Modulation Techniques

Course Code:TE2201

Name: W.A.Asintha Dilshan Jayasekara

Reg No: Eng-17-068|Sri Lanka Technological Campus

1/6/2019

Summery

One of the main aspects in communication transmission is modulation. This technique is used for to increase the frequency level of the message signal and convert it into the foam that will be able to transmit through the channel. To do this we have various modulation techniques. In this report I have analyzed about analog modulation, digital to analog modulation, analog pulse modulation and digital pulse modulation. The choice of modulation has a great impact on the radio communications system. Some forms are better suited to one kind of traffic where as other forms of modulation will be more applicable in other instances. Choosing the correct form of modulation is a key decision in any radio systems communication design. This is made with the help of modulator and demodulator. And I have discussed about the pros and cons of each modulation while comparing that particular invention with its previous invention. I have elaborated my findings throw certain lap experiments and I have produced the pictures for further detail.

Abstract

Modulation plays a key role in communication system to encode information digitally in analog world. It is very important to modulate the signals before sending them to the receiver section for larger distance transfer, accurate data transfer and low-noise data reception. Modulation is the process of changing the characteristics of the wave to be transmitted by superimposing the message signal on the high frequency signal. In this process video, voice and other data signals modify high frequency signals – also known as carrier wave. This carrier wave can be DC or AC or pulse chain depending on the application used. Usually high frequency sine wave is used as a carrier wave signal.

Two major types of modulation techniques:

i. Analog Modulation
ii. Digital Modulation

Types of analog pulse modulation:

i. Pulse Amplitude Modulation. (PAM)
ii. Pulse Width Modulation (PWM)
iii. Pulse Position Modulation (PPM)

Types of digital pulse modulation:

i. Pulse Code modulation (PCM)
ii. Delta Modulation (DM)

Table of Contents

Summery 1

Abstract 2

1.Phase Shift Keying (PSK) Modulation and Demodulation 10

- 1.1.Objective 10
- 1.2.Components and Apparatus 10
- 1.3.Background 10
- 1.4.Procedure 11
- 1.5.Observations 12
- 1.6. Discussion 15

2. Sampling and reconstruction 16

- 2.1.Objective 16
- 2.2 Components and Apparatus 16
- 2.3 Background 16
- 2.4 Procedure 18
- 2.5 Observations 19
- 2.6 Discussion 20

3.Amplitude modulation and demodulation 21

- 3.1 Objective 21
- 3.2 Components and Apparatus 21
- 3.3 Background 21
  - 3.3.1 AM modulation 21
  - 3.3.2 Modulation index 22
  - 3.3.3 AM Demodulation 23
- 3.4 Procedure 23
- 3.5 Observations 24
- 3.6 Discussion 26

4.Amplitude Shift Keying Modulation and Demodulation 27

- 4.1.Objective 27

4.2 Components and Apparatus 27
4.3 Background 27
4.3.1 ASK Modulation 27
4.3.2 ASK Demodulation: 28
4.4 Procedure 28
4.5 Observations 29
4.6 Discussion 30
5.Balanced Modulator 31
5.1 Objective 31
5.2 Components and Apparatus 31
5.3 Background 31
5.4 Procedure 32
5.5 Observations 32
5.6 Discussion 34
6.DSPK Modulation and Demodulation 35
6.1 Objective 35
6.2 Components and Apparatus 35
6.3 Background 35
6.4 Procedure 36
6.5 Observations 37
6.6 Discussion 40
7.Principal of Modulation to the Real Signal 41
7.1 Objectives 41
7.2 Components and Apparatus 41
7.3 Background 41
7.4 Procedure 43
7.5 Observations 43
7.6 Discussion 45
8.Frequency Shift Keying (FSK) Modulation and Demodulation 46

