

Reception of Amplitude Modulated Signals

AM Demodulation

OBJECTIVES

The purpose of this experiment is to show how the amplitude-modulated signals are demodulated to obtain the original signal. Also, in this experiment you will be able to see the demodulated signal in the oscilloscope and its power spectrum.

EQUIPMENT LIST

1. Spectrum Analyzer with cables
2. Oscilloscope and probes
3. ANACOM 1/2 DSB/SSB AM Receiver Trainer
4. ANACOM 1/1 Trainer
5. Power supply
6. Jumpers, Cables
7. N to BNC connector adapter
8. Microphone with Audio Input Module

DISCUSSION

AM Detection

Detection is the process of detecting the intelligence out of the carrier and sidebands. We said if two different frequencies were passed through a mixer (non-linear device), the sum and difference components would be generated. The carrier and sidebands of the AM signal are separated in frequency by an amount equal to the intelligence frequency. It follows that passing the AM signal through a mixer device will provide detection. When the input to an ideal mixer is a carrier and its sidebands, the output contains the following frequencies:

- ✓ The carrier frequency
- ✓ Upper sideband
- ✓ Lower sideband
- ✓ DC component
- ✓ A frequency equal to the carrier minus the lower sideband and the upper sideband minus the carrier.

The detector reproduces the signal frequency by producing a distortion of a desirable kind. When the output of the detector is impressed upon a low-pass filter, the radio frequencies are suppressed and only the low-frequency intelligence signal and dc components are left.

We have previously observed that $s(t)$ is recovered from $s_m(t)$ by remodulating $s_m(t)$ and then passing the result through a low-pass filter. This yields the demodulator

system block diagram of figure 1, which is known as a synchronous demodulator. The oscillator is synchronized in both frequency and phase with the received carrier.

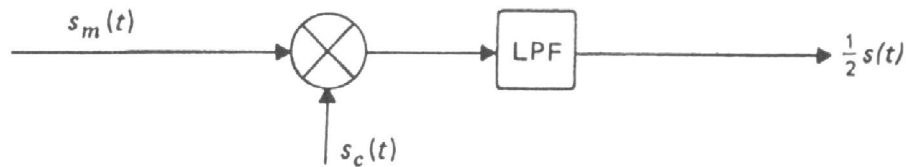


Figure 1: Synchronous AM Demodulator

Envelope Detector

If $A + s(t)$ never goes negative, the upper outline or envelope, of the AM wave is exactly equal to $A + s(t)$. See figure 2. It's possible to detect this signal using an envelope detector. The envelope detector only sense the $A + s(t)$ of the carrier, which is the desired signal. See figure 3. The RC time constant must be short enough that the envelope can track the changes in peak values of the AM waveform.

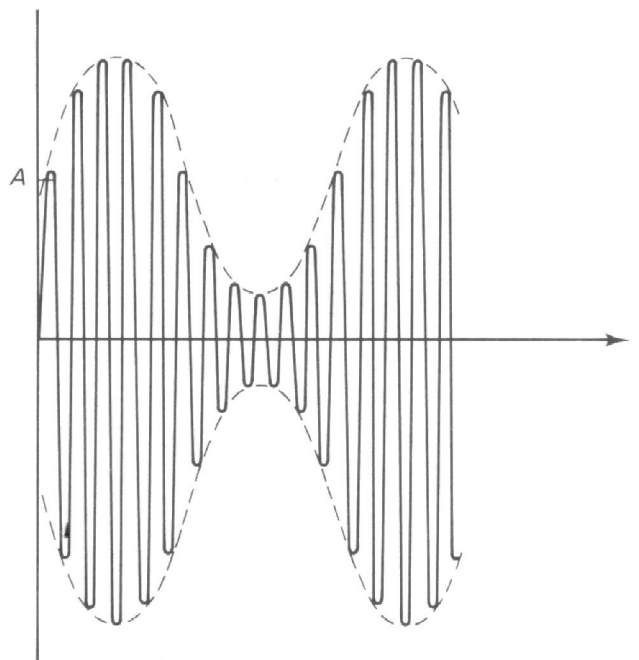


Figure 2: AM Modulation Waveform

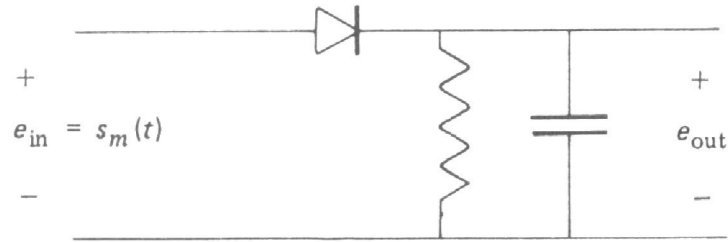


Figure 3: Envelope Detector.

SuperHeterodyne Receiver

A block diagram for a superheterodyne receiver is provided in figure 4. The first stage is a standard RF amplifier. The next stage is the mixer, which accepts two inputs, the output of the RF amplifier and a steady sine wave from the local oscillator (LO). The mixer is a non-linear device utilized to mix the AM signal with a sine wave to generate a new set of sum and difference frequencies (see figure 5). Its output is an AM signal with a constant carrier frequency regardless of the transmitter's frequency. The next stage is the intermediate-frequency (IF) amplifier, which provides the bulk of RF signal amplification at a fixed frequency. This allows for a constant BW over the entire band of the receiver and is the key to superior selectivity of the superheterodyne receiver. Following of the amplifiers is the detector, which extracts the intelligence from the radio signal. A dc level proportional to the received signal's strength is extracted from the detector stage and fed back to the IF amplifiers. This is the automatic gain control (AGC) level, which allows relatively constant receiver output for widely variable received signals.

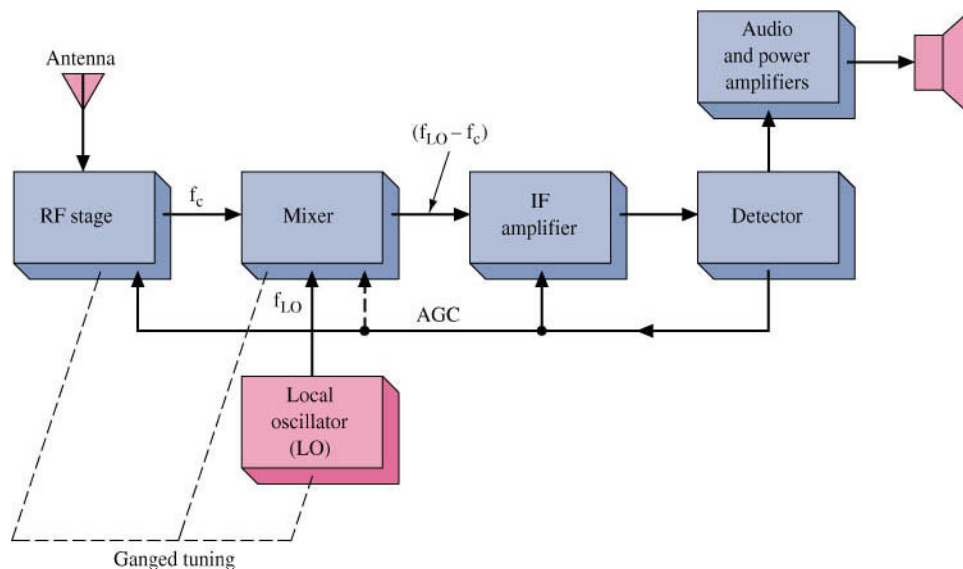


Figure 4: Superheterodyne Receiver

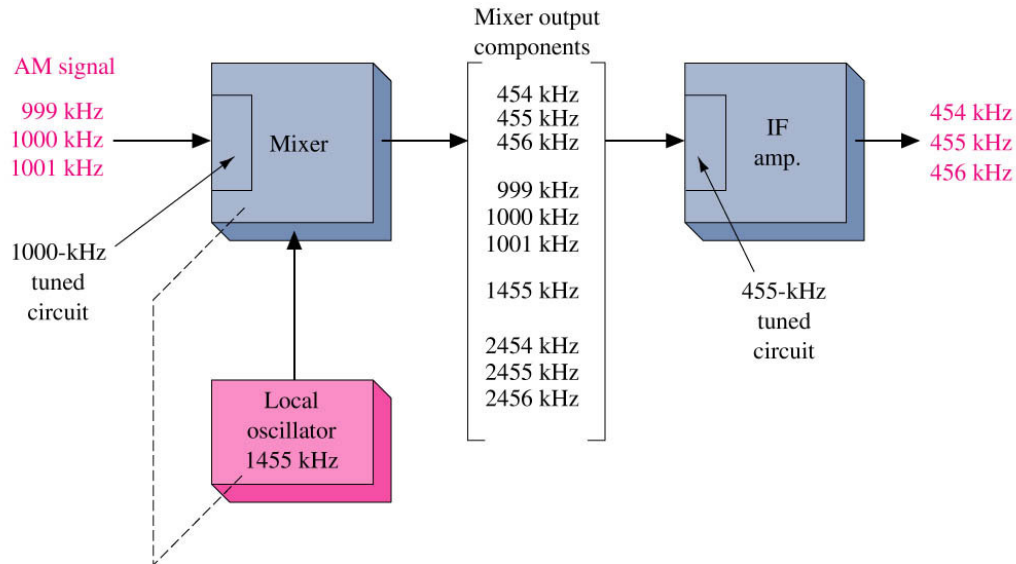
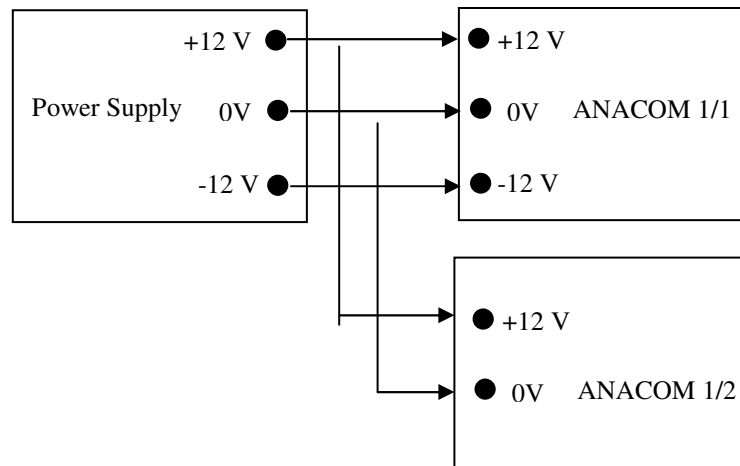


Figure 5: Mixer's Operation

PROCEDURE

1. Connect the power supply to the trainer with all equipment turned off. Follow the following diagram.



2. Select the following conditions in the transmitter trainer
 - a. Audio Input Select : INT
 - b. Mode : DSB
 - c. Output Amplifier Gain : Maximum in clockwise direction
 - d. Speaker Switch : OFF
 - e. Antenna : Fully Extended

3. Select the following conditions in the receiver trainer
 - a. Rx Input Select : ANT
 - b. AGC : IN
 - c. Detector : Diode
 - d. Beat Frequency Oscillator : OFF
 - e. Antenna : Fully Extended
4. Connect the oscilloscope probe of channel one to **test point 14** and ground (transmitter end).
5. Change the audio oscillator amplitude to the maximum value. Using the oscilloscope set the Audio Oscillator Frequency to 3 kHz. This signal is the modulating signal. Note changes in the oscilloscope. (Transmitter end)

$$V_{pp} = \underline{\hspace{2cm}}$$

$$f = \underline{\hspace{2cm}}$$

6. In the OUTPUT AMPLIFIER block set the Gain dial to the maximum position. This secures maximum power to the antenna (transmitter end).
7. In the BALANCED MODULATOR AND BANDPASS FILTER CIRCUIT I block set the Balance dial to the maximum position. This secures maximum power to the carrier (transmitter end).
8. Connect the oscilloscope probe of channel one in **test point 9**. This signal is the carrier. Determine its frequency. (transmitter end).

$$V_{pp} = \underline{\hspace{2cm}}$$

$$f = \underline{\hspace{2cm}}$$

9. Connect the spectrum analyzer to **test point 13**. Determine the carrier, upper and lower sidebands frequencies. (Transmitter end)

$$f_c = \underline{\hspace{2cm}}$$

$$f_{LSB} = \underline{\hspace{2cm}}$$

$$f_{USB} = \underline{\hspace{2cm}}$$

10. Using the receiver tune knob, adjust the knob until the tone is listened.

11. The first stage you will find in almost any receiver is the front-end amplifier. This amplifier is tuned with the sintonized frequency of the receiver. Connect the Oscilloscope to **test point 12**. Determine the carrier frequency. Disconnect the oscilloscope and connect the spectrum analyzer. Try to find the carrier and sidebands of the modulated signal. Print out the modulated signal spectrum and determine the carrier and sideband frequencies (receiver end).

$$f_c = \underline{\hspace{2cm}}$$

$$f_{LSB} = \underline{\hspace{2cm}}$$

$$f_{USB} = \underline{\hspace{2cm}}$$

12. Connect the oscilloscope to **test point 40** and determine the oscillator's frequency. (Receiver end)

$$f_c = \underline{\hspace{2cm}}$$

13. The next stage of our receiver is the mixer. The mixer is a non-linear device utilized to mix the AM signal with a sine wave to generate a new set of sum and difference frequencies. The receiver tuner was designed to always have the LO frequency 455 kHz over the carrier frequency. The mixer was designed to attenuate all frequency components except the 455 kHz component. The down converted signal was centralized in 455 kHz. Connect the spectrum analyzer to **test point 20**. Try to find the down converted signal. Determine the new carrier and sidebands frequencies. Print the down converted spectrum. Set spectrum analyzer's start frequency to 2 kHz and stop frequency to 3 MHz. See all the harmonics produced by the mixer. Determine a few harmonic frequencies. (receiver end). Could you tell me how the modulated signal is down converted? Which formula is used to determine the new carrier frequency? Record these values in table #2

