Topic 4: Introduction to Communication Systems

Academic Year 2013 - 2014

P1.- Suppose a transmitter with 1W of transmitted power through the air. The received power in the antenna of the receiver is -40dBm. Obtain the attenuation suffered by the signal through the air. If the system needs a power of -15dBm in the receiver, what would be the gain (in natural and in logarithmic units) of the required amplifier?

P2.- A system consists of two amplifiers with 20dB and 15dB gain, respectively, connected by a length 12km line whose attenuation is 2dB/km. Obtain the power delivered to the output if the input power is 4mW.

P3.- Let $x(t)$ be a continuous signal with Fourier transform $X(j\omega)$. $x(t)$ is sampled with a pulse train to generate

$$x_p(t) = \sum_{n=-\infty}^{\infty} x(nT)\delta(t - nT)$$

where $T = 10^{-4}$. Suppose the following restrictions to indicate if the sampling theorem guarantees that $x(t)$ can be recovered accurately from $x_p(t)$.

a) $X(j\omega) = 0$ when $|\omega| > 5000\pi$
b) $X(j\omega) = 0$ when $|\omega| > 15000\pi$
c) $Re\{X(j\omega)\} = 0$ when $|\omega| > 5000\pi$
d) $x(t)$ real y $X(j\omega) = 0$ when $\omega > 5000\pi$
e) $x(t)$ real y $X(j\omega) = 0$ when $\omega < -15000\pi$
f) $|X(j\omega)| = 0$ when $\omega > 5000\pi$

P4.- Suppose an analog signal whose amplitude follows a Laplacian distribution with $f_x(x) = 4e^{-8|x|}$. This signal is quantified with a 4-level uniform quantizer with a dynamic range between -1 and 1 volt. Obtain the quantization noise power. Compare this noise with the case of a uniform distribution $f_x(x) = U[-1,1]$.

P5.- A digital recording system for Compact Disk alternately samples the two channels of a stereo system taking 44000 samples/second for channel. The CD uses PCM code words of 16 bits. Obtain the SNR_q for a sinusoidal signal with amplitude A. Assume uniform quantization, white noise and the amplitude of the signal coincides with the range of the quantizer.

P6.- A PCM system multiplexes the information the information of 14 channels in a signal of 350Kbps. Each channel is the output of an analog/digital converter with uniform quantization and a dynamic range of ± 2 volts. The number of quantization levels is such that the SNR_q for a 2 volt amplitude sine is approximately 38dB. The input signals to the A/D are sampled at 1.4 times the Nyquist frequency. Obtain:

a) The number of quantization levels.
b) The bandwidth of the analog signals input to each A/D converter.

P7.- Consider an analog signal whose amplitude is a uniform distribution U [-5,5] (in volts). This signal is quantized using a 4-level uniform quantizer with a dynamic range of 4 volts. Obtain:

a) The quantization noise power.
b) List two possible modifications of the quantizer to reduce the quantization noise calculated in the previous section. Which of these two changes would be most effective? Justify your answer.

P8.- Suppose you want to transmit three voice signals ($s_1(t)$, $s_2(t)$ y $s_3(t)$), simultaneously, through an ideal bandpass channel with cutoff frequencies 100KHz and 140KHz. Each voice signal is low-pass type , with 4KHz bandwidth . To transmit these signal, there are three possible schemes:

- DBL modulation (DSB- SC): with carrier amplitude $A = 1$.
- AM modulation: with carrier amplitude $A = 1$; modulation index $k = 1$ and signal power $P_m = 1$W.
- FM modulation: with modulation index $\beta_f = 1$ and normalized power $P_{m_n} = 1$.

a) If we want the best SNR in reception, what modulation scheme should we use?
b) Draw the complete schematic (indicating the signals involved , adders , multipliers, filters with cutoff frequencies...) modulator and demodulator to transmit and retrieve the three voice signals, depending on your choice in the previous section.

P9.- Suppose you want to transmit audio signals (lowpass signals with 8KHz of bandwidth) through an ideal bandpass channel (cutoff frequencies 100KHz and 200KHz). There are two possible schemes:

- AM modulation: with carrier amplitude $A = 1$; modulation index $k = 1$ and signal power $P_m = 1$W .
- FM modulation: with modulation index $\beta_f = 1$ and normalized power $P_{m_n} = 1$.

