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SKEE 3732
SCHOOL OF ELECTRICAL ENGINEERING, FACULTY OF ENGINEERING,
UNIVERSITI TEKNOLOGI MALAYSIA, JOHOR BAHRU

BASIC COMMUNICATION LABORATORY

AMPLITUDE MODULATION (AM)

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1.0 OBJECTIVES

- To simulate basic communication system of amplitude modulation (AM) signals using gnu-radio companion (GRC).
- To understand the concept of different types of AM signals in terms of time and frequency domain representations.
- To examine the main parameters of AM signals.
- To develop AM signals on Universal Serial Radio Peripheral (USRP) Software Defined Radio (SDR) platform

2.0 MODULATION

Modulation is a process of translating information signal from low band frequency to high band frequency that suits the transmission medium. The inputs to the modulator are carrier and information (modulating) signals while the output is called the modulated signal. Modulating or information signal is usually of low frequency, so it cannot travel far. It needs a carrier signal of higher frequency for long distance destination. Figure 2.1 shows a basic block diagram of a modulator.

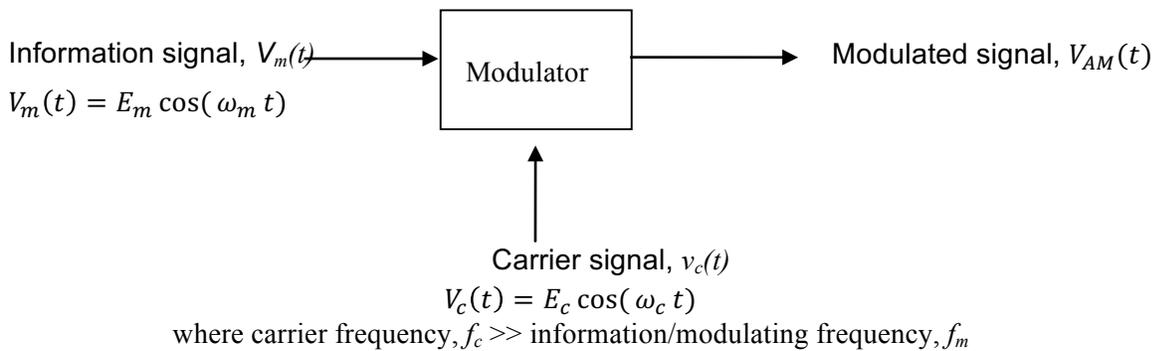


Figure 2.1: Basic Block Diagram of A Modulator

Figure 2.2 illustrates the use of Fourier Transform where the modulating/information signal and the carrier are simply multiplied together. Assuming a sinewave information signal for simplicity, the result will be Amplitude Modulation-Double Sideband Suppressed Carrier (AM-DSBSC) whose modulation process translates the Fourier Transform $M(\omega)$ of $m(t)$ up to the frequency range from $f_c - f_m$ to $f_c + f_m$ (and the negative frequency range from $-f_c - f_m$ to $-f_c + f_m$).

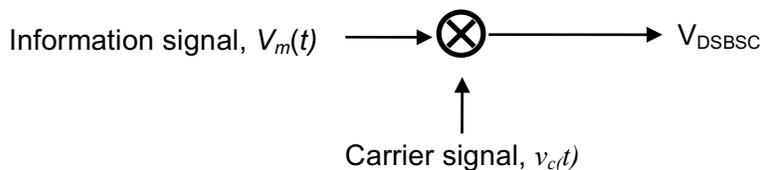


Figure 2.2 AM-DSBSC modulation

2.1 AMPLITUDE MODULATION (AM)

Conventional or Full AM can be understood as the classic AM technique for transmitting messages as it is still used today for radio broadcasting on short, medium and long waves. It involves the transmission of the carrier and the double sideband signals. Amplitude Modulation (AM) refers to the modulation technique where the carrier's amplitude is varied in accordance to the modulating signal's amplitude. The major advantage of this modulation technique is in the simple demodulation process.

