EC312 Security Exercise 12 – Intro to Signals and AM

Discussion: This lab demonstrates a Sinusoidal Signal and an Amplitude Modulated Signal as described in class and in the text. In this lab you will identify the different waveform parameters from the pure Sinusoidal signal in the time domain, and then you will see the carrier signal and information signal that combine to produce the Amplitude Modulated waveform displayed on an oscilloscope. From this information you will make some calculations and solve the frequencies. You will be able to solve for the equation of both a simple Sinusoid and an Amplitude Modulated waveform, and then answer questions regarding the signal’s bandwidth.

II. Equipment

Standard Lab Bench setup (We will be using the Function Generator, and the Oscilloscope and cables).

III. Lab Procedure

For the first portion of the lab you will be investigating a Sinusoidal signal from the function generator at your lab bench and displaying it on the Oscilloscope. Then you will investigate an AM signal and display it.

PART I: INTRODUCTION & SINUSOIDAL SIGNALS

Step One: Function Generator setup. [Turn Bench power on- 120V switch on upper right]

☐ Locate the Function Generator on your lab bench and turn the power on.
☐ Select the sinusoidal function by pressing the button with the Sine wave on it. The Function Generator display should indicate a small sine wave.
☐ Ensure that the “Mod” button is NOT illuminated

We will set the frequency to 1.75 kHz using the key pad method. (You can also adjust frequency with the dial on the right front of the Function Generator and using the arrow buttons under the dial to select the desired digit to change.)
☐ Select the Frequency (Freq) function using the soft keys under the display screen.
☐ Enter the desired frequency (1.75) using the key pad.
☐ Enter the desired units (kHz) by pressing the button under kHz on the screen.
☐ Ensure the Output button is illuminated

We will set the size of the waveform to 10 Vpp (volts peak-to-peak) using the key pad method. (You can also adjust amplitude with the dial on the right front of the Function Generator, using the arrow buttons under the dial to select the desired digit to change.)

☐ Select the Utility function and Output Setup soft key and Load should be HighZ and push Done.
☐ Select the Amplitude (Ampl) function using the soft keys under the display screen.
☐ Enter the desired amplitude (10) using the key pad.
☐ Enter the desired units (Vpp) by pressing the button under Vpp on the screen.
This will be twice the size of our variable Vm which is the peak value of the signal.
☐ Ensure the Output button is illuminated.
**Step Two**: Oscilloscope re-familiarization.

☐ Locate the oscilloscope and turn its power on. (Power push button is located on the top left of the oscilloscope).

The oscilloscope can receive electrical signals from two probes, channel 1 (CH 1) and channel 2 (CH 2). We have attached adaptors to CH 1 and CH 2, so that they can receive electrical signals via our banana plug cables.

☐ Locate the CH 1 input on your oscilloscope. It will have a two-input (RED / BLACK) banana plug adaptor installed.

☐ Connect with banana plug cables (under bench on plastic Quad board) from the Function Generator’s output (red to red and black to black) to CH 1 input on the oscilloscope.

Note: The oscilloscope has the ability to measure and display two different electrical signals, but only with respect to one common reference point. The BLACK CH 1 input provides this common reference point for CH 1 and CH 2. Therefore, CH2 has an adaptor for only one banana plug. We will not be using CH2 for this lab.

☐ With the CH 1 menu selected, adjust the position of the vertical axis zero level by rotating the position knob under the vertical section in the CH 1 column, so that the “1→” on the left side of the LCD is adjacent to the center horizontal major axis (centered vertically on the display).

**Step Three**: Display a sine wave with the oscilloscope

☐ Press the CH2 Menu button twice to turn off the CH 2 trace, since nothing is connected to CH 2 for this lab.

☐ Press the AUTOSET button( top right) on the oscilloscope for best settings.

☐ Press CH 1 MENU on the oscilloscope and make the following settings.
  - Coupling: AC
  - BW Limit: OFF
  - Volts/Div: COARSE
  - Probe: 1X
  - Invert: Off

☐ Adjust the VOLTS/DIV knob under the vertical section in the CH 1 column, so that CH 1 indicates 2 Volts/Div.

☐ Adjust the SEC/DIV knob under the horizontal axis, so that the oscilloscope indicates 100 µs per major division on the LCD.
**Step Four**: Measuring the waveform on the oscilloscope.

**Manual method.** The first method is by counting the divisions of grid and applying the scale (volts/div for vertical, or sec/div for horizontal). This will only provide you with approximate values with little precision.

**Question 1.** Fill out the tables on answer sheet (and also below) using this manual measurements method.

- Using the vertical scale, determine the peak-to-peak voltage of amplitude for CH1; fill in the values on your answer sheet.

