but it could be any shape and A and B can have any signs.



Denote the four probabilities as $p^{(AA)}_k$ and so on. Since slot m and slot n must each be filled with either an A or a B, this picture shows the only four possibilities, so (different scaling relative to AMI analysis)

$$p^{(AA)}_k + p^{(AB)}_k + p^{(BA)}_k + p^{(BB)}_k = 1 \quad .$$

Note that $p^{(AA)}_k$ is the probability of slot m and slot n both having ampitude A in the statistical pulse stream. With these probabilities, we will have

$$\langle y_m y_n \rangle = p^{(AA)}_k\, AA + p^{(AB)}_k\, AB + p^{(BA)}_k\, BA + p^{(BB)}_k\, BB \quad . \tag{38.2}$$

In case 1, there are a certain number of holds and changes during the gap such that the overall effect is a hold. The number of changes must have been even. But this same statement can be made about case 4, so cases 1 and 4 have the same probability of existing in the pulse stream. Similarly, cases 2 and 3 have the same probability and in those cases the number of changes must be odd. So now we have two variables to worry about and they add to 1/2 :

$$p^{(AA)}{}_k + p^{(AB)}{}_k = 1/2 \tag{38.3}$$

$$\langle y_m y_n \rangle = p^{(AA)}{}_k \, AA + p^{(AB)}{}_k \, AB + p^{(AB)}{}_k \, BA + p^{(AA)}{}_k \, BB$$

$$= p^{(AA)}{}_k \, (AA + BB) + p^{(AB)}{}_k \, (AB + BA)$$

so

$$\langle y_m y_n \rangle = p^{(AA)}{}_k (A^2 + B^2) + p^{(AB)}{}_k \, 2AB \tag{38.4}$$

If the gap is zero, what is the probability of having an adjacent AA in the pulse stream? The probability of having the left A is 1/2, and the probability for an A being followed by a A is 1-p. Therefore

$$p^{(AA)}{}_0 = (1/2)(1-p) \tag{38.5}$$

Consider now the gap as shown at value k. We claim that

$$p^{(AA)}{}_{k+1} = p^{(AA)}{}_k \, (1-p) + p^{(AB)}{}_k \, p \tag{38.6}$$

If it was an AA to start with with gap k, then to be AA with gap k+1 we have to add another A which has probability (1-p) since this is a hold. Conversely, if it was an AB we have to add an A which is a change, which has probability p. Then we can write

$$p^{(AA)}{}_{k+1} = p^{(AA)}{}_k \, (1-p) + (1/2 - p^{(AA)}{}_k \,) \, p \tag{38.7}$$

To simplify notation, let $X_k \equiv p^{(AA)}{}_k$ so that $p^{(AB)}{}_k = 1/2 - X_k$. Then ** and ** become

$$\langle y_m y_n \rangle = X_k \, (A^2 + B^2) + (1/2 - X_k) 2AB = (A-B)^2 X_k + AB \tag{38.8}$$

$$X_{k+1} = X_k \, (1-p) + (1/2 - X_k) \, p = (1-2p) X_k + p/2 = a X_k + p/2 \qquad a \equiv 1-2p \tag{38.9}$$

Maple can solve this recursion equation as follows,

```
p := (1-a)/2:
Xk := rsolve({ X(k+1) = (1-2*p)*X(k) + p/2, X(0) = (1-p)/2}, X):
simplify(%);
```

$$\frac{1}{4} a^{(k+1)} + \frac{1}{4}$$

so we find that

$$X_k = (1 + a^{k+1})/4 = p^{(AA)}{}_k \tag{38.10}$$

As a check, suppose p = 0 so there can be no changes. Then a = 1 and $p^{(AA)}{}_k = 1/2$. We can now have only case 1 or case 4, so we know $p^{(AB)}{}_k = 0$, and that is consistent with $p^{(AA)}{}_k + p^{(AB)}{}_k = 1/2$.

Continuing,

$$\langle y_m y_n \rangle = (A-B)^2 X_k + AB = (A-B)^2(1 + a^{k+1})/4 + AB$$

$$= [\,(A-B)^2/4]\, a^{k+1} + (A-B)^2/4 + AB$$

$$= [\,(A-B)^2/4]\, a^{k+1} + [(A+B)^2/4]$$

$$= (1/4)\,[\,(A-B)^2\, a^{k+1} + (A+B)^2\,] \qquad (38.11)$$

and we note that the result is indeed symmetric under A↔ B. Again for p = 0 (a=1) we find that $\langle y_m y_n \rangle = (A^2+B^2)/2$ which is the same then as $\langle y_n^2 \rangle$. For a constant pulse train, the amount of slot separation makes no difference.

