The LNM Institute Of Information Technology

Course Project: Principles Of Communication

QUADRATURE AMPLITUDE MODULATION

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Chapter 1

Abstract

This is the project report of the 'Principles Of Communication' course. In our project we have implemented Quadrature Amplitude Modulation(QAM) scheme in Matlab, Multisim and Hardware. Our goal from this project is to modulate the baseband signals using QAM and then recover the original signals by demodulation of the modulated QAM signal. We have successfully implemented this modulation scheme at all the three platforms- Hardware, Matlab and Multisim. Related theory and all the results, simulation, graphs and circuits are included in this report.

Chapter 2

Introduction

Baseband signals are not always suitable for direct transmission therefore, these signals are usually further modified to facilitate the transmission. This process of conversion is known as **Modulation**. A carrier signal is a sinusoid signal of high frequency. One of the method of modulation is **Amplitude Modulation**, where the carrier signal's amplitude is varied in accordance with the information bearing signal. The amplitude modulated signal's envelope or boundary embeds the information bearing signal.

QAM (Quadrature Amplitude Modulation) or **Quadrature Amplitude Multiplexing** is a method of combining two amplitude-modulated (AM) signals into a single channel, thereby doubling the effective bandwidth. These two signals have the same frequency but differ in the phase by $\pi/2$ radians. These two signals in quadrature can be equivalently viewed as both amplitude modulating and phase modulating a single carrier.

The Process of recovering the original signal from the modulated signal is referred to as **demodulation** or **detection.** At the destination, demodulation takes place in which the carriers are separated, the data is extracted from each, and then the data is combined into the original modulating information.

2.1 Readings and Literature survey

The literature is mainly taken from the book Modern Digital and Analog Communication Systems- *B.P. Lathi.* However, we also took help of google to find out: Phase shifter circuit, summing amplifier, multiplier circuit etc. Further, we referred to a pdf available on net on Quadrature amplitude modulation by Roshni A Chaudhari (ME EC). For MATLAB coding, we took help of the lecture delivered in the class about Amplitude Modulation. We made the Multisim part and the hardware part, using the Lab Experiment 5 (We expanded this to QAM).

2.2 Theory

Modulation:

In QAM the two the signals are combined at the receiver for the transmission which differs in phase by $\pi/2$ radians, thereby doubling the effective bandwidth.

Let the two baseband signals to be transmitted are $m_1(t)$ and $m_2(t)$, therefore the corresponding QAM signal would be-

$$\phi_{AM}(t) = m_1(t)\cos w_c t + m_2(t)\cos(w_c t - \pi/2)$$

or $$\boldsymbol{\phi_{AM}(t) = m_1(t)\cos w_c t + m_2(t)\sin w_c t}$$

This signal $\phi_{AM}(t)$ is transmitted by the transmitter.

Demodulation:

Both modulated signals occupy the same band but they can be separated at the receiver by synchronous detection of coherent demodulator. Such kind of receiver multiplies the receiver signal separately by two local carriers in phase quadrature (sine and cosine signals).

So, $m_1(t)$ and $m_2(t)$ are recovered by multiplying the transmitted signal $\phi_{AM}(t)$ by $2\cos w_c t$ and $2\sin w_c t$ respectively and then passing the resulting signal through the low-pass filter. If we consider the multiplier output at receiver end as $x_1(t)$ and $x_2(t)$ then-

$$x_1(t) = 2\,\phi_{AM}(t)\cos w_c t = 2[\,m_1(t)\cos w_c t + m_2(t)\sin w_c t\,]\cos w_c t$$

$$= m_1(t) + m_1(t)\cos 2w_c t + m_2(t)\sin 2w_c t$$

and

$$x_2(t) = 2\,\phi_{AM}(t)\sin w_c t = 2[\,m_1(t)\cos w_c t + m_2(t)\sin w_c t\,]\sin w_c t$$

$$= m_2(t) - m_2(t)\cos 2w_c t + m_1(t)\sin 2w_c t$$

In the expression of both $x_1(t)$ and $x_2(t)$, the last two terms are suppressed when we pass them through low-pass filter, yielding the desired output $m_1(t)$ and $m_2(t)$. Thus this all scheme of modulation and demodulation is known as Quadrature amplitude modulation or Quadrature multiplexing.

Quadrature Amplitude Multiplexing [1]:

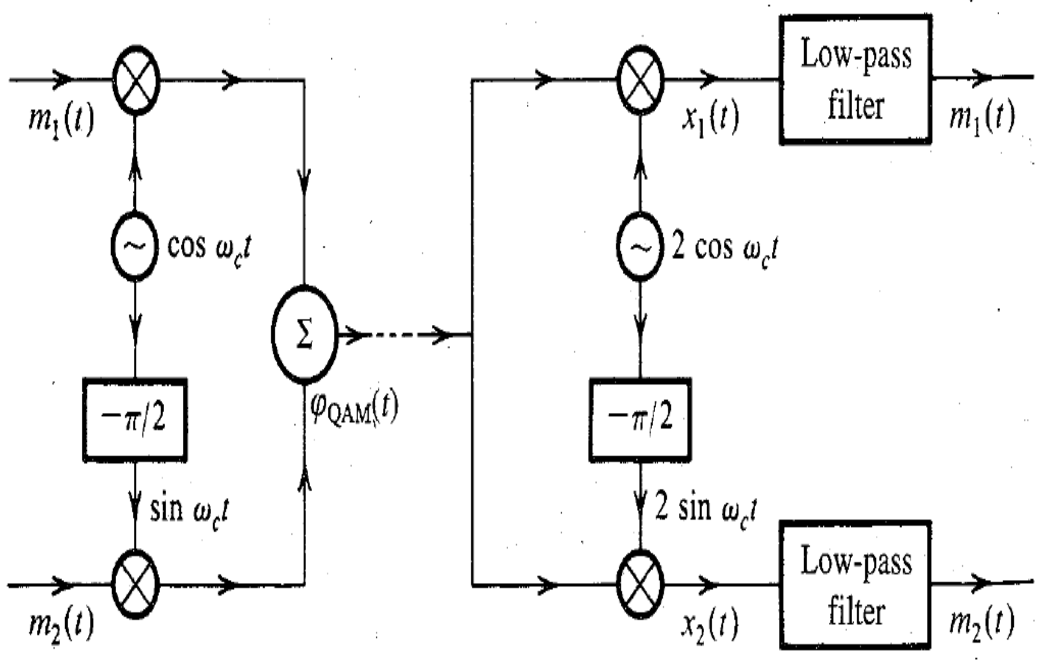


Figure 4.14 Quadrature amplitude multiplexing.

