Experiment 11: Modulation Index and Power Considerations

Purpose and Discussion

The purpose of this simulation is to demonstrate the various characteristics of AM modulation measuring techniques and power efficiency in an AM spectrum. The modulation index of an amplitude modulated signal refers to the ratio of the amplitude of the carrier as compared with that of the message signal.

The modulation index or the percentage of modulation is an important part of the modulation process. An under-modulated AM signal is not an efficient means of transmitting information due to power considerations. At a modulation index of 1, both the upper and lower sidebands have amplitudes which are half of that of the carrier amplitude. Over modulation occurs with a modulation index of greater than one. Over modulation causes distortion at the receiver as well as interference with other stations due to the undesired sideband frequencies that are generated. Ideally, a modulation index of one is desirable. In practice, however, the envelope should be slightly under modulated to make allowances for diode clipping losses during the demodulation process.

The modulation index can be determined from the envelope itself which will be displayed on the oscilloscope. As the amplitude of the message signal is increased, extra lobes appear in the envelope. These lobes indicate over modulation. As the amplitude of the message signal is decreased below 100% modulation, measurements of the maximum and minimum envelope amplitude yield the modulation index:

$$m = \frac{v_{\max} - v_{\min}}{v_{\max} + v_{\min}}$$

The modulation index is defined as:

$$\frac{modulating\ signal\ amplitude}{carrier\ signal\ amplitude}$$

The percentage of modulation may be found by multiplying the modulation index by 100. The modulation index may also be determined from the frequency spectrum by measuring the difference in dB between the amplitude of the carrier and the amplitude of the sidebands. This difference is then used to calculate the modulation index:

$$m = 2 / 10^{[(carrier\ dB\ -\ sideband\ dB)/20]}$$

Amplitude modulation is not an efficient means of transmitting voice and music information. At a modulation index of one, AM modulators are only 33% efficient. This is due to the sidebands only containing one third of the total power. The other two thirds are used up by the carrier, which carries no useful information. Other more efficient methods such as Double Sideband which suppresses the carrier and even

Single Sideband which suppresses the carrier and one sideband are sometimes used. The inherent problem with these two methods is the complexity of the receivers necessary to demodulate the signals. Amplitude modulation remains a popular modulation technique because the simplicity of the receivers involved renders them inexpensive and small in size.

The total power contained within an AM signal is the addition of the sideband power and the carrier power, both in mW:

$P_T = P_{USB} + P_{LSB} + P_C$

The transmission efficiency is a comparison of the useful power contained in the sidebands to the unused power contained in the carrier. The transmission efficiency may also be determined from the modulation index m. At:

$u = m^2/(2 + m^2),$

and with a modulation index of 1, the maximum efficiency

$u = 1^2/(2 + 1^2) = 1/3$ can be calculated.

