Experiment
4

DSB-SC & AM Modulation with coherent & non-coherent Detection

Hardware Experimentation

Objectives

The goal of this lab is to allow the students to experiment with various types of amplitude Modulation & demodulation hardware systems. The detailed objectives include the following:

1) Implementing DSB-SC with coherent detection.
2) Implementing AM with non-coherent envelope detection.
3) Experimenting with the super-heterodyne receiver structure for commercial AM radio.

Pre-Lab Work

Answer the following questions:

1. Explain the difference between coherent and non-coherent detection of AM signals
2. Can DSB-SC be detected non-coherently with an envelope detector? Explain why.
3. Explain the meaning of "super-heterodyne" receiver (refer to your textbook, Ch.4).

Overview

Refer to your textbook and to the previous experiment for an overview of AM modulation and the related mathematical expressions. Also refer to Experiment 3 for a description of the ACB board that will be used in this lab.

Basically, Amplitude Modulation (whether it is DSB-SC or AM with a carrier component) is the process of varying the carrier signal in accordance with the message signal. The AM receiver can use coherent or non-coherent detection. In the first case, the receiver is able to extract a synchronized local version of the transmitted carrier (by using carrier synchronization techniques such as a Costas loop for example, or through other methods).

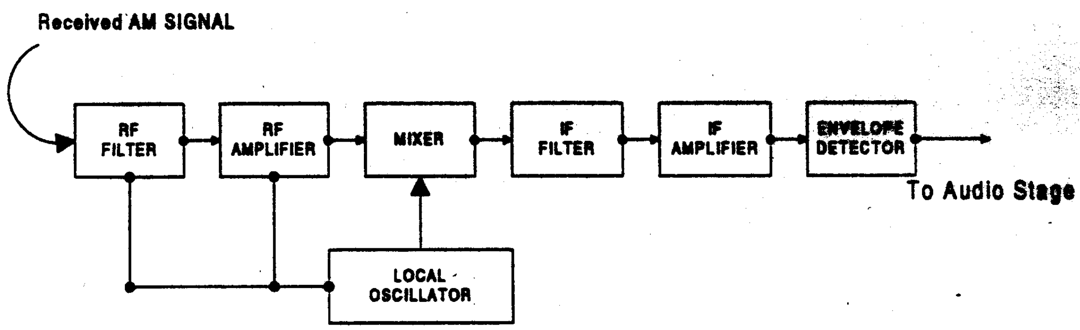
In the case of this experiment, you will be "artificially" testing coherent detection by feeding the same carrier signal used at the transmitter directly to the receiver.

In the second case of non-coherent detection, the receiver doesn't have access to a synchronized local replica of the carrier, so other techniques are necessary. For example, AM (in contrast with DSB-SC) is specifically devised to allow non-coherent detection by transmitting a pure un-modulated carrier component in addition to the one modulated by the message signal. This mechanism allows the receiver to perform simple non-coherent envelope detection (as you studied in class). Notice that it is also possible to detect AM coherently (just like DSB-SC!).

Because of the simple, low-cost receiver architecture for non-coherent AM detection, it is widely used in commercial systems such as radio broadcasting. In this experiment, you will be studying a basic example of a non-coherent AM receiver (known as the super-heterodyne receiver) as illustrated in the block diagram below.

In this radio architecture, the RF stage and local oscillator are simultaneously adjusted to select the desired station, and the RF stage amplifies the AM signal. By adjusting the band-pass RF filter on the ACB board, you can select a frequency range that covers the desired AM signal. The RF amplifier can also be tuned by adjusting the variable inductors to maximize its gain. The following Mixer stage converts the AM frequency to an IF (Intermediate Frequency) of 455 kHz. It is this mixing operation that gives the name of heterodyne receiver to this architecture (see your textbooks for more details). The fixed IF frequency allows the AM receiver to be highly optimized regardless of the selected RF frequency. The IF filter stage is a high-performance ceramic band-pass filter with 20 kHz bandwidth from 445 kHz to 465 kHz. This filter essentially performs the selectivity required to tune to a certain station. The final envelope detector stage demodulates the 455 kHz IF signal to recover the original message signal (which, in the case of voice, can be applied to the audio stage and converted to sound by the Speaker).

Figure 1: Super-heterodyne AM Receiver



Lab Work

1) **Part 1: DSB-SC Modulation Set-up**

   a. Adjust the VCO-LO circuit to produce a 1000 KHz sinusoidal signal, and connect it to Terminal C (carrier) of the Modulator block in the transmitter. This signal will be the carrier signal.

   b. Use the signal generator to obtain a sinusoidal signal of frequency 10 KHz and amplitude 50 mV peak-to-peak. Use this signal as a message signal and connect it to Terminal M of the modulator block.

   c. Set Switch S1 to “ON” (so that a DSB waveform is generated). S2 and S3 should be OFF. Then observe and sketch the modulated signal on the oscilloscope.

2) **Part 2: DSB-SC Demodulation**

   a. Connect the modulated signal directly to the message input M of the Product Detector block (i.e., bypass the RF and IF stages of the receiver), and connect the same carrier to the carrier-input of the Product detector. Make sure the input signal level is <u>100mV</u>.

   b. Compare the demodulated signal (output of the audio filter) and the message signal. Sketch both waveforms.

   c. Try increasing the frequency of the message signal (up from 10 KHz), and observe at which frequency does the demodulated signal disappear. Explain your observations.

3) **Part 3: DSB-SC with Triangular Signal**

   a. Now, change the message signal to a triangular waveform of frequency 10 KHz. Observe if this signal is successfully recovered at the demodulator. Explain.

   b. Reduce the frequency of the triangular waveform to 2 KHz. Is there any improvement in the demodulated signal? Explain why?

4) **Part 4: Effect of Frequency Mismatch**

   a. Now, you need to explore the effect of <u>frequency mismatch</u>. First, start by disconnecting VCO-LO from the Product Detector, and connect instead a signal from the external function generator (with frequency 1000 KHz). Observe the output of the audio amplifier. Can you recover the message signal? Explain why?

   b. Try varying the frequency of the oscillator finely around 1000 KHz, and observe what happens.

5) **Part 5: AM Setup**

   a. Re-connect VCO-LO (at 1000 KHz) to the carrier terminal C of the Modulator, and adjust its amplitude to 1V peak-to-peak. Then apply a sinusoidal message signal of frequency 10 KHz and 0.1 V peak-to-peak to Terminal M of the modulator.

   b. Turn Switch S1 and Switch S2 OFF, and set Switch S3 to ON.

c. Adjust the modulator potentiometer knob so that the AM modulation index μ is about 50%. Sketch the modulated waveform.

d. Try setting the modulation index to 100%, and then over 100%. Sketch the signals. Discuss your observations.

6) **Part 6: AM super-heterodyne receiver**

a. Connect the following in series: Modulator Output-Resistor R1-RF Power Amplifier-Antenna Matching Network with 3 two-post connectors.

b. Using a two-post connector, connect the modulator output to the 1 MΩ R8 resistor from the Receiver Block (to simulate transmission losses), and then adjust the L4 and L5 inductors to maximize the RF amplifier output signal.

Important Notes: 1) the L4&L5 inductors are quite fragile and often get damaged (by the students!!!). Care should be exercised while tuning them very slightly with the special tools provided.

2) If these inductors are damaged, or can not be tuned properly, connect the antenna matching network output directly to the Mixer input M of the receiver, and go to step c)

c. Connect the output of the 1455 KHz VCO-HI to the carrier input C of the Receiver Mixer, and set the potentiometer knob on the VCO-HI fully clockwise. Also connect the RF received signal to the Receiver Mixer input M.

d. While observing the IF filter output, adjust the mixer potentiometer knob and the positive supply knob on the base unit to obtain the maximum signal at the filter output.

e. Compare the signal at the output of the envelope detector to the original message signal. Sketch both waveforms.

f. Now, adjust the modulator potentiometer to obtain a modulation index of 100%, and repeat the above.

Homework Questions

Q1. In Part 2 above, explain why the received signal disappears at some point when the transmitter message frequency exceeds a certain threshold

Q2. In Part 3, explain why there is an improvement when the message frequency is 1 KHz.

Q3. In Part 4, analyze mathematically the effect of frequency mismatch between the transmitter and receiver carrier signals, and show that the demodulated baseband signal appears as a modulated signal.