$$V_{AM}(t) = (E_c + V_m(t))\cos(\omega_c t)$$

$$V_{AM}(t) = (E_c + E_m \cos(\omega_m t))\cos(\omega_c t)$$

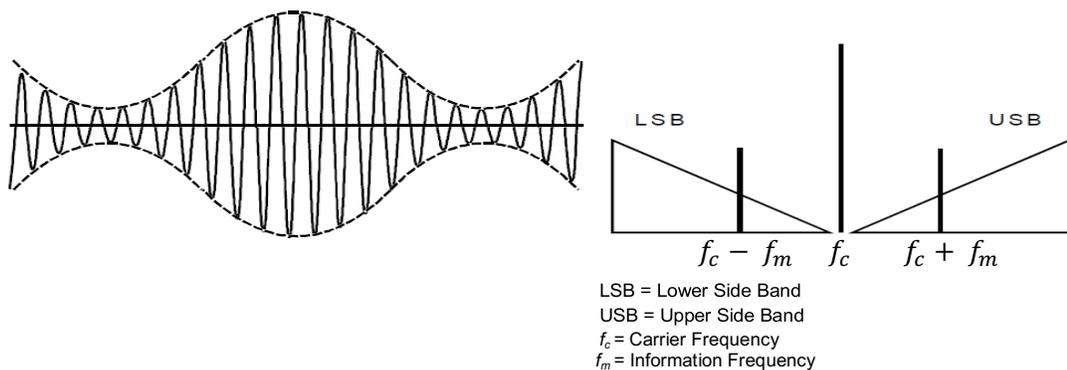
$$V_{AM}(t) = (E_c(1 + m \cos(\omega_m t)))\cos(\omega_c t)$$

where:

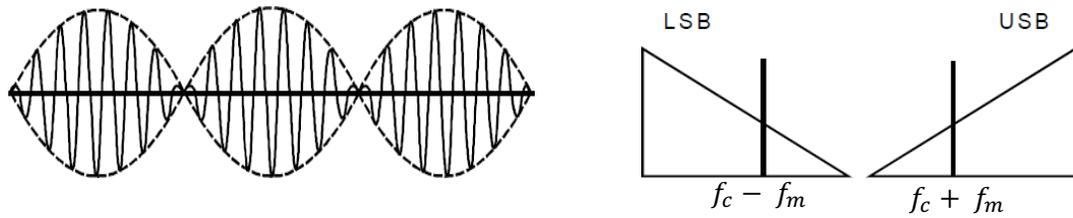
$$\text{modulation index, } m = \frac{E_m}{E_c}$$

In addition to this technique, there are a number of other techniques which differ within the spectrum of AM techniques. A disadvantage of conventional AM is that a carrier is transmitted which does not represent a message. In addition, two sidebands are transmitted with the same information. The aim of the further developed AM is to save bandwidth or transmitter power or to utilize it more economically.

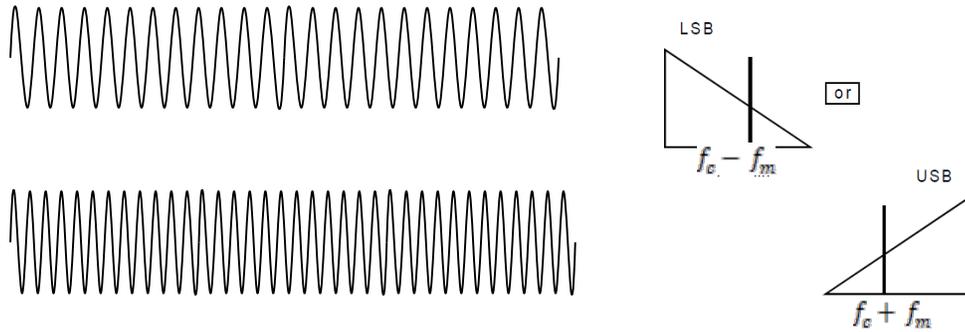
Figure 2.3 lists the different types of amplitude modulation. The line diagram and frequency spectrum are illustrated under the relevant terms. The frequency band(s) to be transmitted are often represented graphically as discrete band(s) or triangles for periodic and non-periodic signals, respectively. In the spectrum of the AM double sideband modulation, the upper sideband appears in normal position, the lower sideband in inverted position. The top diagram shows the conventional AM of which the frequency spectrum is composed of the carrier frequency, f_c , upper sideband, $f_c + f_m$ and lower side band, $f_c - f_m$.



