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

**BASIC COMMUNICATION LABORATORY**

AMPLITUDE MODULATION (AM)

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| Prepared by | : **HEAD OF BASIC COMMUNICATION LABORATORY** | Approved by | : **HEAD OF COMMUNICATION ENGINEERING DEPARTMENT** |
| Name | : **DR. NURUL ASHIKIN DAUD**<br>**: TS. DR. NIK NOORDINI NIK ABD MALIK** | Name | : **ASSOC. PROF. IR. TS. DR. NURUL MU'AZZAH BINTI LATIFF** |
| Assisted by | : **PN. NORHIDAYU BASIR**<br>: **CIK NORAZAH ADZHAR**<br>: **PN. SYUKHIRIZA ALI** | | |
| Signature & | : | Signature & | : |
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## 1.0 OBJECTIVES

a) To simulate basic communication system of amplitude modulation (AM) signals using gnu-radio companion (GRC).
b) To understand the concept of different types of AM signals in terms of time and frequency domain representations.
c) To examine the main parameters of AM signals.
d) 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.

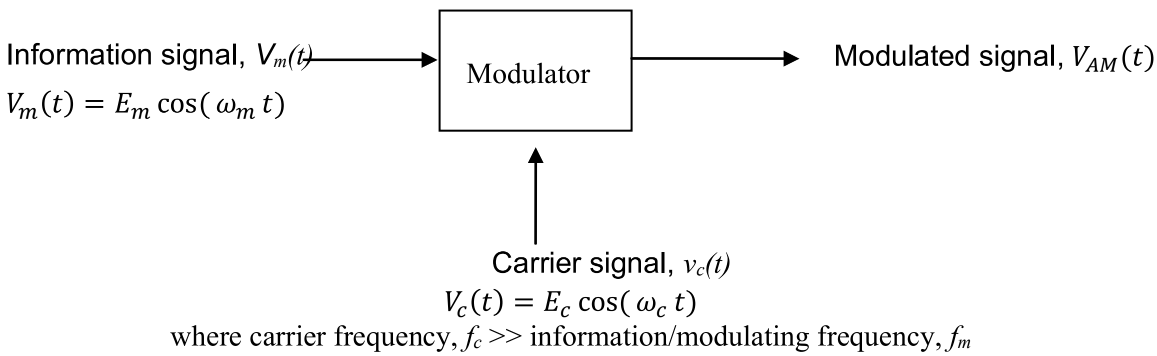



Figure 2.1: Basic Block Diagram of A Modulator

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 $–f_c + f_m$).

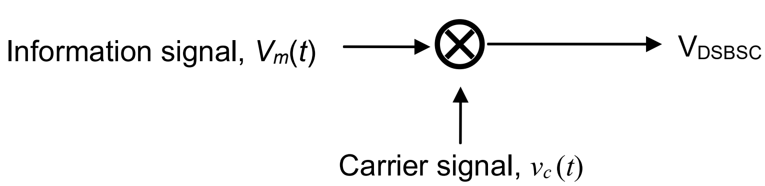



Figure 2.2 AM-DSBSC modulation

## 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.

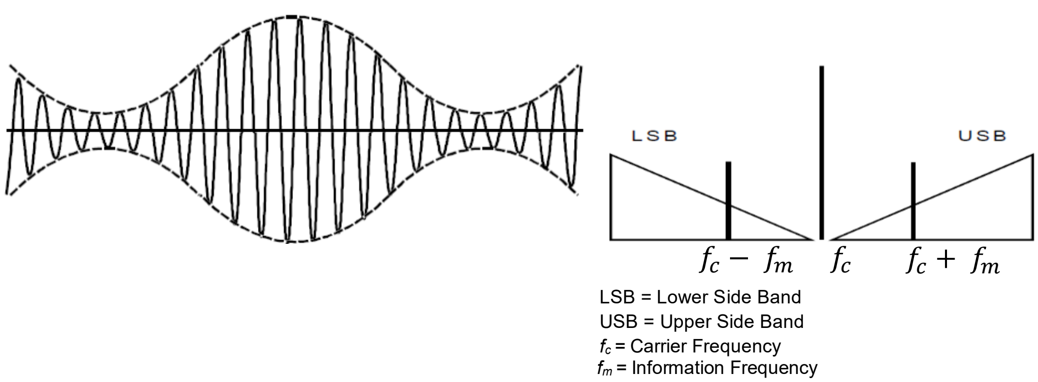
$$V_{AM}(t) = (E_c + V_m(t))\cos(\omega_c t)$$
$$V_{AM}(t) = (E_c + E_m\cos(\omega_m t))\cos(\omega_c t)$$
$$V_{AM}(t) = (E_c(1 + m\cos(\omega_m t))\cos(\omega_c t)$$

$where$:

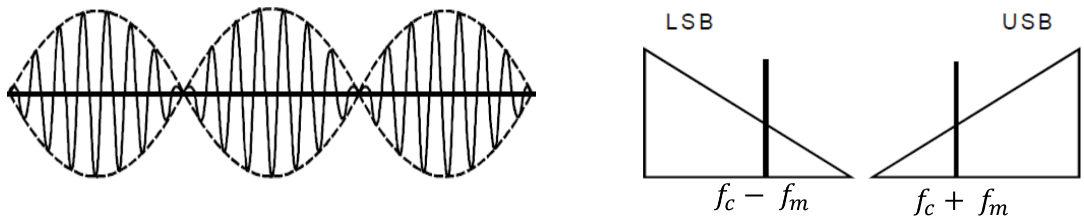
$$modulation\ index, m = \frac{E_m}{E_c}$$

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.

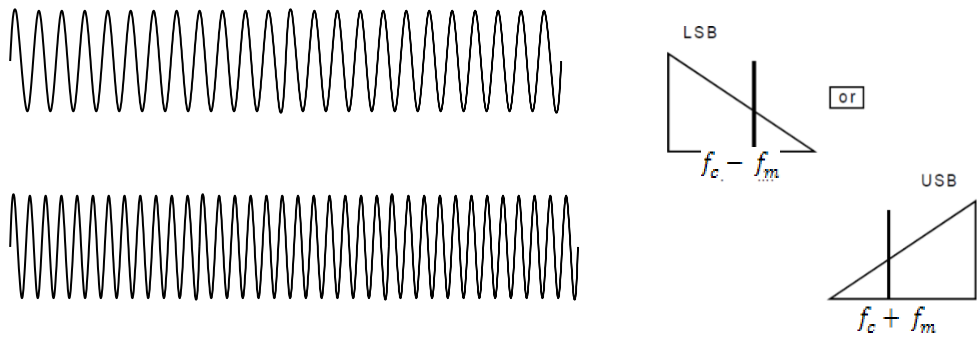
Figure 2.3 lists the different types of amplitude modulation. The line diagram and frequency spectrum are illustrated under the relevant terms. The frequency band(s) to be transmitted are often represented graphically as discrete band(s) or triangles for periodic and non-periodic signals, respectively. 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)




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

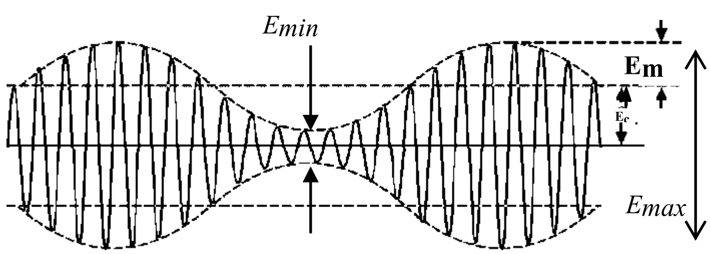



(c) AM- SSB (AM – Single Side Band)

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.



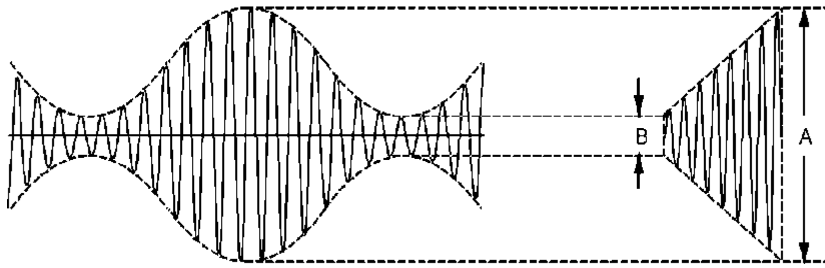

$$m = \frac{E_{max} - E_{min}}{E_{max} + E_{min}}$$

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.




