BIRZEIT UNIVERSITY

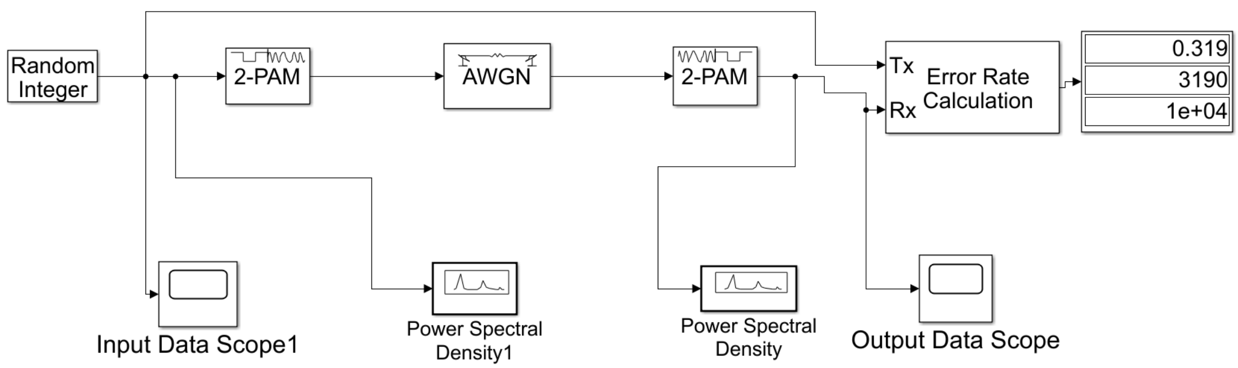
Faculty of Engineering and Technology

Department of Electrical and Computer Engineering

Second Semester 2021/2022

ENEE 4103- COMMUNICATIONS LAB

Lab Assignment



The block diagram, above, shows the generation, demodulation, and error rate calculation for baseband digital pulse amplitude modulation system. The data generated by the random integer generator is mapped into a baseband signal by the M-PAM modulator baseband unit. Additive white Gaussian noise (AWGN) is added to the transmitted signal during transmission. The noisy channel is modeled by the AWGN unit. The received corrupt signal (message + noise) is decoded into data by the M-PAM demodulator baseband unit. The error rate, obtained by the error-rate calculator unit, is calculated by comparing the discrepancies between the generated and decoded data.

Random Integer Generator: • M-ary number to 2 • Initial seed to 37 • Sample time to 0.1 • Output Data Type to double	**M-PAM Demodulator**: • M-ary number to 2 • Output type to Integer • Constellation ordering to Binary • Normalization method to Peak Power • Peak power (watts): to 1 • Samples per symbol to 1
M-PAM Modulator Baseband: • M-ary number to 2 • Input type to Integer • Constellation ordering to Binary • Normalization method to Peak Power • Peak power (watts) to 1 • Samples per symbol to 1	Set the simulation parameters (**Simulation** -> **Configuration Parameters**) as follows: • Start time to 0.0 • Stop time to 1000.0 (but will change) • Type to Variable-step • Solver to discrete (no continuous states) • Max. step size to auto
AWGN Channel: • Initial seed to 37 • Mode to Signal-to-noise ratio (Es/No) • Es/No (dB) to 10 (but will change this over the range -10, 7 dB) • Input signal power (watts) to 1	

• Symbol period(s) to 0.1

Table 1: **Unit Settings**

Project Outcomes:

1. Build your complete system using Simulink, subject to the specifications given in table 1.
2. Set M = 2, the simulation time to 1 sec (with the power spectral density components disconnected) and Es/No = - 5 dB. Run the program and compare the input data sequence to the output data sequence, as observed on the oscilloscopes. Comment on the result.
3. What is the 90% and 95% power bandwidth of the baseband signal in Hz?
4. Set the simulation time to 1000 sec and Es/No = 0 dB. Run the program and obtain the probability of error. Compare this value with the theoretical result.
5. Compare the input and output power spectral densities and explain the reason for the similarity or/ differences when Es/No = 0 dB (with the power spectral density units connected)
6. Set the simulation time to 1000 sec. Adjust the value of the Es/No (dB) in the AWGN block, starting from – 10 dB, incrementing by 1dB every step, and ending at 7 dB. Observe the error rate displayed in the Display block. Make a table recording the value of Es/No and the corresponding BER. Plot the error rate vs. Es/No in dB.