(a) Conventional Amplitude Modulation, AM (DSBFC)



(a) AM- DSB (AM – Double Side Band) or SCAM (Suppressed Carrier AM)

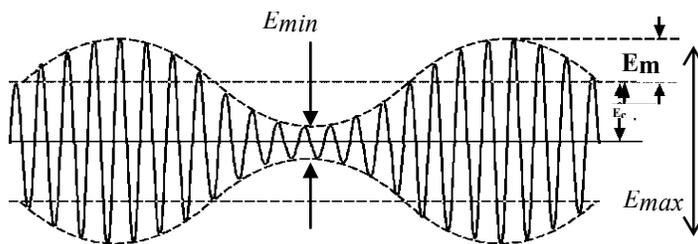


(c) AM- SSB (AM – Single Side Band)

Figure 2.3 Different types of amplitude modulation

2.2 THE MODULATION FACTOR, m

The change in the carrier amplitude is proportional to the change in the modulation signal amplitude. The ratio of this change to the unmodulated carrier amplitude is known as the modulation factor, m . It is often specified as a percentage. As high a modulation percentage as possible is aimed at in a transmission system. The highest value of m under ideal scenario is $m = 1$.



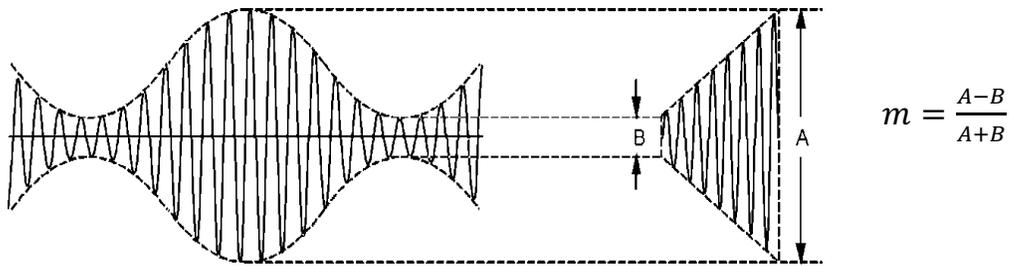
$$m = \frac{E_{max} - E_{min}}{E_{max} + E_{min}}$$

where:

$$E_{max} = 2(E_c + E_m)$$

$$E_{min} = 2(E_c - E_m)$$

The method of measuring the modulation factor from the oscilloscope is of a very theoretical nature because a sinewave voltage with constant amplitude is very rarely transmitted. Measuring with the modulation trapezium allows a very simple and quick check of the modulation factor, even for speech and music signals. The oscilloscope is switched to XY-mode for this; the information signal is applied in X-direction, the AM in Y-direction



2.3 AM DEMODULATION

Demodulation is the process of recovering the modulating signal or the information signal from the modulated signal. This process is conducted at the receiver. The demodulation process is depending on which type of modulated signal is transmitted at the transmitter. For the Full AM Modulation or Double Side Band Full Carrier (AM-DSBFC), there are two types of demodulation circuits, i.e. the envelope detector and square law detector.

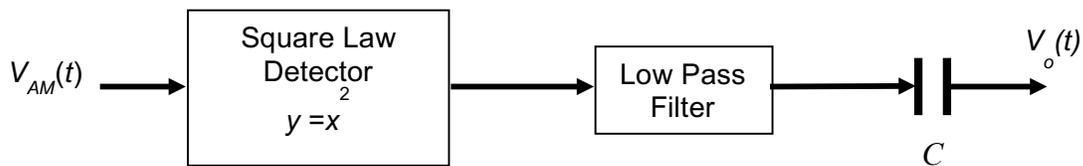


Figure 2.4 AM Square-Law Detector

The synchronous detector or also known as the coherent detector is used to demodulate AM-DSBSC signal.

