BIRZEIT UNIVERSITY

Information Technology Department

Communication Lab

ENEE4113

Course Project

Student 1: Abdelfattah Hasanat

ID: 1160663

Student 2: Mahmoud Nobani

ID: 1180729

Student 3: Basheer Rjoub

ID: 1180291

Instructor: Ashraf Al-Rimawi

Section: 5

June, 2022

Abstract
The aim of this project is to study how does the noise affect a pulse train of zeros and ones after it gets modulated through PAM channel

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Introduction

Data can be represented either by analog or digital signal. Line coding is a scheme in which digital data is converted into digital signals, so we have a set of discrete integers for example, then we present them in a discrete signal which have several discrete values represented by voltages.

After representing these data values then encoding them into signals, these signals are to be recreated in the other side of the demodulation, then after that decoding them to the original data again.

Here we consider polar non-return to zero baseband transmission, in this type of transmission, after encoding data, hence we have zeroes and ones, then ones usually represented by positive values, and zeroes are represented usually by negative values, so unlike the return to zero, signals here stay at the same signal, and don't return to zero at the half of the period of transmission that bit, also this scheme needs synchronization, because NRZ is not a self-clocking signal.

Polar NRZ-L

In this transmission the binary data may be presented by high voltage signals for the ones and negative voltages for the zeroes, or the opposite, for example the following figure shows how to represent the data 10110101, here we consider positive voltages for zeroes and negative voltages for ones.

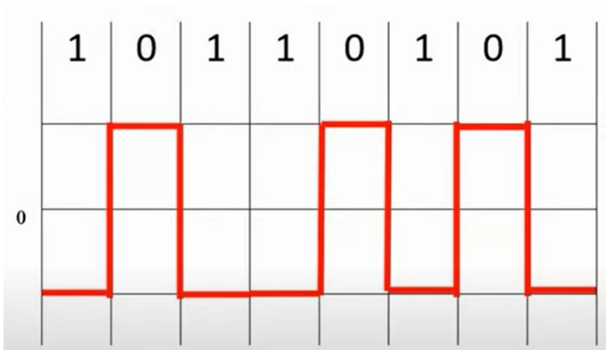


Figure 1:Polar NRZ-L

Polar NRZ-I

In this type of transmission, the ones are representing the change or the transmission, and the zeroes representing no transmission, or in other words, when we transmit zeroes we don't change the signal, and when we transit ones we change the signal from high to low or from low to high, as in the following example, assuming positive logic.

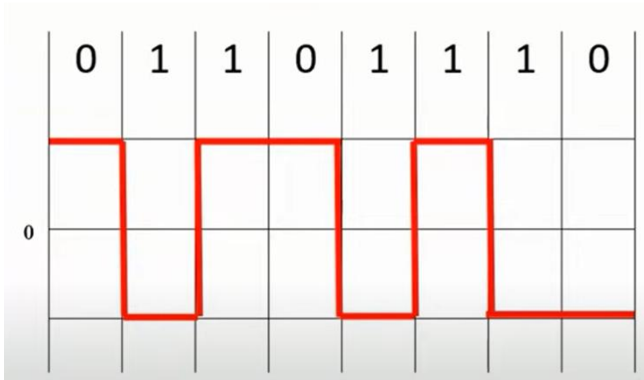


Figure 2: Polar NRZ-I

In this project we are dealing with the first scheme of polar modulation NRZ-L.

Additive White Gaussian Noise

When transmitting signals in channel, we encounter some interference this can be from other signals, and there is usually some noise that also interfere the signal from other sources which known as Additive White Gaussian Noise AWGN, which comes from natural noise sources such as the thermal vibrations of atoms in a conductor, shot noise, black-body radiation.

The summation of many random processes will tend to have distribution called Gaussian or Normal Distribution, so the noise N which we have in this project will act as a probability distribution function for error.

The receiver on the other hand has to decide if the signal is the same as the transmitted one, such that the probability or error is minimized, the receiver which satisfies this condition is known as the optimum receiver.

