Daffodil International University
Department of Electrical and Electronic Engineering
EEE 316: Communications Engineering Laboratory

EXPERIMENT NO: 05

NAME OF THE EXPERIMENT: Study of Frequency modulation (FM)

Objective and Theory

A disadvantage of the AM, DSBSC and SSB communication systems is that they are susceptible to picking up electrical noise in the transmission medium (the channel). This is because noise changes the amplitude of the transmitted signal and the demodulators of these systems are affected by amplitude variations.

As its name implies, frequency modulation (FM) uses a message's amplitude to vary the frequency of a carrier instead of its amplitude. This means that the FM demodulator is designed to look for changes in frequency instead. As such, it is less affected by amplitude variations and so FM is less susceptible to noise. This makes FM a better communications system in this regard.

There are several methods of generating FM signals but they all basically involve an oscillator with an electrically adjustable frequency. The oscillator uses an input voltage to affect the frequency of its output. Typically, when the input is 0V, the oscillator outputs a signal at its rest frequency (also commonly called the free running or center frequency). If the applied voltage varies above or below 0V, the oscillator's output frequency deviates above and below the rest frequency. Moreover, the amount of deviation is affected by the amplitude of the input voltage. That is, the bigger the input voltage, the greater the deviation.

Figure 1 below shows a simple message signal (a bipolar square wave) and an unmodulated carrier. It also shows the result of frequency modulating the carrier with the message.

There are a few things to notice about the FM signal. First, its envelopes are flat- recall that FM doesn't vary the carrier's amplitude. Second, its period (and hence its frequency) changes when the amplitude of the message changes. Third, as the message alternates above and below 0V, the signal's frequency goes above and below the carrier's frequency. (Note: It's equally possible to design an FM modulator to cause the frequency to change in the opposite direction to the change in the message's polarity.)

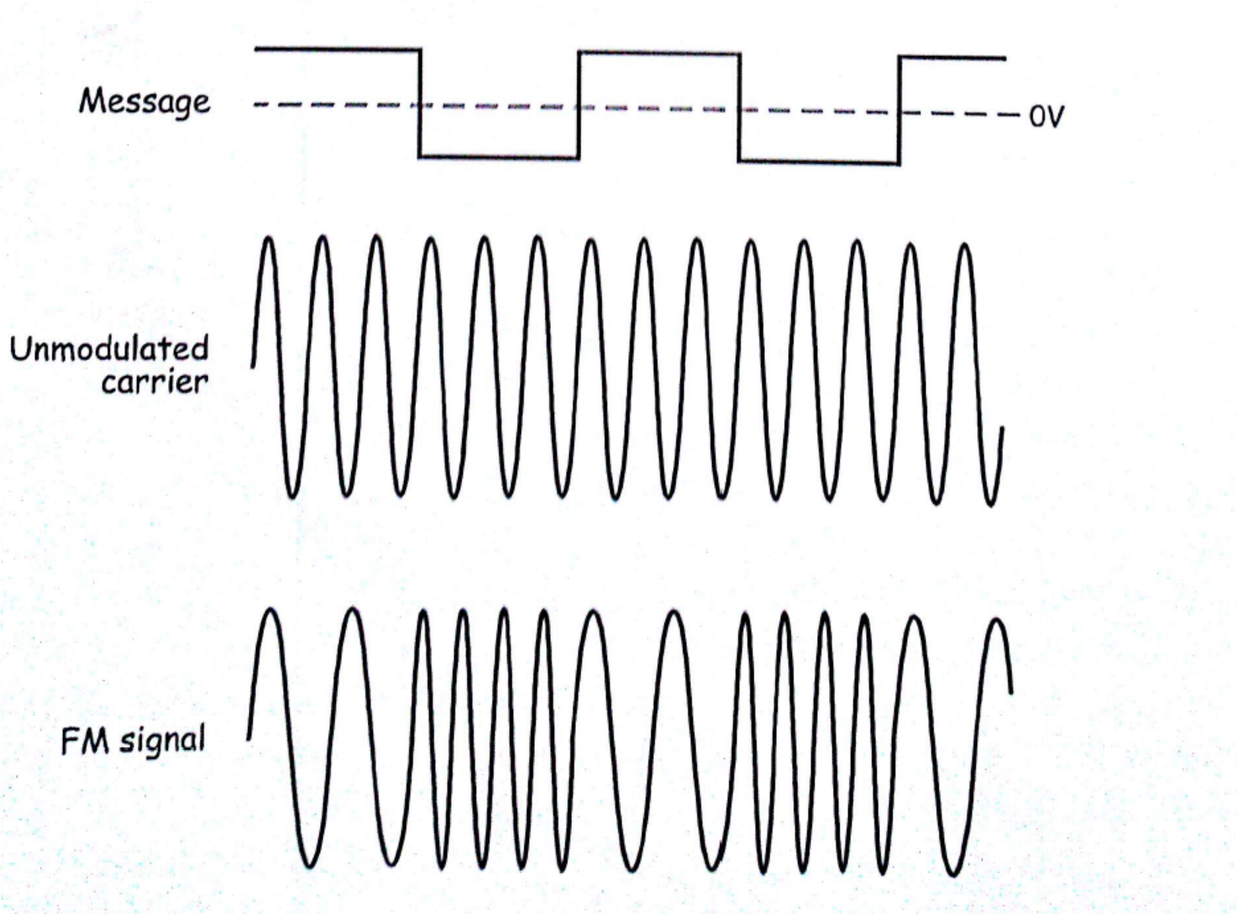

Figure: 01

Before discussing FM any further, an important point must be made here. A square wave message has been used in this discussion to help you visualize how an FM carrier responds to its message. In so doing, Figure 1 suggests that the resulting FM signal consists of only two sinewaves (one at a frequency above the carrier and one below). However, this isn't the case. For reasons best left to your instructor to explain, the spectral composition of the FM signal in Figure 1 is much more complex than implied.

This highlights one of the important differences between FM and the modulation schemes discussed earlier. The mathematical model of an FM signal predicts that even for a simple sinusoidal message, the result is a signal that potentially contains many sine waves. In contrast, for the same sinusoidal message, an AM signal would consist of three sine waves, a DSBSC signal would consist of two and an SSBSC signal would consist of only one. This doesn't automatically mean that the bandwidth of FM signals is wider than AM, DSBSC and SSBSC signals (for the same message signal). However, in the practical implementation of FM communications, it usually is.

Finally, when reading about the operation of an FM modulator you may have recognized that there is a module on the Emona Telecoms- Trainer 101 that operates in the same way the VCO module. In fact a voltage-controlled oscillator is sometimes used for FM modulation (though there are other methods with advantages over the VCO).

The experiment

In this experiment you'll generate a real FM signal using the VCO module on the Emona Telecoms-Trainer 101. First you'll set up the VCO module to output an unmodulated carrier at a known frequency. Then you'll observe the effect of frequency modulating its output with a square wave then speech. You'll also use the speech signal to demonstrate the effect that a message's amplitude has on an FM modulator. Finally, you'll use a sinewave to observe the spectral composition of an FM signal (in the time domain). It should take you about 45 minutes to complete this experiment.

Equipment

- Emona Telecoms-Trainer 101 (plus power-pack)
- Dual channel 20MHz oscilloscope
- Two Emona Telecoms-Trainer 101 oscilloscope leads
- Assorted Emona Telecoms-Trainer 101 patch leads

Procedure

Part A - Frequency modulating a square wave

1. Gather a set of the equipment listed on the previous page.

2. Set up the scope per the instructions in Experiment 1. Ensure that:
- The Trigger Source control is set to the CHJ (or IN7) position.
- The Mode control is set to the CHJ position.

3. Locate the VCO module and turn its Gain control to about two thirds of its travel (about the position of the number 2 on a clock face).

