Tutorial No.5

Period 3 - 2006

Topic: ISI, Bandpass modulation and demodulation

Exercise 1

Consider a BPSK system with equally likely waveforms $s_1(t) = \cos(\omega_0 t)$ and $s_2(t) = -\cos(\omega_0 t)$. Assume that the received E_b/N_0=9.6 dB, giving rise to a bit error probability of 10^{-5}, when the synchronization is perfect. Consider that carrier recovery with the PLL suffers some fixed error ϕ associated with the phase estimate, so that the reference signals are expressed as $\cos(\omega_0 t + \phi)$ and $-\cos(\omega_0 t + \phi)$.

1. How badly does the bit-error probability degrade when $\phi = 25$ degrees?
2. How large a phase error would cause the bit-error probability to degrade to 10^{-3}?

Exercise 2

The output of a channel sampled at time kT is

$$x_k = h_0 a_k + h_1 a_{k-1} + v_k$$

where the data symbols $a_k = \pm 1$, are equal probable and uncorrelated. Moreover, v_k are independent, zero-mean samples of noise with variance σ^2. a linear equalizer with 3-tap coefficients is used to process the channel's output. The equalizer output at time kT is

$$y_k = \sum_{n=0}^{2} c_n x_{k-n}.$$

The three tap coefficients are required to minimize the mean square value of the error between the kth equalizer output sample at the kth data symbol, a_k. Determine the coefficients and the minimum MSE for $h_0 = 1$ and $h_1 = 0.3$, and $\sigma^2 = 0.01$.

Exercise 3

A coherent binary PSK system using a correlation receiver is transmitting 100 [kbps]. Noise power spectral density at the receiver is $N_0/2 = 2.5 \times 10^{-7}$

[Volts^2/Hz] and the channel attenuates the amplitude of the transmit signal by 75% (so that only 25% of the transmitted signal arrives at the receiver). The amplitude of the transmitted carrier signal is 3.0 [volts] and the carrier frequency is 800 [kHz].

- Determine the channel bandwidth required for the transmitted signal if ideal Nyquist pulse shaping is used. Also state the maximum lower cutoff frequency of the channel (f_l) and the minimum acceptable upper cutoff frequency of the channel (f_h).
- Determine the probability of bit error of the received signal.
- Suppose that we want to improve the accuracy by raising the power of the transmitted signal. What is the minimum average power of the transmitted signal that will produce a probability of bit error of 10^{-7} or less?

Exercise 4

Repeat Exercise 3, except the system is transmitting coherent binary FSK with $\Delta f = 50$ [kHz]. Compare the results and comment on them.

Exercise 5

- An M-ary PSK, ISI-free system is to operate with 2^k PSK symbols over a 120 [kHz] channel. The minimum required bit rate is 900 [kbps]. What minimum SNR is required to maintain reception without a P_b no worse than 10^{-6}?
- Repeat the above task for an M-ary QAM system, recalculating the new value for the minimum required SNR to maintain reception with a P_b no worse than 10^{-6} and comment on this new result.