$$m = \frac{A-B}{A+B}$$

## 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.

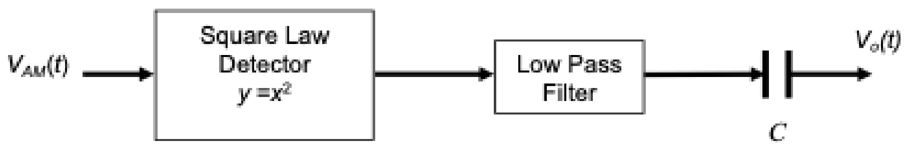



Figure 2.4 AM Square-Law Detector

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

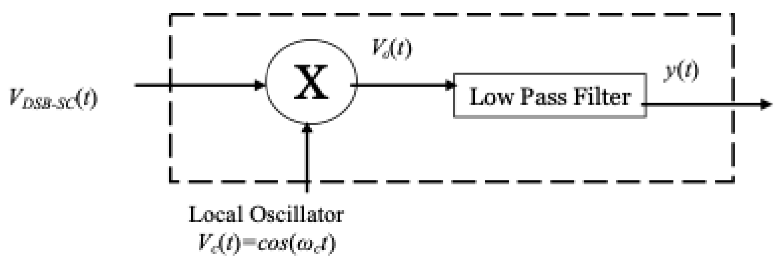



Figure 2.5 AM Synchronous Detector

*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

## 3.0 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.***

## 4.0 PRE-LAB PROCEDURE

- Each group **must complete the Pre-Lab experiment and discussion before attending the laboratory session**. The completed answers (including flow graph and output signals) must be **printed**, brought **to the lab** and **shown to the supervisor for verification** at the beginning of the session.
- Students **must** save all flow graph files on a **portable storage device** (e.g., pendrive, external hard disk, or other suitable media) or **cloud storage** (gdrive) to ensure they can be readily accessed and executed during the lab session.

**Experiment 4.1: Full AM Modulator/Transmitter**

(1) Install the windows-based GNUradio by referring to the link provided

Link: https://drive.google.com/drive/u/1/folders/1N0SzktKDeLhIFOKOJ9C608CLeK9litxl

(2) 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**.

(3) 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**".

(4) Connect the signal source block to a **Throttle** block. Then connect the **Throttle** output to a **WX GUI Scope Sink** and **WX GUI FFT Sink**. (Ensure all block types are set to **Float,** and the sampling rate is set to **samp_rate**).

(5) Execute the file by hitting the gear icon in the GRC menu (taskbar), then click run. Observe the signal in both **time domain (Scope Sink)** and the **frequency domain (FFT Sink)**.

(6) Take the save screenshots of both outputs. Save the GRC flow graph as **PreLab_AM.grc** for use in the in-lab session.

## 5.0 IN-LAB EXPERIMENT PROCEDURES

**WEEK1**

### 5.1 EXPERIMENT CONVENTIONAL/FULL AMPLITUDE MODULATION (AM-DSBFC)

#### 5.1.1 Full AM Modulator/Transmitter

(1) Open the **PreLab_AM.grc** flow graph created in **4.0 Pre-Lab 4.0 Step (6)**.

(2) 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**.

(3) 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**.

(4) Add **WX GUI Scope Sink**. Set Num inputs to **2**. Connect output of **Add Const** block to

the first input and **Multiply** block to the second input **of WX GUI Scope Sink.**

(5) Finally, add another **WX GUI FFT Sink** and connect it to the output of **Multiply** block.

(6) Save the generated modulated signal using **File Sink** block by connecting the block to the output of the **Multiply** block. Choose the folder in which you want to save the file and name it as **AMsinuswave.dat**.

(7) 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.

(8) Analyze and compare these signals with signals from **4.0 Pre-Lab 4.0 Step (6)**. Change the modulation index, m to **m<1** and **m>1**. Discuss what happen to the signals. (Refer to Amplitude Modulation theory).

**Additional Task (Not Compulsory):**

1. 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.
2. 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.**
3. 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 **Experiment 5.1.1 step (9).**

**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.
3. Ensure that signal source block is connected to **Throttle** block

### 5.1.2 Full AM Demodulator/Receiver

(1) Create new flow graph. **Add** File Source block. Choose the folder in which you have saved the filename AMsinuswave.dat from **Experiment 5.1.1.**

(2) Add a **Null Source** block (under Sources). The Null Source just creates a stream of zeros.

(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 and File Source block output to the first input of Max block.

(4) 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.

(5) 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.

(6) Save the flow graph and execute.

(7) Observe the demodulated signals in both time and frequency domains. Take the snapshot, analyze and compare with **Experiment 5.1.1**.

**Additional Task (Not Compulsory):**

Repeat **step of Experiment 5.1.2** for file **AMsquarewave.dat** from Experiment 5.1.1. (**Hint**: Need to set the suitable cutoff frequency for LPF). Observe the different signals obtain from Experiment 5.1.2.