Let's consider a digital binary communication system, where bits 1 and 0 are represented by the signals S1(t) and -S(t), for this case E1 = E2 = E = $\int_0^{\tau} S1(t)^\wedge 2dt$

The probability of error is:

$$P_b^* = Q\left(\sqrt{\frac{\int_0^{\tau}(s_1(t) - s_2(t))^2 dt}{2N_0}}\right)$$

Equation 1: probability of error general formula

$$P_b^* = Q\left(\sqrt{\frac{\int_0^{\tau}(s_1(t)+s_1(t))^2dt}{2N_0}}\right)$$

$$P_b^* = Q\left(\sqrt{\frac{4\int_0^{\tau}(s_1(t))^2dt}{2N_0}}\right)$$

And now we define a new variable that represent the error for a 1-bit system caller BER:

$$\boldsymbol{P_b^* = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)}$$

Equation 2: Probability of error BER

So, from the equations above, to reduce the error we have to increase the Amplitude of the signal, or to reduce the data rate,

For an M-ary baseband signal the time domain representation of this signal as follows:

$$S(t) = \sum_{n=-\infty}^{\infty} Zn * V(t - n\tau)$$

Z is a discrete random variable

The power spectral density for this signal is:

$$G_s(f) = \frac{1}{\tau}|V(f)|^2 \cdot \left(\sigma_Z^2 + \frac{\mu_Z^2}{\tau}\sum_{m=-\infty}^{\infty}\delta\left(f - \frac{m}{\tau}\right)\right).$$

Equation 3: Power spectral density

And from the equation above we can derive the power spectral density equation for the polar non return to zero which is as follows:

$$G(f) = A^2\,\tau sinc(f\tau)$$

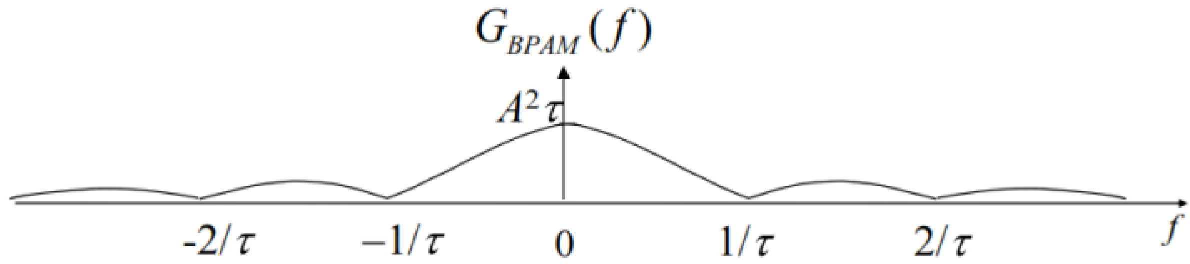


Figure 3: Power spectral density

Because the bandwidth for the Sinc is infinite, we need a practical approach to derive the bandwidth of the signal, so we found that 90% of the signal is within the first null when bandwidth = $1/\tau$ and 95% within the first two nulls, when B = $2/\tau$.

Procedure:

- At first, we started by connecting the needed blocks for this project, as shown in the figure below:

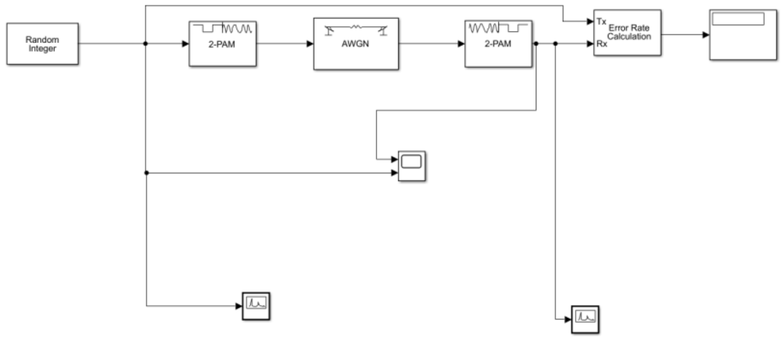


Figure 4: Block diagram

The blocks we used are, random integer generator that will generator a signal between 1 and 0, then PAM modulator and demodulator, AWGN unit that will produce noise, for calculation/display purposes we used error rate calculation unit, a scope, and spectral density unit.