<table>
<thead>
<tr>
<th>$v(t)$ (CH1)</th>
<th>Peak-to-peak (Vpp)</th>
<th>Amplitude (V)</th>
</tr>
</thead>
</table>

- Using the horizontal scale on Figure 2, determine the period (T) using this manual measurements method. Use the measurement to determine frequency, and fill in the values on your answer sheet.

<table>
<thead>
<tr>
<th>$v(t)$ (CH1)</th>
<th>Period (µs)</th>
<th>Frequency (kHz)</th>
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</table>

**Taking automatic measurements.** The oscilloscope has the ability to take automated measurements of voltage, period and frequency.

- Note: at any point in the lab if the measurements appear to be jumping around, ensure the Average is selected once the Acquire menu button is pushed (top row, middle).
- Press the Measure button (top middle) to view the measurement menu on LCD, then push the top menu box button to highlight Source and select CH1 for Measure 1.
- Then choose the Type of measurement to be Pk-Pk by cycling through the options on the button associated with this menu option, and then hit button for Back option.
- Press the second to top menu box button to highlight Source and select CH1 for Measure 2.
- Then choose the Type of measurement to be Freq by cycling through the options on the button associated with this menu option, and then hit button for Back option.
- You can add new measurements for all 5 buttons. Amplitude is not automatically measured but can still be calculated from the peak-to-peak voltage as before. Record your results in Question 2 tables and on back page.

**Question 2.** Fill out the tables on answer sheet using automatic measurements method.

<table>
<thead>
<tr>
<th>$v(t)$ (CH1)</th>
<th>Peak-to-peak (Vpp)</th>
<th>Amplitude (V)</th>
</tr>
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</table>

- Continue cycling the menu box buttons to obtain the measured values of the period and frequency.

<table>
<thead>
<tr>
<th>$v(t)$ (CH1)</th>
<th>Period (µs)</th>
<th>Frequency (kHz)</th>
</tr>
</thead>
</table>
How closely do the values of $V_m$ compare for each measurement method?

Exact __________  Very close __________  Very Different ________

Describing the sinusoidal signal as an equation:

$$v(t) = V_m \sin \left(2\pi f t + \theta \right) \text{ [volts]}$$

**Question 3.**

Enter the results from your measurements from the previous pages into the equation:

$$v(t) = \text{________________________} \text{ (Show values)}$$

**Step Five:** Measuring a pure sine wave in the frequency domain.

Our scope can also provide a frequency spectrum of a signal (mathematically). For this particular sinusoidal signal we know it is periodic and has a single frequency, $f$, described by the previous measurements and showing in our equation. So let us try to understand how this signal is displayed in the frequency domain. The oscilloscope performs a Fast Fourier Transform (FFT) and displays the magnitudes of the frequencies present in the signal vs. frequency, so the horizontal scale shows frequency not time.

- Press AUTOSET (top right) and select the option to display in the frequency domain (FFT). If FFT doesn’t show up, press the MATH button and cycle through the “Operations” until you find it.
- Push the button next to the FFT and you will see a spike at a particular frequency.
- Set the horizontal scale to read 250Hz per division.

**Question 4.** Count the number of boxes from the left edge and multiply by 250Hz to determine the value of the frequency component. $f =$ ________.

**Question 5.** Sketch your frequency plot on your answer sheet. Label your axes!

**PART II: AMPLITUDE MODULATED SIGNAL**

The Amplitude Modulation signal looks somewhat like Figure 1. This particular depiction includes an imaginary envelope. The message or information signal modulates the amplitude of the carrier.

![Modulating signal envelope]
Reset the Oscilloscope back to the time domain from the frequency domain, by pressing the button next to the multiple cycles of a sinewave, above the FFT button.

On the Function Generator select the Store/Recall button and then push Recall State and then push State 2 and then Recall State again. Make sure the output button is lit.

Push AUTOSET on the Oscilloscope and you will see the changing amplitude of the carrier wave at its frequency. Turn off Channel 2, and adjust the horizontal range sec/div so that you can see the AM waveform (Fig 1). Use vertical adjustment so that your AM signal is at the midpoint of the screen. You may have to adjust the knob for trigger level (it is to the far right below the AUTOSET button) to clean up the signal. Once the display is properly adjusted, use the boxes on the oscilloscope to measure the following parameters and use the equations from Table 1 and record your results in Table 2 and place your answers in Question 6.