Parts
AM Source

Test Equipment
- Oscilloscope
- Spectrum Analyzer

Formulae

Modulation Index

$$m = \frac{v_{max} - v_{min}}{v_{max} + v_{min}}$$

Equation 11-1

$$m = 2/10^{[(\text{carrier dB - sideband dB})/20]}$$

Equation 11-2

$$m = \frac{modulating\ signal\ amplitude}{carrier\ signal\ amplitude}$$

Equation 11-3

Efficiency

$$\mu = \frac{P_{USB} + P_{LSB}}{P_T} = m^2/(2 + m^2)$$

<div align="right">Equation 11-4</div>

Power in Watts

$$P_T = P_{USB} + P_{LSB} + P_C$$

<div align="right">Equation 11-5</div>

$$P = V_{rms}{}^2 / R_L$$

<div align="right">Equation 11-6</div>

$$P_T = P_C (1 = m^2/2)$$

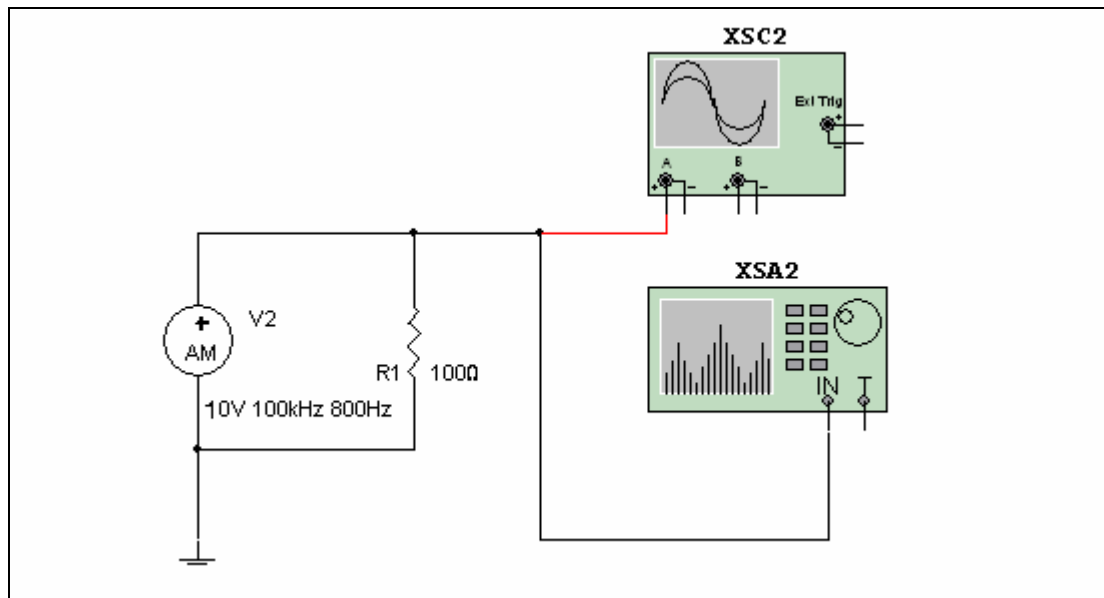<div align="right">Equation 11-7</div>

Procedure

Figure 11-1 Modulation Index and Power Example

1. Connect the circuit illustrated in Figure 11-1.
2. Double-click the AM Source. Select Carrier Frequency = 100 kHz, Modulation Frequency = 800 Hz and Modulation Index = 0.6.
3. Double-click the Oscilloscope to view its display. Set the time base to 1 ms/Div and Channel A to 10 V/Div. Select Auto triggering and DC coupling.
4. Double-click the Spectrum Analyzer to view its display. Select *Set Span* and select *Span* = 10 kHz, *Center* = 100 kHz and *Amplitude* = Lin. Press *Enter*.
5. Start the simulation and double-click the Oscilloscope to view its display. Measure v_{max} which is represented by the maximum peak-to-peak amplitude of

the carrier in the modulated waveform. Measure v_{min} which is represented by the minimum peak-to-peak amplitude of the carrier in the modulated waveform. Calculate the modulation index and compare it with value of the AM Source modulation index. Record your results in Table 11-1.

6. Double-click the Spectrum Analyzer to view its display. Move the red vertical marker over the carrier frequency and measure its amplitude in dB. Measure the number of decibels of one of the sidebands using the same method. Calculate the modulation index and record your results in Table 11-1. Calculate the amplitude of the modulating signal and record your results in Table 11-1.

7. Repeat for a modulation index of 0.33.

8. Double-click the AM Source and set the Carrier Amplitude = 20 V, Carrier Frequency = 100 kHz, Modulation Frequency = 500 Hz and the Modulation Index = 0.5.

9. Restart the simulation and observe the envelope on the Oscilloscope and the spectrum on the Spectrum Analyzer. Using the Spectrum Analyzer, move the red vertical marker to each side band and the carrier, noting and recording the voltage levels. Calculate the power of each, then the total power P_T. Determine a measured value of μ.

10. Set the AM Source modulation index setting to 0.5 in order to determine a calculated value of the efficiency. Record your results in Table 11-2.