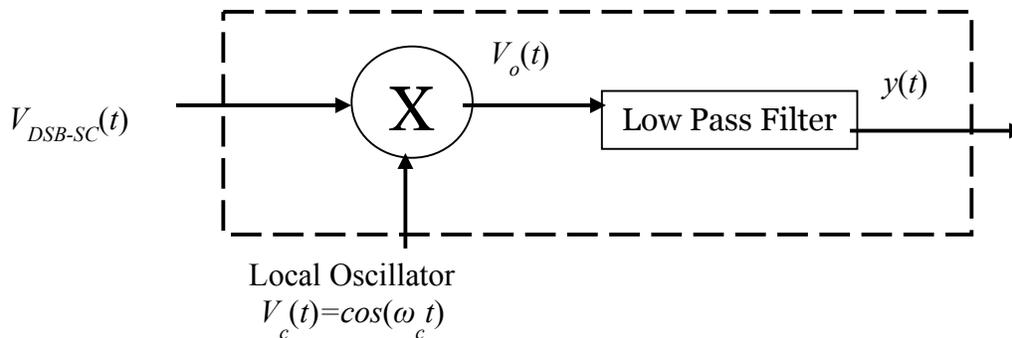


Figure 2.5 AM Synchronous Detector

References:

1. Rozeha A. Rashid & et al., *Prinsip Kejuruteraan Telekomunikasi*, Penerbit UTM 2007
2. Abu Sahmah & et al., *Principles of Communication*, Pearson 2011
3. https://www.csun.edu/~skatz/katzpage/sdr_project/sdrproject.html

INSTRUMENT REQUIRED

1. Universal Software Radio Peripheral (USRP) Software Defined Radio (SDR) B200.
2. LP0965 Log Periodic PCB Antenna (850 MHz to 6.5 GHz).
3. SMA-SMA Cable.
4. GNU-Radio Companion (GRC).

• *Read all procedures before you do this experiment. If you have any problems, get the lab instructor/supervisor to help you.*

EXPERIMENT PROCEDURES

EXPERIMENT 1 : CONVENTIONAL/FULL AMPLITUDE MODULATION (AM-DSBFC)

Experiment 1.1: Full AM Modulator/Transmitter

- 1.1.1 Start a new file in GNU Radio Companion (GRC). There will be two blocks in the workspace, i.e. **Options** block and **Variable** block. Open **Variable** block. Set the Sampling Rate in the Variable block to 200 kHz and variable name to samp_rate. In **Options** block, select WX GUI.
- 1.1.2 Create a signal source block by selecting **Signal Source** block. It should already be set to generate a cosine of frequency 1 kHz and amplitude 1. Change the frequency to 4kHz. Change the output type from “Complex” to “Float”.
- 1.1.3 Connect the signal source block to a **Throttle** block. Then connect the output of the throttle to a **WX GUI Scope Sink** and **WX GUI FFT Sink**. Set also all the block to Float to match the source block and sampling rate to samp_rate.
- 1.1.4 Execute the file by hitting the gear icon in the GRC menu (taskbar), then click run. Observe and print screen the signal both in time and frequency domain representations.
- 1.1.5 Change the frequency and amplitude of the signal source. Verify that the signal is correct and discuss in your lab report.
- 1.1.6 For AM experiment, connect the output of the throttle block to a **Multiply Const** block. Set value constant to 1. Then connect this block to **Add Const** and set the value constant to 1.
- 1.1.7 Add another **Signal Source** block which acts as a carrier signal. Change the frequency to 30 kHz. This will be the carrier frequency. After that, connect both the output of the carrier signal and **Add Const** block to a **Multiply** block (under Operators). Change all the sampling rate value to samp_rate and Type to Float.
- 1.1.8 Add **WX GUI Scope Sink**. Set Num inputs to 2. Connect output of **Add Const** block to the first input of **WX GUI Scope Sink**.
- 1.1.9 Then, connect the output of the **Multiply** block to the second input of **WX GUI Scope Sink**.