Remarks:

1. Work is allowed in groups, with at most 3 students in each group. Every group of students will be evaluated according to the following:
   a. A power point presentation (about 5 minutes)
   b. A written report that includes the assignment results, used equations, figures, discussion and conclusions.
   c. The group are requested to run the program to make sure that the results agree with those in the report.
2. Bring your own laptop to run and test your project.
3. It is important for everyone to be aware that he or she will be responsible for his own work. You may consult with your colleagues, but do depend on yourself in understanding the operation of the program.
4. **Project discussion dates will be announced in due time**

Some Theoretical Background on

Baseband Data Transmission

Binary data transmission by means of two voltage levels is referred to as baseband signaling. Manchester encoding, for example, is used in the Ethernet local area network as the signaling scheme. Here, we consider polar non-return to zero baseband transmission scheme in terms of probability of error, optimum receiver structure, power spectral density and bandwidth.

Polar nonreturn to zero (also known as binary pulse amplitude modulation)

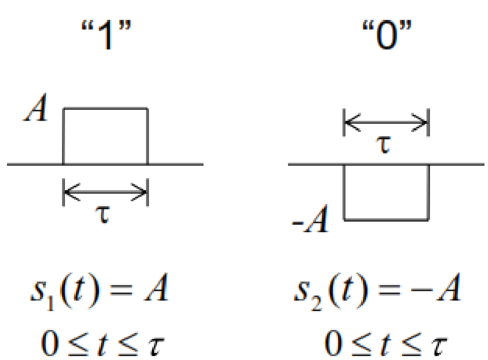
Signal Representation

The baseband signals representing digits 1 and 0 are:

$$s_1(t) = A\,, \qquad 0 \leq t \leq \tau$$

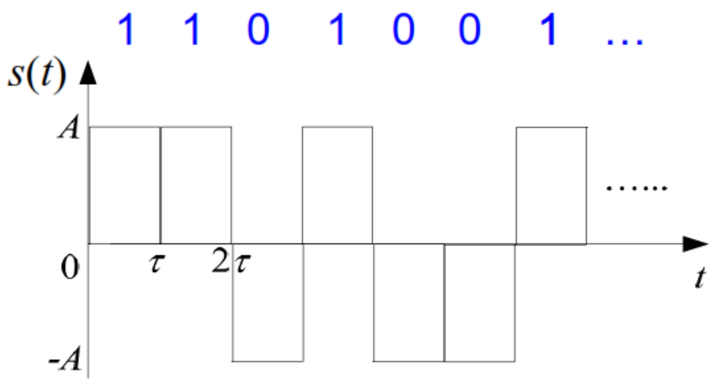
$$s_0(t) = -A\,, \qquad 0 \leq t \leq \tau$$

where, τ is the symbol duration and $R_b = 1/\tau$ is the data rate in bits/sec.



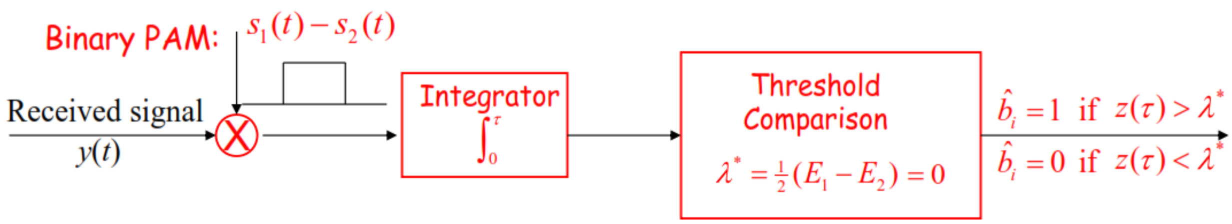
Generation:

The input to the modulator is a sequence of binary digits (0's and 1's). The modulator converts the sequence into a polar nonreturn to zero waveform (also known as binary pulse amplitude modulated waveform BPAM). The pulses are transmitted through the channel to the receiver.



Optimum Receiver

The optimum receiver is, of course, the matched filter, also implemented as a correlator, as shown in this figure.



