Telecommunications I

Project 2

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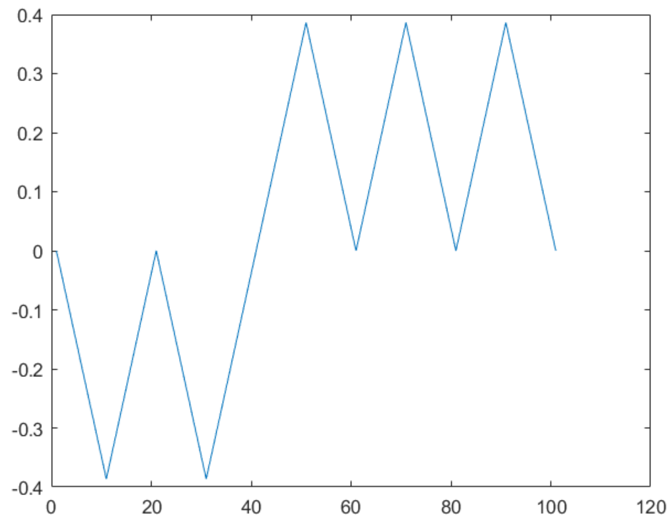
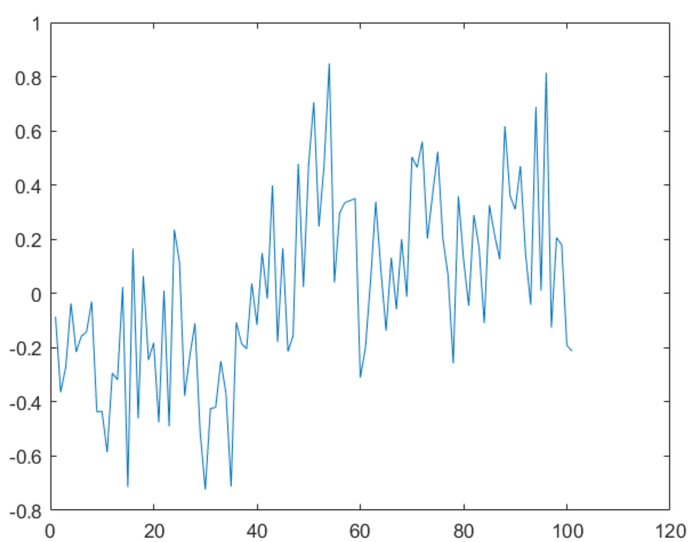
In this project we are simulating signal transmission over AWGN channels. First of all 100000 random bits are generated. To perform binary Pulse Amplitude Modulation (PAM), a triangular pulse is used. Initially 20 samples per bit are used to modulate.

The bits (0,0,1,1,1) are modulated using the triangular pulse as can be seen below:



A similar sequence of length 100000 is generated corresponding to the generated bits.

To simulate the AWGN channel and testing the receiver implementation, we add noise to the modulated signal after which the signal may look like this (with SNR = 10dB):



Abdul Basit Anees
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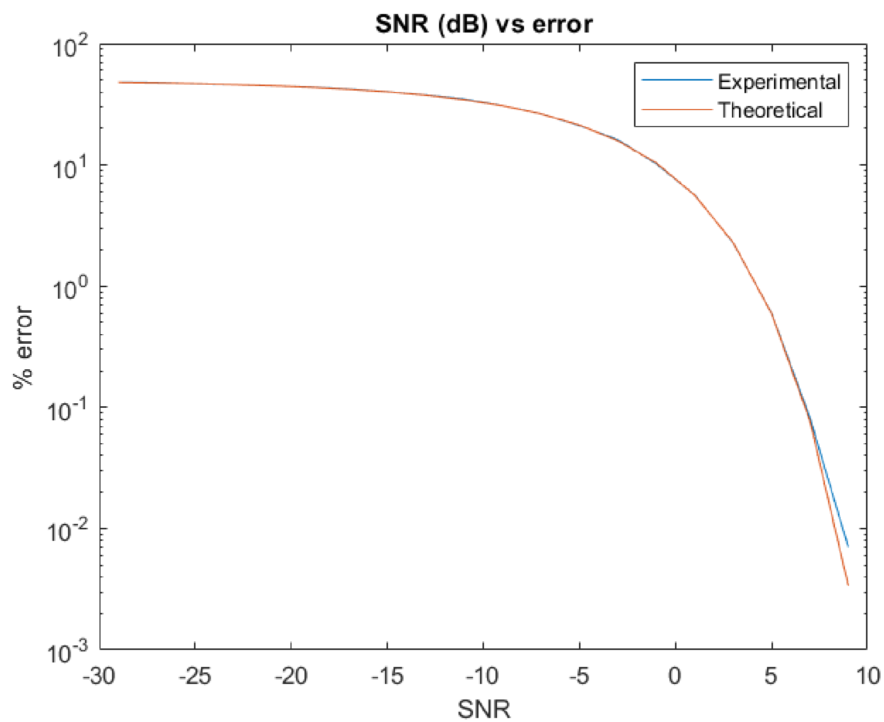
EEE-431