Phase Shifter Circuit:

The phase shifter circuit shifts the incoming wave by a phase of π/2 radians. The phase shifter circuit can be composed of an All-pass Filter or a differentiator using operational amplifiers.

Multiplier Circuit:

The multiplier circuit is used for giving the product of the two incoming waves. In this case, we use multiplier mainly to take the product of either the message signal to the carrier wave or the modulated wave to the carrier wave.

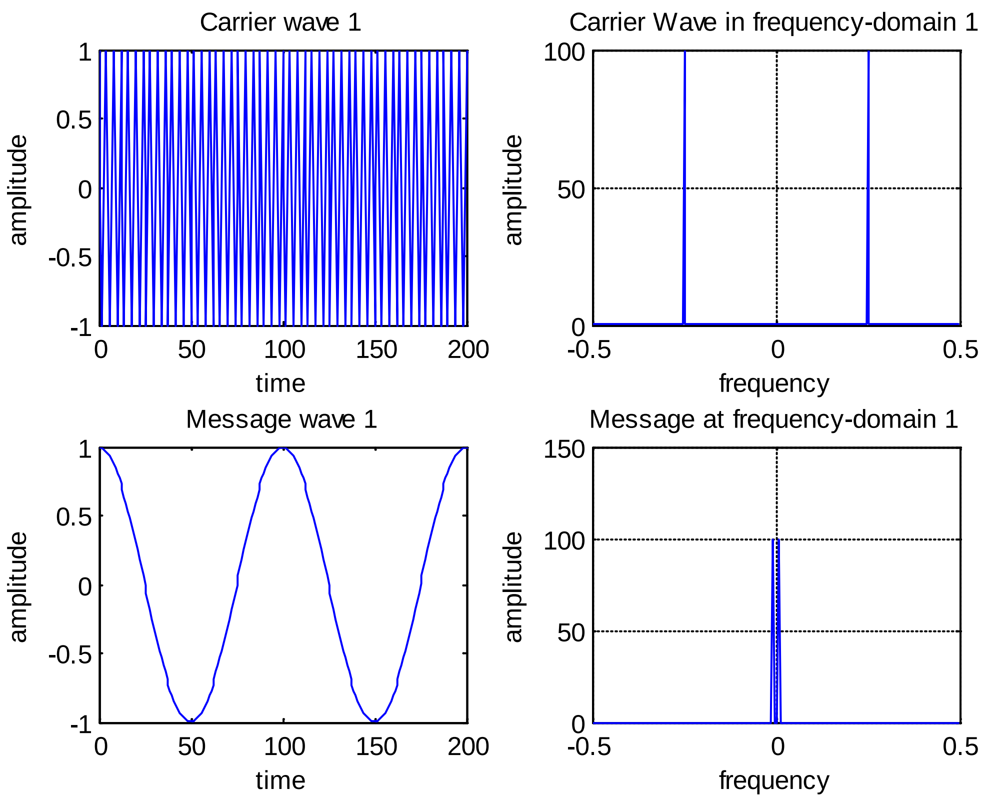
Summing Amplifier Circuit:

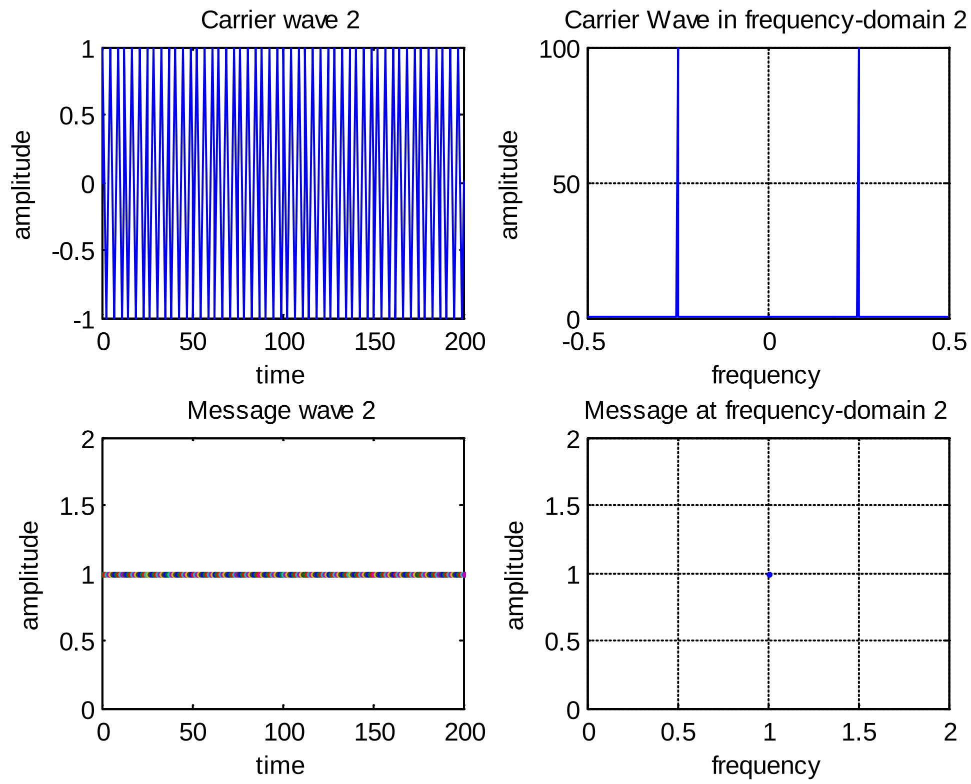
The summing amplifier circuit is used to add up the two incoming waves. To make a Quadrature Amplitude Modulated wave, we need to add two Amplitude Modulated waves.