4. Set the VCO module's Frequency Adjust control to about the middle of its travel.

5. Set the VCO module's Range control to the LO position.

6. Connect the setup like Figure 2 below.

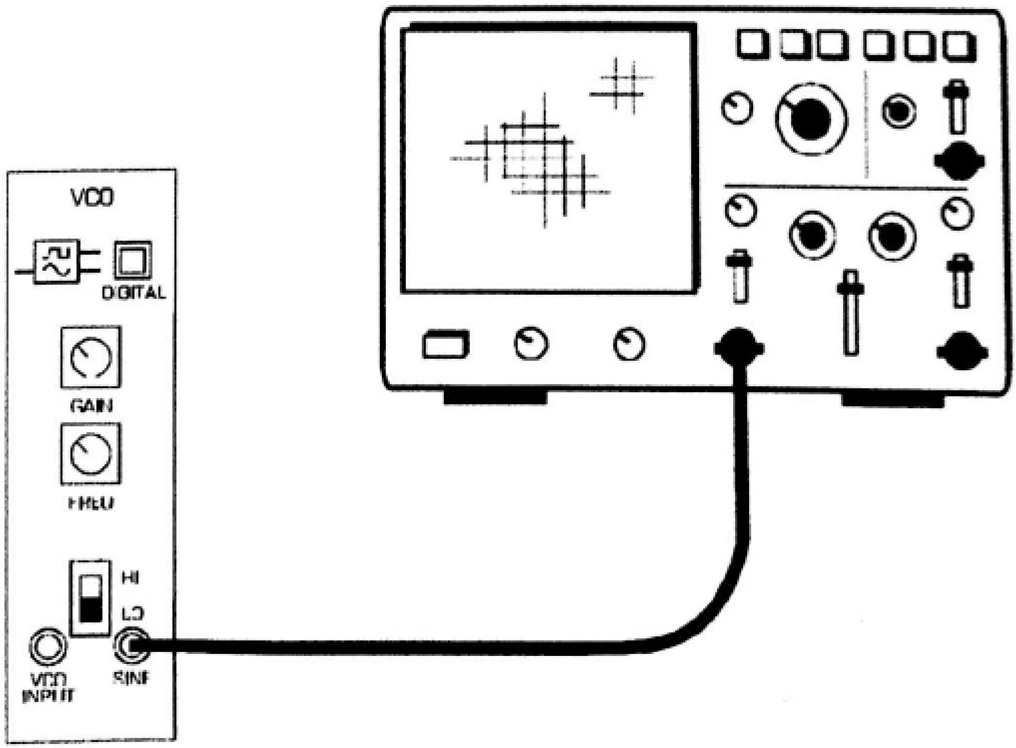

Figure: 02

7. Set the scope's Timebase control to the 20 µs/div position.

8. Adjust the VCO module's Frequency Adjust control so that one cycle of its output is exactly 5 divisions.

9. Set the scope's Timebase control to the 0.1ms/div position.

10. Modify the set-up as shown in Figure 3 below.

Note: Notice that the scope's connection to the VCO module's output has changed.

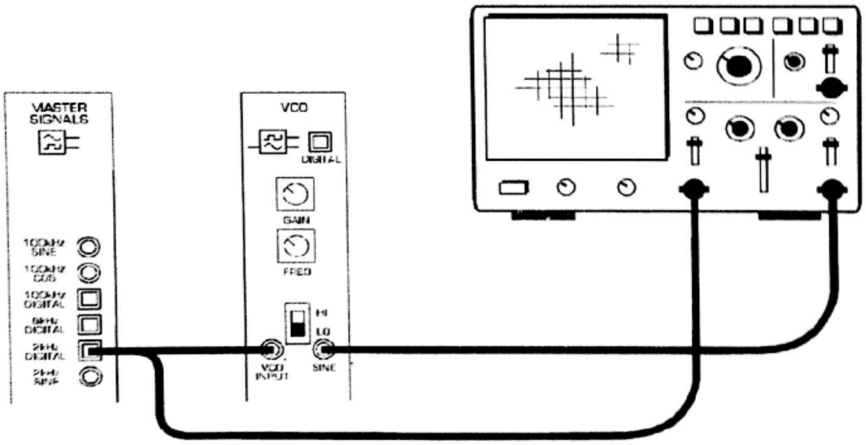

Figure: 03

The set-up in Figure 3 can be represented by the block diagram in Figure 4 below. The Master Signals module is used to provide a 2 kHz square wave message signal and the VCO module is the FM modulator with a 10 kHz carrier.