1. Measure $V_{\text{min}}$ and $V_{\text{max}}$ (shown in Figure 1) in voltage mode.
2. Measure the period of the carrier, $T_{\text{carrier}}$ (higher frequency signal)-adjust the horizontal (sec/div).
3. Measure $T_{\text{message}}$, the period of the message (lower frequency signal)- adjust back the horizontal (sec/div). Note: $T_{\text{message}}$ measures the cycle of the wave that rides along the top of the carrier as the carrier is modulated.
4. Calculate $m$, $f_{\text{carrier}}$, $f_{\text{message}}$, $V_{\text{carrier}}$, and $V_{\text{message}}$ using the equations of Table 1 and the measured values.

\[V_c = \frac{V_{\text{max}} + V_{\text{min}}}{2}\]
\[V_m = \frac{V_{\text{max}} - V_{\text{min}}}{2}\]
\[f = \frac{1}{T}\]
\[m = \frac{V_m}{V_c}\]

\[v_{AM} = V_c \sin 2\pi f_c t + (V_m \sin 2\pi f_m t)(\sin 2\pi f_m t)\]

Table 1: AM Equations

<table>
<thead>
<tr>
<th>$V_{\text{max}}$</th>
<th>$V_{\text{min}}$</th>
<th>$V_c$</th>
<th>$V_m$</th>
<th>$T_c$</th>
<th>$T_m$</th>
<th>$f_c$</th>
<th>$f_m$</th>
<th>$m$</th>
</tr>
</thead>
</table>

Table 2: Measured Signal Parameters for AM Signal from AM signal.

**Question 7:** Using the form of the AM equation from Table 1, solve for your equation of the amplitude modulated waveform displayed on the oscilloscope.

\[v_{AM}(t) = \quad \text{ (Show values)}\]

**Measuring an AM signal in the frequency domain.**

Let’s look at the frequency spectrum of this signal. For this AM signal we know that it has at least 2 frequencies involved, but one, $f_m$, is modulating the other frequency, $f_c$, described by the previous measurements and showing in our time equation. In class we manipulated this equation to show us what frequencies will show up in the frequency domain.

\[v_{AM}(t) = V_c \sin(2\pi f_c t) + \frac{V_m}{2} \cos(2\pi(f_c-f_m)t) - \frac{V_m}{2} \cos(2\pi(f_c+f_m)t)\]

There are 3 frequencies in the AM signal: the carrier and its 2 Sidebands. The upper and lower sideband have half the amplitude and are reflected about the carrier.
So let us try to see this signal as it is displayed in the frequency domain. Again, the oscilloscope performs a Fast Fourier Transform (FFT) and displays the magnitudes of the frequencies present in the signal vs. frequency, so the horizontal scale shows frequency instead of time.

☐ Press AUTOSET and you will see the options to display the signal in time or in frequency (FFT).
Or Press the Math Menu button next to CH1 Menu button.
☐ Push the button next to the FFT or keep in FFT operation and you will see spikes at specific frequencies.
☐ Set the horizontal scale to read 12.5 kHz per division.

**Question 8.** Count the number of boxes from the left edge and multiply by 12.5 kHz to determine the value of the frequencies $f_c = \text{_______}$, $f_{lsb} = \text{_______}$, $f_{usb} = \text{_______}$.

**Question 9.** Sketch your frequency plot. Label the axes with your values and have your instructor check it.

**Question 10.** Do the values for your frequencies above make sense using our values of $f_c$ and $f_m$? Using our formulas from class, what is the lowest frequency ($f_{lsb} = f_c - f_m$), highest frequency ($f_{usb} = f_c + f_m$) and the bandwidth ($BW = f_{usb} - f_{lsb} = 2f_m$) of the Amplitude Modulated waveform?

$$v_{AM}(t) = V_c \sin(2\pi f_c t) + V_m/2 \cos(2\pi(f_c-f_m)t) - V_m/2 \cos(2\pi(f_c+f_m)t)$$

Fill in all the values for this equation of the AM waveform which shows us our distinct frequencies.

**Question 11.** If the carrier signal in the AM Signal was equivalent to the tuning frequency on an AM Radio dial, would this signal be within the range of AM Radio frequencies?

**Question 12.** If this AM signal was broadcast and then demodulated on the receiving end, what would the demodulated signal (i.e. the information being transmitted) sound like?

**Question 13.** If the Amplitude Modulated signal from the AM Signal contained many frequencies in the information signal (higher than the $f_m$ seen in Table 2), how would this affect the bandwidth of the Amplitude Modulated Waveform?
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Name:

Question 1:

<table>
<thead>
<tr>
<th>V(t) (CH1)</th>
<th>Peak-to-peak(Vpp)</th>
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Question 2:

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</table>

Exact__________   Very close__________ Very Different_________

Question 3:

Question 4:

Question 5:

![Plot]

Question 6:

<table>
<thead>
<tr>
<th>V_{max}(V)</th>
<th>V_{min}(V)</th>
<th>V_c(V)</th>
<th>V_m(V)</th>
<th>T_c(µs)</th>
<th>T_m(µs)</th>
<th>f_c(kHz)</th>
<th>f_m(kHz)</th>
<th>m</th>
</tr>
</thead>
</table>

Question 7: