

ELG3175: Introduction to Communication Systems

Laboratory II: Amplitude Modulation

Introduction:

In this lab, we shall investigate some fundamental aspects of the conventional AM and DSB-SC modulation and demodulation.

Reference:

Chapter on AM modulation in the course textbook.

Preparation:

1. State in the most general form of a conventional AM modulated signal with sinusoidal $m(t)$ and modulation index M . Sketch what the power spectrum of such a signal would be, showing explicitly how the power spectrum relates to M .
2. In the demodulation of DSB-SC, if the sinusoidal carrier input to the demodulator was replaced by a periodic signal at the same frequency as the carrier used in the receiver, would the receiver still work? Assume that the periodic signal has a large component at the fundamental frequency.
3. Bring at least 2 USB sticks to the Lab to record all your measurements (as screenshots in .png or .jpg files), 2nd stick is required in case 1st one does not work/fails. The format of the USB should be FAT32. All screenshots must be recorded on the USB (pictures taken by cell phones are **not acceptable**) and must be included in the reports in the original form, **no editing at all** (e.g. cropping etc.).

All preparation questions have to be answered in writing before coming to the lab and will be inspected by the TA.

All measurements have to be done and analyzed in the Lab. It is very important to do a preliminary analysis and interpretation of the measured data in the Lab so that if any inconsistencies or gaps are discovered, they can be corrected with extra measurements while still in the Lab.

Apparatus:

1. Waveform Generator (Agilent 33500B Series)
2. Spectrum Analyzer (Rohde & Schwarz HMS3010)
3. Dual Channel Oscilloscope (Rohde & Schwarz HMO722)
4. Krohn-Hite 3384 Filter Unit
5. Lab-Volt (91018-20)

CAUTION**CAUTION****CAUTION**

Spectrum analyzers are very expensive, delicate and sensitive pieces of equipment which can be very easily abused. Make sure that at all times the signals you apply to the input does not exceed the maximum allowable input level noted on the front of the unit. If you are unsure of a signal level, measure it on your oscilloscope or with a voltmeter before you apply the signal to the spectrum analyzer.

Procedure

Part I: The Spectra of AM modulated signals

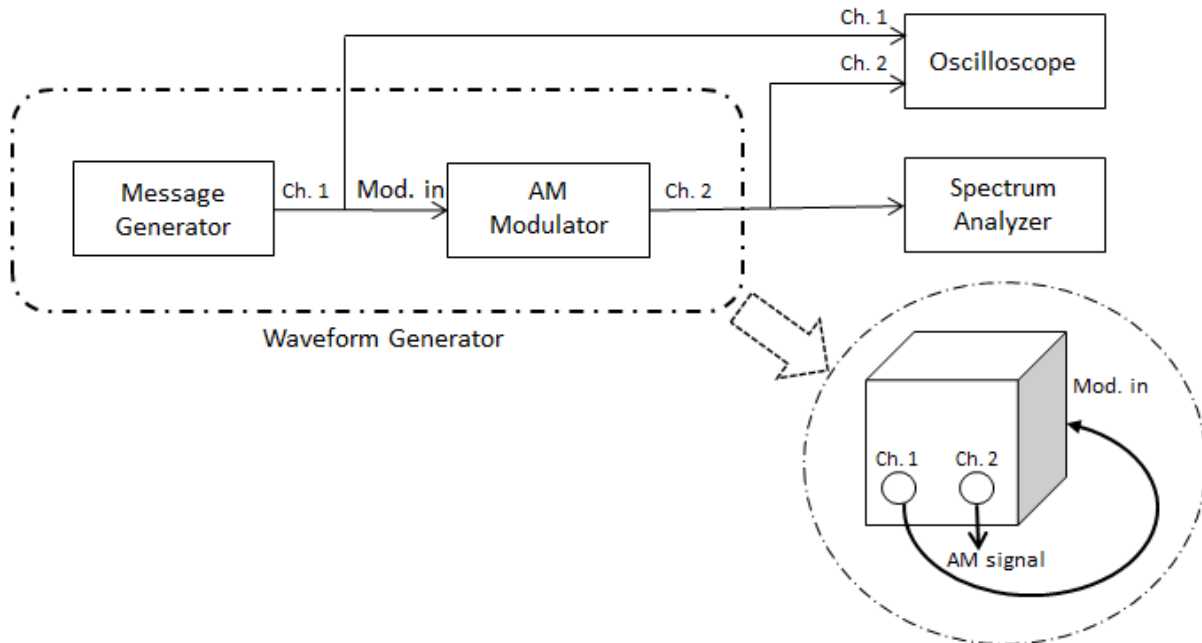


Fig. 1: Generation and measurement of AM modulated signals and their spectra.