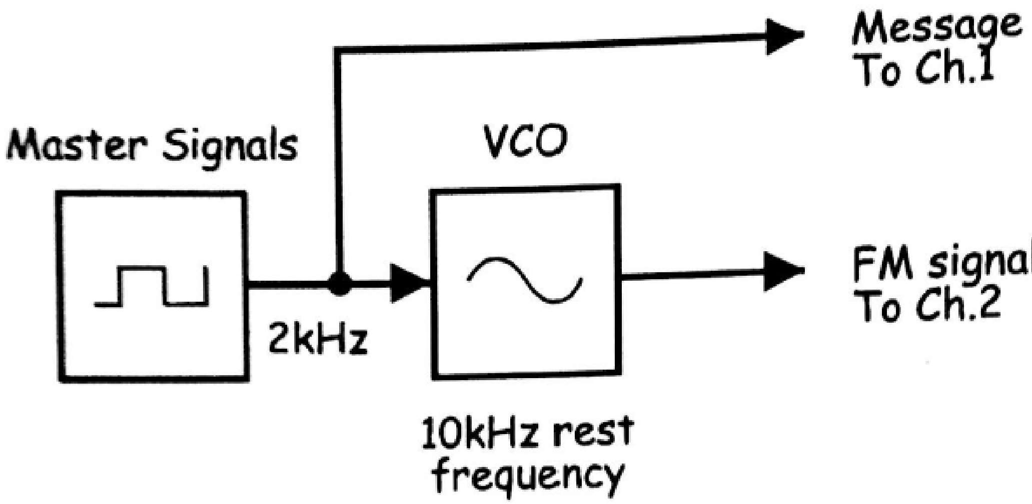

Figure: 04

11. Set the scope's Mode control to the DUAL position.

12. If necessary, tweak the VCO module's Gain control until you obtain an output from the VCO that's similar to the FM signal in Figure 1 (in the preliminary discussion).

13. Use the scope's Channel l Vertical Position control to overlay the message with the FM signal and compare them.

Question 1

Why does the frequency of the carrier change?

Part B- Generating an FM signal using speech

So far, this experiment has generated an FM signal using a square wave for the message. However, the message in commercial communications systems is much more likely to be speech and music. The next part of the experiment lets you see what an FM signal looks like when modulated by speech.

14. Disconnect the plug to the master signal module's 2 kHz DIGITAL output.

15. Connect them to the Speech module's output as shown in Figure 5 below.

Remember: Dotted lines show leads already in place.

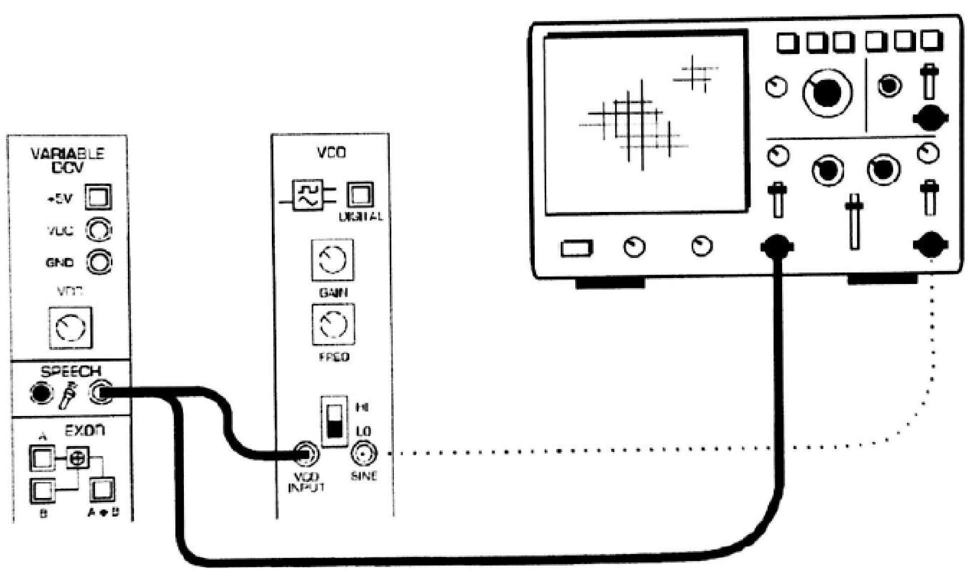

Figure: 05

16. Set the scope's Trigger Source control to the CH2 position.

17. Talk, sing or hum while watching the scope's display.

18. Set the scope's Time-base control to about the 20µs/div position.

19. Quietly hum into the Speech module's microphone while watching the scope's display.

20. Slowly make your hum louder and louder without changing its pitch.

Question 2

What is the relationship between t FM signal’s1frequency deviation (that is, the VCO module's output) and the amplitude of the message?

Question 3

What is the relationship between the FM signal's frequency deviation and the frequency of the message? Tip: This relationship may not be observable with the present set-up.

Part C- Considering the spectral composition of FM signals

Regardless of the type of message signal used the spectral composition of FM signals is rich in sinewaves. The next part of this experiment demonstrates this.

21. Set the scope's Mode control to the CH2 position so that you're only looking at the FM signal.

22. Disconnect the VCO module's input from the Speech module's output.

23. Modify the set-up as shown in Figure 6 below.

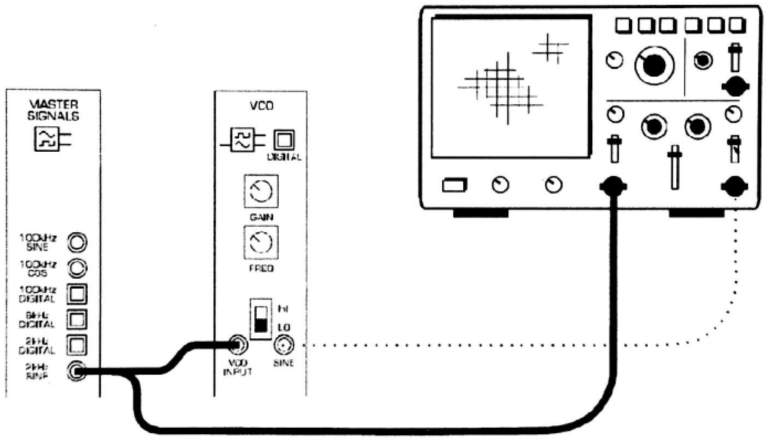

Figure: 06

You should now see a display that looks similar to Figure 7 below.

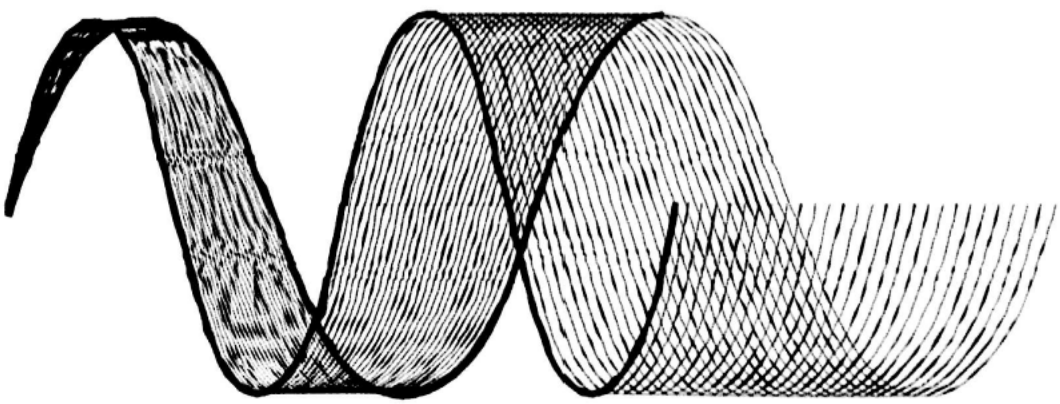

Figure: 07

24. If you don't have a display similar to Figure 7, slowly turn the VCO module's Gain control anti-clockwise until you do.

When viewed this way you can clearly see the highest frequency sinewave that the FM modulator is outputting, the lowest frequency sinewave and many of the sinewaves in between.

25. Connect the VCO module's input to the Master Signals module's 2 kHz DIGITAL output instead of the 2 kHz SINE output.

26. Note the spectral composition of the FM signal.

27. Connect the VCO module's input to the Speech module's output instead of the Master Signals module's 2kHz DIGITAL output.

28. Note the spectral composition of the FM signal.

Notice that the spectral composition of the FM signal is complex regardless of the message's waveshape .