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. Also, 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.

For this lab, MATLAB was used to display and manipulate some of the functions (i.e. signals) considered in class. Screenshots are taken so you can look at the signals and do your lab work.

Note the results and your observations in the notebook or word document.

2.1. Representing Signals

Look at the images for part 1 (part1-1, part1-2, part1-3, part1-4). A box in the image is displaying a sine or cosine wave. Measure the period, and hence calculate the frequency of each wave. Also measure the peak-to-peak (p-p) amplitude in volts. (Show these calculations in your log book).

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

Look at the images for part 2 (part2-1, part2-2, part2-3, part2-4, part2-5, part2-6).

This time, the window shows two superimposed sine waves. Look at the image part2-1, the frequency of the first wave is set to 10 Hz, (you can see this in the title of the graph) and the frequency of the second one is 5 Hz (field fundamental). What is the resulting waveform?

What you are seeing here is complex waveforms that 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.

Look at the images part2-2, part2-3 and part2-4. What are the amplitudes and frequencies of the waves?

If the Signal 2 is changed to a cosine, what will be the result? Look at the images part2-5 and part2-6.

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.

Look at the images for part 3 (part3-1, part3-2, part3-3, part3-4, part3-5).

Measure the period and the peak-to-peak amplitude of the square wave which appears (look at image part3-1). Calculate the average voltage of the displayed signal.

Now we will investigate the effect of noise on this square wave. Look at the images part3-2, part3-3, part3-4, part3-5, all represent different amplitudes for the “noise”. 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)

Look at the images for part ASK (ASK-1, ASK -2, ASK -3, ASK -4).

Look at the image ASK-1, it is 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 baud rate and the length of time the signal stays in the high state to represent a single ‘1’ (this is referred to as the symbol duration).

Now, add some noise to the signal (images ASK -2, ASK -3, ASK -4). The noise in this case is called “White Noise” as it has an 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 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)

Look at the images for part FSK (FSK-1, FSK -2, FSK -3).

Look at the image FSK-1, it is displaying 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).

Look at the image FSK-2, the high frequency is 15 Hz and the low frequency is 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, let add some noise to the signal (image FSK-3). Does the noise affect the frequency of the 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.