8.1 Objective 46
8.2 Components and Apparatus 46
8.3 Background 46
8.3.1 FSK Modulation 46
8.3.2 FSK Demodulation 46
8.4 Procedure 47
8.5 Observations 48
8.6 Discussion 50
9.Frequency Modulation (FM) and Demodulation 51
9.1 Objective 51
9.2 Components and Apparatus 51
9.3 Background 51
9.3.1 Frequency Modulation 51
9.3.2 Frequency Demodulation 52
9.4 Procedure 52
9.5 Observations 53
9.6 Discussion 55
10.Pulse Amplitude Modulation and Demodulation 57
10.1 Objective 57
10.2 Components and Apparatus 57
10.3 Background 57
10.4 Procedure 58
10.5 Observations 59
10.6 Discussion 60
11.Quadrate phase shift keying modulation and demodulation 61
11.1 Objective 61
11.2 Components and Apparatus 61
11.3 Background 61
11.4 Procedure 62

11.5 Observations ... 63
11.6.Discussion ... 65
12.Pulse Code Modulation and Demodulation ... 66
12.1 Objective ... 66
12.2 Components and Apparatus ... 66
12.3 Background ... 66
12.4 Procedure ... 67
12.5 Observations ... 67
12.6 Discussion ... 69
13. Conclusion ... 70
14.References ... 70

List of Figures

Figure 1-Phase shift keying signal 10
Figure 2 -Message signal 12
Figure 3-Carrier signal 12
Figure 4-Modulated signal 01 with data 12
Figure 5- Demodulated signal 01 with message signal 13
Figure 6 - Modulated signal02 with data 13
Figure 7-Demodulated signal 02 with data 13
Figure 8-Modulated signal 03 with data 14
Figure 9-Demodulated signal 03 with data 14
Figure 10- 8-PSK 15
Figure 11-Sampling Techniques 17
Figure 12-Output waveform 19
Figure 13- Sample and hold output 19
Figure 14- Demodulation output 19
Figure 15-Sampling and Holding 20
Figure 16-AM modulation 21
Figure 17-modulation index 22
Figure 18- AF-Waveform 24
Figure 19- Carrier signal 24
Figure 20- Demodulated (Not amplified) Signal 24
Figure 21- Modulated Signal 25
Figure 22- Demodulated output signal (Amplified) 25
Figure 23-A still overview of the most important modulation depths (0, 50, 100 and 200%).... 26
Figure 24-Amplitude shift keying modulation 27
Figure 25- Message Signal 29
Figure 26- Carrier Signal 29
Figure 27-ASK Modulation signals 29
Figure 28-Demodulated signal 30
Figure 29- Balanced modulator 31
Figure 30- Block diagram of balanced modulator 31
Figure 31- Message Signal 32
Figure 32- Carrier signal 33
Figure 33- Modulated Signal 33
Figure 34-Time Domain 34
Figure 35-Frequency Domain 34
Figure 36- DPSK modulation 35

Figure 37- Block diagram of DPSK Modulator 36
Figure 38- Clock Signal 37
Figure 39- Carrier Signal 37
Figure 40- Message Signal 37
Figure 41- Message Signal 38
Figure 42- Modulated Signal with Message Signal 38
Figure 43- Demodulated Signal with Message Signal 38
Figure 44- Modulated Signal with Message Signal 39
Figure 45- Demodulated Signal with Message Signal 39
Figure 46- Types of modulations 41
Figure 47- Carrier Signal 43
Figure 48- Modulated Signal 44
Figure 49- Modulated Signal in Frequency Domain 44
Figure 50- Frequency shift keying modulation 46
Figure 51- Clock Signal 48
Figure 52- Message Signal 48
Figure 53- Message Signal with modulated Signal 48
Figure 54- Modulated Signal with Message signal 49
Figure 55- Demodulated output and message Signal 49
Figure 56- Demodulated output and message Signal 49
Figure 57- FM modulation 51
Figure 58- AF Signal 53
Figure 59- Carrier Signal 53
Figure 60- Modulated Signal With AF Signal 53
Figure 61- Modulated Signal With AF Signal 54
Figure 62- Modulated Signal with AF Signal 54
Figure 63- frequency modulated signal and phase modulated 56
Figure 64-PAM signal 57
Figure 65-Block diagram of PAM signal 58
Figure 66- AF Signal 59
Figure 67- Pulse output 59
Figure 68- Modulated Signal 59
Figure 69- Demodulated Signal With AF Signal 60
Figure 70-QPSK Time Diagram 61
Figure 71- Message Signal 63
Figure 72- Carrier Signal 63
Figure 73- Modulated Signal 63
Figure 74- Demodulated Signal 64