Q.1

For the matched filter implementation, we convolve the signal with the pulse and sample it at the sample rate which is equal to the number of samples used in the pulse. Then the decision rule of r > 0 is used with which we decide the transmitted bit. Then the accuracy is calculated using the ratio of true prediction with the actual transmitted bit. After repeating the procedure for different SNRs, we see that the error rate decreases. Following is the plot of the error rate with SNR on a log scale.



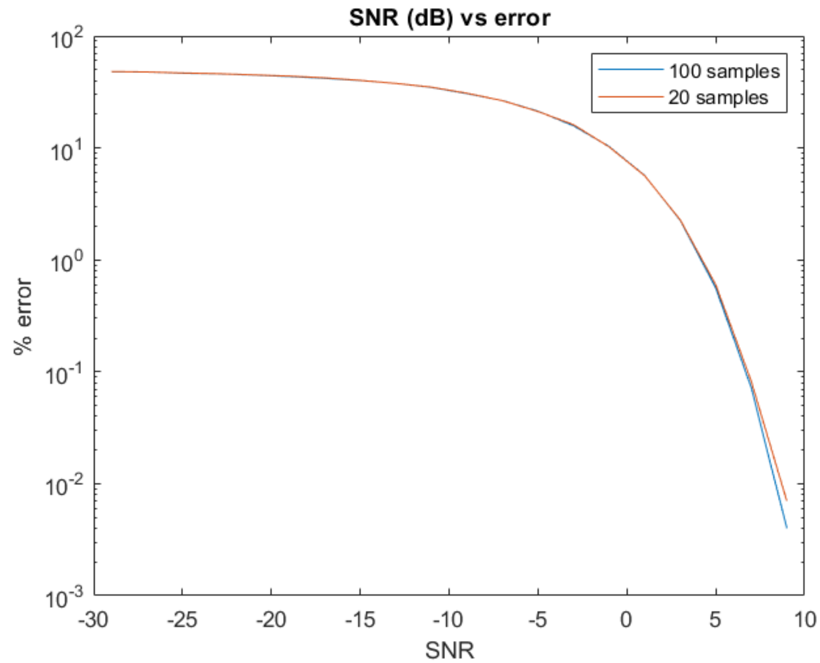
It can be seen that error decreases with the increase of SNR which corresponds to less noise in the received signal.

Moreover, the experimental error is almost same as theoretical error. For high SNRs there is a small difference observed which may be due to limitations of discretization/ sampling of the signal. The theoretical error is obtained using:

$$P_e = Q(\sqrt{2 * SNR})$$

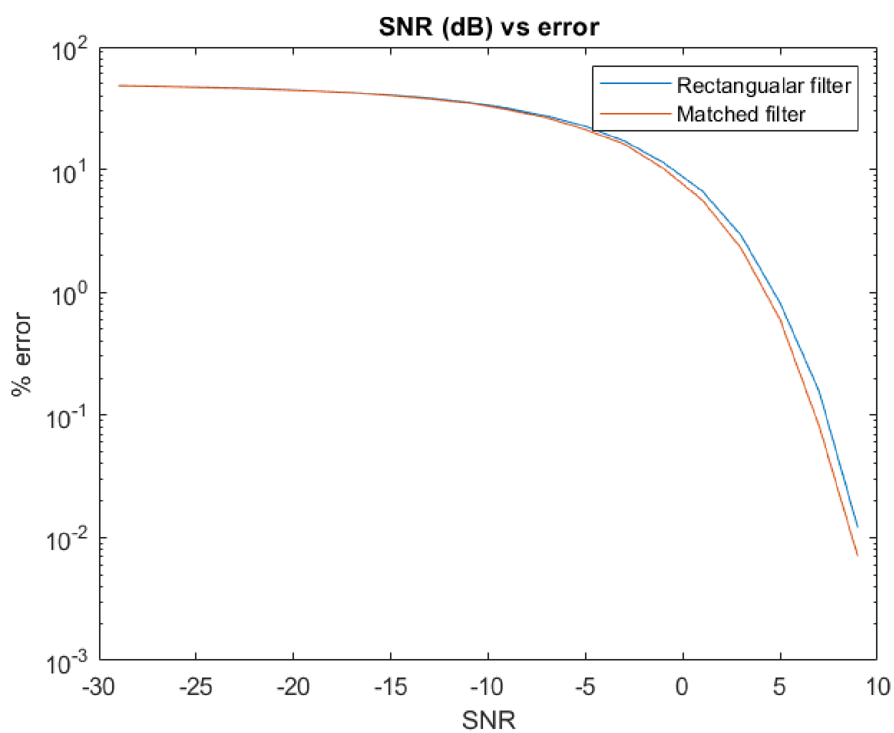
Q.2

In this part, the same receiver is used but with different (100) sample for the carrier pulse. By comparison, we can see that increasing the number of samples decreases the error rate which confirms my previous hypothesis of limitations of sampling.



Q.3

With the rectangular impulse response, we are still able to decode the bits, however, the error rate increases as can be seen below.



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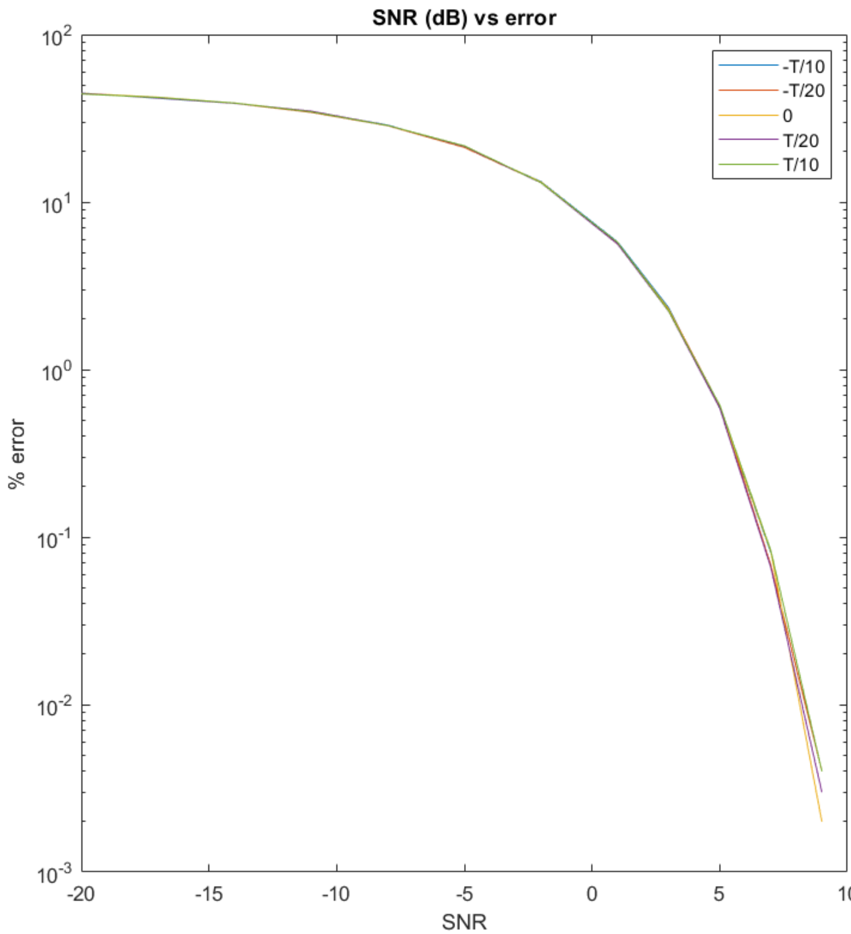
Q.4

By considering single bit as a time transmitted with noise on both side, following are the errors obtained.



