Tutorial No.2

Period 3 - 2006

Topic: Sampling, Quantization and baseband transmission

Exercise 1

We wish to transmit a 100-character alphanumeric message in 2 s, using 7-bit ASCII coding, followed by an eighth bit for error detection, per character. the eight bit is chosen so that the number of ones in the 8 bits is an even number. A multilevel PAM waveform with M=32 level is used.

1. Calculate the effective transmitted bit rate and the symbol rate.

2. Repeat part(1) for 16-level PAM, eight-level PAM, four-level PAM, and PCM (binary) waveforms.

Exercise 2

Aliasing will not occur if the sampling rate is greater than twice the signal bandwidth. However, perfectly bandlimited signals do not occur in nature. Hence, there is always some aliasing present.

1. Suppose that a filtered signal has a spectrum described by a Butterworth filter with order $n = 6$, an upper cutoff frequency $f_u = 1000$ Hz. What sampling rate is required so that aliasing is reduced to the -50 dB point in the power spectrum?

2. Repeat for a Buttherworth filter with order $n = 12$.

Exercise 3

The information in an analog waveform, whose maximum frequency $f_m = 4000$ Hz, is to be transmitted using a 16-level PAM system. The quantization distortion must not exceed $\pm 1\%$ of the peak-to-peak analog signal.

1. What is the minimum number of bits per sample or bits per PCM word that should be used in this PAM transmission system?

2. What is the minimum required sampling rate, and what is the resulting bit rate?

3. What is the 16-ary PAM symbol transmission rate?

Exercise 4

An analog signal has a pdf that is symmetric around 0 and that takes the value 0.1 between -2.5 V and -1 V, 0.3 between -1 V and -0.5 V, and 0.4 between -0.5 V and 0 V. The signal is quantized by an ADC that has four quantization levels and operates between -1 V and 1 V. The quantization levels are uniformly distributed over the dynamic range, and the ADC outputs the middle values of the respective intervals. Calculate the quantization noise variance (both linear and saturation noise) and the probability of saturation.

Exercise 5

A compact disc (CD) recording system samples each of two stereo signals with a 16-bit AD-converter at 44.1 kilosamples/s.

1. Determine the output signal-to-noise ratio for a full-scale sinusoid.

2. If the recorded music is designed to have a crest factor (peak-to-rms ratio) of 20, determine the average output signal-to-quantization noise ratio.

3. The bit stream of digitized data is augmented by the addition of error-correcting bits, substitution bits to aid the clock extraction by a phase-locked loop (PLL), and display and control bit fields. These additional bits represent 100% overhead; that is, 2 bits are stored for each bit generated by the ADC. Determine the output bit rate of the CD recorder system.

4. The CD can record an hour's worth of music. Determine the number of bits recorded on a CD.

5. For a comparison, a good collegiate dictionary may contain 1500 pages, 2 columns/page, 100 lines/column, 7 words/line, 6 letters/word, and 6 bits/letter. Determine the number of bits required to describe the dictionary and estimate the number of comparable books that can be stored on a CD.