2. Laboratory 2 - Introduction to Signals and Modulation

In class you have been introduced to the Physical Layer, and in particular, some of the common techniques for encoding data. In this lab, these techniques will be investigated. In class you have also been introduced to techniques used to transmit digital information using an analog signal. This is achieved by “modulating” the analog signal with the digital data. In this lab, we will investigate some of these techniques, in particular Amplitude Shift Keying (ASK) and Frequency Shift Keying (FSK).

Note: This experiment uses the files located in the Lab 2 zip file provided on the subject website. Download this zip file to your computer and copy onto the Desktop.

2.1. Representing Signals

In this laboratory, you will be using MATLAB, a commonly used and very powerful package which manipulates and displays mathematical functions. In particular, you will use MATLAB **(2012 version)** to display and manipulate some of the functions (i.e. signals) considered in class.

Log in to Windows. Create a directory in your home account called ‘lab_2’. Copy all the files found under LAB2 on the webCT site into lab_2.

Now double click on the MATLAB icon on your desktop. You will see a text window appear. This is the MATLAB command window. Change into the lab_2 directory in your home account. Enter the following (in uppercase): **PART1**

A box will appear on your screen, displaying a sine wave. Measure the period, and hence calculate the frequency of this sine wave. Also measure the peak-to-peak (p-p) amplitude in volts. (Show these calculations in your log book).

Using the buttons within your screen box, double the frequency of your sine wave, and halve the peak-to-peak amplitude. Also, compare the sin and cos waves. Phase is a very important property of signals. Take note of the difference phase between the sin and cos signals. Describe this change in phase either in degrees or radians. Note this in your lab book.

2.2. Superposition of Signals

Close the window used for part l. Return to the MATLAB command window, and enter the following:

PART2

This time, the window will show two superimposed sine waves. The frequency of the first wave is set to l0 Hz, (you can see this in the title of the graph). Set the frequency of the second one to 5 Hz. Sketch the resulting waveform.

Now change the amplitude of the 5 Hz sine wave, so that it is l/l0 of the amplitude of the l0 Hz one. Sketch the resulting waveform. What you are seeing here is that complex waveforms can be created by combining individual sinusoids. In fact, any signal can be generated using an arbitrary number of sinusoidal signals of different frequency and amplitude. Experiment with different parameters for Signal 2.

Change Signal 2 to a cosine. Sketch the resulting signal. Here you are seeing the effect of phase changes. Phase differences are an important mechanism for transmitting digital information.

2.3. Encoding Signals

The square wave is a fundamental encoding method for digital information (e.g. it is used in Ethernet systems). Here you will investigate some fundamental square wave properties.

Enter the following: **PART3**

Measure the period and the peak-to-peak amplitude of the square wave which appears. Calculate the average voltage of the displayed signal.

Now we will investigate the effect of noise on this square wave (recall that the capacity of a communications channel, as expressed by the Shannon Theorem, is a function of the noise). In the pull down menu under Signal 2 select ‘square + noise’ which adds a sine wave to the existing square wave. Experiment with different amplitudes for your “noise”, and sketch the results. Can you determine the amplitude at which errors will appear in the detected signal? (i.e. when it gets difficult to determine the actual voltage of the received signal).

Note: the 50 Hz sine wave used here closely models the interference arising from the 240V mains power supply.

2.4. Amplitude Shift Keying (Amplitude Modulation or AM)

Now double click on the MATLAB icon on your desktop. You will see a text window appear. This is the MATLAB command window. Change into the lab_2 directory in your home account.

Enter the following (in uppercase): **ASK**

A box will appear on your screen, displaying a sine wave with multiple segments. Sketch the resulting waveform. You are observing an ASK (or AM) waveform where “1’s” are represented as a high amplitude and “0’s” are represented as a low amplitude.

Measure the period, and hence calculate the frequency of this sine wave. Also measure the peak-to-peak amplitude of the high and low components in volts. (Show these calculations in your report).

As stated above, the amplitude of this waveform has been modulated, with a high voltage representing a 1, a low voltage representing a 0. This waveform is carrying 10 bits of information. Determine the bit sequence this waveform represents. Also, determine the length of time the signal stays in the high state to represent a single ‘ I’ - this is referred to as the symbol duration.

Now, add some noise to the signal. The noise in this case is called “White Noise” as it has a equal power across a wide range of frequencies. Determine the noise power required to induce errors in the received ASK signal. This illustrates a significant problem with ASK - the amplitude of the signal is very susceptible to noise. As we are carrying the digital ‘information’ in the amplitude of the signal, we have now have a system which is not very resilient to noise (which generally affects the amplitude of a signal).

2.5. Frequency Shift Keying (Frequency Modulation or FM)

Close the window used for part 1. Return to the MATLAB command window.

Enter the following: **FSK**

You will see a dialog box illustrating a waveform that represents an FSK signal. Record the waveform. In this case, the frequency of the signal has been ‘modulated’ to represent the binary information. A higher frequency represents a 1, a lower frequency represents a 0. Measure the period and hence calculate the frequency of the waveform for both the high and low frequency components.

Again, this signal represents a 10 bit sequence. Determine this sequence, and also see if you can determine the length of time the signal stays at the same frequency to represent a 1 or 0 (i.e. The symbol duration). Set the high frequency to 15 Hz and the low frequency to 5 Hz. Record the waveform. This is an example of a significant difficulty with FSK. The symbol duration must be an integer multiple of the period of both components in the signal.

Now, add some noise to the signal. Does the noise affect the frequency of the signal’? Determine the noise power required to introduce errors in the received FSK signal. This illustrates a significant benefit of FSK - the frequency of the signal is not susceptible to most noise. As we are carrying the digital ‘information’ in the frequency of the signal, we have now have a system which is quite resilient to noise.