The Waveform Generator (Agilent 33500B Series) has 2 channels and various waveforms with specific frequency, amplitude, or DC offset can be produced in either of the channels. This equipment has also the capability to modulate a signal; therefore an unmodulated signal or a modulated signal can be generated by each channel. In this Lab, such capability of Waveform Generator will be utilized to generate AM modulated signals. The message signal of the modulator can be of three different types:

External: signal generated from other devices or the other channel can be used as a message signal, which must be connected physically by a cable to “Mod. In” port in the rear of the device.

Internal: In this mode the message signal is generated internally. There is no need to make any physical connections; frequency of the message signal and percentage of modulation (i.e. modulation index) can be set via softkeys.

The other channel: In this mode, there is still no need to make a physical connection. The other channel’s signal serves as a message, transmitted internally from the other channel. We will use various types of the source of the message signal throughout this lab.

Set up the system as in Fig. 1. Select AM (modulation) in channel 2 before setting up any other modulation parameters. Press “Modulate” and then select “AM” using the “Type” softkey. Also turn the modulation on using “Modulate” softkey. Use “Source” softkey to set the source as “External” in this part. As mentioned earlier, the external source could be another function generator, but here we use channel 1 as the external source. Connect the output of channel 1 to the “Modulation In” on the rear panel of the Waveform Generator. Set the “AM Depth” to 100% in channel 2. (this parameter should be kept 100% during all stages of this lab). Note that ‘AM Depth’ is not the actual percentage modulation and it is affected by the message amplitude. We will measure the actual modulation index by Spectrum Analyzer (SA) or Oscilloscope.

1. Set the carrier frequency of channel 2 of Waveform Generator to 400 kHz with 1 V_{pp} amplitude. Please note that this amplitude is not the carrier amplitude but rather is the peak-to-peak voltage of the modulated signal when the modulation index is 100%. With no signal applied to the modulator as message (this can be done simply by turning off the output of channel 1), observe the modulator output on the Oscilloscope and SA. Verify that there is just one spectral line at the carrier frequency on the SA and record its amplitude. On the SA, set the Unit to V, the Ref. level to 200 mV, and the start and stop frequencies to 350 kHz and 450 kHz respectively, to see clearly the spectrum. For all measurements on the SA and OS, make snapshots and record them on your USB stick, to be used later on in your report.

2. In this part we will observe an AM modulated signal and its spectrum for different modulation indices. Note that

$$\text{percent modulation} = \frac{A_{max} - A_{min}}{2A_c} \times 100\% = \frac{2A_{SB}}{A_c} \times 100\%,$$

where A_c is the carrier amplitude you recorded in step 1 and A_{SB} is the sideband amplitude; $M = (A_{max} - A_{min})/2A_c$ is the modulation index. You can determine A_{SB} from this formula for a specific percentage modulation, and then adjust the message signal's amplitude on the Waveform Generator (channel 1) to observe the desired A_{SB} on the SA. Set the message signal to 10 kHz sinusoidal signal. Adjust its amplitude to obtain 25%, 50%, and 100% modulation. In each case: (a) observe and record both modulating and modulated signal on the Oscilloscope, set the trigger source on the Oscilloscope to channel 1 to freeze the relative motion of the carrier and signal envelope; (b) record the SA displays and measure the carrier and sideband amplitudes and compare it to the modulated signal you observe on Oscilloscope.

Part II: Conventional AM and DSB-SC Modulation

1. Keep the system set-up as in Fig.1. With the carrier frequency set to 400 kHz, the amplitude of the modulated signal set to 1 V_{pp}, and the message set to 10 kHz with 5 V_{pp} amplitude, observe the output of the modulator on the SA and Oscilloscope.

