HW#8

SIMULATING EQUALIZERS

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Zero Forcing Equalizer:

For simulating how this equalizer works, 2 different ways are used.

In the first way, bits are convolved with *h*(-t)*, then AWGN goes through the same channel and is added to the resulting bits. (This signal is called *y1* in code.) After finding channel response of equalizer, the resulting y1 signal goes through channel *d(t)*.

In the second way, *q(t)* which is *x(t)*d(t),* and bits go through this channel. Then using the below equation, noise is calculated and added to the last signal, resulting in a new received signal, *y2*.

$$v = n * h^*(-t)\ .\ \eta = v * d(t)$$

$$S_\eta(z) = ٢\ N_o X(z)D(z)D^*\left(\frac{١}{z}\right) \rightarrow R_\eta(m) = ٢\ N_o\ x(m) * d(m) * d^*(-m)$$

Since in ZF we assume q_i = 0 for $i \in \{-k. -k+١. \ldots . -١. ١. ٢. \ldots . k\}$:

$$\sigma_\eta^٢ = ٢\ N_o\big(q(m) * d(m)\big) = ٢\ N_o\ d_o$$

For calculating the probability of error based on the calculations in class, as was used above, q_i = 0 for $i \in \{-k. -k+١. \ldots . -١. ١. ٢. \ldots . k\}$, but as can be seen in simulations, some of them are not exactly zero. Their value is about 10^{-16} which is considered zero in matlab, but since assuming they are zero or not made difference in calculating pe, 2 different pe is calculated, the first one considering their exact value, and the other way is neglecting these values.

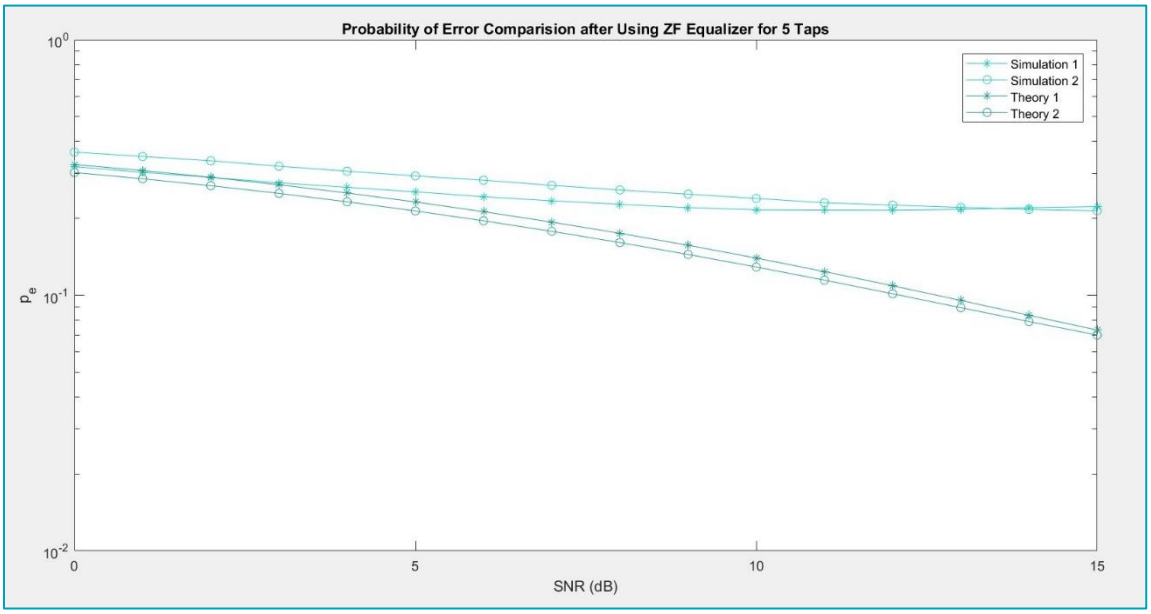
With considering their value, formula for finding pe is: (For 5 taps)

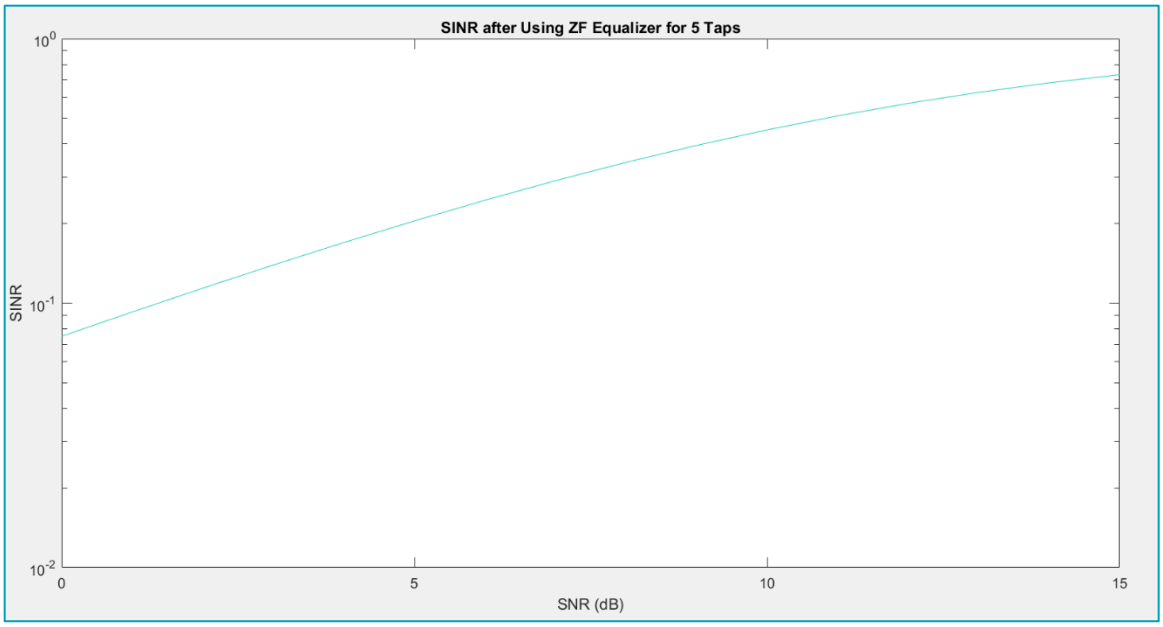
$$pe = \frac{١}{٢^٨}\sum_{\varepsilon_i \in \{\pm ١\}} Q\left(\frac{q_o + \varepsilon_{١}q_{١} + \varepsilon_{-١}q_{-١} + \varepsilon_{-٢}q_{-٢} + \varepsilon_{٢}q_{٢} + \varepsilon_{٣}q_{٣} + \varepsilon_{-٣}q_{-٣} + \varepsilon_{٤}q_{٤} + \varepsilon_{-٤}q_{٤}}{٠.٥\sigma_\eta^٢}\right)$$

But if we don't consider the almost zero ones we have: (For 5 taps)

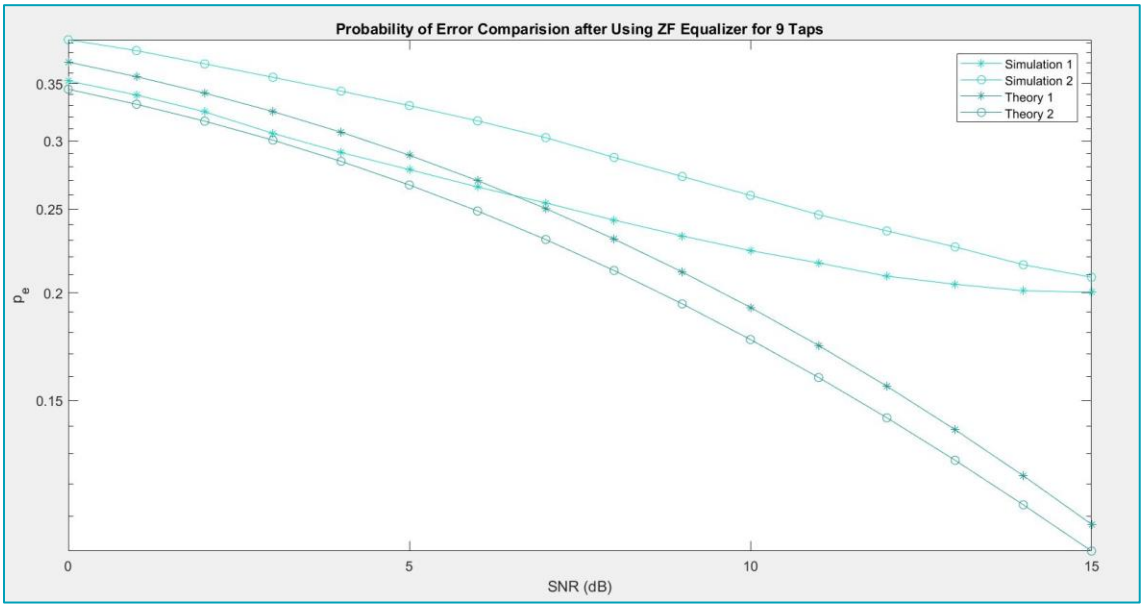
$$pe = \frac{١}{٢^٨}\sum_{\varepsilon_i \in \{\pm ١\}} Q\left(\frac{q_o + \varepsilon_{٣}q_{٣} + \varepsilon_{-٣}q_{-٣} + \varepsilon_{٤}q_{٤} + \varepsilon_{-٤}q_{٤}}{٠.٥\sigma_\eta^٢}\right)$$