Since k = |m-n| - 1 in general, we get these final results

$$\alpha_{n,m} = \langle y_m y_n \rangle = (1/4)\,[\, a^{|m-n|}\,(A-B)^2 + (A+B)^2\,]$$

$$\beta = \langle y_n^2 \rangle = (A^2+B^2)/2 \qquad (38.12)$$

To save space, we define

$$c \equiv (A-B)^2/4 \qquad d \equiv (A+B)^2/4 \qquad (38.13)$$

so then

$$\alpha_{n,m} = \langle y_m y_n \rangle = c\, a^{|m-n|} + d \qquad (38.14)$$

For later use, notice that

$$\beta - d = c \qquad (38.15)$$

Spectrum.

The spectrum is determined by (37.9) as in the AMI case,

$$\langle |X(\omega)|^2 \rangle = |X_{pulse}(\omega)|^2 \;\{ \sum_{n=-\infty}^{\infty} \sum_{m \neq n} \alpha_{n,m}\,[\, e^{i\omega(m-n)T_1}] + \beta \sum_{n=-\infty}^{\infty} \sum_{m=n} [1] \;\} \;. \qquad (38.16)$$

As in the AMU case, the β term in {...} is just

$$\beta \sum_{n=-\infty}^{\infty} \sum_{m=n} [1] = \beta \sum_{n=-\infty}^{\infty} [1] \;. \qquad (38.17)$$

Since $\alpha_{n,m} = c\, a^{|m-n|} + d$, the first double sum has two terms. Again looking at the AMI case, we find that the first term is given by, again using $b \equiv e^{i\omega T_1}$,

$$c \sum_{n=-\infty}^{\infty} \sum_{m \neq n} a^{|m-n|}\, b^{(m-n)} = c\, \frac{a(1+b^2-2ab)}{(b-a)(1-ab)} \sum_{n=-\infty}^{\infty} [1] \quad . \qquad |a| < 1 \qquad (38.18)$$

To get the second term in the first double sum, we *cannot* just replace c by d and then set a = 1 to get

$$d\, \frac{a(1+b^2-2ab)}{(b-a)(1-ab)} \sum_{n=-\infty}^{\infty} [1] \text{ (with a = 1)} \quad = \quad d\, \frac{(1+b^2-2b)}{(b-1)(1-b)} \sum_{n=-\infty}^{\infty} [1] \quad = -d \sum_{n=-\infty}^{\infty} [1] \qquad \text{// wrong}$$

This is because the result is not valid at a = 1 for $\omega = 2\pi n$. So we have to do this d sum separately:

$$d \sum_{n=-\infty}^{\infty} \sum_{m \neq n} [\, e^{i\omega(m-n)T_1}] = d \sum_{n=-\infty}^{\infty} \sum_{m \neq n} b^{m-n} \quad .$$

We now omit the d for a while to evaluate this sum

$$\sum_{n=-\infty}^{\infty} \sum_{m \neq n} b^{m-n} = \sum_{n=-\infty}^{\infty} [\, \sum_{m=-\infty}^{\infty} b^{m-n} - \sum_{m=n} b^{m-n} \,]$$

$$= \Big(\sum_{n=-\infty}^{\infty} b^{-n} \Big) \Big(\sum_{m=-\infty}^{\infty} b^{m} \Big) - \sum_{n=-\infty}^{\infty} [\, 1 \,] \quad .$$

In the first factor, since $b \equiv e^{i\omega T_1}$, we are facing squared delta functions, so we have to back off to finite N in our processing and later take $N \to \infty$, so we continue doing this,

$$= (\, 2\pi\delta_5(\omega T_1, N) \,)^2 \; - \; (2N+1)$$

$$= (2N+1) \, [\; (\, 2\pi\delta_5(\omega T_1, N) \,)^2 / \, (2N+1) \; - \; 1 \;]$$

$$= (2N+1) \, [\; (2\pi\delta_6(\omega T_1, N) \; - \; 1 \;]$$

Then we return to $N = \infty$ and use

$$\lim_{N \to \infty} \delta_6(k,N) = \sum_{m=-\infty}^{\infty} \delta(k - 2\pi m) \qquad \textit{(A.21)}$$

to get our result

$$\sum_{n=-\infty}^{\infty} \sum_{m \neq n} [\, e^{i\omega(m-n)T_1}] \;=\; [\, \sum_{m=-\infty}^{\infty} 2\pi\, \delta(\omega T_1 - 2\pi m) \;-\; 1\,] \sum_{n=-\infty}^{\infty} [\, 1\,] \qquad (38.19)$$

