Lab 3 — FM Modulation

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Objective

1. Illustrate the concept of a frequency-modulated (FM) waveform

2. Learn to perform the following tasks in Agilent-VEE:

   - Use a control panel for the Agilent 33120A Arbitrary Waveform Generator
   - Add inputs for FM-FREQ and FM-DEVIATION

3. Remotely control the carrier frequency, modulation frequency, and fm deviation of the waveform generator.

Equipment

- Agilent VEE software package
- Agilent 33120A 15 MHz Function/Arbitrary Waveform Generator
- Agilent 54645A Deep Memory Oscilloscope

Introduction

An amplitude modulated signal conveys its information by changing the amplitude, but not the frequency, of its carrier waveform. A frequency modulated signal conveys its information by changing the frequency, but not the amplitude, of its carrier waveform. The amount by which the carrier frequency is changes is called the deviation and is measured as a shift f from the carrier fo. The modulation frequency determines how fast the frequency shift occurs. When a complex audio signal is sent via FM, the frequency of the carrier changes in step with the audio signal.

Part I:

After turning on your computer, sign out a cable box, then perform the following tasks. Be prepared to explain or discuss with instructors those concepts marked with an asterisk (*).

1. Start Agilent-VEE and turn on the Agilent 33120A arbitrary waveform generator and the Agilent 54645A oscilloscope.

2. Connect a coaxial cable from the OUTPUT of the waveform generator to the channel 1 input of the oscilloscope.

3. For this experiment, do not connect an external trigger signal from the SYNC output of the waveform generator. Instead, set the scope Trigger Source to channel [1]. An FM waveform is easier to see if the scope is synchronized to the carrier, rather than to the modulating signal.

4. Bring up a control panel in Agilent-VEE for the function (arbitrary waveform) generator. Click on Main Panel, and choose Modulation Panel from the menu. Click on Amplitude Panel, then choose Frequency Panel from the menu. The Frequency Panel will allow you to control the frequency modulation (FM) functions of the waveform generator. With [FM State] set of "off", set the carrier frequency to 1 kHz.

5. Turn the Time/Div knob on the scope counterclockwise until about ten or so cycles of the sinusoidal carrier waveform are visible. You can adjust the Time/Div knob as needed throughout the remainder of this experiment to properly observe the waveform.

6. Push Autoscale on the scope, then turn the Delay knob (located within the HORIZONTAL group of controls) counterclockwise until the little "zero" marker at the top center of the graph moves to the far left hand corner of the display. This setting places the origin of the graph at the far left and will make the FM waveform easier to see on the scope.

7. Now add an input terminal for FREQ to the control panel, and connect to it the data output of a real slider. Label this slider "Carrier Frequency", set its limits to 100 minimum and 10,000 (i.e., 10k) maximum, and set its increment value (the value by which the setting changes when you click on the up or down arrows) to 100. The increment setting is called "Detents" under the Properties selection available from the upper left hand pull down menu of the slider box. Double click on the title bar of this slider and label it "Carrier Frequency."

   • Make sure that your slider is set to "auto execute."
   • Set the slider to several values and observe the frequency of the waveform on the scope.

8. Use your slider to set the frequency of the carrier to 1 kHz. Set the entries on the Frequency Modulation panel to the following values:

   Function: Triangle
   User Name: (doesn't matter)
   Frequency: 0.1
   Deviation: 100
   FM State: on

   These settings will cause the signal from the waveform generator to shift from 1 kHz by ±10 Hz in a linear pattern every 10 seconds (i.e., the frequency will shift between 900 Hz and 1100 Hz.) Can you see the frequency shift on the scope? Try different values of FM frequency and deviation and observe the change in the waveform. Is the amplitude constant or does it vary?

9. Now add inputs for FM_FREQUENCY and FM_DEVIATION to the function generator control panel. FM_FREQUENCY will set remotely the rate at which the carrier frequency will change and FM_DEVIATION will set the amount by which the carrier frequency will change. Connect real sliders to these FM_FREQ input and FM-DEV inputs, label their title bars appropriately, and set the slider limits as follows:

   0.1 to 50 for FM_FREQ
   1 to 1000 for FM_DEV

   With the FM State set to "on", make the following adjustments:
   Begin with the lowest settings of FM_FREQ and FM_DEV, then gradually increase the FM_DEV. You should see the frequency of the waveform increase with FM deviation. Chose any one setting for FM-DEV and gradually increase the FM_FREQ. What effect does FM-FREQ have on the waveform for fixed FM deviation?

<u>Optional:</u>
Create a system in which you can switch between AM and FM states of modulation by flipping an on-screen switch in Agilent-VEE. Slider or knob controls should set all relevant AM and FM parameters.

Part II:

In this portion of the experiment, you will produce a signal that can be received by your FM radio. The Agilent 33120A Waveform Generator can produce a signal of 15 MHz maximum frequency. The FM broadcast band begins at 87 MHz and goes up to 108 MHz. As you can see, the Agilent 33120A Waveform Generator is incapable of producing a sine wave that can be received by your radio. It can, however, produce a square wave signal at a lower frequency that will have a harmonic in the 87 MHz to 108 MHz band. As we learned in Lab #1, a square wave is made up of an infinite sum of odd harmonic sinusoids. If the fundamental frequency of the square wave is fo, then the sine waves from which it's made will have frequencies fo, $3fo$, $5fo$, $7fo$... etc. The amplitude of each harmonic is reduced by 1/n relative to the magnitude of the fundamental at fo, where n is the harmonic number, hence the extreme high harmonics have very small amplitudes. By producing a square wave of appropriate frequency, you should be able to produce a sinusoidal harmonic in the FM broadcast band that can be heard on your radio.

Note: If you modulate a square wave with a particular FM deviation, then all its sinusoidal harmonic components also will be FM modulated with the same deviation.

10. Find a quiet spot on the FM broadcast band where no commercial stations can be heard. Record or remember this frequency. Adjust the Waveform Generator to produce a square wave, and choose the square wave frequency such that the lowest order harmonic possible will coincide with your chosen FM broadcast frequency. Make sure to connect an antenna to the Waveform Generator as you did in the AM modulation lab so that the signal will radiate.

11. Choose a value for FM_FREQ that falls in the low end of the audio range (500 Hz to 500 kHz). Change the FUNCTION setting in the FM MODULATION panel from TRIANGLE to SINE, so that the modulation signal produced by the Waveform Generator will be a sinusoid.

12. Tune your radio until you can hear the signal produced by the Waveform Generator. Alternatively, keep the dial on your radio fixed and make slight adjustments in the frequency of the square wave "carrier." You should be able to hear the sinusoidal FM modulation on your radio. Experiment with different modulation frequencies and verify that you can hear the changes. Also try different FM MODULATION signals. What does a triangle wave sound like? A square wave? A cardiac waveform? Noise?