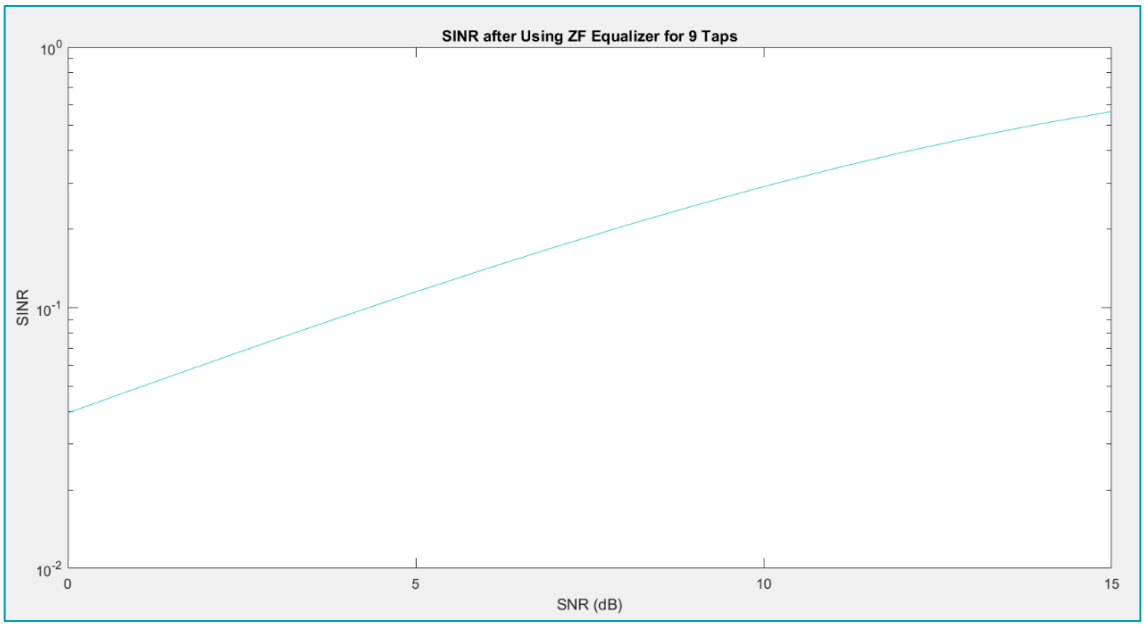
The first formula is labeled as Theory 1 and the second can be found under Theory *2 label:*

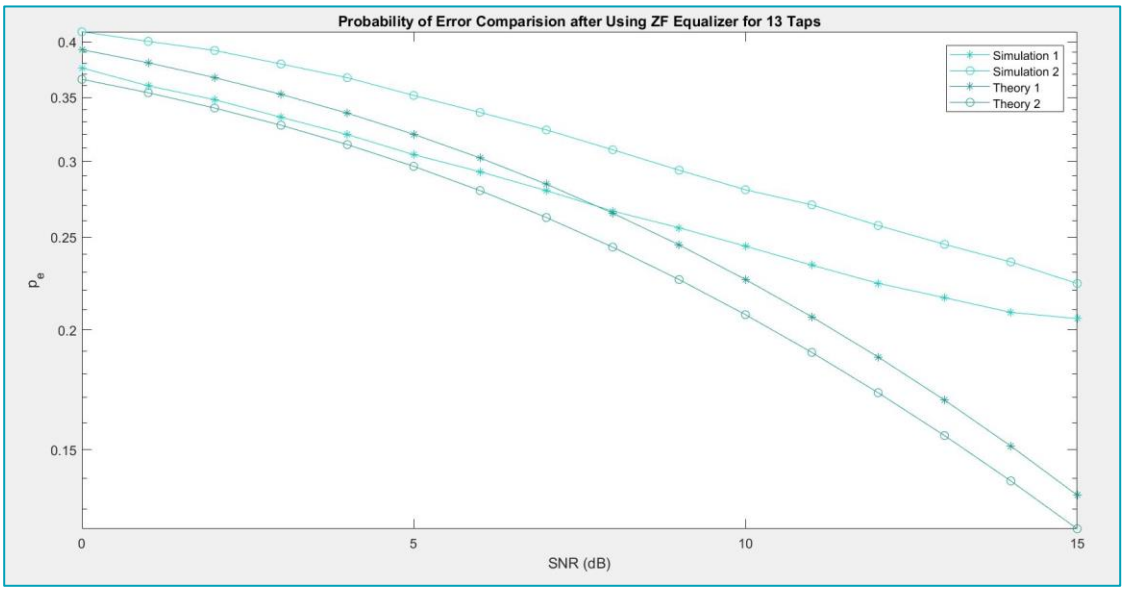

Probability of Error Comparision after Using ZF Equalizer for 5 Taps
Simulation 1
Simulation 2
Theory 1
Theory 2
10^0
10^{-1}
10^{-2}
p_e
0
5
10
15
SNR (dB)

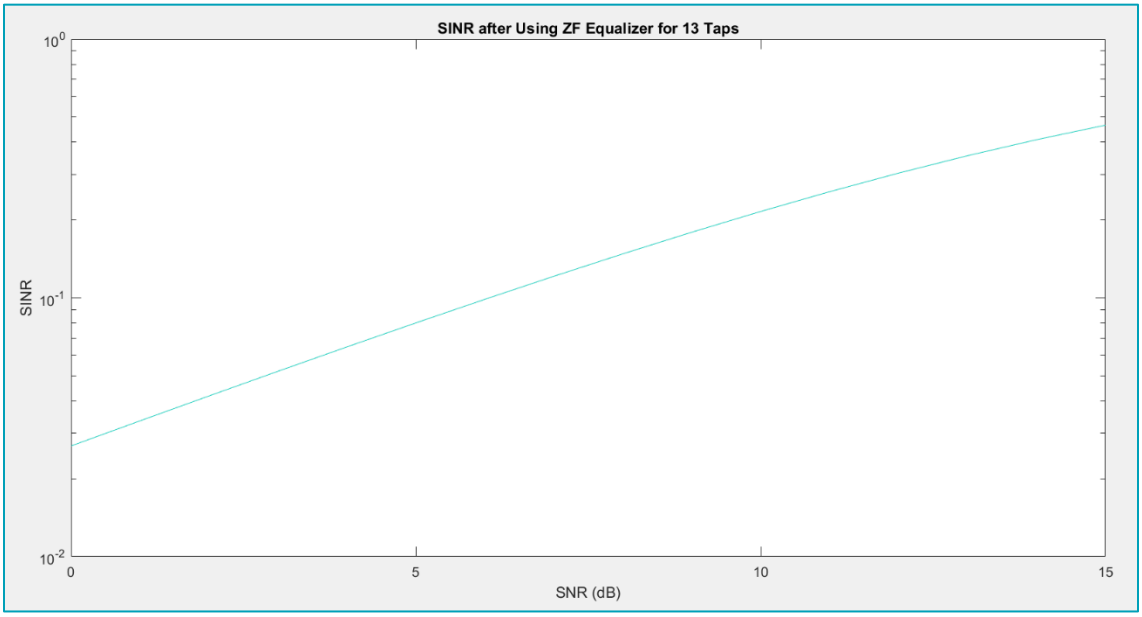

SINR after Using ZF Equalizer for 5 Taps
10^0
10^{-1}
10^{-2}
SINR
0
5
10
15
SNR (dB)

The same ways are done for the other taps too:

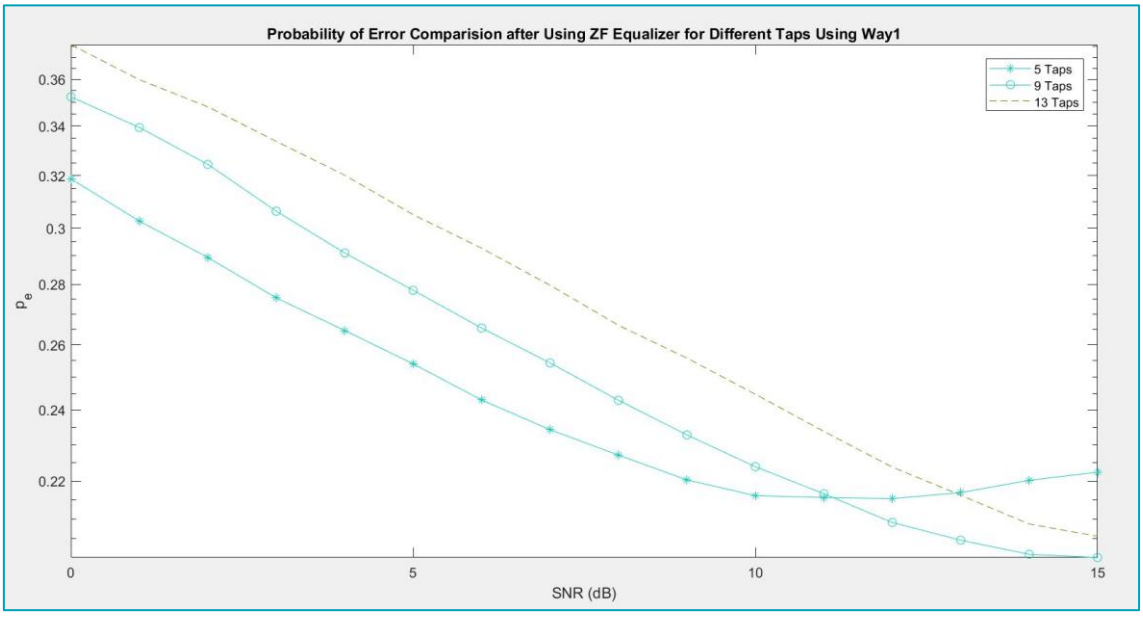


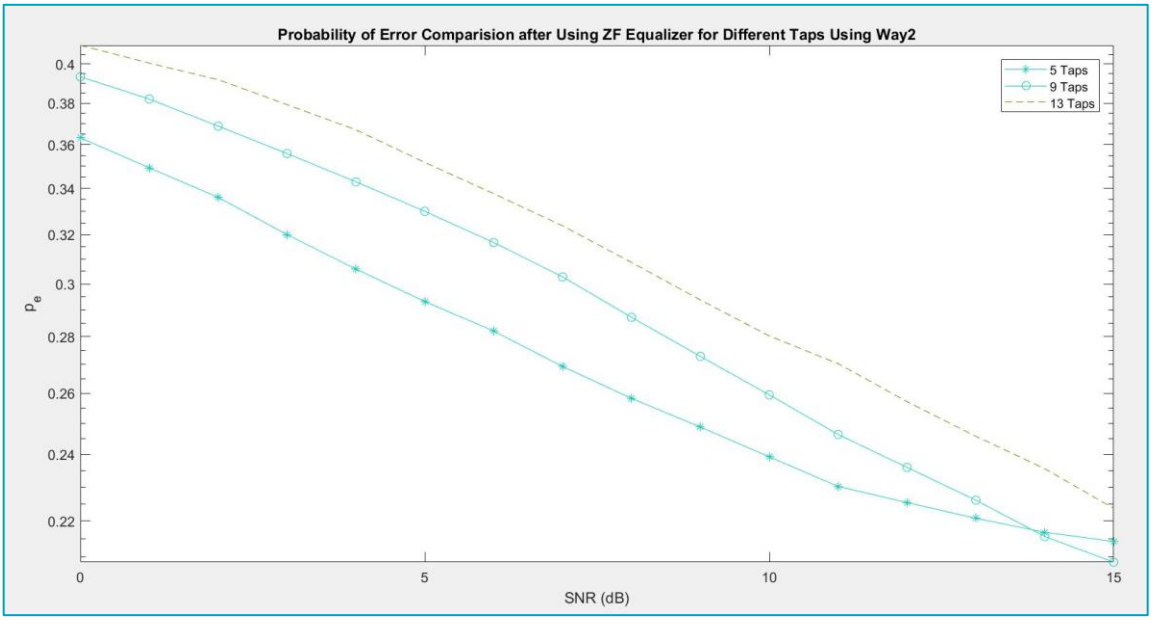


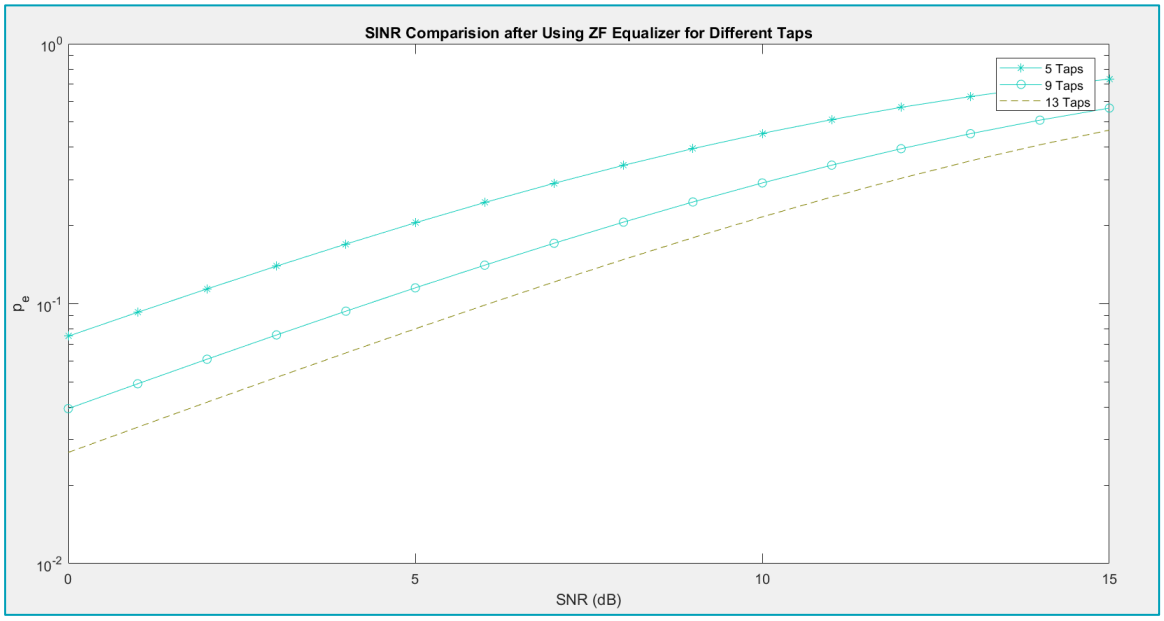




So each ones you want to compare, just commend the other way and check the plot.

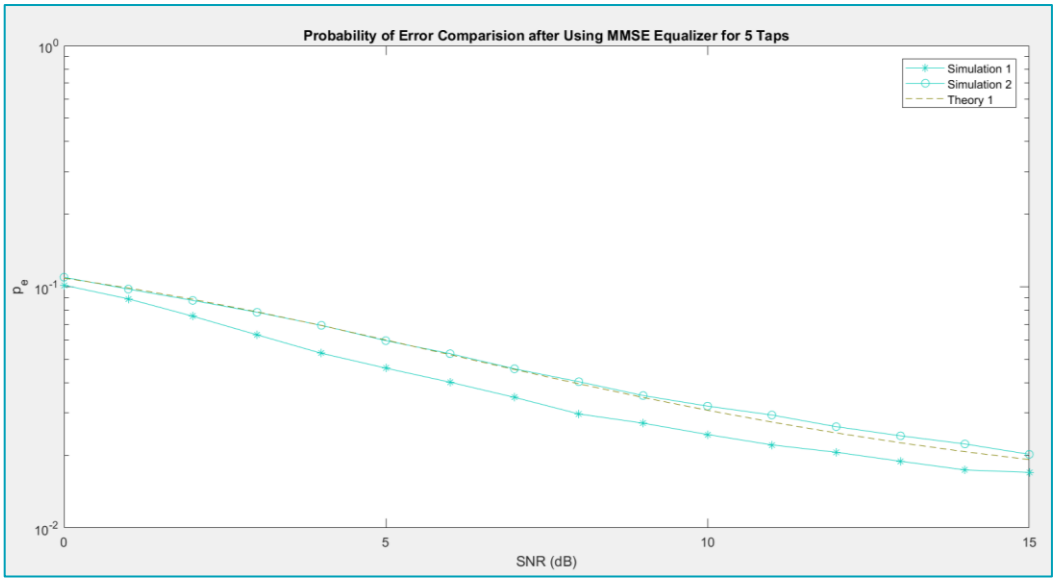

Probability of Error Comparision after Using ZF Equalizer for Different Taps Using Way1
5 Taps
9 Taps
13 Taps
p_e
SNR (dB)
0.36
0.34
0.32
0.3
0.28
0.26
0.24
0.22
0
5
10
15

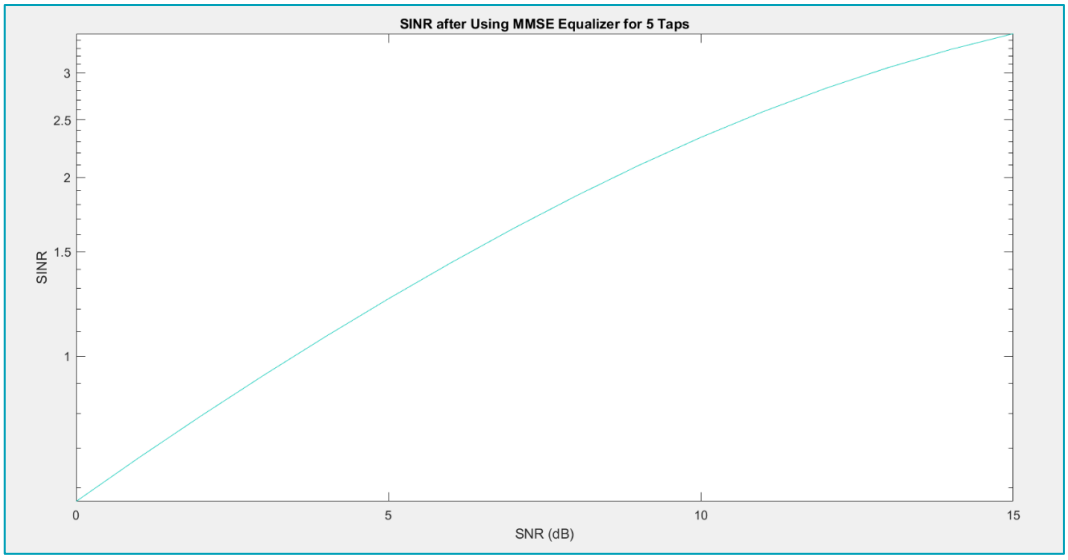

Probability of Error Comparision after Using ZF Equalizer for Different Taps Using Way2
5 Taps
9 Taps
13 Taps
p_e
SNR (dB)
0.4
0.38
0.36
0.34
0.32
0.3
0.28
0.26
0.24
0.22
0
5
10
15

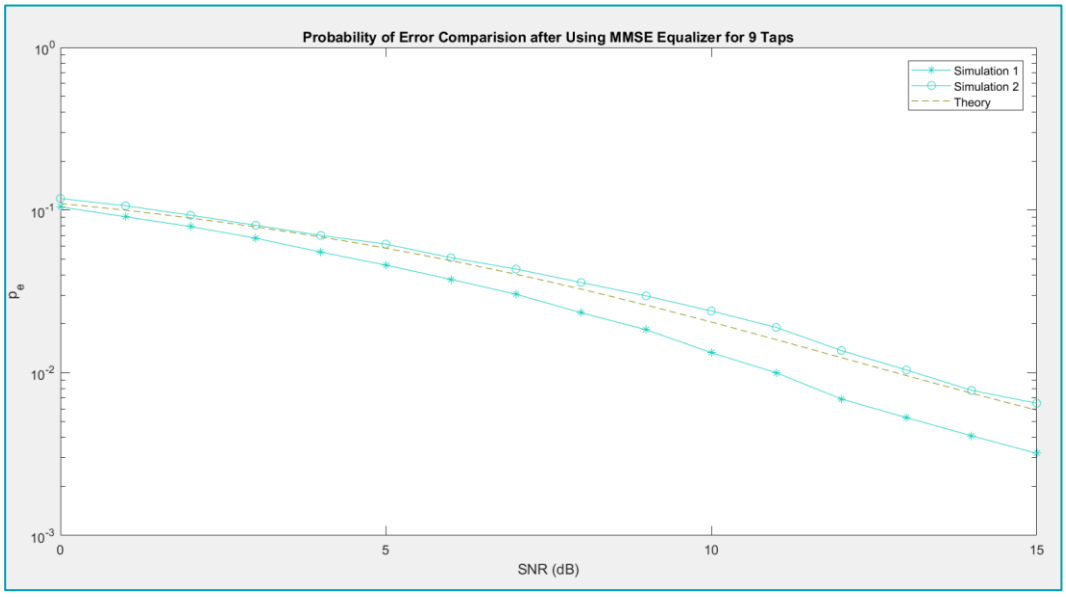

SINR Comparision after Using ZF Equalizer for Different Taps
5 Taps
9 Taps
13 Taps
10^0
10^{-1}
10^{-2}
P_e
0
5
10
15
SNR (dB)

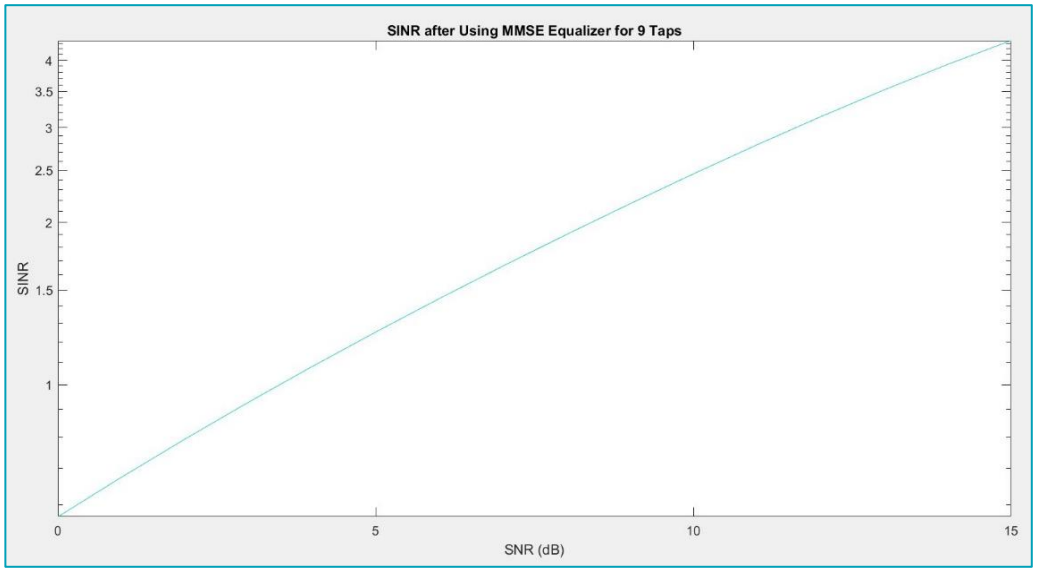
MMSE:

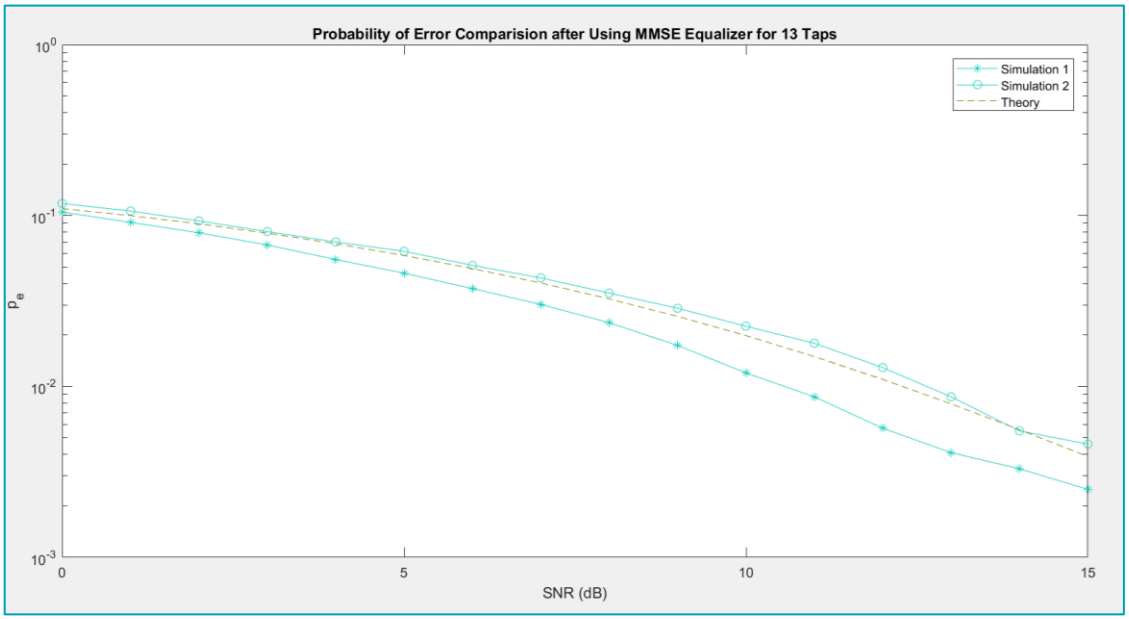
For this equalizer, same as the last one, 2 different methods of simulating noise is used. But since all q coefficients must be used, only one way for simulating pe using theory is used. The result is as below:

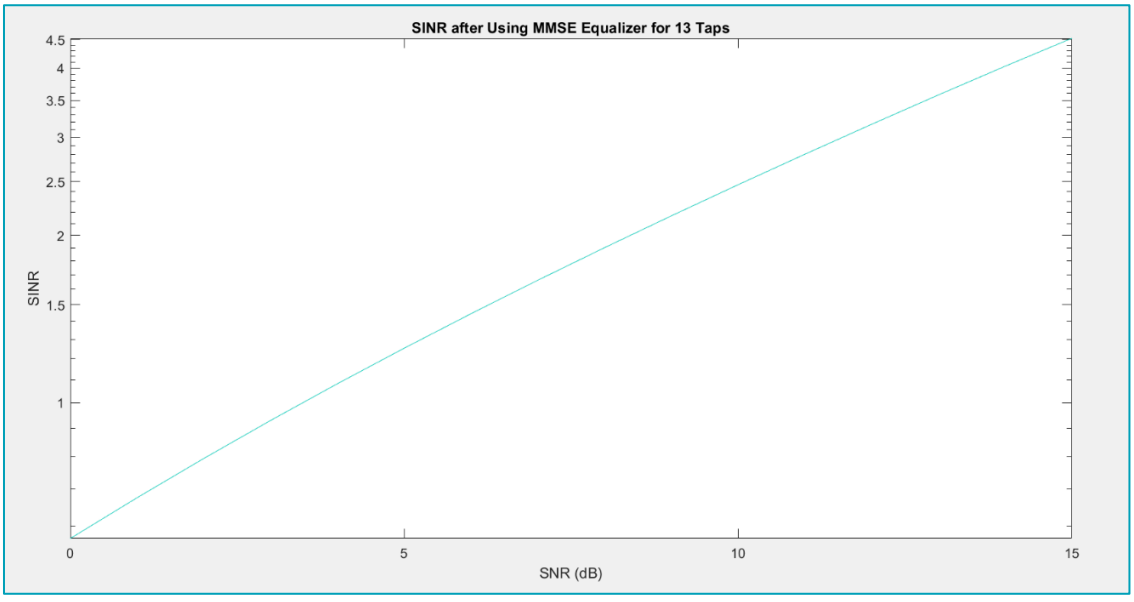




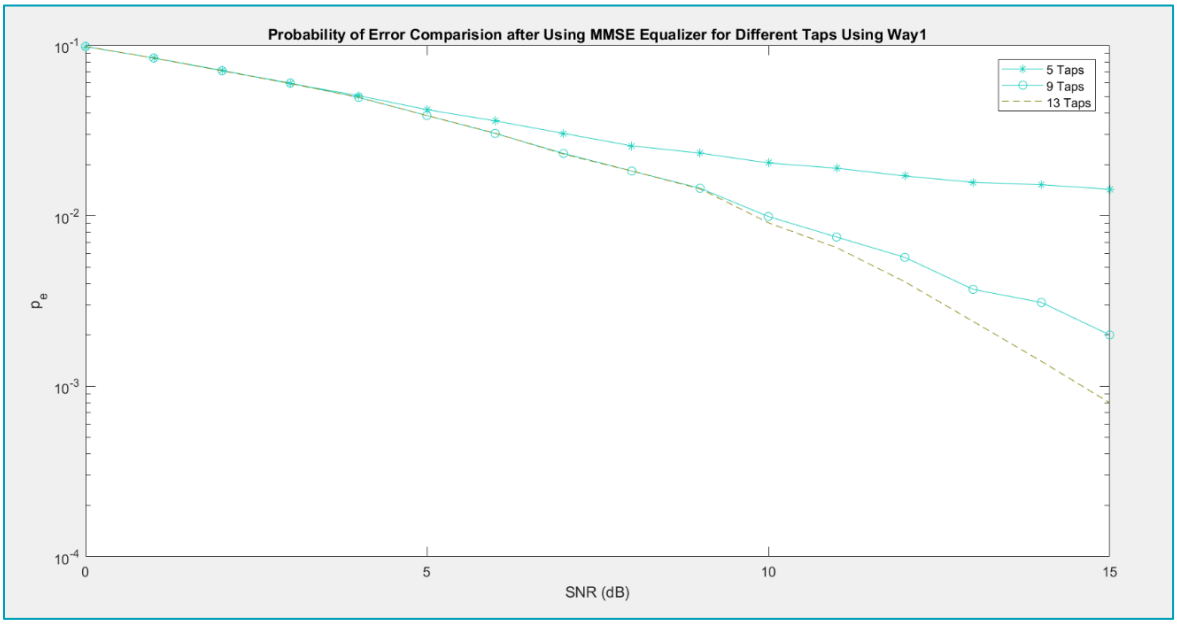

Probability of Error Comparision after Using MMSE Equalizer for 9 Taps
Simulation 1
Simulation 2
Theory
10^0
10^{-1}
10^{-2}
10^{-3}
p_e
0
5
10
15
SNR (dB)

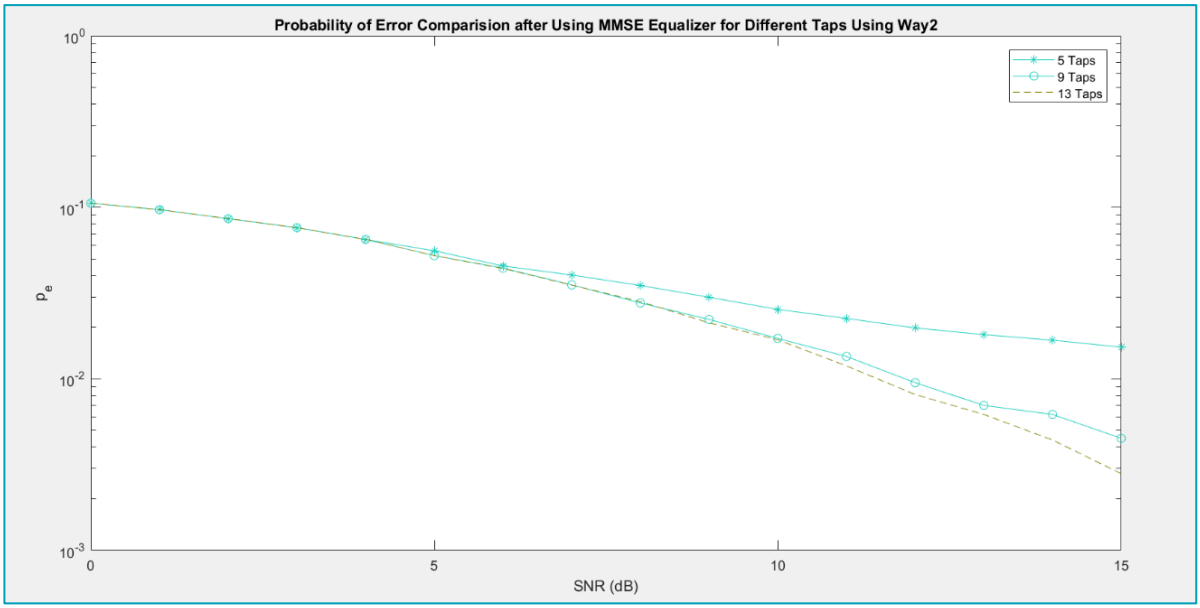

SINR after Using MMSE Equalizer for 9 Taps
4
3.5
3
2.5
2
1.5
1
SINR
0
5
10
15
SNR (dB)

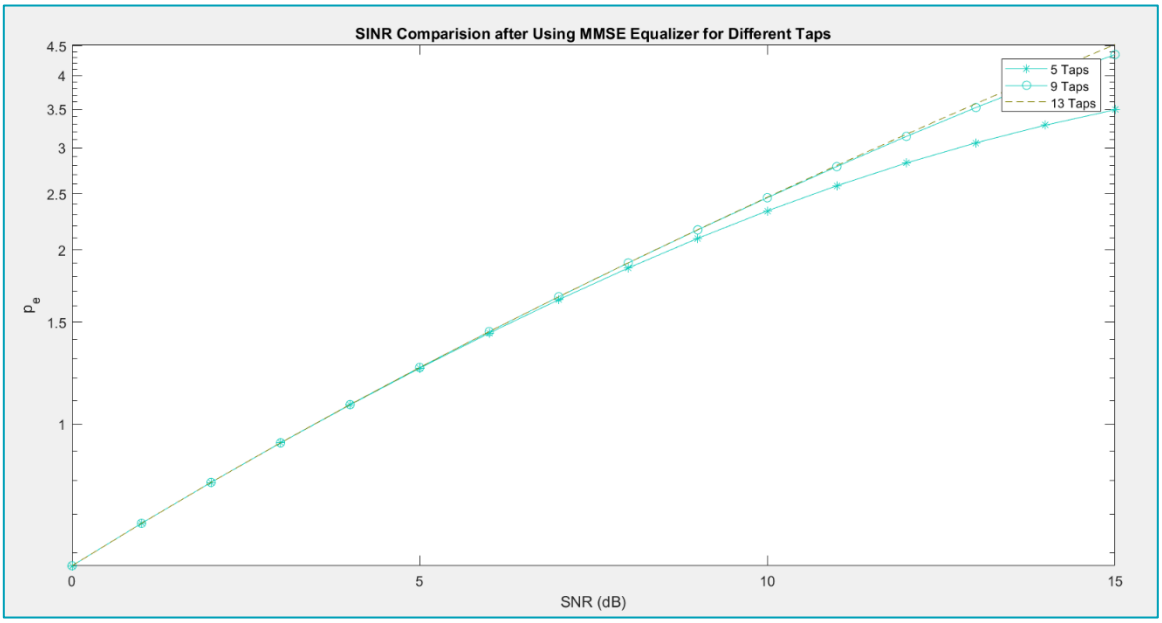




So each ones you want to compare, just commend the other way and check the plot.

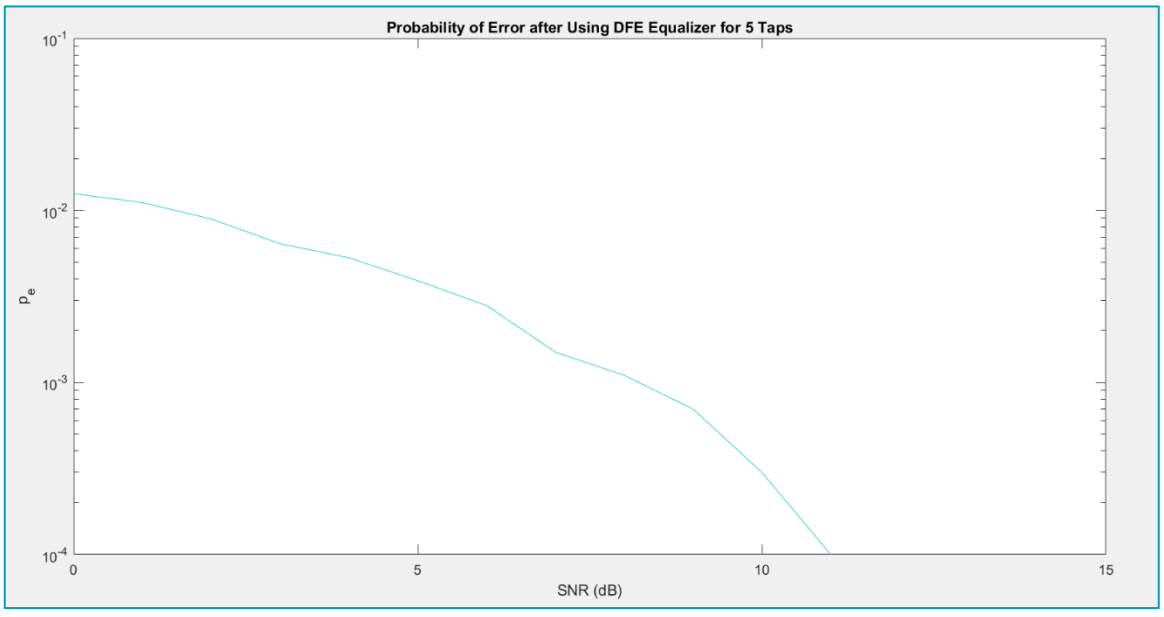

Probability of Error Comparision after Using MMSE Equalizer for Different Taps Using Way1
5 Taps
9 Taps
13 Taps
p_e
SNR (dB)

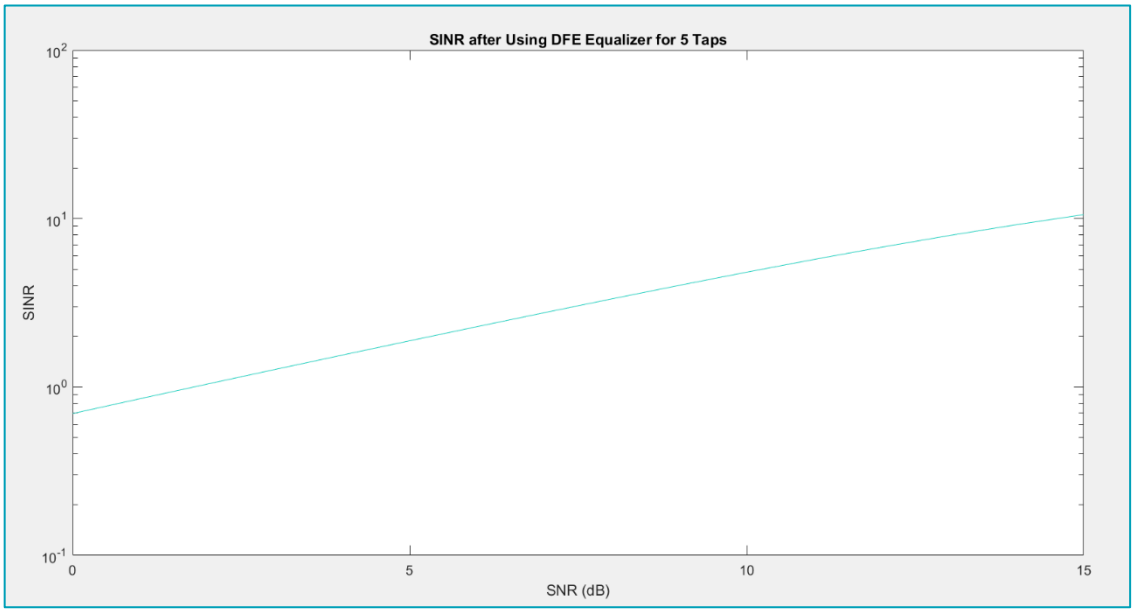

Probability of Error Comparision after Using MMSE Equalizer for Different Taps Using Way2
5 Taps
9 Taps
13 Taps
p_e
SNR (dB)