2. Press “Modulate” on channel 2 and then select DSB-SC modulation using the “DSSC” softkey. Observe the signal on the SA and Oscilloscope and compare it to the conventional AM signal. Note the 180° phase reversals of the carrier at the zero-crossing instants of the message signal. Set up the OS parameters so that you can clearly see this.

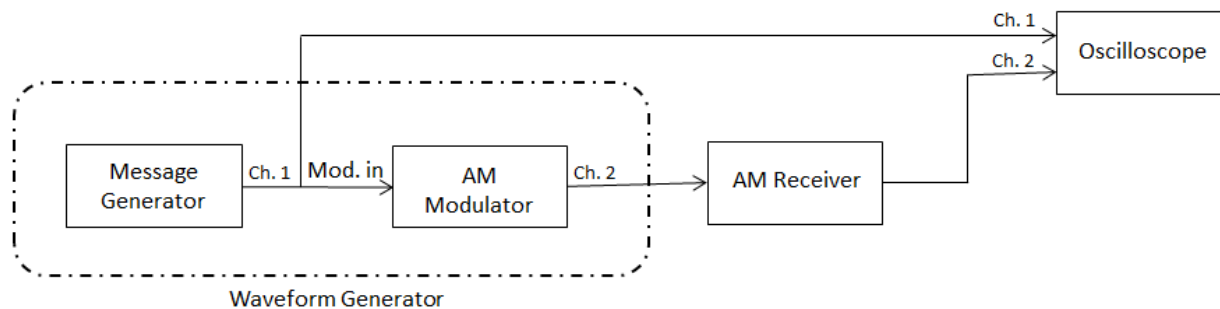
Part III: Demodulation of AM-modulated signals

Fig. 2: Generation and demodulation of AM signals.

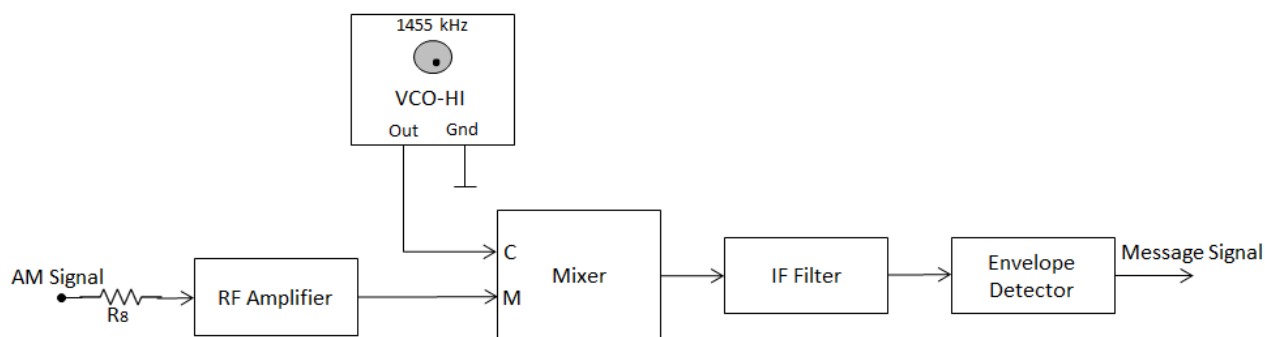


Fig. 3: AM receiver block diagram.

1. Set up the system as shown in Fig. 2 using a 2 kHz sinusoidal message signal with 3 V_{pp} and a 1 MHz carrier frequency with 2 V_{pp} (the peak to peak amplitude of the modulated signal for 100% modulation). Turn off DSSC of Channel 2. Use “AM/SSB Receiver” part in the Lab-Volt for receiver part. The block diagram of the receiver is shown in Fig. 3. To set the VCO-HI frequency to 1455 kHz, adjust the positive supply knob on the right side of the base unit. You can measure this frequency by connecting the output of the VCO-HI to the Oscilloscope. The potentiometer knob on the VCO-HI circuit block adjusts the output amplitude. Set it fully clock wise to maximize the output signal amplitude. Connect the Mixer to the IF filter with a two-post connector. Adjust the Mixer’s balanced potentiometer knob until the desired signal appears on the Oscilloscope. The IF filter has 20 kHz bandwidth between 445 kHz and 465 kHz. Verify that the output of the system is a 2 kHz sinusoidal signal.
2. Change the message frequency to 10 kHz and observe the output.
3. Set the message to 2 kHz again. Change the message amplitude to 5 V_{pp} and 1 V_{pp} and observe the output.
4. Change the message signal to a triangular signal (named as a ramp signal with 50% symmetry in the Waveform Generator) and a square wave and verify that the output of the system is the same as the message signal. Explain any discrepancies.
5. Generate a DSB-SC modulated signal and repeat parts 1 to 4 and explain the observed output.

