



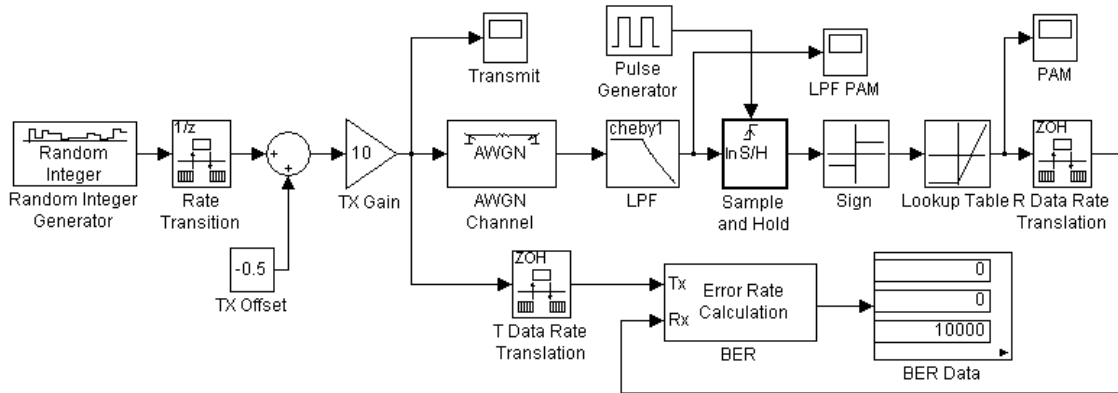
EE4513 Analog and Digital Communications Laboratory

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Bit Error Rate Determination in LPF Rectangular PAM

The performance of a digital communication system in the presence of additive white Gaussian noise (AWGN) can be assessed by the measurement of the bit error rate (BER). The *Simulink* model *Fig29.mdl* shown below is a rectangular polar pulse amplitude modulation (PAM) system with an AWGN channel and a simple (sample-and hold) receiver with a low pass filter.



The parameters of the Random Integer Generator block data source and the rectangular PAM transmitter is a rate of r_b b/sec, $M = 2$ levels (binary) and an resulting amplitude of ± 5 V. You are to chose a single *random amplitude* from the values $A = 1.2, 1.8, 3.3, 5$ or 12 V and a single *random bit time* from $T_b = 50$ μ sec to 500 μ sec ($r_b = 20$ kb/sec to 2 kb/sec) in steps of 50 μ sec.

$A =$ _____ V $T_b =$ _____ μ sec

The analog lowpass filter types available are Bessel, Butterworth, Chebyshev I, Chebyshev II and Elliptic. The BER simulation is to use an analog LFP of a type based on the first letter of your last name: A-E: Bessel; F-J: Butterworth; K-O: Chebyshev I; P- T: Chebyshev II; and U-Z Elliptic. You are also to report of the characteristics of your analog filter (cutoff frequency performance, ripple in passband, stop band attenuation) with research references from any source.

You must choose an appropriate simulation step time T_s . This data rate is somewhat higher than the *Simulink* example model (1 kb/sec) which used a 20 μ sec simulation step time T_s or a simulation frequency $f_s = 1/T_s = 50$ kHz.

Therefore the simulation step time $T_S = 1/f_S$ and the parameters of the Data Rate Translation blocks, Pulse Generator block as the control voltage for the Sample and Hold block, the bandwidth of the LPF, the values in the Lookup Table block for the correct polar received amplitude and the delay between the transmitted and received bits in the Error Rate Calculation block must all be carefully chosen for the simulation to be correct.

In particular, the pulse period (sec), pulse width (%) and phase delay (sec) parameters of the Pulse Generator block must be an integer multiple of the simulation step size T_S . For example, with a selected bit time $T_b = 450 \mu\text{sec}$, the simulation step size T_S was set to $10 \mu\text{sec}$ and the pulse period was $450 \mu\text{sec}$ ($45 \times T_S$), the pulse width was 20% ($0.2 \times 450 \mu\text{sec} = 90 \mu\text{sec}$ or $9 \times T_S$) and the phase delay was $220 \mu\text{sec}$ ($22 \times T_S$ and not $225 \mu\text{sec}$ since 22.5 is not an integer multiple) which is approximately $T_b/2$. The simulation step size $T_S = 10 \mu\text{sec}$ for $T_b = 450 \mu\text{sec}$ is an approximate scaling from the Fig29.mdl model ($T_S = 20 \mu\text{sec}$ for $T_b = 1 \text{ msec}$) but is appropriate to facilitate parameter selection.

The bandwidth of the LPF with 9 poles can be taken to be approximately 1.2 times the first spectral null bandwidth ($1/r_b$) for this baseband rectangular PAM signal. A good design practice would be to first scale the simulation step size T_S nearly linearly for the new bit time T_b and to temporarily use a Scope block to verify the system performance at various signal points. The performance of the LPF binary PAM digital communication system can be first verified by a small number of binary PAM data samples sent with *no* AWGN ($\sigma^2 = 0 \text{ V}^2$) which should result in 0 BER. Once the system is configured properly use a total *Simulation Stop Time* that would produce a data transmission of approximately 10 000 points or $10^4 T_b = 10^4 / r_b$ for your Laboratory.

Obtaining 0 BER with no AWGN for each of the Laboratory simulations is crucial since all other reported measurements will be incorrect if this is not met. If a non-zero BER with no AWGN is obtained, timing parameters and delays are the usual problems that can cause this performance error and could be different in each of the simulations specified.

Calculate the power in the transmitted signal and compute the SNR in dB in the standard range ∞ ($\sigma = 0$), 6, 2, 0, -2, -6, -10 dB by first determining then setting σ appropriately. Note that MS Table 2.3 shows the BER performance for fixed steps in the value of σ and not steps in the SNR as you are to have in this Laboratory. Your data will be a different table but the results in MS Table 2.3 can be used in your discussion of BER performance in your Laboratory Report. Note that it is not reasonable in digital communications to even report a BER greater than approximately 0.2 (2 in 10 bits in error).