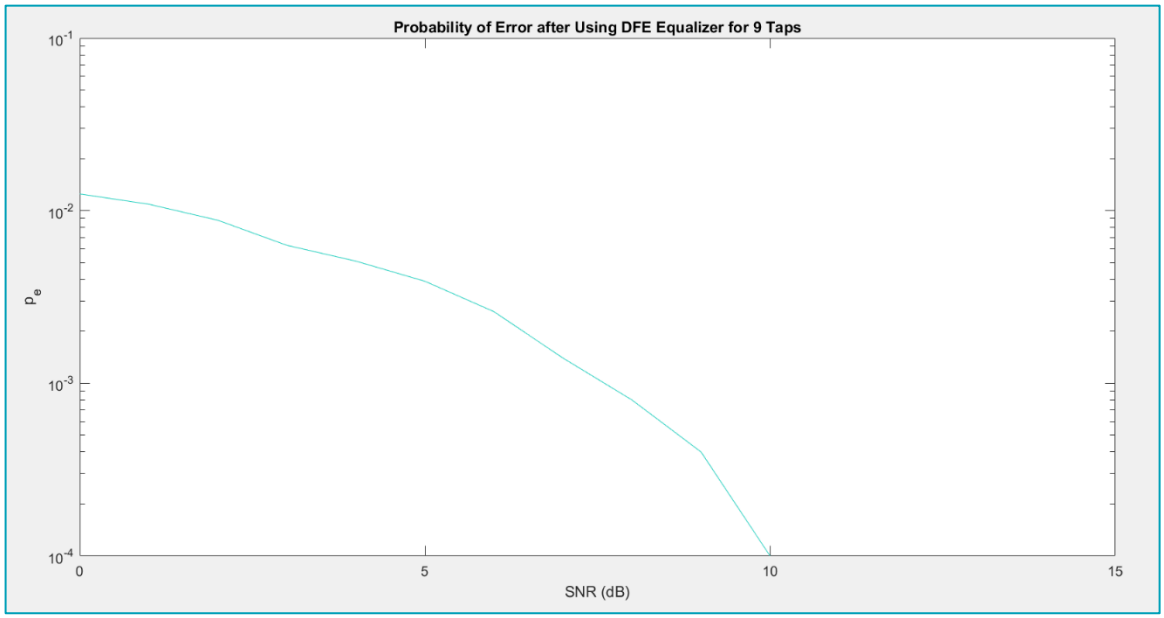


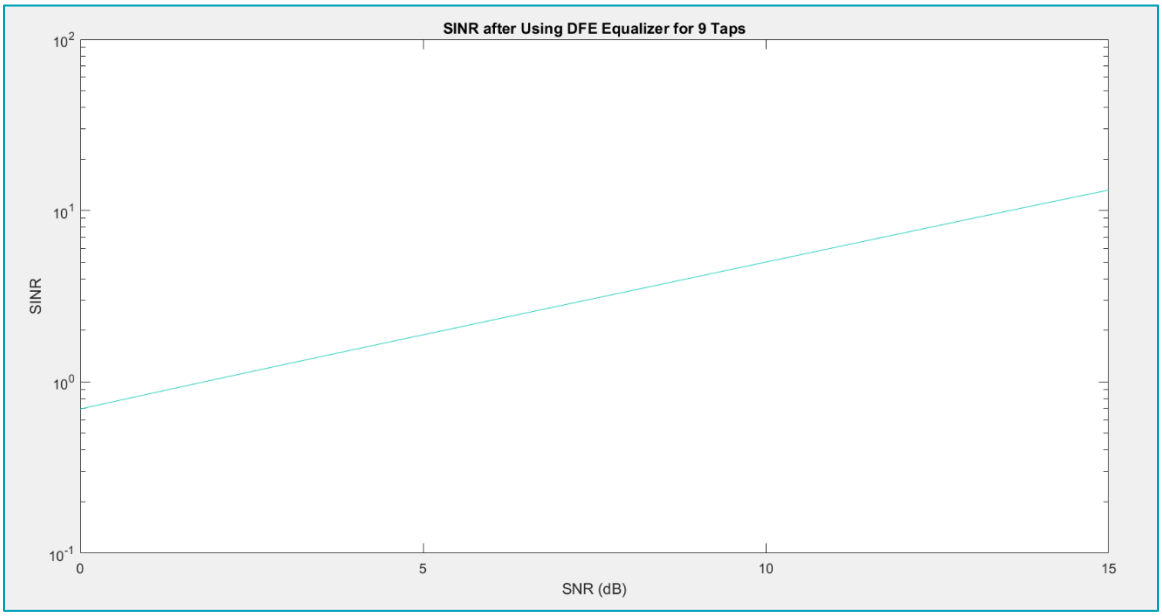
DFE:

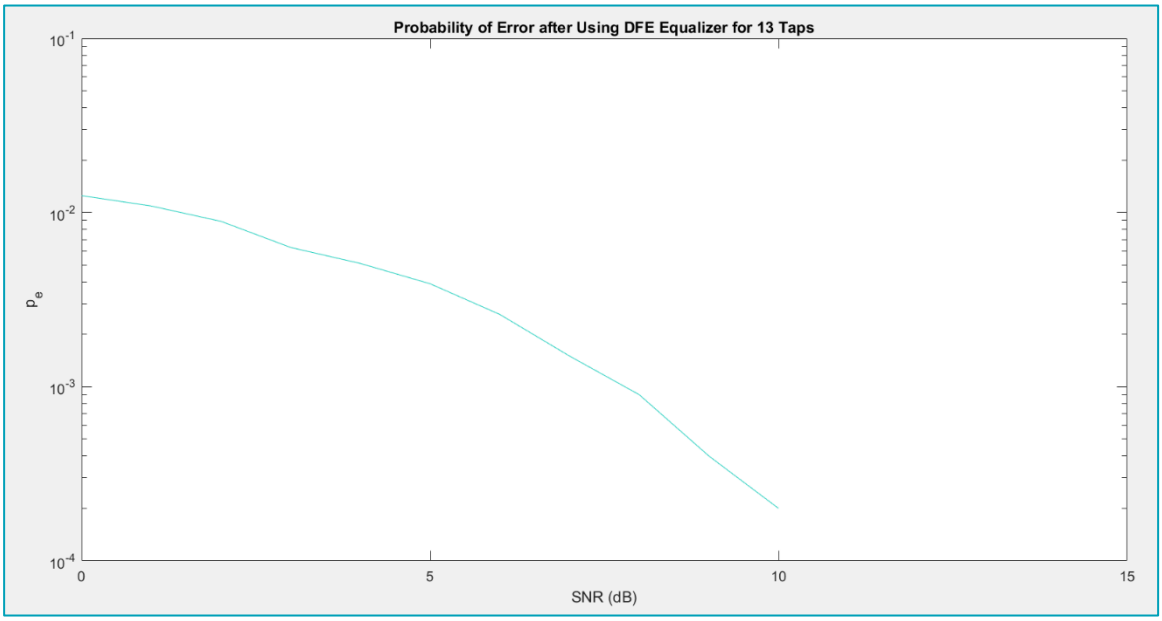
For this equalizer only the first way of noise is simulated and the results can be seen as below:

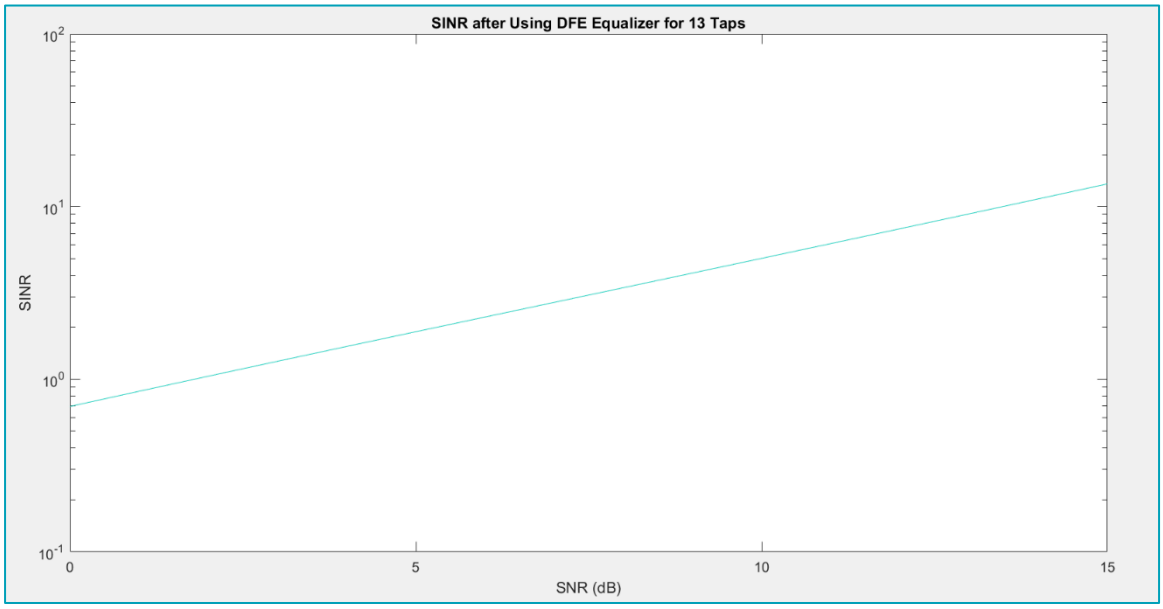


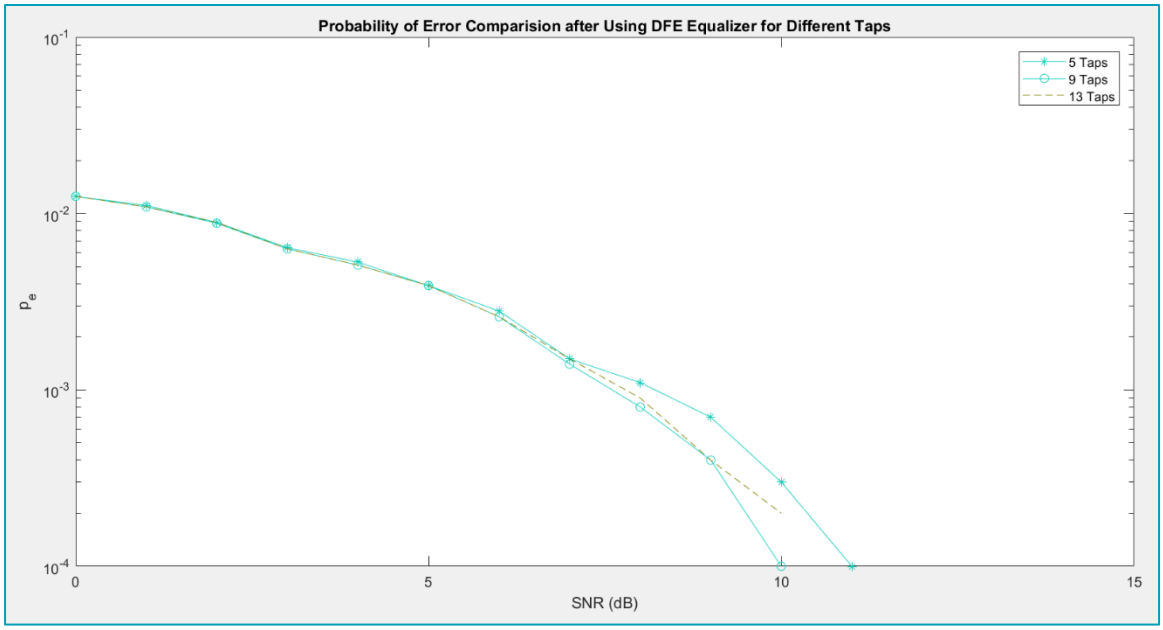

SINR after Using DFE Equalizer for 5 Taps
SINR
SNR (dB)
10^{2}
10^{1}
10^{0}
10^{-1}
0
5
10
15

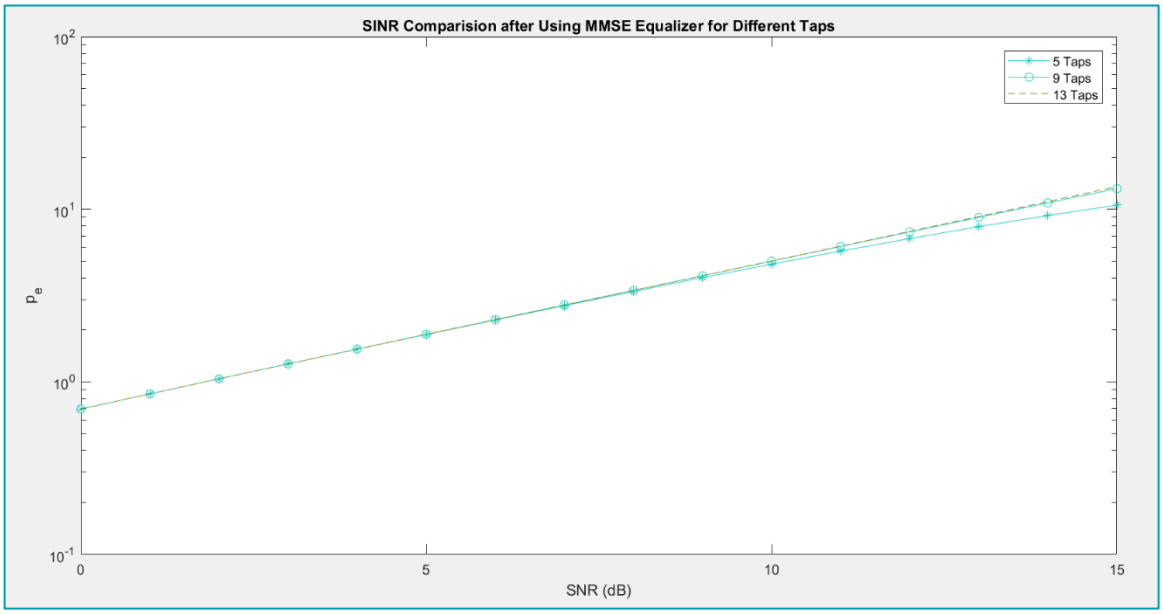

Probability of Error after Using DFE Equalizer for 9 Taps
p_e
SNR (dB)
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0
5
10
15

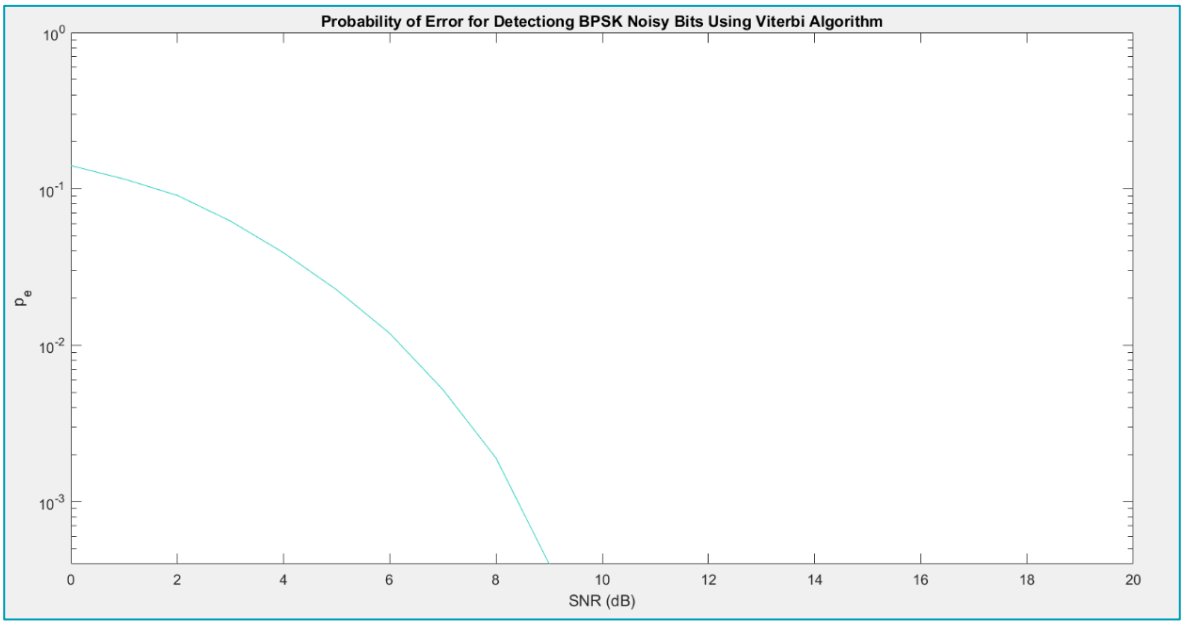

SINR after Using DFE Equalizer for 9 Taps
SINR
SNR (dB)
10^{2}
10^{1}
10^{0}
10^{-1}
0
5
10
15


Probability of Error after Using DFE Equalizer for 13 Taps
p_e
SNR (dB)
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0
5
10
15


SINR after Using DFE Equalizer for 13 Taps
SINR
SNR (dB)
10^2
10^1
10^0
10^{-1}
0
5
10
15


Probability of Error Comparision after Using DFE Equalizer for Different Taps
p_e
SNR (dB)
5 Taps
9 Taps
13 Taps
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0
5
10
15


SINR Comparision after Using MMSE Equalizer for Different Taps
5 Taps
9 Taps
13 Taps
10^2
10^1
10^0
10^{-1}
p_e
0
5
10
15
SNR (dB)


Probability of Error for Detectiong BPSK Noisy Bits Using Viterbi Algorithm
10^0
10^{-1}
10^{-2}
10^{-3}
p_e
0
2
4
6
8
10
12
14
16
18
20
SNR (dB)