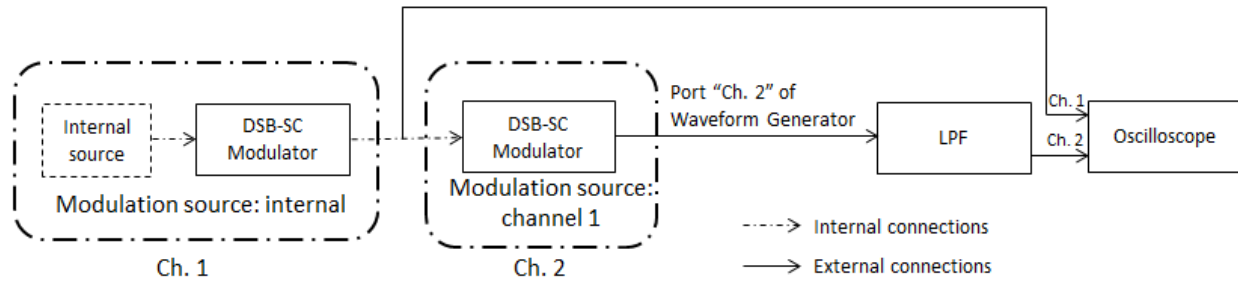
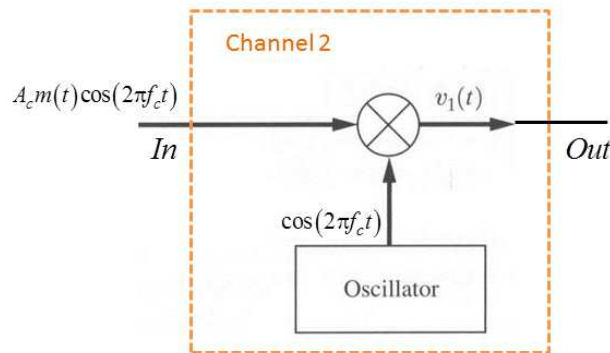
Part IV: DSB-SC Demodulation via Secondary DSB-SC Modulator (Ch. 2)

Fig. 4: DSB-SC demodulation.

In this part, both channels of the Waveform Generator are used. Channel 1 generates a DSB-SC modulated signal using “Internal” source. Channel 2 serves here as a multiplier and oscillator as shown below



and, in combination with the LPF, as a demodulator of the DSB-SC modulated signal of Channel 1.

1. Set up the system as shown in Fig. 4. In Channel 1, turn on the modulation, select “AM”, set the source as “Internal”, and turn on DSSC. Set the carrier frequency to 1 MHz and the modulated signal’s amplitude to 1 Vpp and the sinusoidal message frequency (shown as “AM freq” on the Waveform Generator) to 10 kHz. This signal is demodulated by Channel 2. To do so, turn on the modulation of Channel 2. Select “AM”, set the source as “Channel 1” and turn on DSSC. Set the carrier frequency to 1 MHz and the modulated signal’s amplitude to 1 Vpp. Please note that you do not need to connect channel 1 of the Waveform Generator to Channel 2 with cable as they are connected internally (as shown in Fig. 4). Connect the output of Channel 2 to a low pass filter (LPF). Set the cut off frequency of the LPF to 15 kHz. On the Oscilloscope, set the trigger source to Channel 2. Observe the output of the filter on the Oscilloscope and compare it with the message. Adjust the scales of both axes so that you see a clear picture of both signals and can observe their differences and similarities.

2. Increase the cutoff frequency of the LPF to 150 kHz. Change the message signal of Channel 1 to triangular and then a square wave and explain what you observe on the Oscilloscope. To do so, activate “Modulate” of Channel 1 and then change the signal using “Shape” softkey. Repeat this part with the cutoff frequency = 15 kHz and explain the difference. What is the appropriate cutoff frequency?