It can be seen that the timed filter has the least error and the error increases as the timing difference increases

Abdul Basit Anees
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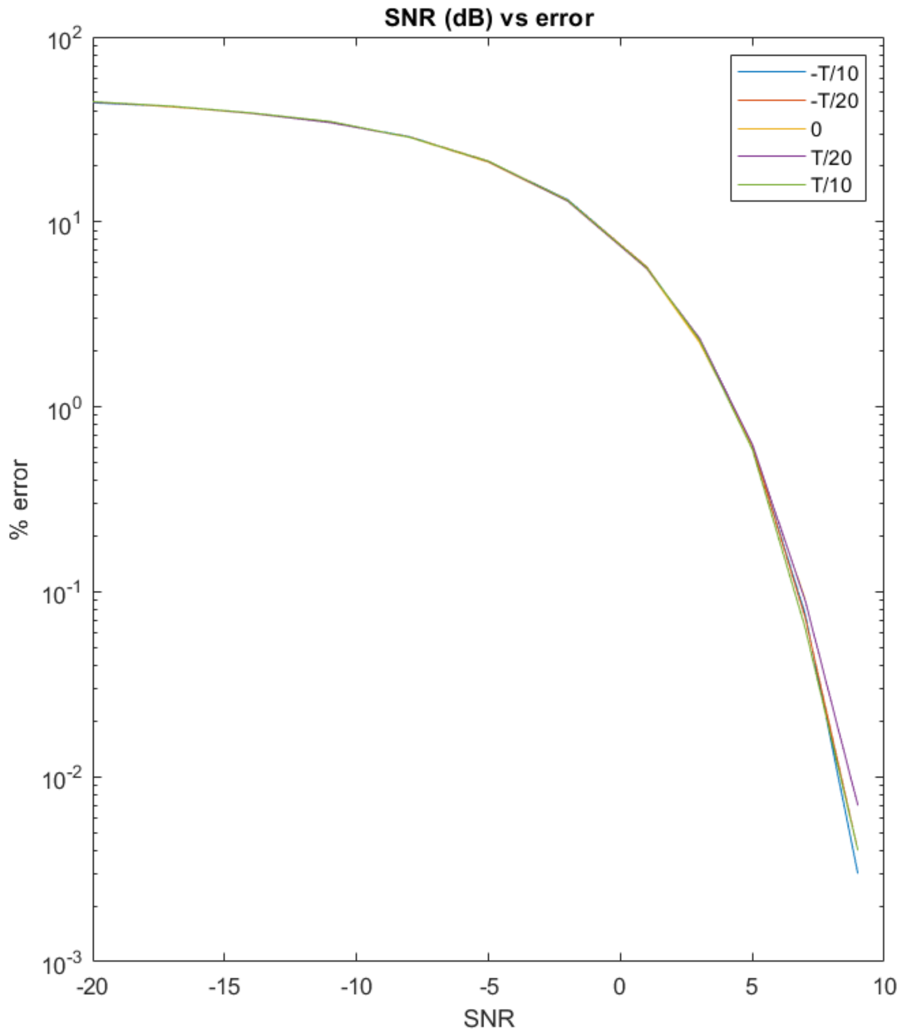
EEE-431

Q.5



Compared to the previous part, we can observe an increase in error due to interference by other bits.

