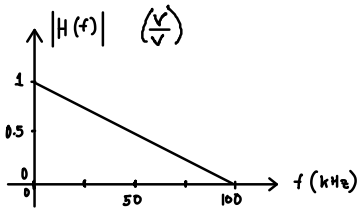
ELEX 4340 : Data Communications
2013 Fall Session

Assignment 3

Due Monday, October 27. Show your work. Hand in your assignment at the lecture or during office hours. Assignments submitted after the solutions are made available will be given a mark of zero.

Question 1

The diagram below shows the magnitude of the transfer function (frequency response) of a low-pass channel. What are the (one-sided) 3dB and 6dB bandwidths?



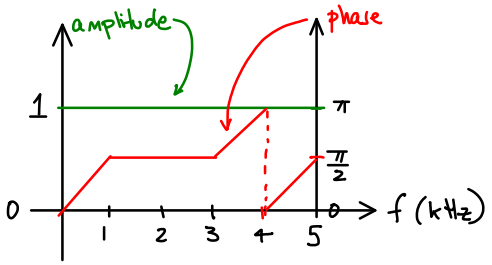
Question 2

Sketch a (low-pass) root raised-cosine (RRC) frequency response with $\alpha = 0.35$ designed for a symbol rate of 1 MHz. Label the frequencies at which the response is zero and a maximum. What is the magnitude of the frequency response at 500 kHz?

The datasheet for a transmit filter claims no ISI will result if the receiver has this frequency response (a 1 MHz RRC $\alpha = 0.35$). However, the frequency response of the transmit filter does not match what you drew. Why not? Assume these filters are designed for a channel that does not affect the frequency content of the signal (e.g. a satellite link).

Question 3

What is the (minimum possible) delay of a 2 kHz signal passing through the channel with the frequency response shown in the following diagram? What is the next largest possible delay?

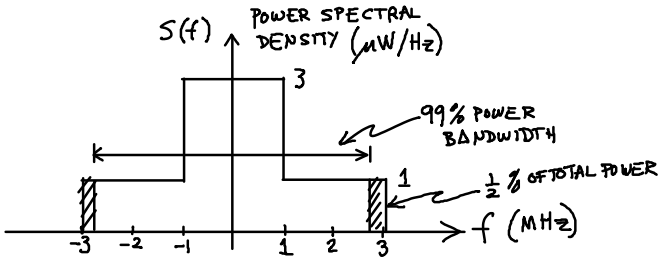


Will a 2 kHz sine-wave signal be distorted? How about a signal that contains both 1 kHz and a 2 kHz frequency components?

What is the maximum group delay of this channel?

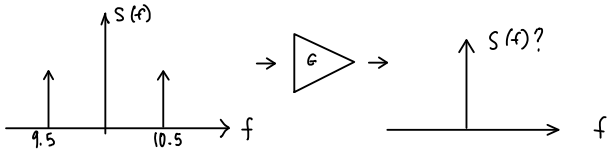
Question 4

The graph below shows the power spectrum (power versus frequency) measured for a radio signal. The frequency axis is labelled as the offset from the center frequency of the signal. What is the 99% power bandwidth? *Hint: the power between two frequencies is the area under the power vs frequency curve between those frequencies.*



Question 5

Two signals at frequencies of 10 MHz $\pm$ 500 kHz are input to a non-linear amplifier. What are the frequencies of the third-order intermodulation products? Which of these will appear within 1 MHz of the center frequency (10 MHz)?



Question 6

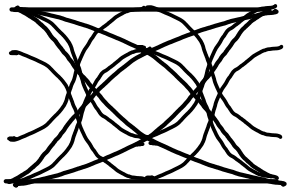
What is the probability that a normally-distributed random variable with a standard deviation of 5 and a mean of 50 exceeds 60? *Hints: the standard deviation is the square root of the variance. See below for how to calculate values of the Gaussian CDF.*

Question 7

Gaussian noise with a variance of $0.5\ V^2$ is added to a bipolar NRZ signal with levels $\pm 1\ V$. What is the SNR? The signal is sampled and a decision is made based on whether the signal level is positive or negative. Under what condition will the noise cause an error? What is the error rate?

Question 8

You input a random NRZ pulse into a cable and connect an oscilloscope to the other end of the cable. You set up the 'scope to trigger once per pulse and observe the following waveform:

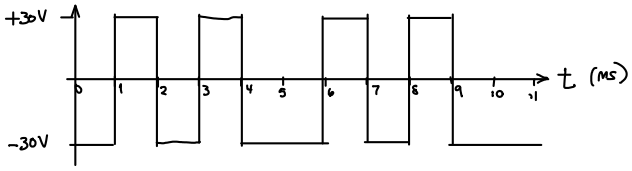


What is the common name for this diagram? Does this channel meet the Nyquist no-ISI criteria? How can you tell? What does this imply about the ability of the receiver to recover the transmitted data without error?

Question 9

What is the minimum number of pins that can be used to exchange data in both directions over an "RS-232" serial interface?

You capture the following waveform:



Is this signal compliant with the RS-232 standard? What is the data rate? What character was sent?

Question 10

You need to select appropriate parameters for an OFDM system operating over a channel with a bandwidth of 1 MHz and an impulse reponse which is typically less than $10\mu s$.

What sampling rate would you use if you want the sampling rate to be 20% larger than the Nyquist sampling rate ($2\times$ the bandwidth)?

If the guard time is to be equal to the maximum duration of the channel impulse response but no more than 10% of the OFDM block duration (not including the guard time) what is the minimum block duration in seconds? In samples?

What block size would you use if the block size had to be larger than the value computed above but also a power of 2?

Question 11

Broadcast TV channels are about 6 MHz wide and can be received over the service area at an SNR of at least 16 dB. What is the (minimum) Shannon capacity of this channel?

The digital TV data rate requirement is about 20 Mb/s. What is the minimum SNR that would allow error-free transmission at this rate, assuming no constraints (limitations) on the transmitter and receiver design?

Computing Gaussian CDFs

The calculators commonly used at BCIT can compute the values of the Gaussian (Normal) cumulative distribution function (CDF). This is the area under the Gaussian curve to the left of a certain value. Check your calculator's documentation for more details.

Sharp ELW-516

Press: MODE, 1 (STAT), 0 (SD), MATH, 1 (P)

The argument to the Gaussian CDF, the $P()$ function, is calculated by subtracting the mean $\overline{x}$ and dividing by the standards deviation σ_x of the distribution:

$$t = \frac{x - \overline{x}}{\sigma}$$

Casio 991ES

Press: MODE 3 (DIST), 1 (Normal PD)

Enter the offset (x), standard deviation (σ) and mean (μ) each followed by equal sign ($=$). The probability, p, is displayed.

Other Calculators

You can use the Logistic function approximation[1]:

$$F(t) = \frac{1}{1 + e^{-1.7t}}$$

where t is calculated by subtracting the mean and dividing by the standard deviation as above. This approximation has a maximum error of about 0.01 which is sufficient for our purposes.

[1] S. Bowling *et al*, *A logistic approximation to the cumulative normal distribution*, *JIEM*, vol. 2, no. 1, pp. 114-127,