- 1.1.10 Finally, add another **WX GUI FFT Sink** and connect it to the output of **Multiply** block.
- 1.1.11 Save the generated modulated signal using **File Sink** block. Choose the folder in which you want to save the file and name it as **AMsinuswave.dat**.
- 1.1.12 Save the flow-graph. Execute the file by hitting the gear icon and click run. Now, observe and print screen the output signals on both in time and frequency domain representations as well as its trapezoid form.
- 1.1.13 Analyze and compare these signals with signals from Step 1.1.4. Change the modulation index, m to $m < 1$ and $m > 1$. Discuss what happen to the signals. (Refer to Amplitude Modulation theory).
- 1.1.14 Now, change the sinusoid message signal to square wave signal. Set the parameters of the **Signal Source** block to square waveform, amplitude 2 and offset -1.
- 1.1.15 Save the generated modulated signal using **File Sink** block. Choose the folder in which you want to save the file and name it as **AMsquarewave.dat**.
- 1.1.16 Save the flow-graph. Execute the file by hitting the gear icon in the GRC menu (taskbar) and click run. Now, observe and print screen the output signals both in time and frequency domain representations. Discuss what happened to the signals. Compare with signals from Step 1.1.12.

Additional Hint:

1. **WX GUI Notebook** block enables to show several plots in a single window using different tabs.
2. **WX GUI Slider** block enable to change the values of any variables that you want. Example: modulation frequency, carrier frequency or modulation factor.

Discussion and Analysis

- a) Based on your experiment, state the frequencies of the carrier and the modulating signals. Change the amplitude of both message/modulating signal and carrier signal. Change both frequencies of the carrier and the modulating signals. Analyze and discuss.
- b) What is the function of **Multiply Const** block and **Add Const** block in your experiment?
- c) If the value of constant in **Multiply Const** is 1, describe what happened to the output signals. Analyze the changes of the output signals if you increase or decrease the values, i.e. less than 1 and greater than 1. Discuss in details.
- d) Observe three types of modulation states of AM signal with three different modulation factors.
- e) From your observation, what type of AM signal is this?
- f) What is the amplitude of the two sidebands relative to the carrier for 50% modulation with a sinusoidal wave?
- g) How are different amplitudes of the message/modulating signal represented in the modulated

signal?

Experiment 1.2: Full AM Demodulator/Receiver

- 1.2.1 For AM demodulation experiment, add **File Source** block. Choose the folder in which you have saved the filename **AMsinuswave.dat** from Experiment 1.1.
- 1.2.2 Add a **Null Source** block (under Sources). The Null Source just creates a stream of zeros.
- 1.2.3 Then, add **Max** block (under operators). Change Num Inputs to 2. Connect the output of **Null Source** block to the second input of **Max** block.
- 1.2.4 Connect the File Source block output to the first input of **Max** block.
- 1.2.5 Connect the **Max** block output to the **Low Pass Filter** block. Open the low pass filter's properties. Change the FIR Type of the filter to Float (Decimating). Set cutoff frequency to 5kHz and the transition width to 1kHz.
- 1.2.6 Finally, connect the output of the **Low Pass Filter** block to the throttle and then to **WX GUI Scope Sink** and **WX GUI FFT Sink** to view the demodulated signals.
- 1.2.7 Save the flow graph and execute.
- 1.2.8 Observe the demodulated signals in both time and frequency domains. Take the snapshot, analyze and compare with Experiment 1.1.
- 1.2.9 Repeat for file **AMsquarewave.dat** from Experiment 1.1. (Hint: Need to set the suitable cutoff frequency for LPF). Observe the different from previous Step 1.2.8. Discuss in your lab report.

Discussion and Analysis

- a) Observe the signal waveforms in time and frequency both before and after modulation. How are different amplitudes and frequencies of the message/modulating signal represented in the modulated signal? How it relates to modulation factor.
- b) Based on your experiment, what is the name of the method of demodulation? Why it is more popular than DSBSC?
- c) Can we use this demodulation process with suppressed carrier modulation, i.e. AM-DSBSC?
- d) Looking at the time and frequency domain plots of the demodulated signal, there should still be a DC component. How this DC component can be taken out?