Q.6

In the part, we perform binary Frequency Shift Keying. For modulation, two cosine waves are used as basis functions. One with frequency f and the other with frequency 2f. (or f + 1/T) shown as:

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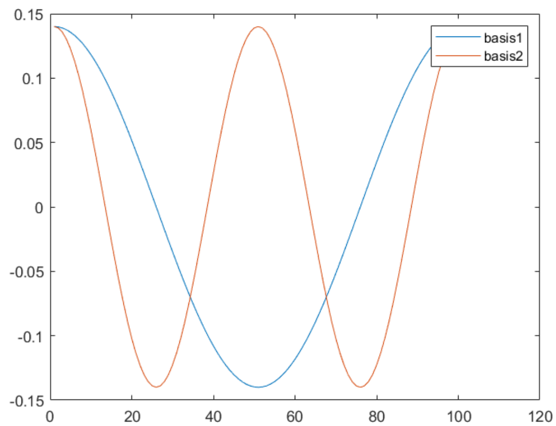
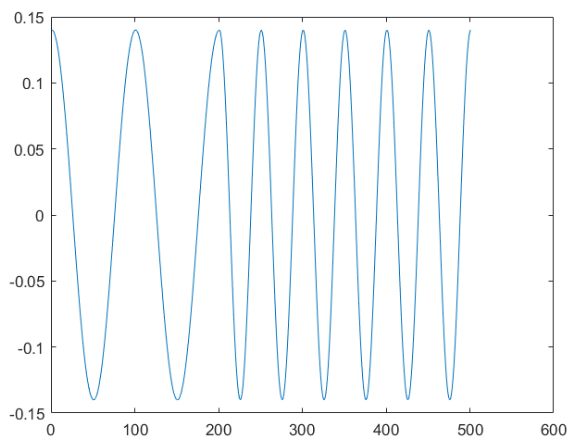
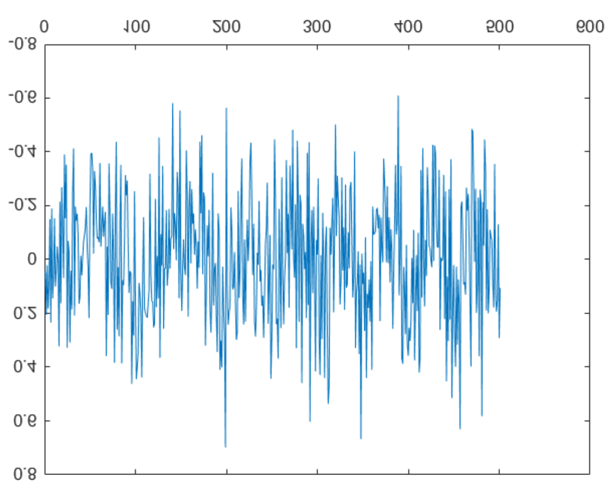
21600659
EEE-431



After modulating the bits with these two basis function, we get the following signal for the first five bits (0,0,1,1,1)

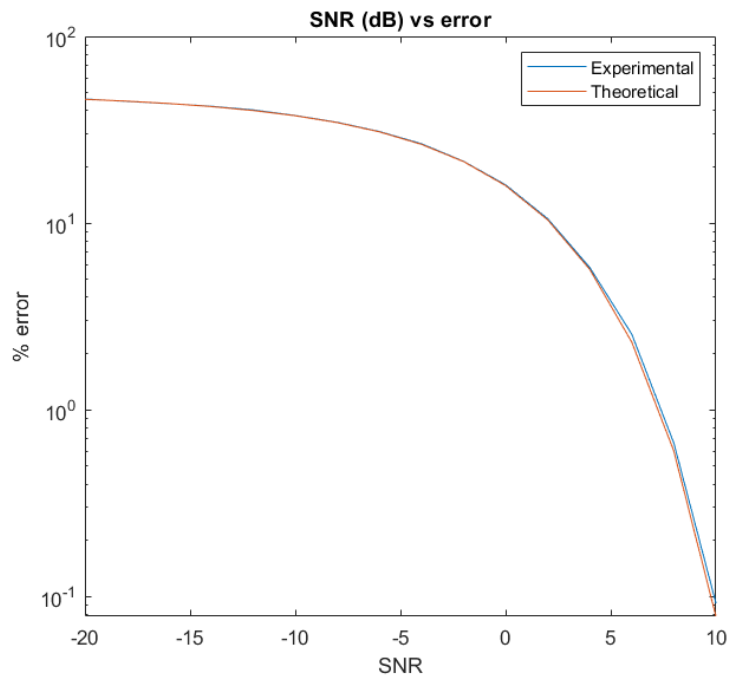


After adding some noise(SNR = 10 dB)



