Performance Study of the M-PAM Bandpass Wireless System

In this exercise you are asked to compare the performance of the M-PAM configuration for M=2 and M=8 respectively. This comparison will be based on Bit Error Rate (BER) and Symbol Error Rate (SER) probability measurements performed on a homodyne bandpass system with orthogonal pulse.

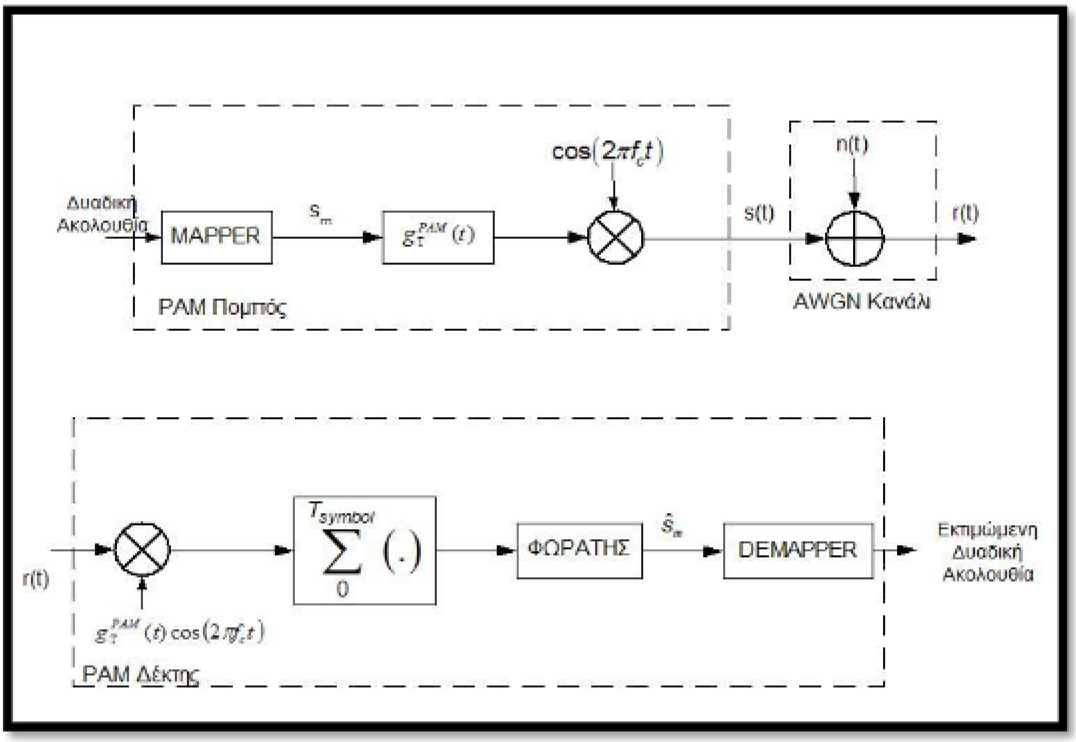

Figure 3. M-PAM Homodyne Live Passing System

Homodyne M-PAM

As shown in Figure 3, the transmitter of the M-PAM system receives as input a binary sequence, converts it into symbols, multiplies it by the orthogonal pulse, and then the signal is transferred to the transmission band through the modulator. AWGN noise is added to the sent signal, and it reaches the system's receiver. There it is demodulated to produce a one-dimensional vector, which is fed into the receiver where it is decided which symbol was sent. Finally, the demapper does the reverse mapping from symbols to bits. The system is described below.

Binary Input Sequence

The input of the system is a sequence of bits, where the values 0 and 1 are displayed isochronously. Such a sequence can be generated if you use any of the functions randsrc, rand, randn appropriately. The number of bits to send should be of the order of Lb = 10000 - 100000 bits.

Matching Bits – Symbols

The mapper is essentially a converter from bits to symbols. Each symbol corresponds to a specific sequence of M binary digits. Therefore, the mapper must for each M binary digits output one of the symbols in the configuration. Similarly, the demapper takes as input the symbol detected by the receiver's decision device (decision device), and outputs the corresponding sequence of M binary digits.

In the case of PSK, PAM, QAM configurations, an important element in this mapping is the Gray coding. According to this, if two symbols are adjacent in two-dimensional or one-dimensional signal space, then they are assigned arrangements of binary digits that differ by only one binary digit from each other.

