

EE3101 Communication Engineering

Tutorial 4

- (1) Consider the waveforms in Fig.1a are used to transmit binary signals and a receiver in Fig.1b is used for signal detection.
- (a) Assume that the reference signal $\psi = B$ and B is a non-zero constant, show that the probability of bit error is:

$$P_B = Q\left[\sqrt{\frac{3E_b}{2N_0}}\right].$$

- (b) Is the receiver in (a) an optimum receiver? Why?
- (c) Choose an optimum reference signal ψ for the receiver in Fig.1b and then derive the probability of bit error P_B in terms of $\frac{E_b}{N_0}$. Hence evaluate P_B for $\frac{E_b}{N_0} = 12dB$ by using the approximation that $Q(x) \sim \frac{1}{x\sqrt{2\pi}} \exp(-\frac{x^2}{2})$.

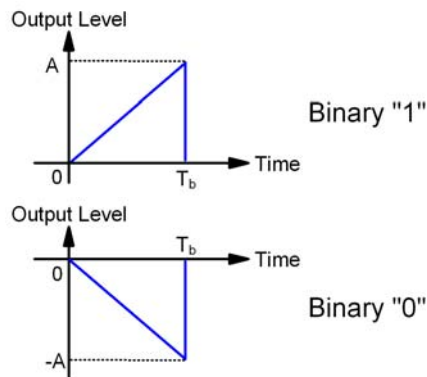


Fig.1a Waveform Representation for Binary “1” and “0”

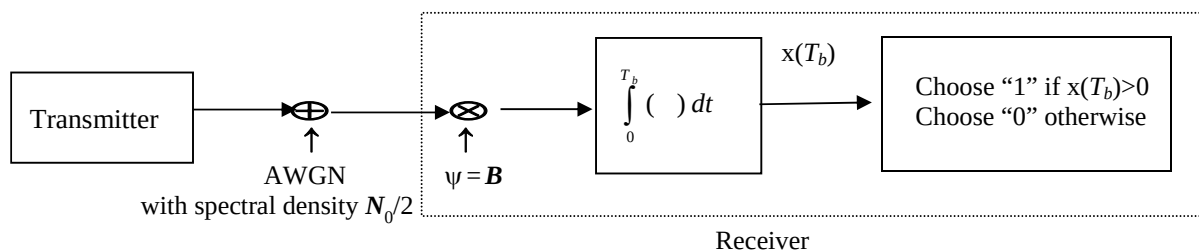


Fig.1b Block Diagram of a Digital Communication System

- (2) If the reference signal in Section 1.7.1 is replaced by a constant B , derive the bit error probability P_B in terms of E_b/N_0 for the Unipolar NRZ signal.
- (3) Use the same receiver block diagram as in (2) and with the reference signal equals B , derive the bit error probability P_B in terms of E_b/N_0 for the Bipolar NRZ signal (i.e. NRZ-L).
- (4) Use the block diagram of the receiver as in Section 1.7.2, derive the bit error probability P_B in terms of E_b/N_0 for the Unipolar NRZ signal.

** (5) Phase response of a filter is important in narrowband digital communication systems.

- (a) The transfer function of a 2nd order low pass filter can be expressed as:

$$H(\omega) = \frac{\omega_0^2}{(j\omega)^2 + j\frac{\omega\omega_0}{Q} + \omega_0^2} \quad \omega_0 = \omega_1\omega_c$$

where Q and ω_1 are filter parameters for various type of filters, ω_c is the cutoff frequency of the filter.

Plot the phase response $\varphi(\omega)$ of the following 2nd order low pass filters with $\omega_c = 1000 \text{ rad/s}$

- (i) Butterworth: $Q = 0.7071, \omega_1 = 1$.
- (ii) Bessel: $Q = 0.57735, \omega_1 = 1$.
- (iii) 0.5dB Chebyshev: $Q = 0.86372, \omega_1 = 1.23134$.
- (b) Let Group Delay to be defined as: $GD = -\frac{d\varphi(\omega)}{d\omega}$
Plot GD of the 3 filters in (a).
- (c) Plot GD of the 2nd, 4th and 6th order Butterworth low pass filters with $\omega_c = 1000 \text{ rad/s}$

$$H(\omega) = \prod_{i=1}^n \frac{\omega_i^2 \omega_c^2}{(j\omega)^2 + j\frac{\omega\omega_i\omega_c}{Q_i} + \omega_i^2 \omega_c^2}$$

$n = 1, 2, 3$ for 2nd, 4th and 6th order respectively.

order	ω_1	Q_1	ω_2	Q_2	ω_3	Q_3
2	1.00000	0.70711				
4	1.00000	1.30656	1.00000	0.54120		
6	1.00000	1.93185	1.00000	0.70711	1.00000	0.51764

**** The PLOTTING won't be included in Quiz/Test/Exam**