The -1 is what one gets from the limit a→1 of $\frac{a(1+b^2-2ab)}{(b-a)(1-ab)}$, but we see that there is more.

We can now assemble the pieces to get

$$\langle |X(\omega)|^2 \rangle = \; |X_{\mathbf{pulse}}(\omega)|^2 \;\; \{ \;\; c\, \frac{a(1+b^2-2ab)}{(b-a)(1-ab)} + \beta \;- d \;+\; d \sum_{m=-\infty}^{\infty} 2\pi\, \delta(\omega T_1 - 2\pi m) \,\} \sum_{n=-\infty}^{\infty} [\, 1\,]$$

Recalling that β - d = c we write this as

$$\langle |X(\omega)|^2 \rangle = \; |X_{\mathbf{pulse}}(\omega)|^2 \;\; \{ \;\; c\, [\, \frac{a(1+b^2-2ab)}{(b-a)(1-ab)} + 1] \;+\; d \sum_{m=-\infty}^{\infty} 2\pi\, \delta(\omega T_1 - 2\pi m) \,\} \sum_{n=-\infty}^{\infty} [\, 1\,]$$

and using **** we get

$$\langle \mathcal{P}(\omega) \rangle \;=\; \mathcal{P}_{\mathbf{pulse}}(\omega)\; \{ \;\; c\, [\, \frac{a(1+b^2-2ab)}{(b-a)(1-ab)} + 1] \;+\; d \sum_{m=-\infty}^{\infty} 2\pi\, \delta(\omega T_1 - 2\pi m) \,\} \qquad (38.20)$$

$a = (1-2p) \qquad b = e^{i\omega T_1} \qquad c = (A-B)^2/4 \qquad d = (A+B)^2/4$

Maple now computes the square bracketed expression:

```
b := exp(I*w*T1):
c := (A-B)^2/4:
sb := 1 + a*(1+b^2-2*a*b)/((b-a)*(1-a*b)):
sb1 := convert(sb,trig):simplify(%);
```

$$\frac{-1+a^2}{2\,a\,\cos(w\,T1) - 1 - a^2}$$

so that

$$[\, \frac{a(1+b^2-2ab)}{(b-a)(1-ab)} + 1] \;=\; \frac{(1-a^2)}{1+a^2-2a\cos(\omega T_1)}$$

and then here is the final result for a Change/Hold line code :

$$\langle \mathcal{P}(\omega) \rangle \;=\; \mathcal{P}_{\mathbf{pulse}}(\omega)\; \{ \;\; [\, \frac{(A-B)}{2} \,]^2 \, \frac{(1-a^2)}{1+a^2-2a\cos(\omega T_1)} \;+\; [\, \frac{(A+B)}{2} \,]^2 \sum_{m=-\infty}^{\infty} 2\pi\, \delta(\omega T_1 - 2\pi m) \,\} \qquad (38.21)$$

where a = (2p-1) and p is the probability of a change while 1-p is the probability of a hold.

We shall now investigate various limits of this result.

Limit A → B.

$$\langle \mathcal{P}(\omega) \rangle = \mathcal{P}_{\mathbf{pulse}}(\omega) \{ A^2 \sum_{m=-\infty}^{\infty} 2\pi \, \delta(\omega T_1 - 2\pi m) \} \tag{38.22}$$

In the case that the pulse is a box we use (34.22),

$$\mathcal{P}_{\mathbf{pulse}}(\omega) = (1/\omega_1) \, \mathrm{sinc}^2(\omega T_1/2) \tag{38.23}$$

we get

$$\langle \mathcal{P}(\omega) \rangle = A^2 \, \mathcal{P}_{\mathbf{pulse}}(\omega) \sum_{m=-\infty}^{\infty} 2\pi \, \delta(\omega T_1 - 2\pi m)$$

$$= A^2 \sum_{m=-\infty}^{\infty} 2\pi \, \delta(\omega T_1 - 2\pi m) \, (1/\omega_1) \, \mathrm{sinc}^2(\pi m) = A^2 \, 2\pi \, \delta(\omega T_1) \, (1/\omega_1)$$

$$= A^2 \, \delta(\omega) \tag{38.24}$$

This is exactly what we expect when A = B, since the pulse train is then just a constant value A !