Probability of Error:

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

Note that: $E_1 = E_2 = \int_0^\tau A^2 dt = A^2\tau \Rightarrow \lambda^* = (E_1 - E_2) = 0$

Average Energy per bit: $E_b = \frac{1}{2}(E_1 + E_2) = A^2\tau$

Optimal BER:

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

General Result on the Power Spectral Density of a digital M-ary baseband signal

The time-domain representation of a digital M-ary baseband signal is

$$s(t) = \sum_{n=-\infty}^{\infty} Z_n \cdot v(t - n\tau)$$

where Z_n is a discrete random variable with $\Pr\{Z_n = a_i\} = 1/M$, $i = 1, \ldots, M$,

$v(t)$ is a unit-baseband signal, and symbols in different time slots are assumed independent. Under these assumptions, the power spectral density of $s(t)$ is given by

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

Power Spectral Density of the polar non-return to zero baseband signal

The general result stated above for the M-ary baseand signal can be specialized to the polar nonreturn to zero transmission as follows

- The signal amplitude assumes two equally likely values. i.e., $\Pr\{Z_n = \pm 1\} = 1/2$
- The basic unit pulse is $v(t) = \begin{cases} A, & 0 \le t \le \tau \\ 0, & \text{otherwise} \end{cases}$
- The Fourier transform of the basic unit pulse is $V(f) = A\tau sinc(f\tau)$
- The mean and variance of Z are: $\mu_Z = 0, \ \sigma_Z^2 = 1$

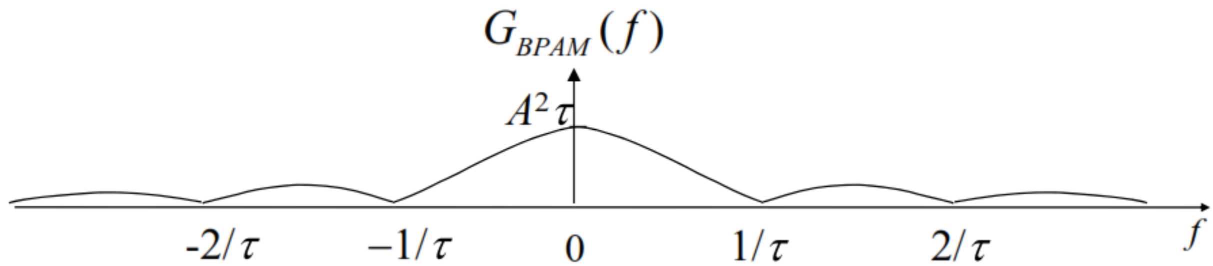
Remark: Recall that for a discrete random variable Z, the mean and variance are defined as

$$E(Z) = \sum_{all\ z_i} z_i P(Z = z_i)$$

$$Var(Z) = \sigma_Z^2 = \sum_{all\ z_i} (z_i - E(Z))^2 P(Z = z_i)$$

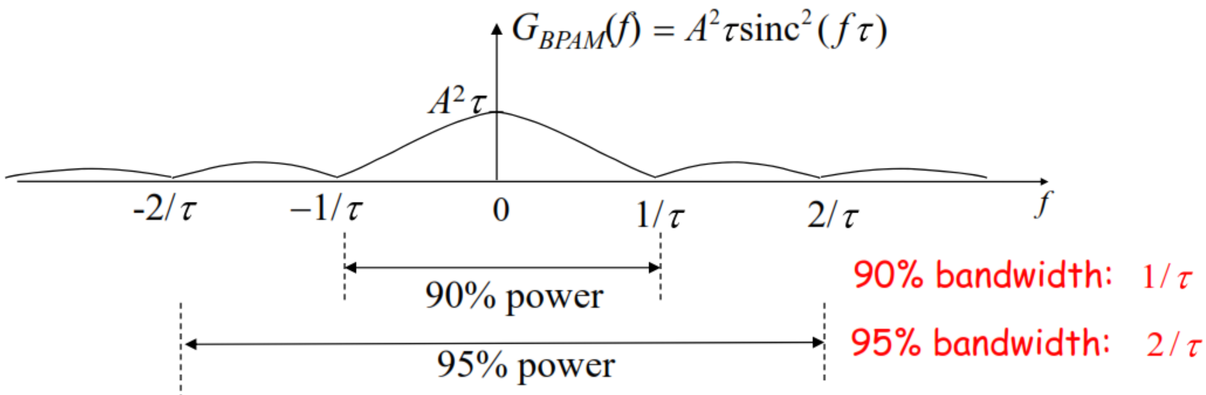
Therefore, the power spectral density of the polar non-return to zero signal is

$$G_{BPAM}(f) = A^2 \tau \text{sinc}^2(f\tau)$$



Bandwidth

The bandwidth can be obtained from the power spectral density.



The 90% power bandwidth = $\frac{1}{\tau} = R_b$ (data rate)

The 95% power bandwidth = $\frac{2}{\tau} = 2R_b$ (twice the data rate)

4-ary Line Coding

- Data patterns of size 2 bits are encoded as one signal element belonging to a four-level signal.
- Data is sent two time faster than with polar non-return to zero.
- Receiver has to discern 4 different thresholds

Binary Input	Output Voltage
00	-3
01	-1
10	1
11	3