Figure 75-Block Diagram of QPSK 65
Figure 76-PCM block diagram 66
Figure 77- AF Signal 67
Figure 78- Clock Signal 68
Figure 79- Output of Sample and hold circuit 68
Figure 80- Wave Output 68
Figure 81- Sample and hold output 69
Figure 82- Demodulated output with message signal 69

1.Phase Shift Keying (PSK) Modulation and Demodulation

1.1.Objective

In this experiment you will be studying the operation of PSK modulation and demodulation and to plot the PSK waveforms for binary data at different frequencies.

1.2.Components and Apparatus

- OHM PSK Trainer Kit
- CRO (or DSO)
- Digital Multi meter
- Set of Patch tips

1.3.Background

Phase shift keying, PSK, is widely used these days within a whole raft of radio communications systems. It is particularly well suited to the growing area of data communications. PSK, phase shift keying enables data to be carried on a radio communications signal in a more efficient manner than Frequency Shift Keying, FSK, and some other forms of modulation. With more forms of communications transferring from analogue formats to digital formats, data communications is growing in importance, and along with it the various forms of modulation that can be used to carry data. There are several types of phase shift keying, PSK that are available for use. Each form has its own advantages and disadvantages, and a choice of the optimum format has to be made for each radio communications system that is designed. To make the right choice it is necessary to have a knowledge and understanding of the way in which PSK works.

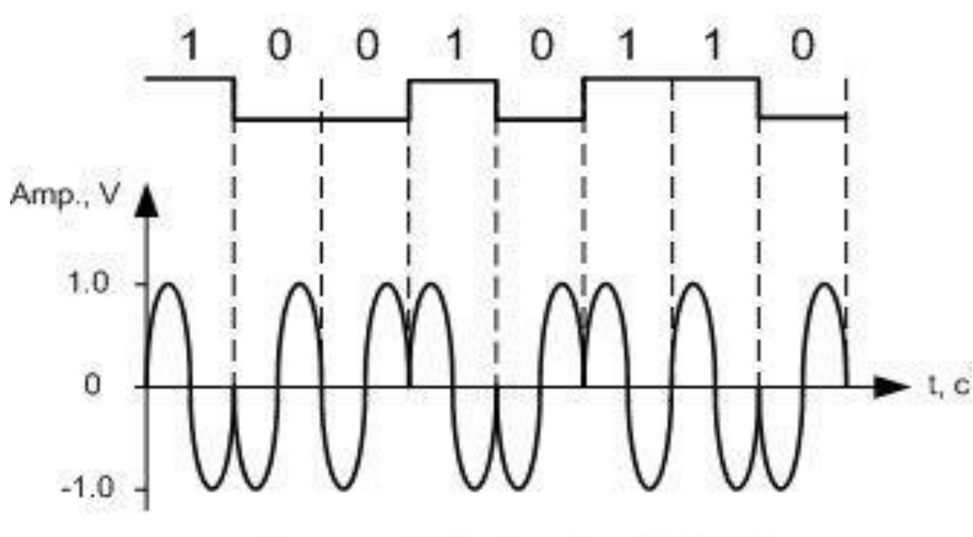


Figure 1-Phase shift keying signal

1.4.Procedure

1. The trainer kit was switched on and the power supply was checked to be +5V and -5V using digital multi meter.
2. The patch tips were connected as per wiring diagram.
3. The carrier signal was measured with the oscilloscope. Outputs can be varied by adjusting trimmer.
4. Various data signals of,
    i. 1kHz
    ii. 2kHz
    iii. 4kHz were observed using oscilloscope.
5. The carrier signal was connected to the carrier input of the PSK modulator.
6. The data signal from data source was connected to the data input of the modulator.
7. The PSK modulator was observed at the corresponding output terminal.
8. The corresponding waveform was plotted.
9. The PSK output was connected to the PSK input of the demodulator.
10. Similarly, the carrier input of the PSK demodulator was connected.
11. The oscilloscope was connected at the demodulated output. The data signal can be observed at the demodulated output.
12. Above steps were repeated for other frequencies.

1.5.Observations

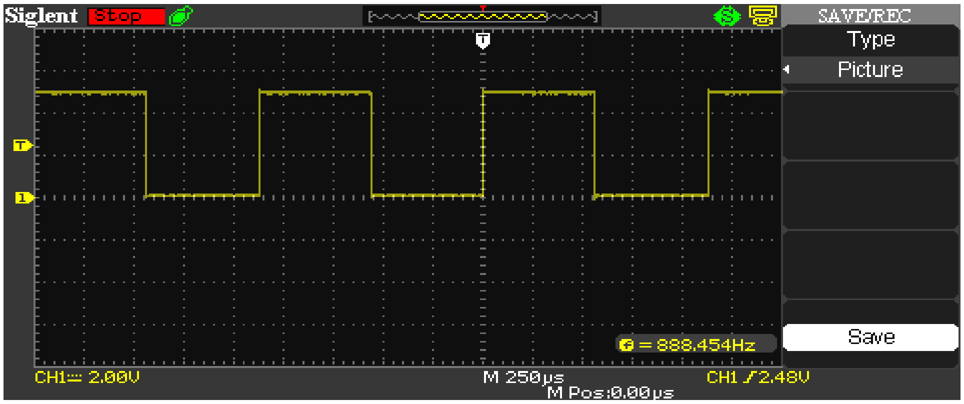


Figure 2 -Message signal

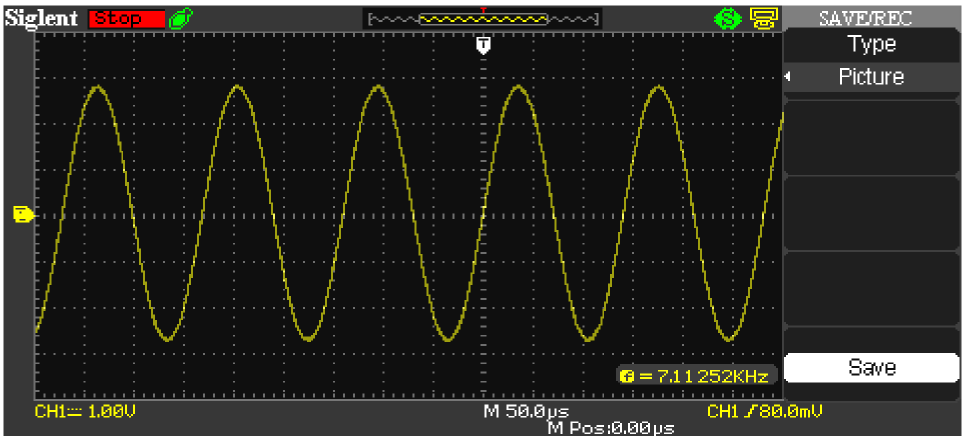


Figure 3-Carrier signal

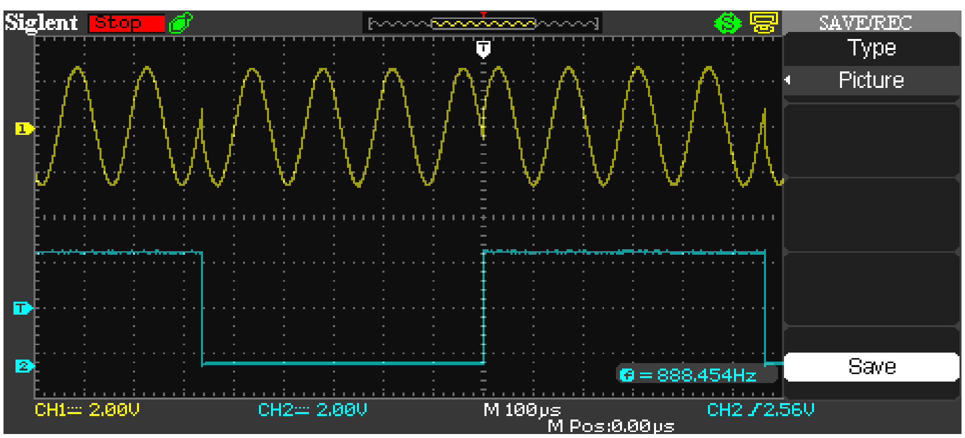


Figure 4-Modulated signal 01 with data

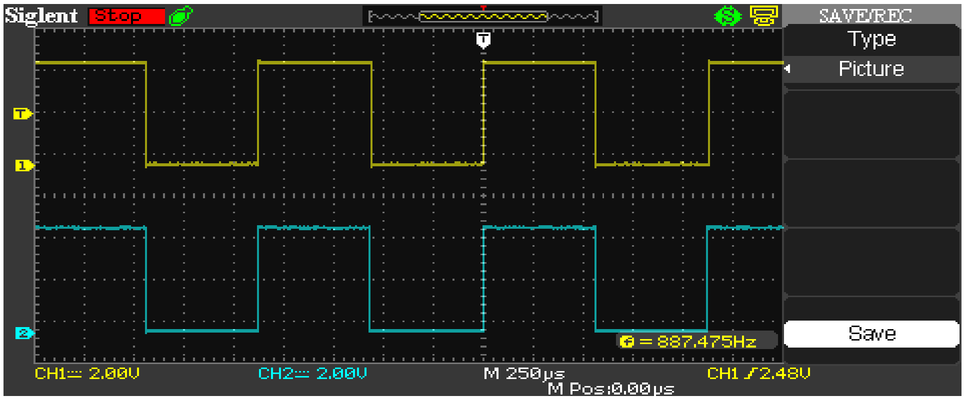


Figure 5- Demodulated signal 01 with message signal

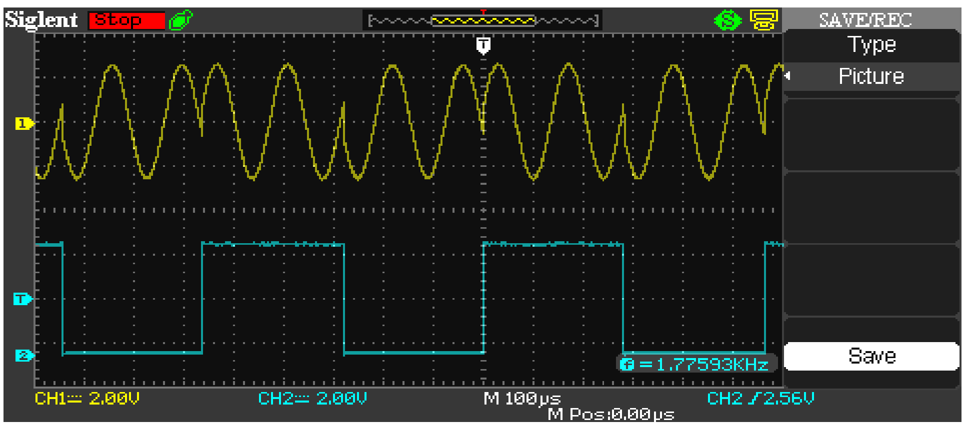


Figure 6 - Modulated signal02 with data

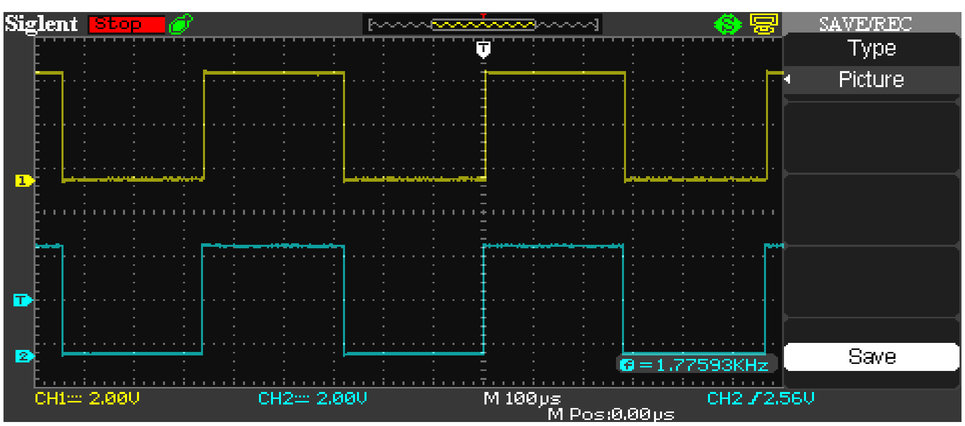


Figure 7-Demodulated signal 02 with data

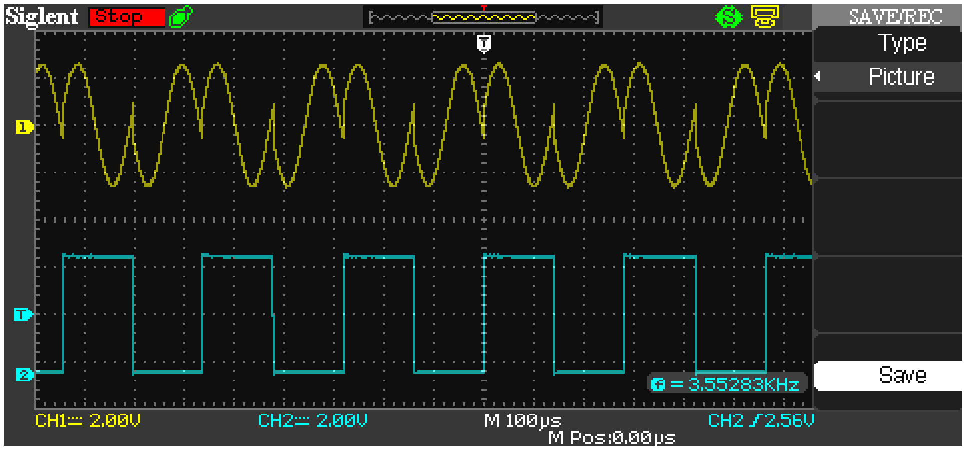


