Experiment 15: Frequency Modulation

Purpose and Discussion

The purpose of this simulation is to demonstrate the characteristics and operation of frequency modulation using Multisim's Frequency Modulator. In frequency modulation (FM), variations in the frequency of the modulated wave are observed with changes in the message signal. Amplitude modulation is easily affected by noises in the atmosphere as well as any other interference from sources of close proximity that generate frequencies in the range of the modulating signal. These spurious frequencies ride upon the modulated signal even after demodulation and appear as static. Noise also amplitude modulates FM signals but since the modulating relationship results in frequency variations, not amplitude variations, the interference has virtually no affect and is easily removed in the demodulation process. Even when the noise falls between the sine waves of the carrier, thus potentially affecting the frequency, almost complete noise suppression is possible by ensuring a large carrier deviation. Frequency deviation is the amount that the frequency deviates from that of the carrier frequency. FM broadcasting limits the maximum frequency deviation to 75 kHz.

A large amplitude modulating signal results in a large maximum frequency deviation. A low amplitude modulating signal results in a small maximum frequency deviation. The amplitude of the modulated wave is not affected by the amplitude of the message signal. The modulation index m is established by the maximum frequency carrier deviation divided by the frequency of the modulating signal which produces the deviation $m = \Delta f/f_m$.

Since amplitude variations directly affect frequency deviation in FM, it follows that a lower frequency modulating signal will cause a slower rate of frequency deviation since the FM signal will be subjected to less message signal amplitude variations per second than that of a higher frequency message signal. Hence, it is important to note that the rate of frequency deviation is dependant upon the frequency of the message signal. FM broadcasting regulations limit the maximum audio frequency to 15 kHz. The bandwidth W of an FM signal is dependant on the number of sideband pairs which are not more than 20 dB down from the height of the highest spectral line. These sideband pairs are the most significant and represent approximately 98% of the total power. The number of sideband pairs is dependant on the modulation index and its value is predictable. For example, for a modulation index of 3, six significant sideband pairs are expected.

Associated time domain variations can be observed using the oscilloscope. Recall that in the frequency spectrum of an AM wave, two sideband frequencies are produced for every modulating signal. One sideband frequency is equal to $f_c - f_m$ and is below the carrier frequency. The other sideband is equal to $f_c + f_m$ and is above the carrier frequency. In FM, however, in addition to the basic pair of sideband frequencies produced by a single modulating signal, an infinite number of sideband frequencies are also produced. f_c - $3f_m$, f_c - $2f_m$, f_c - f_m, f_c, f_c + f_m, f_c + $2f_m$, f_c + $3f_m$ are only a few of the spectral lines that are observed in the frequency domain. The spectral lines decrease in power as they move further from the center frequency. As the modulation index is increased, the power is distributed over more spectral lines.

Parts

FM Modulator

Test Equipment

- Oscilloscope
- Spectrum Analyzer

Formulae

Bandwidth

6 significant sideband pairs @ m = 3,

$$W = 2(\#\ \text{significant sideband pairs})f_m$$

Equation 15-1

Modulation Index

$$m = \Delta f/f_m$$

Equation 15-2

Procedure

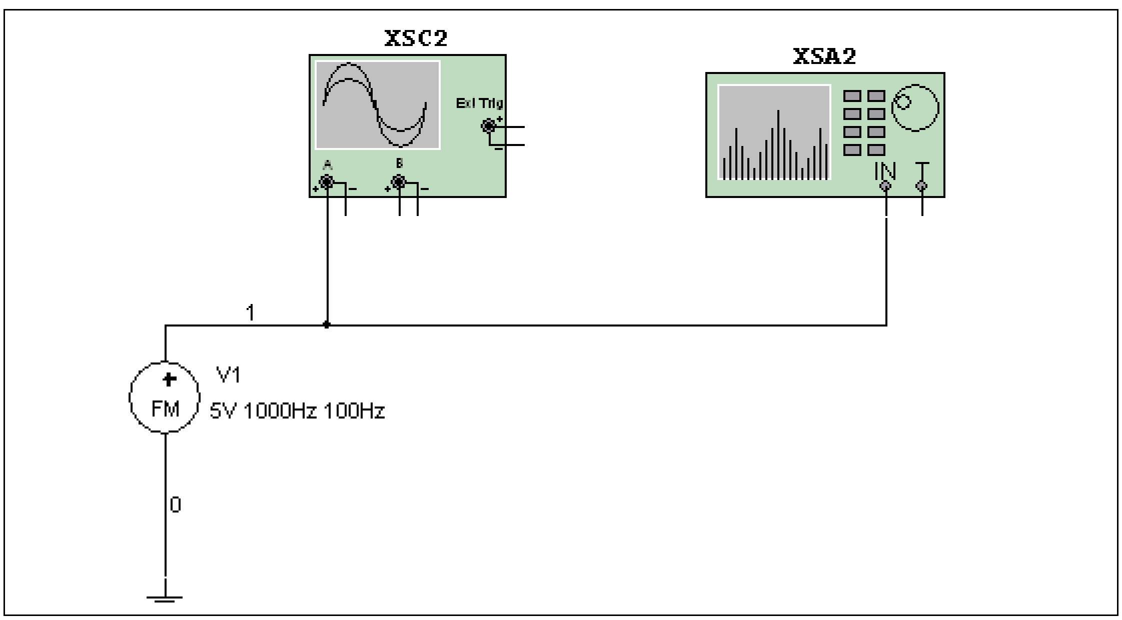

Figure 15-1 VCO AM Modulator Example

1. Connect the circuit as illustrated in Figure 15-1.
2. Double-click the FM Modulator to set its parameters. Set Voltage Amplitude = 10 V, Carrier Frequency = 100 kHz, Modulation Index = 5 and Signal Frequency = 10 kHz.
3. Double-click the Oscilloscope to view its display. Set the time base to 20 us/Div and Channel A to 10 V/Div. Select Auto triggering and DC coupling.
4. Start the simulation and observe the frequency modulated signal in the time versus amplitude domain. Draw the associated output waveform in the Data section of this experiment.
5. Double-click the FM Modulator and change the Modulation Index to 3.
6. Double-click the Spectrum Analyzer to view its display. Select *Set Span.* Set *Span* = 125 kHz and *Center* = 100 kHz. Press *Enter*. This will allow us to view the carrier frequency along with several sideband sets. Calculate and note the expected frequency deviation.
7. Observe the frequency spectrum. Use the red vertical marker to locate the carrier frequency of 100 kHz. Verify that the upper and lower sideband frequencies correspond with f_c - $3f_m$, f_c - $2f_m$, f_c - f_m, f_c, $f_c + f_m$, $f_c + 2f_m$, $f_c + 3f_m$ etc. Move the red marker over the carrier to determine its position.
8. Noting the amplitude of each spectral line, find the highest line to the right of the carrier. Note its amplitude and count the number of spectral lines to the right of the carrier which are no more than 20 dB down from the highest line. Calculate the bandwidth W in the Data section of this experiment.
9. Change the modulation index to 5, run the simulation and observe the spectrum. Change the modulation index to 1.5 and describe what you are observing.

Expected Outcome

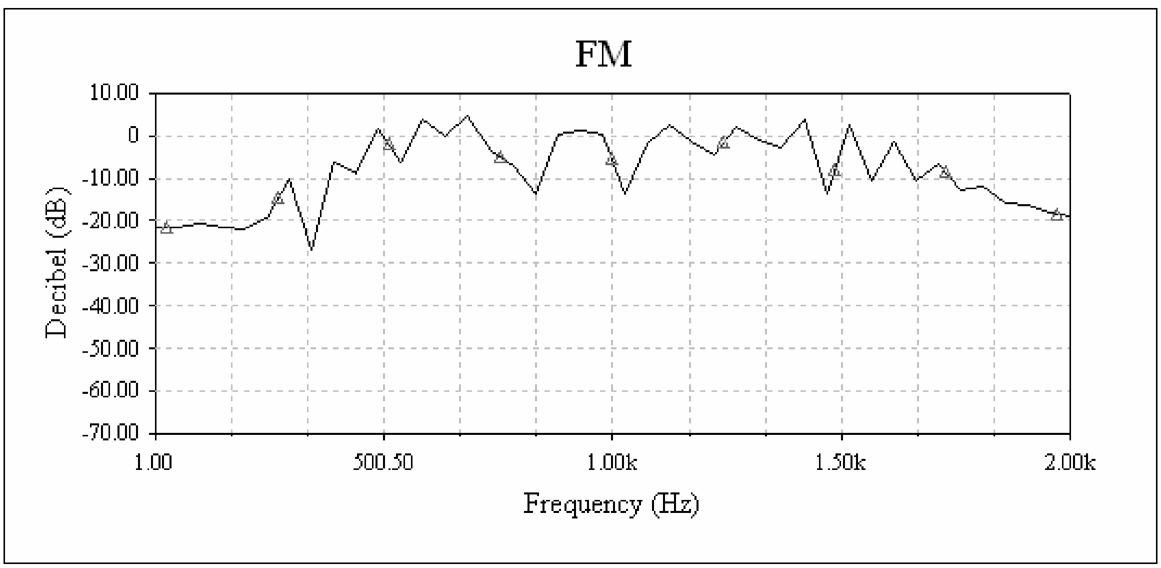

Figure 15-2 Frequency Spectrum of an FM Signal

Data for Experiment 15

FM time versus amplitude sketch

Δf @ ($m = 3_{calculated}$, $f_m = 10\ kHz$) = ______________________

Bandwidth W @ ($m = 3$, $f_m = 10\ kHz$) = ___________________

Describe the difference in the frequency spectrum between a modulation index of 5 and a modulation index of 1.5:

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Additional Challenge

Double-click on the FM Modulator and change the modulation index to 2.4. Run the simulation. Describe the spectrum and explain the characteristics noted (refer to Bessel Coefficients for your explanation).