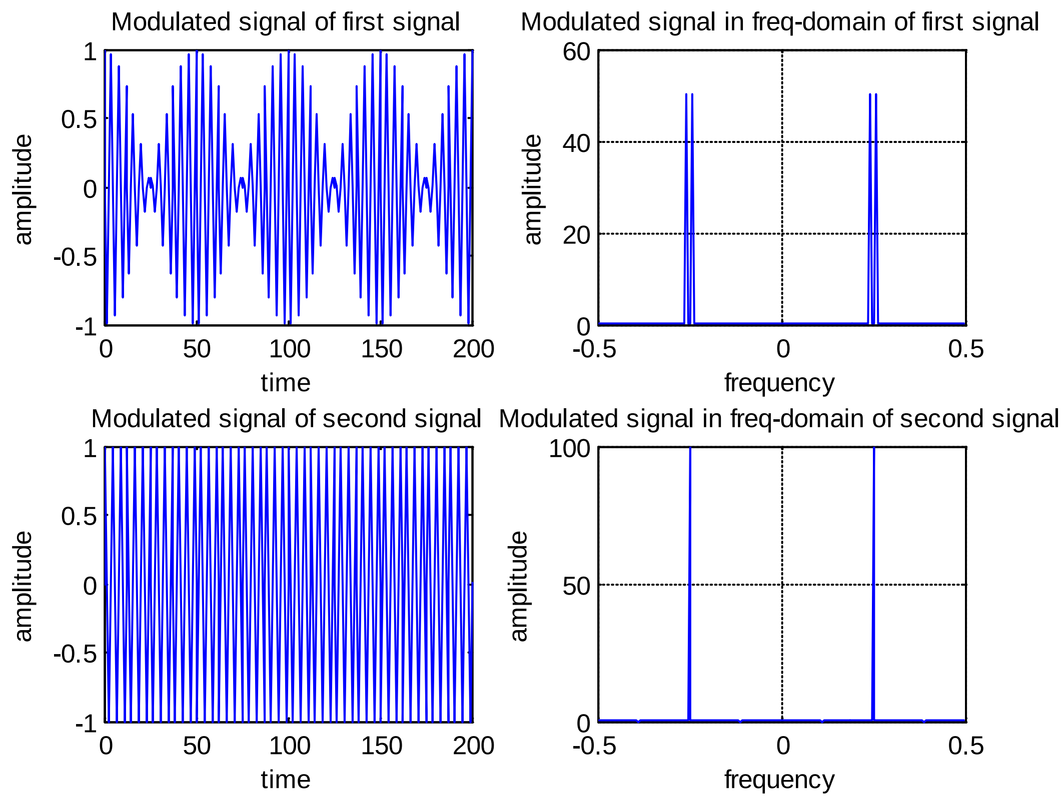
Chapter 3

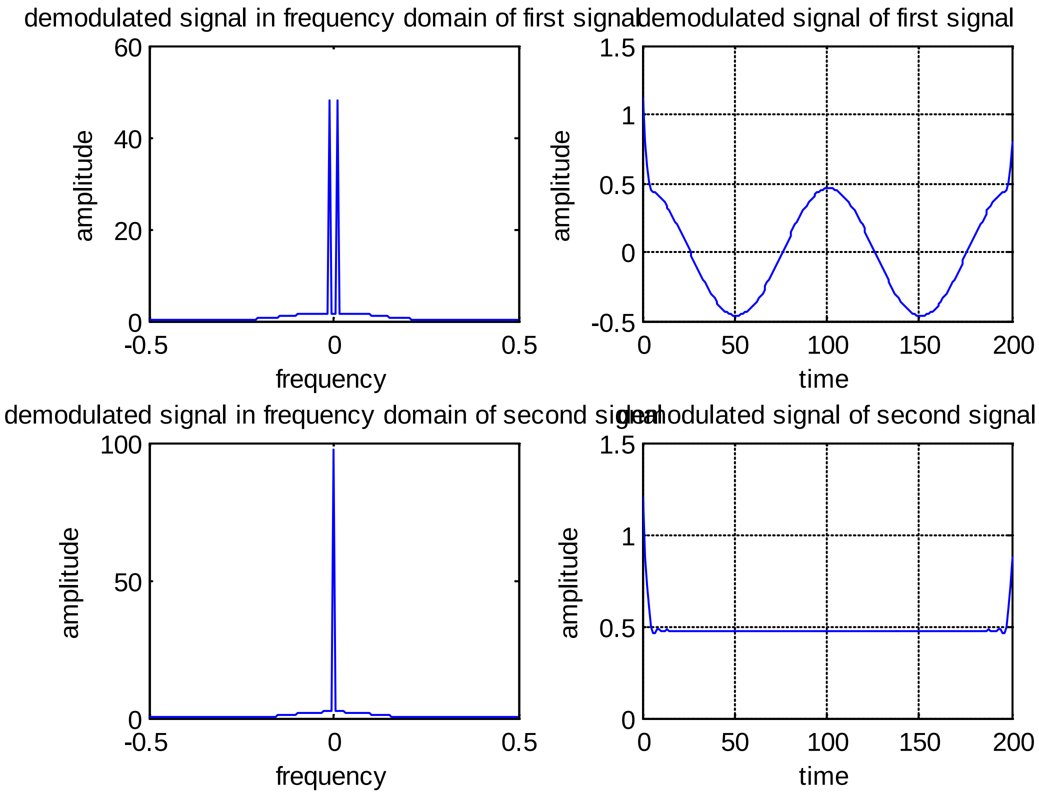
Matlab based simulation

The MATLAB simulation results are as follows:




Carrier wave 2
amplitude
time
Carrier Wave in frequency-domain 2
amplitude
frequency
Message wave 2
amplitude
time
Message at frequency-domain 2
amplitude
frequency