11. Change the modulation index to 0.7 and repeat. Record your results in Table 11-2. Repeat the procedure outlined above for a modulation index of 0.8 and 1. Record your results in Table 11-2.
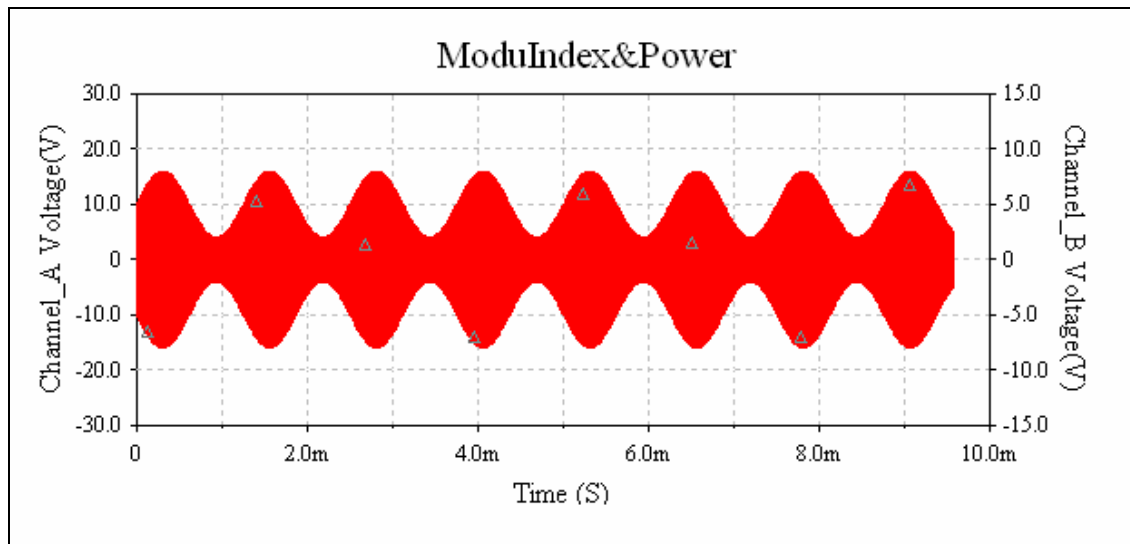
Expected Outcome

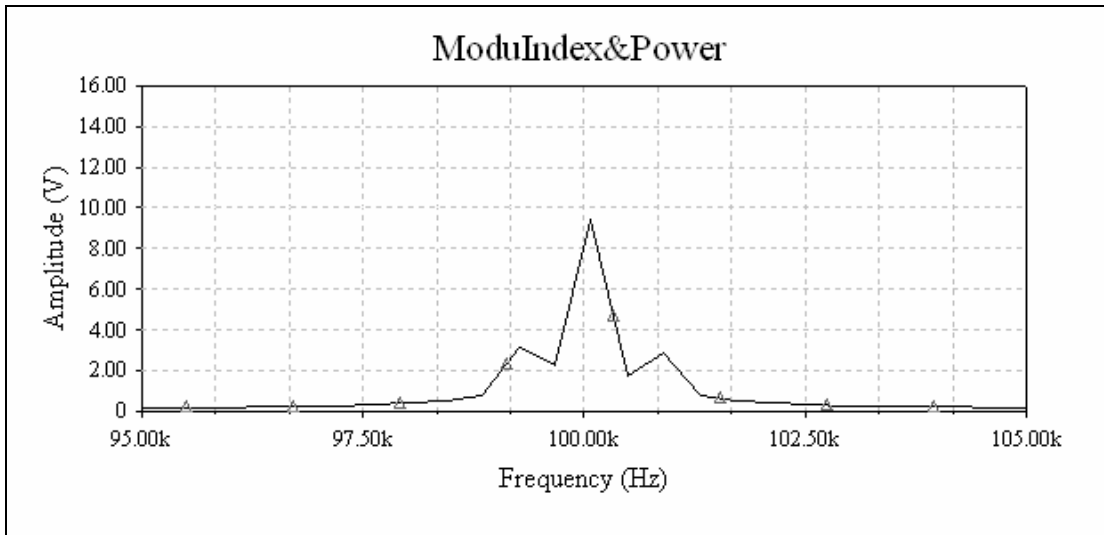Figure 11-2 Oscilloscope Display of m = 0.5

Figure 11-3 Frequency Spectrum of m = 0.5

Data for Experiment 11

	V_{max}	V_{min}	$m_{measured}$	carrier dB	sideband dB	$m_{measured}$	$m_{expected}$	%m	mod. Sig. Amplitude
m = 0.6									
m = 0.33									

Table 11-1

Efficiency

	Measured Value	Calculated Value
m = 0.5		
m = 0.7		
m = 0.8		
m = 1		

Table 11-2

Additional Challenge

Repeat step 2 for a modulation index of 0.80. Set the modulation index to 1.2 and observe the effects of over modulation on the Oscilloscope and Spectrum Analyzer. Set the modulation index to 0.6. Calculate the efficiency of an amplitude modulated signal using power measurements of the carrier and sidebands taken from the frequency spectrum. Use the Spectrum Analyzer in order to obtain your data and the formulae provided for your calculation.