Few of the mixer's output harmonics

F_c

$F_c + 455 \text{ kHz}$

$2F_c + 455 \text{ kHz}$

455 kHz

14. Connect the Oscilloscope channel 1 to **test point 24** and channel 2 to **test point 28**.

$$V_{pp} = \underline{\hspace{2cm}} \text{ (@tp 24)}$$

$$f = \underline{\hspace{2cm}} \text{ (@tp 24)}$$

$$V_{pp} = \text{_____} \text{ (@tp 28)}$$

$$f = \text{_____} \text{ (@tp 28)}$$

15. Disconnect the oscilloscope and connect the spectrum analyzer to **test point 28** and print out signal spectrum. What happen with the carrier and sidebands frequencies? Try to determine the amplifier's gain. To be able to extract the intelligence of the signal, the signal at the mixer's output must be amplified. These amplifiers will only amplify frequencies around the 455 kHz components. Record results in table 2.
16. Connect the oscilloscope to **test point 38**. Explain how the diode detector works. Determine the information frequency.

$$f_i = \text{_____}$$

17. Disconnect the oscilloscope and connect the spectrum analyzer, print the spectrum of the demodulated signal. Notice the diode detector feedback to the AGC. The AGC adjust the amplifier gains to always have the same output level at the detector.

$$f_i = \text{_____}$$

$$\text{PWR LEVEL (dBm)} = \text{_____}$$

18. The last stage of the receiver is the audio amplifier. At the input of the audio amplifier is connected a low pass filter. This filter will only let pass frequencies up to 20 kHz. (Maximum frequency that the ear can listen). This filtered signal is amplified to drive the speakers. Connect the oscilloscope channel 1 to **test point 39** (receiver end) and channel 2 to **test point 14** (transmitter end). Compare the original signal generated in the transmitter with the demodulated one. Determine its frequency. Are they similar? Yes/no? why?

Transmitter End

$$V_{pp} = \text{_____}$$

$$f = \text{_____}$$

Receiver End

$$V_{pp} = \text{_____}$$

$$f = \text{_____}$$

Phase Shift (degrees)

$$\text{_____}$$

19. Turn off the power supply and connect the microphone with the external audio amplifier and the transmitter trainer. Connect the power supply to the external audio amplifier. Change the AUDIO INPUT SELECT (transmitter) switch to EXT. Connect oscilloscope channel one to **point test 16** (transmitter) and channel 2 to **point test 39** (receiver). Try to tune a note with your voice compare both signals. Connect the spectrum analyzer to **test point 28** (receiver). Set the center frequency to 455 kHz and span of 60 kHz. See how your voice spectrum looks like. Print this spectrum and try to identify the carrier, upper and lower sideband frequencies. Use the TRACE Hardkey and MAX HOLD Softkey of the Spectrum Analyzer.

$$f_c = \underline{\hspace{2cm}}$$

$$f_{LSB} = \underline{\hspace{2cm}}$$

$$f_{USB} = \underline{\hspace{2cm}}$$

RESULTS

Table 1: Transmitter End

Test Point	Frequencies to be Measured	Frequencies
9	f_{LO}	
13	f_c	
13	$f_c + f_m$ (USB)	
14	f_m	
13	$f_c - f_m$ (LSB)	

Table 2: Receiver End

Test Point	Frequencies to be Measured	Frequencies
40	f_{LO}	
12	f_c	
12	$f_c + f_m$ (USB)	
12	$f_c - f_m$ (LSB)	
20	$f_{LO} - (f_c + f_m)$ (Demod. USB)	
20	$f_{LO} - (f_c - f_m)$ (Demod. LSB)	
20	$f_{LO} - f_c$ (New Carrier)	
20	$f_{LO} + (f_c - f_m)$ (Harmonics)	
20	$f_{LO} + f_c$ (Harmonics)	
20	f_{LO} (Harmonics)	
20	$f_{LO} + (f_c + f_m)$ (Harmonics)	

Table 3: IF Amplifier

	IF AMP 1		IF AMP 2
Power Level (TP 20)		Power Level (TP 24)	
Power Level (TP 24)		Power Level (TP 28)	
Gain		Gain	
Gain (dB) = Output Power Level – Input Power Level			

QUESTIONS

1. Is the mixer a lineal or non-linear device? Summarize its importance.
2. Is the diode detector used for demodulation of synchronous or asynchronous signals? Why?
3. Why is needed a Audio Amplifier at the end of the receiver?
4. What's an AGC circuit? Why is needed?
5. How the frequency harmonics are generated? How can you get rid of them?