Limit p→1 (a → -1)

In this limit we expect to get a square wave pulse train between values A and B. We make use of this limit from Appendix A with 2k = ωT_1,

$$\lim_{a \to -1} \frac{(1-a^2)}{1+a^2 - 2a\cos(\omega T_1)} = \pi \sum_{m = \pm \mathrm{odd}} \delta(\omega T_1/2 - m\pi/2) = \sum_{m = \pm \mathrm{odd}} 2\pi \, \delta(\omega T_1 - m\pi) \tag{A.25b}$$

and then our Change/Hold spectral power density becomes

$$\langle \mathcal{P}(\omega) \rangle = \mathcal{P}_{\mathbf{pulse}}(\omega) \{ \left[\frac{(A-B)}{2} \right]^2 \sum_{m = \pm \mathrm{odd}} 2\pi \, \delta(\omega T_1 - m\pi) + \left[\frac{(A+B)}{2} \right]^2 \sum_{m=-\infty}^{\infty} 2\pi \, \delta(\omega T_1 - 2\pi m) \}$$

Installing the box pulse shape $\mathcal{P}_{\mathbf{pulse}}(\omega) = (1/\omega_1) \, \mathrm{sinc}^2(\omega T_1/2)$ and using (38.24) the second term becomes just $\left[\frac{(A+B)}{2} \right]^2 \delta(\omega)$ while the first term is

$$\left[\frac{(A-B)}{2} \right]^2 \sum_{m = \pm \mathrm{odd}} 2\pi \, \delta(\omega T_1 - m\pi) \, (1/\omega_1) \, \mathrm{sinc}^2(m\pi/2)$$

$$= \quad \left[\frac{(A-B)}{2}\right]^2 2\pi \sum_{m=\pm odd} \delta(\omega T_1 - m\pi)\,(1/\omega_1)\,(m\pi/2)^{-2}$$

$$= \quad (A-B)^2\ (2/\pi^2) \sum_{m=\pm odd} (1/m^2)\,\delta(\omega - m\omega_1/2)$$

giving a final result,

$$\langle \mathcal{P}(\omega) \rangle = (A-B)^2\ (2/\pi^2) \sum_{m=\pm odd} (1/m^2)\,\delta(\omega - m\omega_1/2) + \left[\frac{(A+B)}{2}\right]^2 \delta(\omega) \qquad (38.25)$$

Comparing the first term with (34.23), we see that it is the spectrum of a square wave whose peak to peak amplitude is (A-B), which is exactly what it should be. The second term then correctly accounts for the expected average DC level of (A+B)/2.

Limit $p \to 0$ ($a \to +1$)

In this case for a square wave we expect to get a result appropriate for an ensemble of pulse trains half of which have constant value A and the other have constant value B, since all pulse trains are in a permanent hold state with p = 0, nothing changes. This time we use this limit (A.23c) with $2k = \omega T_1$

$$\lim_{a \to +1} \frac{(1-a^2)}{1+a^2-2a\cos(\omega T_1)} = \pi \sum_{m=-\infty}^{\infty} \delta(\omega T_1/2 - m\pi) = \sum_{m=-\infty}^{\infty} 2\pi\delta(\omega T_1 - m2\pi) \qquad \textit{(A.23c)}$$

to get

$$\langle \mathcal{P}(\omega) \rangle = \mathcal{P}_{pulse}(\omega)\ \{\ \left[\frac{(A-B)}{2}\right]^2 \sum_{m=-\infty}^{\infty} 2\pi\,\delta(\omega T_1 - 2m\pi) + \left[\frac{(A+B)}{2}\right]^2 \sum_{m=-\infty}^{\infty} 2\pi\,\delta(\omega T_1 - 2\pi m)\ \}$$

Installing the square pulse spectrum (38.23) $\mathcal{P}_{pulse}(\omega) = (1/\omega_1)\ \mathrm{sinc}^2(\omega T_1/2)$, the second term according to (38.24) becomes $\left[\frac{(A+B)}{2}\right]^2 \delta(\omega)$ while the first term is

$$\left[\frac{(A-B)}{2}\right]^2 \sum_{m=\pm odd} 2\pi\,\delta(\omega T_1 - 2m\pi)\,(1/\omega_1)\,\mathrm{sinc}^2(m\pi) = \quad 0$$

giving the result

$$\langle \mathcal{P}(\omega) \rangle = \left[\frac{(A+B)}{2}\right]^2 \delta(\omega) \qquad (38.26)$$

This is the expected result, appropriate for an average DC level of (A+B)/2.

Limit $p \to 1/2$ ($a \to 0$)

Recall the general result

$$\langle \mathcal{P}(\omega) \rangle = \mathcal{P}_{\mathtt{pulse}}(\omega) \left\{ \left[\frac{(A-B)}{2} \right]^2 \frac{(1-a^2)}{1+a^2-2a\cos(\omega T_1)} + \left[\frac{(A+B)}{2} \right]^2 \sum_{m=-\infty}^{\infty} 2\pi\, \delta(\omega T_1 - 2\pi m) \right\}$$

The ratio becomes unity so the result is

$$\langle \mathcal{P}(\omega) \rangle = \mathcal{P}_{\mathtt{pulse}}(\omega) \left\{ \left[\frac{(A-B)}{2} \right]^2 + \left[\frac{(A+B)}{2} \right]^2 \sum_{m=-\infty}^{\infty} 2\pi\, \delta(\omega T_1 - 2\pi m) \right\} \qquad (38.27)$$

Box Shaped Pulse for general p:

$$\langle \mathcal{P}(\omega) \rangle = \mathcal{P}_{\mathtt{pulse}}(\omega) \left\{ \left[\frac{(A-B)}{2} \right]^2 \frac{(1-a^2)}{1+a^2-2a\cos(\omega T_1)} + \left[\frac{(A+B)}{2} \right]^2 \sum_{m=-\infty}^{\infty} 2\pi\, \delta(\omega T_1 - 2\pi m) \right\}$$

$$\mathcal{P}_{\mathtt{pulse}}(\omega) = (1/\omega_1)\, \mathrm{sinc}^2(\omega T_1/2)$$

As usual, the second term becomes $\left[\frac{(A+B)}{2} \right]^2 \delta(\omega)$, so the result is

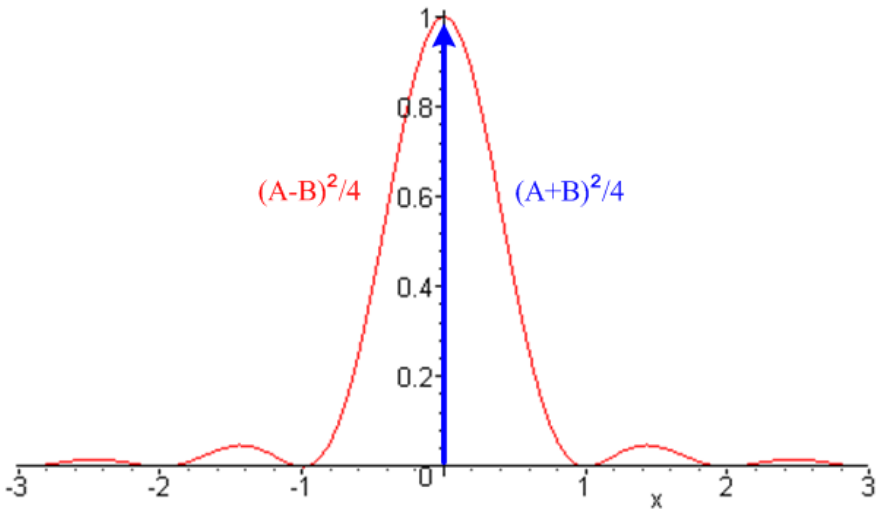
$$\langle \mathcal{P}(\omega) \rangle = \left[\frac{(A-B)}{2} \right]^2 (1/\omega_1)\, \mathrm{sinc}^2(\omega T_1/2) \frac{(1-a^2)}{1+a^2-2a\cos(\omega T_1)} + \left[\frac{(A+B)}{2} \right]^2 \delta(\omega) \qquad (38.28)$$

Box Shaped Pulse for p = 1/2 (a = 0):

$$\langle \mathcal{P}(\omega) \rangle = \left[\frac{(A-B)}{2} \right]^2 (1/\omega_1)\, \mathrm{sinc}^2(\omega T_1/2) + \left[\frac{(A+B)}{2} \right]^2 \delta(\omega)$$

$$\langle \mathcal{P}(\omega) \rangle = (1/\omega_1) \left\{ \left[\frac{(A-B)}{2} \right]^2 \mathrm{sinc}^2(\pi x) + \left[\frac{(A+B)}{2} \right]^2 \delta(x) \right\} \quad x \equiv \frac{\omega}{\omega_1} \qquad (38.29)$$

Ignoring the factor $(1/\omega_1)$ we make this plot of $\langle \mathcal{P}(\omega) \rangle$ which is the same as for unipolar NRZ but with different scaling factors for the two terms,



Example: NRZI line code

Coding: This is a special case of Change/Hold encoding where A = 1 and B = 0.

```
data   =  [ 1   0   1   1   0   0   1]
encode =  [ 1   0   1   1   0   0   1]
```



NRZI means NRZ Invert-on-1, where NRZ means non return to zero (see comments at the start of Secton 36). NRZI does not mean "NRZ inverted". Sometimes people use A = 0 and B = 1 so then transitions happen on 0 instead of 1, as in the standard for USB (Universal Serial Bus). We shall use A=1, B=0. The Change/Hold spectra are symmetric in A↔B, so the NRZI spectra are the same for either convention.

Coefficients $\alpha_{m,n}$ and β:

$$\alpha_{n,m} = \langle y_m y_n \rangle = (1/4)\,[\, a^{|m-n|}\,(A-B)^2 + (A+B)^2\,] = (1/4)\,[\, a^{|m-n|} + 1\,]$$

$$\beta = \langle y_n^2 \rangle = (A^2+B^2)/2 = 1/2 \qquad (38.30)$$

Spectrum.

$$\langle \mathcal{P}(\omega) \rangle = \mathcal{P}_{\mathbf{pulse}}(\omega)\,\{\,[\,\frac{(A-B)}{2}\,]^2\,\frac{(1-a^2)}{1+a^2-2a\cos(\omega T_1)} + [\,\frac{(A+B)}{2}\,]^2 \sum_{m=-\infty}^{\infty} 2\pi\,\delta(\omega T_1 - 2\pi m)\,\}$$

$$= \mathcal{P}_{\mathbf{pulse}}(\omega)\,\{\,\frac{1}{4}\,\frac{(1-a^2)}{1+a^2-2a\cos(\omega T_1)} + \frac{1}{4} \sum_{m=-\infty}^{\infty} 2\pi\,\delta(\omega T_1 - 2\pi m)\,\} \qquad (38.31)$$

Box Shaped Pulse for general p:

$$<\mathcal{P}(\omega)> = \frac{1}{4}\ (1/\omega_1)\ \mathrm{sinc}^2(\omega T_1/2)\ \frac{(1-a^2)}{1+a^2-2a\cos(\omega T_1)} \ + \ \frac{1}{4}\ \delta(\omega) \qquad (38.32)$$

Box Shaped Pulse for p = 1/2 (a = 0):

$$<\mathcal{P}(\omega)> = (1/\omega_1)\ \{\ \ \frac{1}{4}\ \mathrm{sinc}^2(\pi x)\ + \ \frac{1}{4}\ \delta(x)\ \ \} \qquad x \equiv \frac{\omega}{\omega_1} \qquad (38.33)$$

The plot is that just shown above, but with each factor being 1/4.

This spectrum is exactly the same as that for unipolar NRZ shown in (36.3) with V = 1.

One way to understand this fact is that for every NRZ sequence y_n there is a NRZI sequence y'_n given by

$y'_n = y_n - y_{n-1}$ // mod-2 math

This equation can be inverted to give (assume $y_0 = 0$)

$y_n = \Sigma_{m=1}^{n}\ y'_m \quad n = 1,2,3....$

Consider the space of all random sequences of 1's and 0's (random pulse trains p = 1/2). Since we just showed that the relation $\{y_n\} \leftrightarrow \{y'_n\}$ is one-to-one, the mapping f: $\{y_n\} \rightarrow \{y'_n\}$ just reorders the set of random sequences in the ensemble used to compute the spectral power density, so that density cannot change.