### 5.1.3 Full AM USRP

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

#### 5.1.3.1 Full AM USRP Transmitter/Modulator

(1) Open your flow graph from **Experiment 5.1.1 (Full AM Modulator)**. Add **Float to Complex** block. Connect the output of the **Multiply** block to the input of **Float to Complex** block (use the 're' input).

(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 **900MHz**. At RF Option Tab, set the Gain to **20 dB** and set Antenna to **TX/RX**. Connect the Float to Complex block to the input of the UHD:USRP Sink block.

(3) Connect the provided Log Periodic PCB antenna and transmitting USRP to the computer.

(4) Save the flow graph and execute. Observe **time and frequency** representations of modulated signal. Record the signal.

#### 5.1.3.2 Full AM USRP Demodulator

(1) Open your flow graph from **Experiment 5.1.2 (Full AM Demodulator)**.

(2) Disable **File Source** block.

(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 **900MHz**. Set the Gain to **20dB** and set Antenna to **TX/RX**.

(4) Connect the output of the **UHD: USRP Source** block to the input of **Complex to Float** block.

(5) Connect the output of the **Complex to Float** block to the **MAX** block.

(6) Connect the provided Log Periodic PCB antenna and receiving USRP to the computer.

(7) Save the flow graph and execute. Observe time and frequency representations of the received signal. Make sure the transmitting USRP from **Experiment 5.1.3.1** is operating. Compare both signals from AM USRP Transmitter and AM USRP Receiver. Record and analyze the signals.

**DISCUSSIONS AND ANALYSIS**

1. What is the carrier and modulating frequencies observed, and how do changes in their amplitudes or frequencies affect the AM waveform?
2. What is the role of the Multiply Const and Add Const blocks in your experiment?
3. How do different modulation factors ($m < 1$, $m = 1$, $m > 1$) affect the quality of the modulated and demodulated signals?
4. What are the advantages or limitations of full AM demodulation method?
5. Based on the time and frequency domain plots, what differences do you observe between the modulated and demodulated signals, and how can issues such as the DC component be addressed?

**WEEK2**

## 5.2 EXPERIMENT AM-DOUBLE SIDE BAND SURPRESSED CARRIER (AM-DSBSC)

### 5.2.1 AM-DSBSC Modulator and Demodulator

(1) Design an AM-DSBSC modulator and demodulator by referring to **Figures 2.2** and **2.5**, respectively.

(2) Choose your own modulating frequency, $\mathbf{f_m}$ and suitable carrier frequency, $\mathbf{f_c}$.

(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.

(4) Save the flow graph and execute.

(5) Observe the message signal in both time and frequency domains, before and after modulation. Record and analyze the results.

(6) Record the time and frequency representations of signal before low pass filter.

(7) Observe the modulated signal in both time and frequency domains, before and after demodulation. Record and justify your results.

**(Hint: Use WX GUI Notebook to show multiple graphs in single window using different tabs)**

### 5.2.2 AM-DSBSC USRP Modulator and Demodulator

(1) In this experiment, the procedure AM-DSBSC transmission and reception using USRP are similar to **Experiment 5.1.3 (Full AM USRP).**

(2) For modulator, use the flow graph file saved from **Experiment 5.2.1 (AM-DSBSC Modulator)** instead of the Full AM file.

(3) For the demodulator, use the flow graph file saved from **Experiment 5.2.1 (AM-DSBSC Demodulator)**.

(4) Follow the same steps as in Experiment 5.1.3.1 (USRP Transmitter) and 5.1.3.2 (USRP Receiver) but <u>replace the flow graph accordingly</u>.

(5) Observe and compare the transmitted and received signals in both time and frequency domain, then record and analyze your results.

## <u>DISCUSSIONS AND ANALYSIS</u>

1. Why is it important to choose a suitable carrier frequency and cutoff frequency for the AM-DSBSC system design?
2. What differences do you observe between AM-DSBSC and AM-DSBFC in terms of efficiency and bandwidth?
3. Why can’t an envelope detector be used for demodulating AM-DSBSC, and what alternative method applied?
4. How does a phase difference between the local oscillator and the carrier affect the demodulated signal?

## <u>FOR SHORT REPORT</u>

1. Include flowgraph for each experiment
2. Attach the plots, explain the results, and provide your analysis
3. Answer all questions from this handout.

## <u>FOR LONG REPORT</u>

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