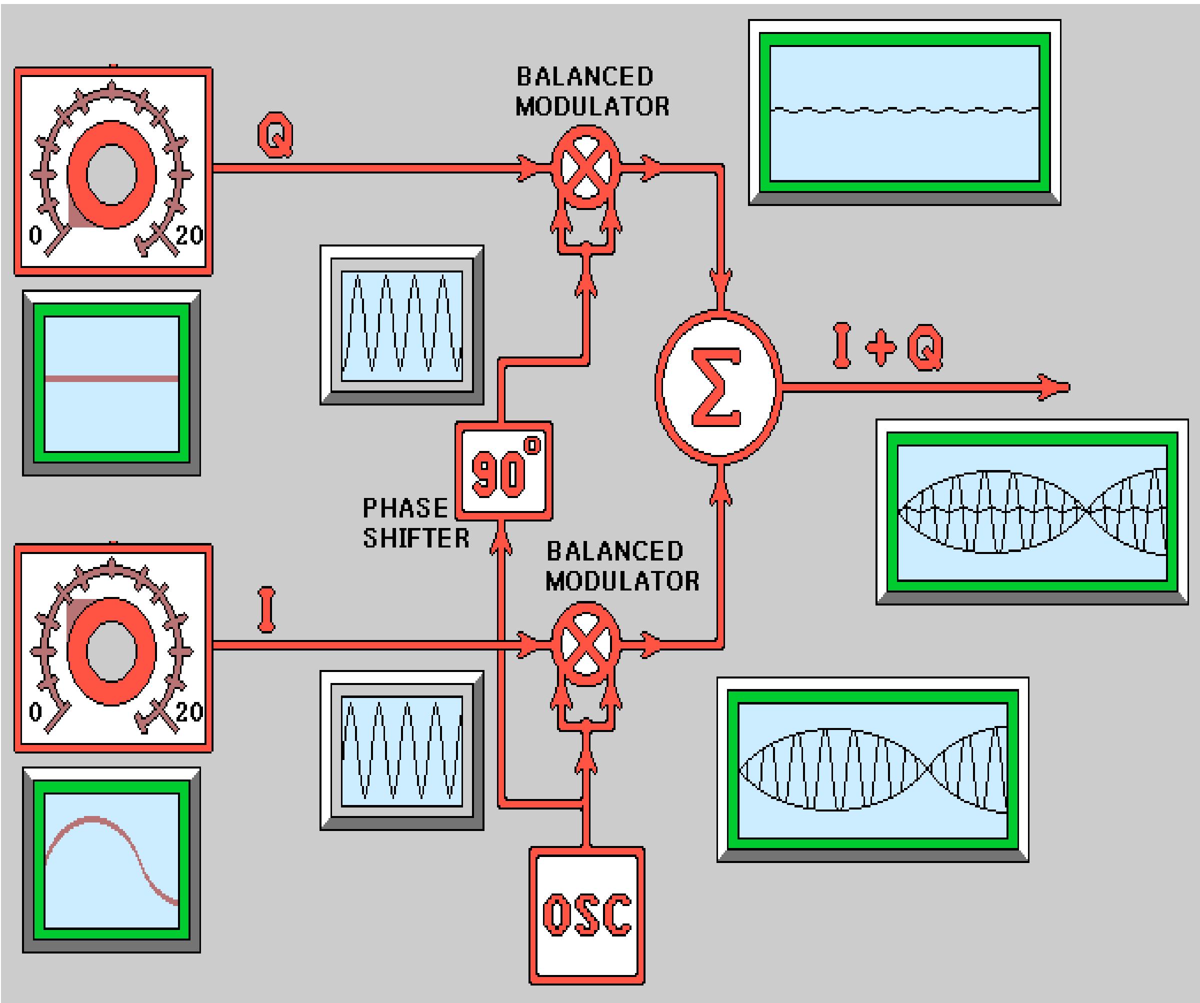

Modulated signal of first signal
amplitude
time
Modulated signal in freq-domain of first signal
amplitude
frequency
Modulated signal of second signal
amplitude
time
Modulated signal in freq-domain of second signal
amplitude
frequency


demodulated signal in frequency domain of first signal
amplitude
frequency
60
40
20
0
-0.5
0
0.5
demodulated signal of first signal
amplitude
time
1.5
1
0.5
0
-0.5
0
50
100
150
200
demodulated signal in frequency domain of second signal
amplitude
frequency
100
50
0
-0.5
0
0.5
demodulated signal of second signal
amplitude
time
1.5
1
0.5
0
0
50
100
150
200

Chapter 4

Circuit details

The basic Quadrature Amplitude Modulator Circuit looks like:



Our main aim is to simulate the above. We also need to take into account the balanced modulator. Also, the phase shifting needs to be taken care of. Thus, we try to simulate the above in Multisim software.

4.1 Analysis

The Quadrature Amplitude Modulation schema we chose is composed of two basic **Amplitude Modulator** circuits. A cosine carrier is generated and fed to the first Amplitude Modulator Circuit. The sinusoidal carrier is generated via a **Phase Shifter Circuit** (here we have used All Pass Filter as the phase shifter). Then the outputs of the above two waves are added through a **Summing Amplifier**. Thus, we get the required Quadrature Amplitude Modulated waveform at the output of the summing amplifier.

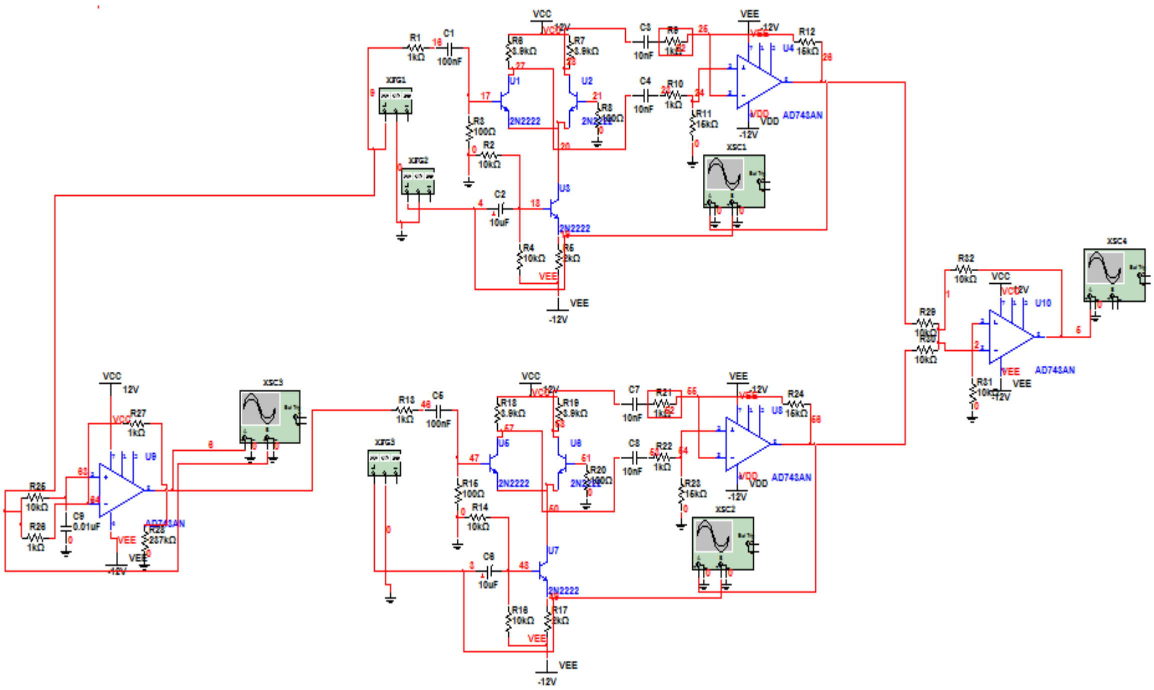
4.2 Working

The working of the above circuit is as follows:

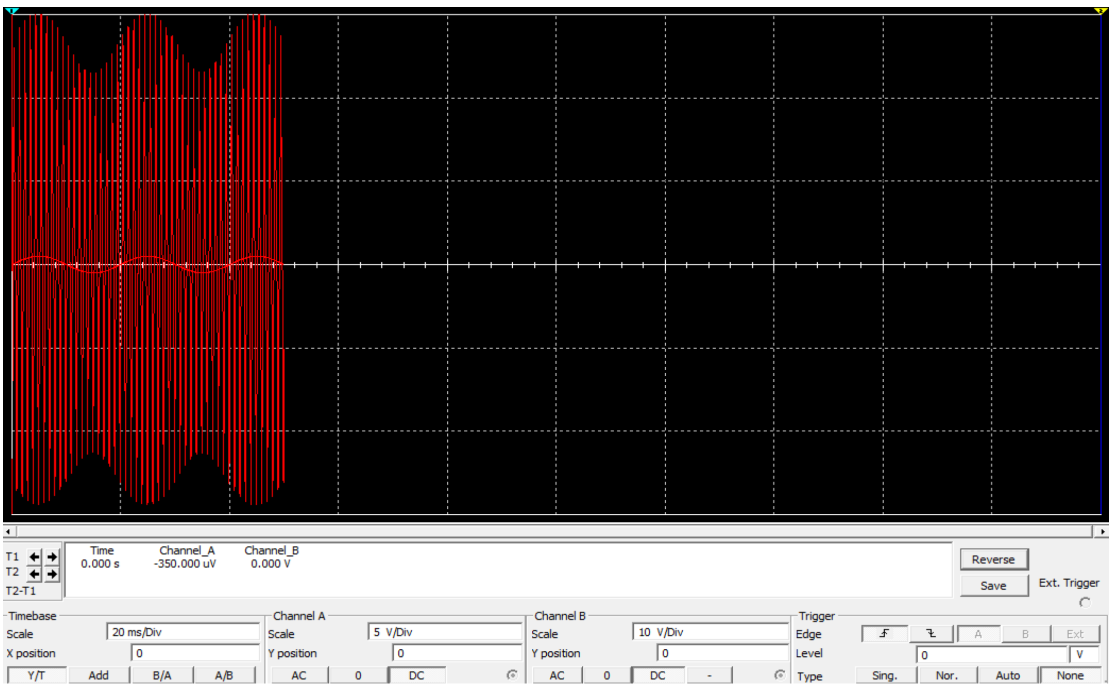
- Firstly, a message signal: cosine wave of 50 Hz frequency and amplitude 1 V peak-to-peak is fed to the first Amplitude Modulator Circuit. The carrier wave is chosen as a cosine wave of 1.5 kHz frequency and amplitude 2 V peak-to-peak. The Amplitude Modulated Waveform 1 is generated.
- Now, a phase shifter circuit is used to generate a $\pi/2$ radians shifted cosine wave(i.e. sinusoidal wave) and fed as a carrier in the second Amplitude Modulator Circuit. The message signal is chosen as a square wave of 50 Hz frequency and amplitude 1 V peak-to-peak.
- Then, similar kind of operation is performed as in first case. Similarly, Amplitude Modulated wave 2 can be generated.
- The outputs of the two amplitude modulated signals are fed to the summing amplifier where the two waves add up.
- The resultant wave at the output of the summing amplifier is the desired Quadrature Amplitude Modulator circuit.

4.3 Circuit simulation

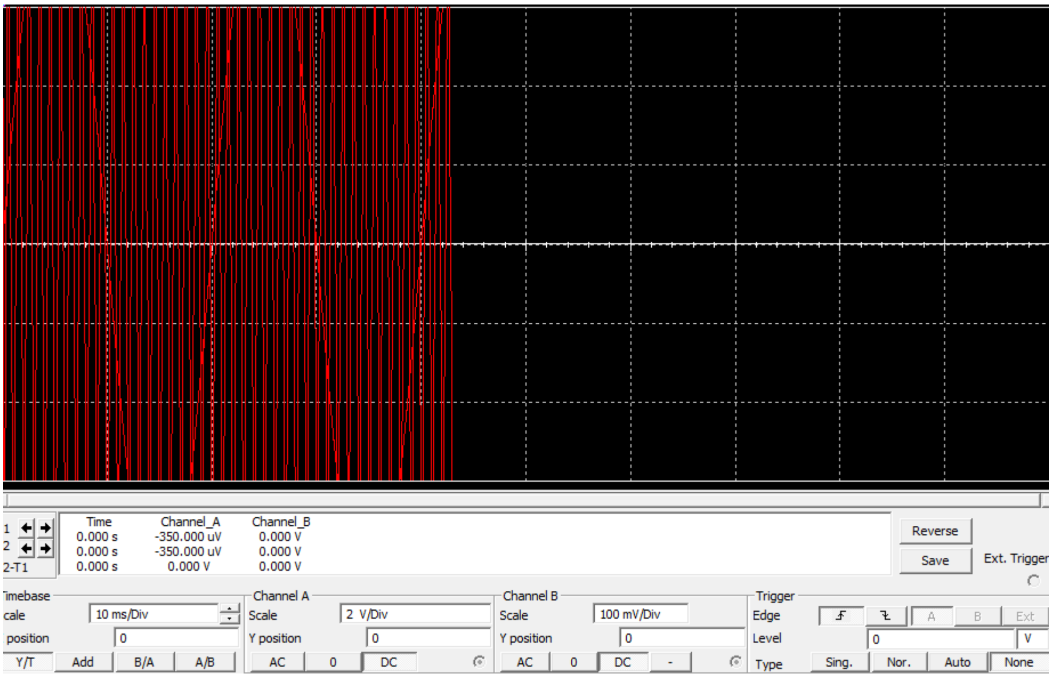
The circuit simulated on Multisim is:



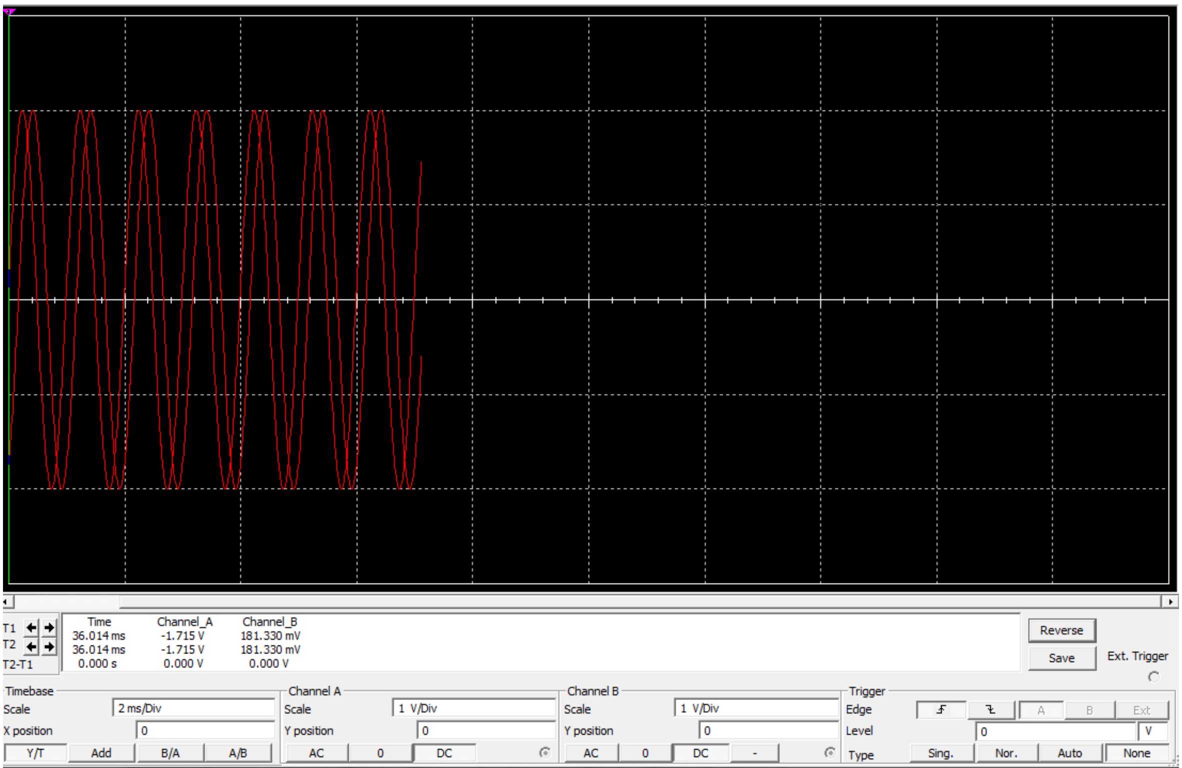
The output at the Amplitude Modulator 1 (Upper Part) :



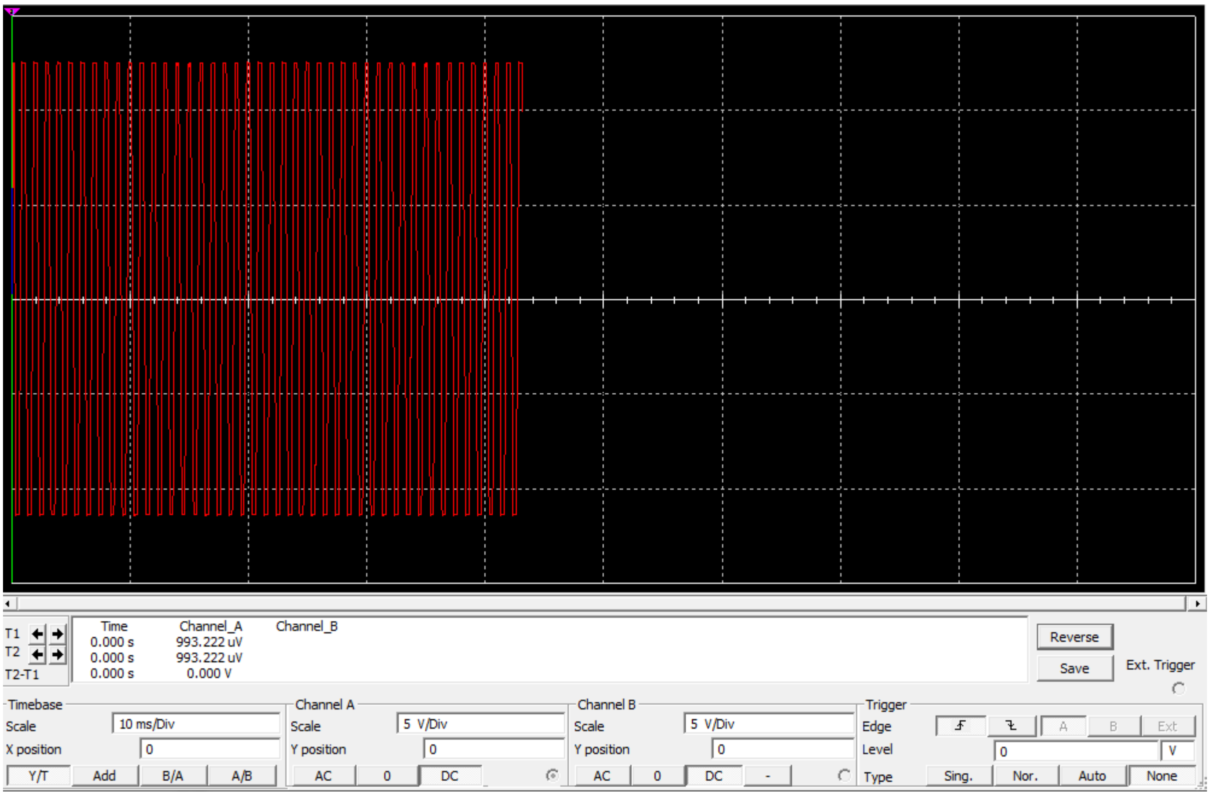
The output at the Amplitude Modulator 2 (Lower Part) :



The Output at the Phase Shifter Circuit:



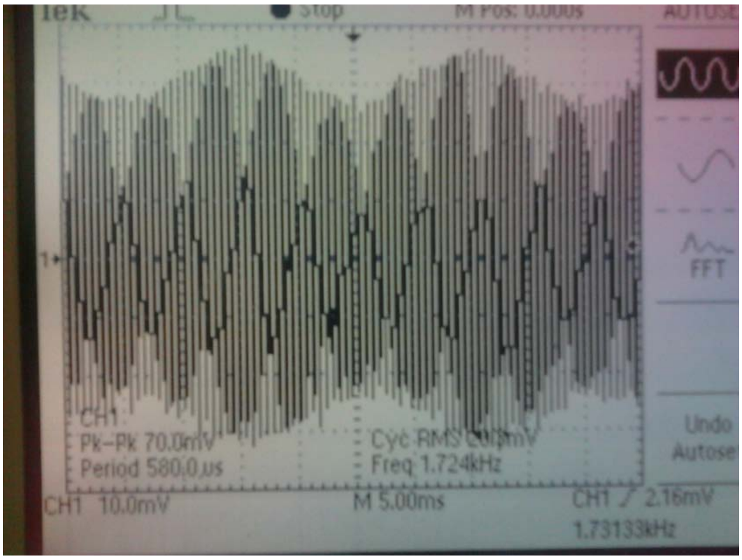
The Quadrature Amplitude Modulated Wave:

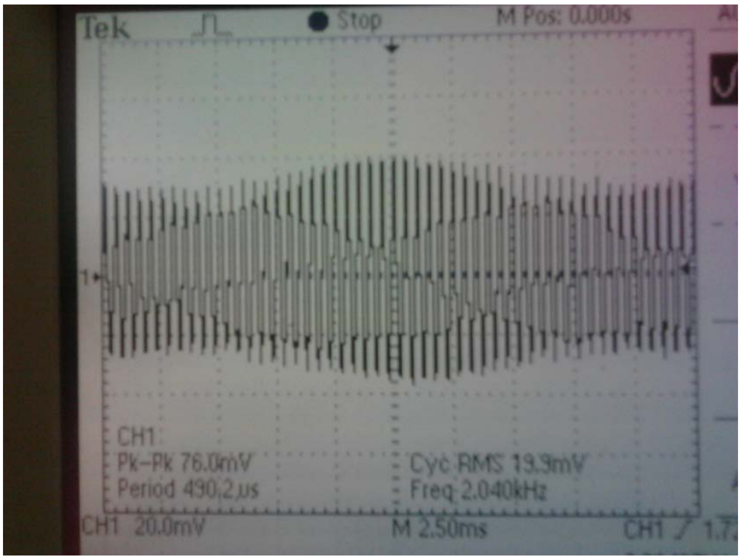


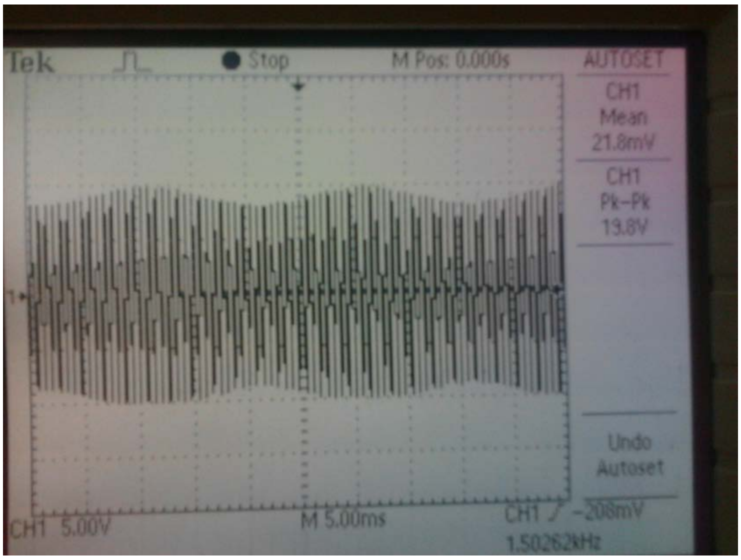
Chapter 5

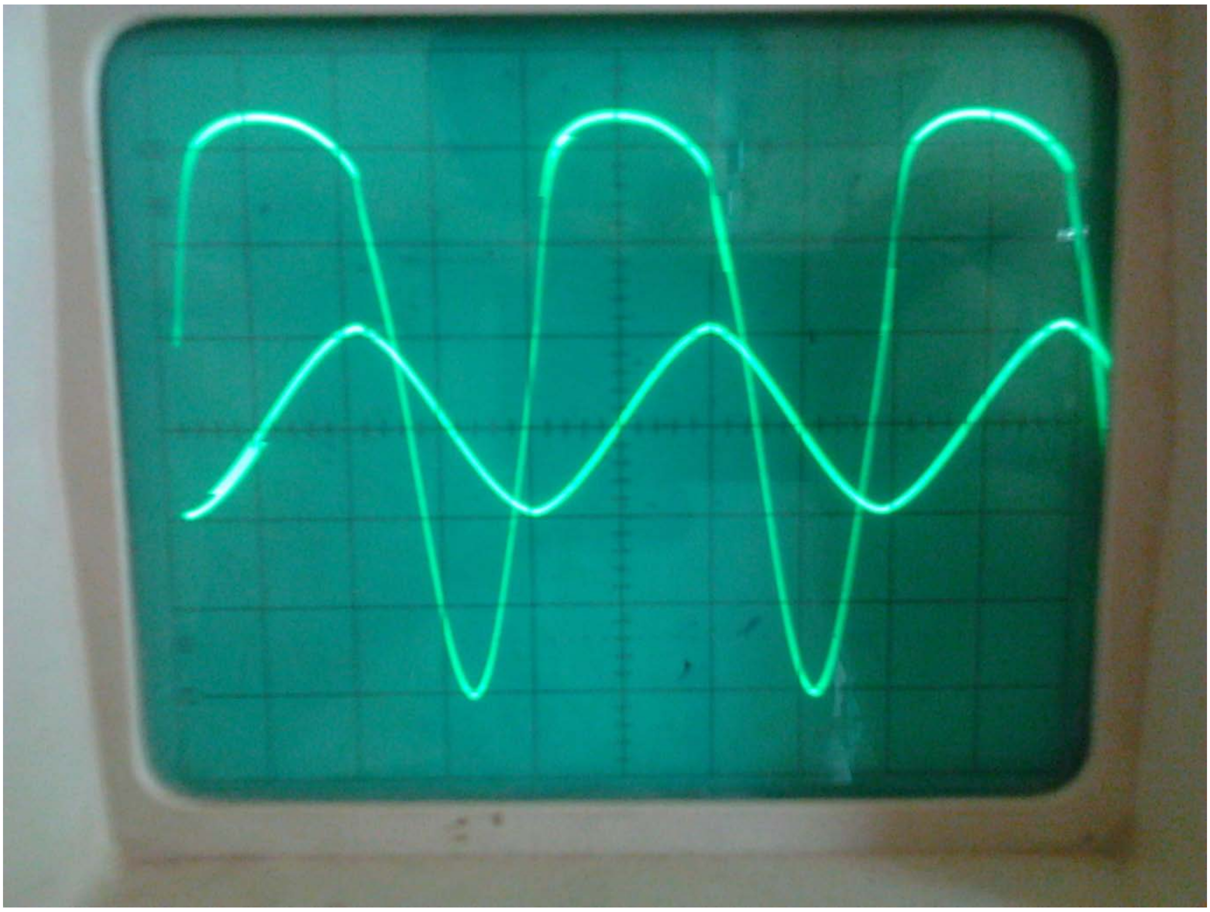
Hardware Implementation

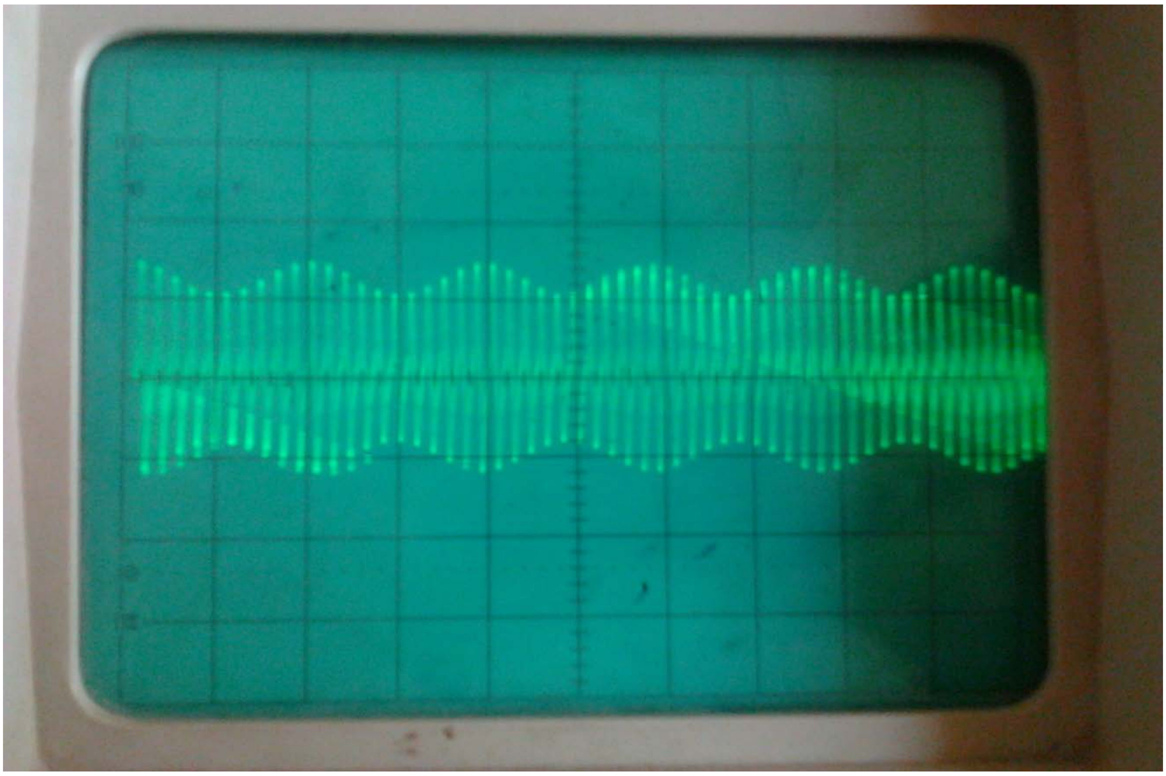
5.1 Observations

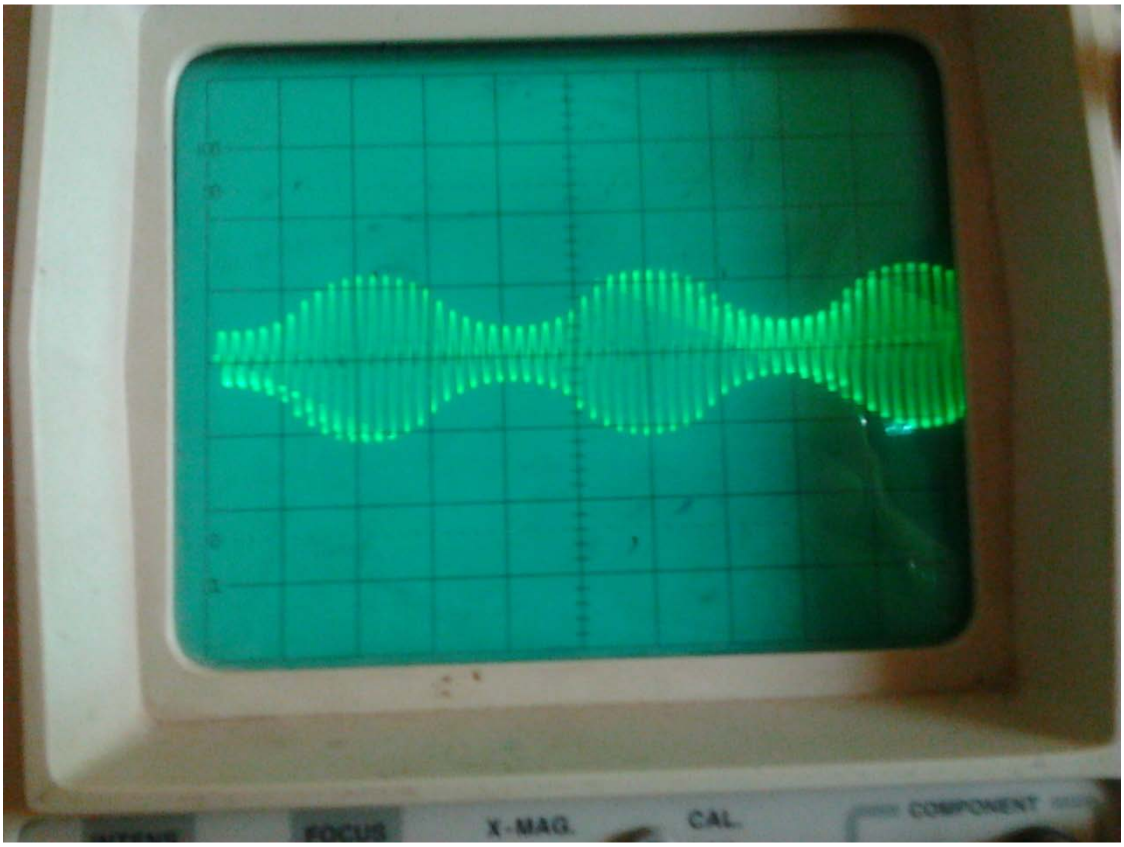





Tek
Stop
M Pos: 0.000s
AUTOSET
CH1
Mean
21.8mV
CH1
Pk-Pk
13.8V
Undo
Autoset
CH1 5.00V
M 5.00ms
CH1 ∕ -208mV
1.50262kHz






FOCUS
X-MAG.
CAL.
COMPONENT

Chapter 6

Conclusion

Modulation is necessary to facilitate the transmission of baseband signals over a given channel. QAM is one of the available modulation schemes to modulate the baseband signal. QAM is advance and better modulation scheme than many others as DSB signals occupy twice the bandwidth required for the baseband and QAM overcomes this advantage by transmitting two DSB signals thus doubling the effective bandwidth. Though QAM is a better scheme from the point of view of bandwidth efficiency but it is somewhat of an exacting scheme because a slight error in phase or the frequency of the carrier at the demodulator will not only result in loss and distortion of signal, but also will lead to interference between two channels. So, we have to be extra careful at the demodulator.

Bibliography

[1] Modern Digital and Analog Communication Systems- *B.P. Lathi*
[2] Wikipedia (only basics of Quadrature Amplitude Modulation)
[3] Principles of Communication Lab Manual
[4] Pdf on Quadrature amplitude modulation by Roshni A Chaudhari (ME EC).