Rectangular Pulse

The M-PAM system you are asked to simulate uses a rectangular pulse to transmit the symbols which is defined as:

$$g_T^{PAM}(t) = \begin{cases} \sqrt{\frac{2E_s}{T_{symbol}}} = \sqrt{\frac{2}{T_{symbol}}}, 0 \leq t \leq T_{symbol} \\ 0, \alpha\lambda\lambda o\acute{\upsilon} \end{cases} \quad (1)$$

where Es is the energy per symbol, which we normalize as Es = 1, and $Tsymbol$ is the symbol period.

M-PAM configuration

The M-adic PAM waveforms are one-dimensional signals, which can be expressed as

$$s_m(t) = A_m g_T^{PAM}(t) cos(2\pi f_c t), 0 \leq t \leq T_{symbol} \qquad (2)$$

where Am = (2m - (M + 1))A, m = 1, . . . , M. A determines the energy of the symbols. In the case where the PAM signals have different energies (e.g., when M > 2), we want the average energy of the transmitted symbols to be equal to 1.

Simulation Time Units

The system we want to simulate transmits symbols at a rate $Rsymbol$ = 250 Ksymbols/sec so the symbol period is $Tsymbol$ = 4 μsec. In the transmission band, the carrier frequency fc = 2.5 MHz is used, so the carrier period is Tc = 0.4 μsec. Within the simulation, in order to obtain a satisfactory representation of the bandpass signals, a sampling 2 times larger than the Nyquist limit is performed, i.e., we obtain 4 samples per carrier period, and thus the sampling period is $Tsample$ = Tc 4 = 0.1μsec.

AWGN channel

The bandpass signal transmitted by the system transmitter passes through an ideal additive noise channel. The noise is white and follows a $Gaussian$ distribution of zero mean and dispersion $\sigma2$ = $N02$. The noise can be generated using the $randn$ function.

The dispersion of the noise is determined each time by SNR/bit that we want to have at the system receiver. Recall that due to the normalizations we have done, the energy per symbol is Es = 1, so the energy per bit Eb = Es /Eb = 1 Es /M is Eb = 1 /M. The calculation of the SNR is based on the relation

$$SNR = 10log_{10}\left(\frac{E_b}{N_0}\right) = 10log_{10}\left(\frac{2E_b}{\sigma^2}\right) = 10log_{10}\left(\frac{2}{M\,\sigma^2}\right).$$

Demodulator M-PAM

The demodulator of the M-PAM system correlates (i.e. multiplies and integrates or sums) the received signal with the carrier and the orthogonal pulse. The correlation is performed in the time frame of a symbol period. In the simulation we assume that the M-PAM system is coherent. This means that the receiver knows the phase of the carrier and the time frames of each symbol, i.e. it is fully synchronized with the transmitter.

The demodulator correlates the received signal with the carrier component, resulting in a value r, which is the estimated value of the current symbol on the M-PAM constellation.

Foratis M-PAM

The node takes as input the value r, and decides which symbol (as defined vectorially above) it is closest to. The symbol Am that will have the smallest distance to r, corresponds to the symbol sent.

BER-SER measurements

To measure the BER (Bit Error Rate), i.e. the probability of a bit error occurring, you need to compare the bit value you received with the one you sent. To make reliable BER measurements, they must be derived from a sufficiently large amount of data. A "rule of thumb" is that to measure a BER value of 10^-2 you need 10^4 bits of data, for a BER of 10^-3 you need 105 bits of data, and so on.

BER curves are usually plotted on a logarithmic scale along the y-axis, i.e., in terms of error probability (see, e.g., Fig. 7.57, where some SER (symbol error probability) curves are shown).

To measure the SER (Symbol Error Rate), i.e. the probability of a symbol error, you need to compare the symbol value received with the one sent. Use the same amount of data that you used to calculate the BER.

Questions - Part B

1. Based on the above suggestions, implement the M-PAM system and describe its main points.

2. Measure the bit error probability and plot the BER curve for M = 2 & 8 for simple coding for values of SNR = 0: 2: 20 dB. Repeat the question for M = 8 if the symbols in the mapping were Gray coded. The curves should all be drawn on the same graph.

3. Measure the probability of symbol error and plot the SER curve for M = 2.8 for simple coding for values of SNR = 0: 2: 20 dB. The curves should again all be drawn on the same graph.