Similarly, we generate a bit stream of length 100000 modulated with BFSK. The two basis are correlated with the signal bits and the prediction is made using the decision rule; r1 > r2

Where r1 is the result of correlating with first basis and r2 is the result of correlating with the second basis. The error rate is calculated in the same way as in the first part.



It be seen that the experimental error is greater than the theoretical one. This could be due to limitations of sampling.

The theoretical SNR for BFSK is calculated as:

$$P_e = Q(\sqrt{SNR})$$

Q.7

For the non-coherent BFSK, assume the effects of channel propagation delay and introduce a phase in the modulated signal.

After modulating the bits with these two cosine with some phase, we get the following signal for the first five bits (0,0,1,1,1)

Abdul Basit Anees
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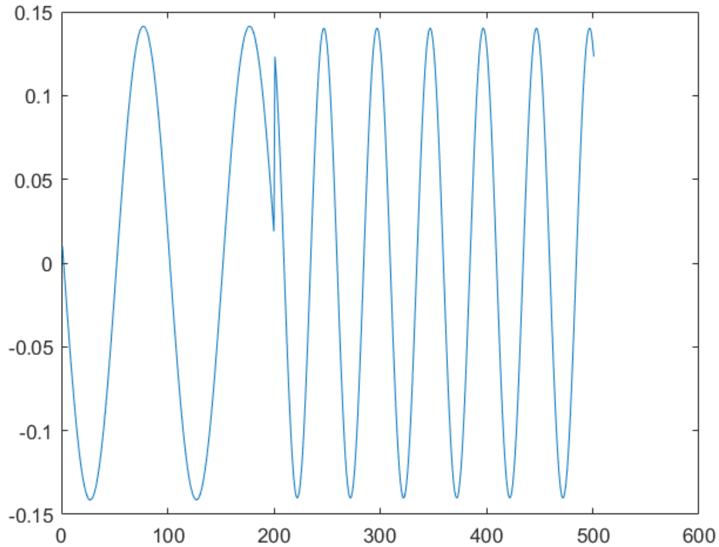
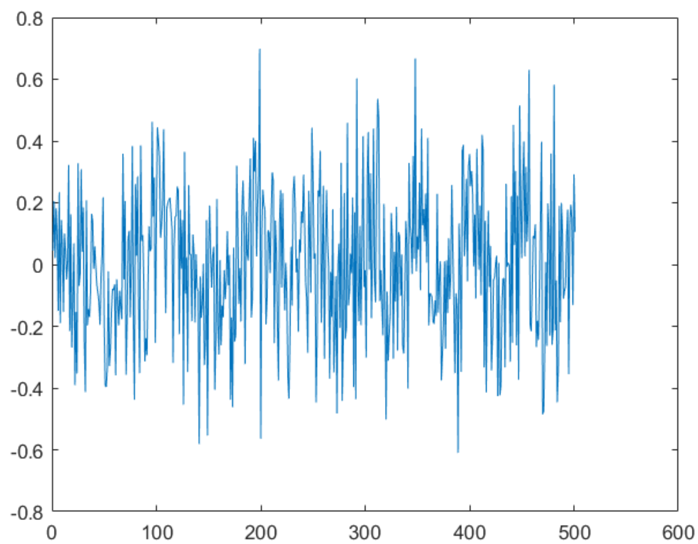


After adding noise (SNR = 10)



Then we generate cosine and sine of frequency f1 and f2 with zero phase and correlate with the received. The correlation outputs of sine and cosine with f1 frequency is added and squared (r1) and similarly for the frequency f2 (r2). Then the bits are predicted according to the decision rule r2 > r1. Accuracy is also found the same way as in previous parts.

It be seen that the experimental error is much greater than the theoretical one.

The theoretical SNR for BFSK is approximated as:

$$P_e = 0.5 * e^{-SNR/2}$$

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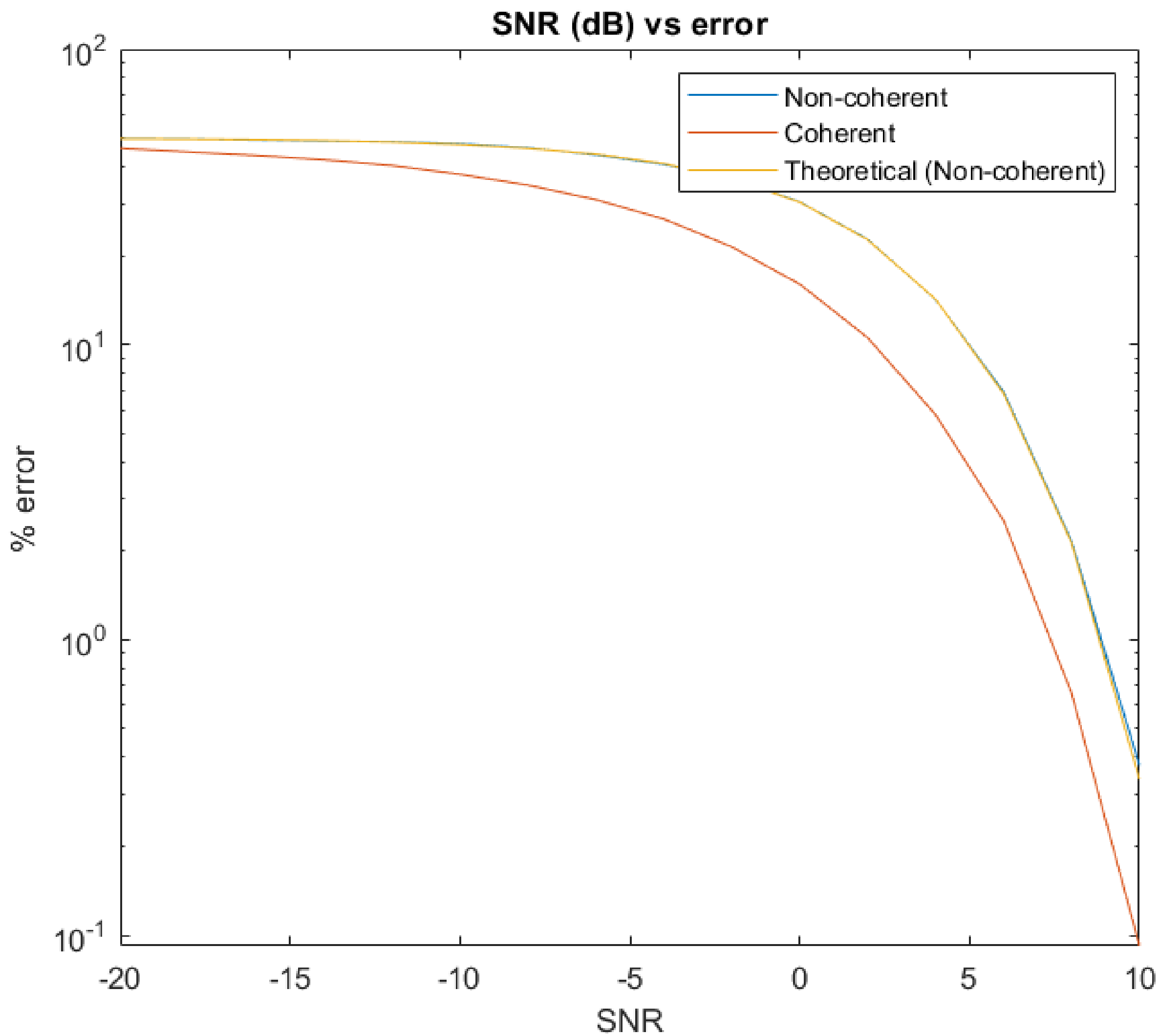

It can be seen that coherent detector performs better as expected. Moreover, the non-coherent detector perform bad at large SNRs compared to the theoretical value.