EXPERIMENT 2: AM-DOUBLE SIDE BAND SUPRESSED CARRIER (AM-DSBSC)

- 2.1 Design an AM-DSBSC modulator and demodulator by referring to Figure 2.2 and 2.5, respectively.
- 2.2 Choose your own modulating frequency, f_m and suitable carrier frequency, f_c .
- 2.3 Verify the most suitable cut off frequency and gain of the low pass filter so that the initial message

signal can be retrieved back.

2.4 Save the flow graph and execute.

2.5 Observe both time and frequency representations of message signal before and after modulation. Record and analysis.

2.6 Record time and frequency representations of signal before low pass filter.

2.7 Observe also time and frequency representations of modulated signal before and after demodulation process. Record and justify.

Discussion and Analysis

- a) Why we need suitable carrier frequency in designing AM-DSBSC modulator system?
- b) What is the selected cut off frequency and gain of the LPF in your design. Explain why you choose the value.
- c) What is the advantages and disadvantages of this AM-DSBSC compared to the AM-DSBFC?
- d) Why we cannot use envelope detector (as refer to previous Experiment 1) to demodulate AM_{DSBSC} signal?
- e) What is the other name of this AM_{DSBSC} demodulation? Describe why?
- f) What happen if there is a phase difference between locally generated carrier frequency and carrier signal in modulator part?

EXPERIMENT 3 : AMPLITUDE MODULATION (USING USRP)

In this experiment, AM signal will be transmitted using USRP as the AM transmitter/modulator and another USRP as the AM receiver/demodulator.

Experiment 3.1 : AM USRP Transmitter/Modulator

- 3.1.1 Open your flow-graph from Experiment 2 (AM-DSBSC Modulator). Add **Float to Complex** block. Connect the output of the **Multiply** block to the input of **Float to Complex** block.
- 3.1.2 To send the modulated signal to the USRP board, add **UHD: USRP Sink** block. Change the properties of the **UHD: USRP Sink** block. Set Sample Rate to `samp_rate`. Set Center Freq to 200MHz. Set the Gain to 20 dB and set Antenna to TX/RX.
- 3.1.3 Connect the provided Log Periodic PCB antenna and transmitting USRP to the computer.
- 3.1.4 Save the flow-graph and execute. Observe time and frequency representations of modulated signal. Record.

Experiment 3.2 : AM USRP Receiver/Demodulator

- 3.2.1 Open your flow-graph from Experiment 2 (AM-DSBSC Demodulator).
- 3.2.2 Disable **File Source** block.
- 3.2.3 To receive signal using USRP, add **UHD: USRP Source** block. Change the properties of the **UHD: USRP Source** block. Set Sample Rate to samp rate. Set Center Freq to 200MHz. Set the Gain to 20dB and set Antenna to TX/RX.
- 3.2.4 Connect the output of the **UHD: USRP Source** block to the input of **Complex to Float** block.
- 3.2.5 Connect the output of the **Complex to Float** block to the **Multiply** block.
- 3.2.6 Connect the provided Log Periodic PCB antenna and receiving USRP to the computer.
- 3.2.7 Save the flow graph and execute. Observe time and frequency representations of the received signal. Make sure the transmitting USRP from Experiment 3.1 is operating. Compare both signals from AM USRP Transmitter and AM USRP Receiver. Record and analyze the signals. Discuss in your lab report.

FOR SHORT REPORT

1. Attach every flow graph for each experiment.
2. Attach all plots and explain the results. Analyze the results.
3. Answer all questions in this handout.

FOR LONG REPORT

1. Attach every flow graph for each experiment.
2. Answer all questions in this handout. Attach all plots and explain the results
3. Give examples of commercial applications of AM.
4. Please include discussion on different types of AM in terms of system and power efficiencies.
5. Include a simulation using MATLAB of one type of AM (Full AM/DSBSC/SSBSC) and compare with the experimental result.