- For the second part, we wanted to see how does the noise affect the signal, so we changed Es/No (which is energy per symbol) in AWGN to -5db and checked on both the modulated and demodulated signals as shown below:

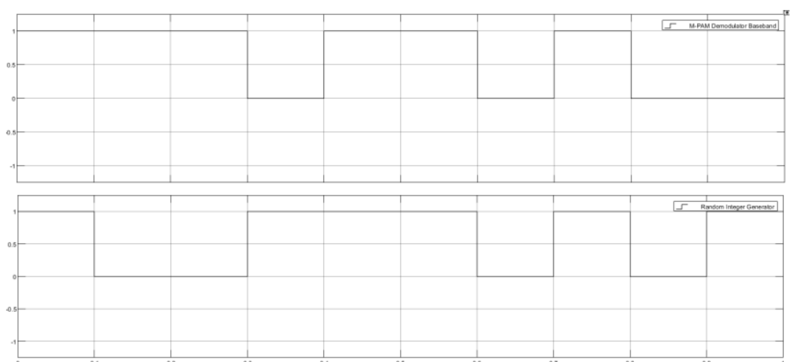
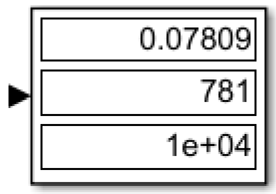


Figure 5: input vs output

we can see how the two signals are different when we changed the Es/No, and that's because the noise introduced by AWGN is high, where Es/No < 0.

- now we need the 90% and 95% bandwidth for the baseband for the signal, referring to the theory we know that 90% bandwidth: 1/tau = Rb = 10hz and the 95% bandwidth is double the 90% = 20hz
- the fourth part wanted the probabilty of the error for the system as a theoritical and an experimantal value,

we changed the parameters to match the desired ones where Es/No = 0, giving us the following error calculations:



Now for the theoretical part we used the following formula:

$$Q(\sqrt{\frac{2 * Eb}{No}})$$

But note that $\frac{Es}{No} = \frac{Es * \log_2 m}{No}$, where m=2, thus Es/No=Eb/No, another thing we need to take in consideration is that Es/No is in dB, 0 = log (Eb/No), Eb/No = 1, and substituting than in the last equation we got the following result: 0.07868 which is so close to the experimental one.

- For the fifth part, we want the spectral density for both the input and output signal, which we were able to get using the spectral density unit as shown in the figure below:

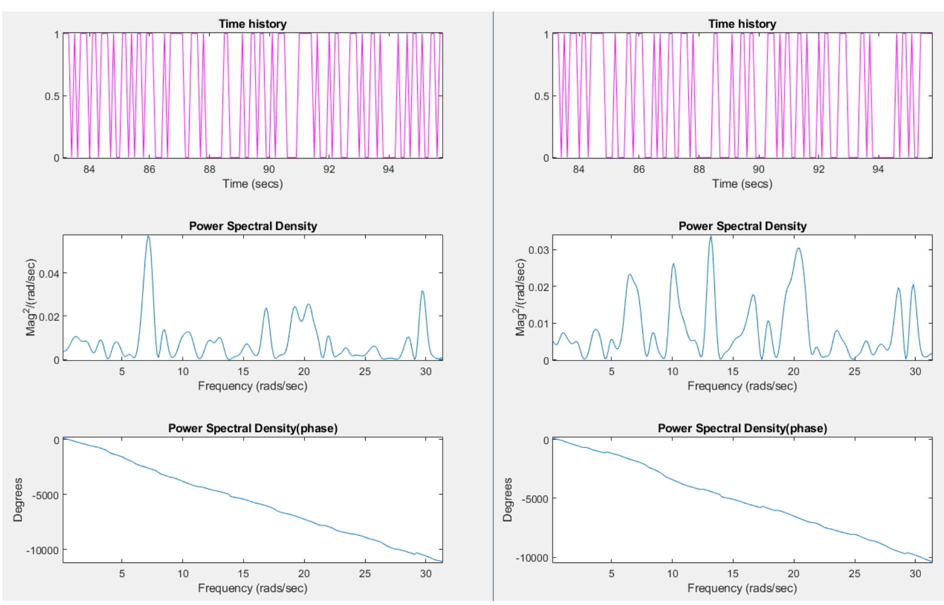


Figure 6: input spectral vs output spectral

First, we can see that apparent difference between the input and output spectral densities, another thing we can point out is the increased number of harmonics in the output spectral density which is directly caused by the noise.

❖ The last part of this project is to see how does the noise affect the signal using the error as a measuring scale:

Using different values of Es/No we got the following table:

Es/No in dB:	*Error calculations:*
-10	0.319 3190 1e+04
-9	0.3 3000 1e+04
-8	0.2808 2808 1e+04
-7	0.2574 2574 1e+04
-6	0.2347 2347 1e+04
-5	0.2097 2097 1e+04
-4	0.1831 1831 1e+04
-3	0.1551 1551 1e+04

-2	0.1299	1299	1e+04
-1	0.104	1040	1e+04
-0	0.07809	781	1e+04
1	0.05979	598	1e+04
2	0.0406	406	1e+04
3	0.0252	252	1e+04
4	0.0132	132	1e+04
5	0.006899	69	1e+04
6	0.0036	36	1e+04
7	0.0009999	10	1e+04

Table 1: Es/No vs BER

Now for the values we plotted the values we got from the table above in the aim to get a broader understanding of the relation between the Es/No and the error, the figure was as shown below:

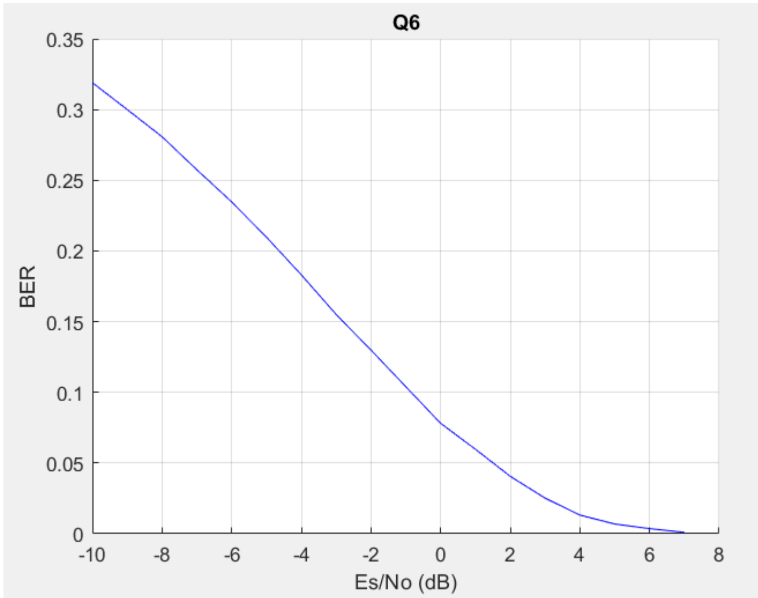


Figure 7: Es/No vs BER graph

Thus, we conclude that the higher Es/No is, the less error we will get.

Conclusion:

From this project we can see how does the noise affect the modulated signal, the measure Es/No and its relation with the error, the higher it is the less the error is, one of the common methods to remove the noise affect is to add the filter, thus reducing AWGN power and its “white property”, the filters we can use are Kalman filter, wiener filter etc.…, other solutions depend on what we are going to do with the signal.