Specify the modulation scheme used, the number of audio signals that can be transmitted simultaneously and the optimal carrier frequencies used to transmit these signals in these two cases:

a) To maximize the number of transmitted audio signals.
b) To transmit the audio signals with the best SNR.

P10.- Consider a wireless digital communications system, which can support BPSK, QPSK and 8PSK modulation. The transmitter and receiver antenna gain are $G_t = 5$dB and $G_r = 3$dB, respectively; the maximum transmission power is $P_{max} = 1$W; the symbol rate is $R_s = 4$Msps; the bit error rate that can support the service is max $BER = 10^{-3}$; and the noise power at the receiver is $N = 10^{-7}$W . The propagation model applicable in the system environment is: $l = 10d^2$, where d represents the distance in meters and l the propagation losses in natural units.

a) Obtain the maximum distance between transmitter and receiver and the bit rate of the system when using the modulation that provides highest speed and lowest robustness.

b) At that maximum distance, obtain the minimum transmitted power to ensure the maximum *BER*, using the two others modulation schemes. Obtain the bit rate of the system in both cases.
c) If a user is 700m away from the transmitter and the transmit power is the highest, which modulation is feasible?
d) To increase the coverage, an analog repeater is installed 500m away from the original transmitter. It amplifies the received signal 50dB, and retransmits (without any noise) using an antenna with the same gain as the original transmission. Assuming the use of 8PSK, obtain the total straight-line distance from the original transmitter, if the signal passes through the installed repeater.

Bit error probability of MPSK modulation: (*snr* in natural units)

$$BER(MPSK) = 0{,}2 \cdot exp\left(\frac{-1{,}5 \cdot snr}{M-1}\right)$$

P11.- A WiFi system can support the modulations QPSK, 16QAM and 64QAM. We want to analyze the performance of an access point located in the outside of a building. The antenna gain of the access point and mobile terminal are G_{AP} = 5dB and G_{MT} = 2dB, respectively; the maximum transmission power is P_{max} = 200mW; the symbol rate is R_s = 20Msps; the maximum probability of error that can support the offered service is *BER* = 10^{-3}; and the noise power at the receiver is N = 10^{-12}W. The losses in the system environment are: $L(d_{km}) = 100 + 25 \cdot log(d_{km})$; where d_{km} represents the distance in kilometers, and *L* the propagation losses in dB.

a) Obtain the maximum distance of the link.
b) Assume that the system misses 20% of the total rate. Obtain the system bit rate (useful) at that point.
c) Assume that the mobile terminal is closing to the base station. At what point the system might start using 16QAM modulation? Obtain the new bit rate at that point.
d) If at that point we want to use 64QAM modulation, and allow us to change the access point antenna with a higher gain, what would be the required antenna gain?
e) Instead of changing the antenna, we add a channel encoder that improves the *BER*. For a given *BER*, there is a coding gain of 5dB (the *SNR* required to achieve the same *BER* decreases 5dB). The encoder adds 3 redundancy bits every 4 useful information bits. If 64QAM modulation is used, what are the new *BER* and useful bit rate?

Bit error probability of M-order modulation: (*snr* in natural units)

$$BER(MPSK) = 0{,}2 \cdot exp\left(\frac{-1{,}5 \cdot snr}{M-1}\right)$$

P12.- A group of three stations share an Aloha channel with 56Kbps. The average bit rate transmitted by each station is R1 = 7.5Kbps, R2 = 10Kbps and R3 = 20Kbps. The size of each packet (or message) is 100bits. Obtain:

a) The normalized total traffic channel.
b) The normalized throughput.
c) The probability of successful transmission.
d) The rate of successfully received packets (without collision).

P13.- Measurements performed on a s-Aloha channel probe that 20% of the time slot are not used.

a) What is the normalized total traffic on the channel?
b) What is the normalized throughput?
c) Is the channel overloaded?

P14.- There are two available channels: with Aloha and s-Aloha protocol, respectively. The normalized total traffic in both channels is 0.9.

a) Is overloaded the Aloha channel? And the slotted Aloha channel?
b) What is the normalized throughput in each channel?
c) What is the probability of successful transmission in each channel?
d) If the total rate of messages transmitted on both channels is 20 messages/s, what is the rate of successfully received messages in each channel?

P15.- A mobile communication system uses 25MHz of uplink bandwidth and 25MHz of downlink bandwidth. This bandwidth is divided into 125 channels. Each of these channels is shared by 8 users using TDMA. Obtain:

a) The total number of users that can be supported in the system.
b) The available bandwidth for every user.