Figure 8-Modulated signal 03 with data

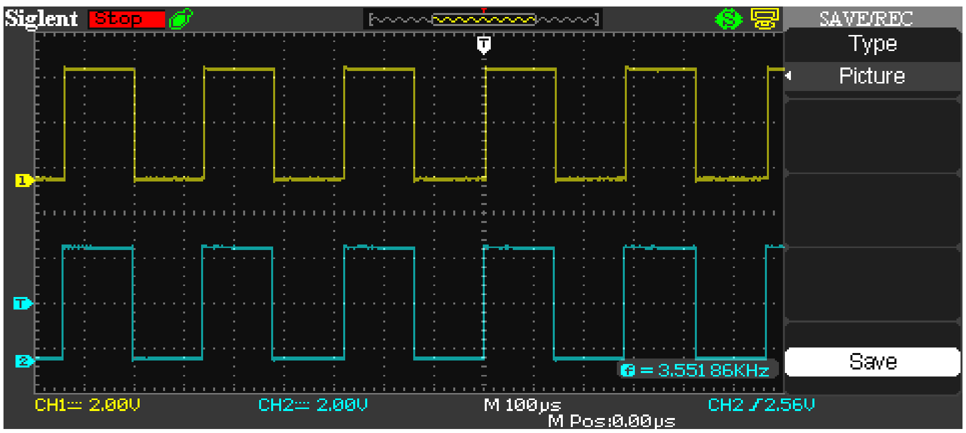


Figure 9-Demodulated signal 03 with data

1.6. Discussion

i. What are the differences you will expect in the output signal in the 7th point in the procedure if the modulator given a data signal like 1111 or 0000 instead of constantly varying 1010?

- If the data signal carries 1111 or 0000, the modulated signal becomes as sinusoidal wave without any phase shift and the demodulated signal becomes as straight line. If we have 1010 data input, we are able to see the phase shift in the modulated signal as the bit transfer from “1 to 0” or “0 to 1” and the same carrier wave will appear as the modulated signal too.

ii. Discuss the impact of noise on the constellation diagram of PSK signal.

- When noise is in the recovered signal the noise will change the constellation diagram points as the noise may vary the amplitude of the signal or the phase of the signal thus the noise, in constellation diagram vary the point by length or with an angle.

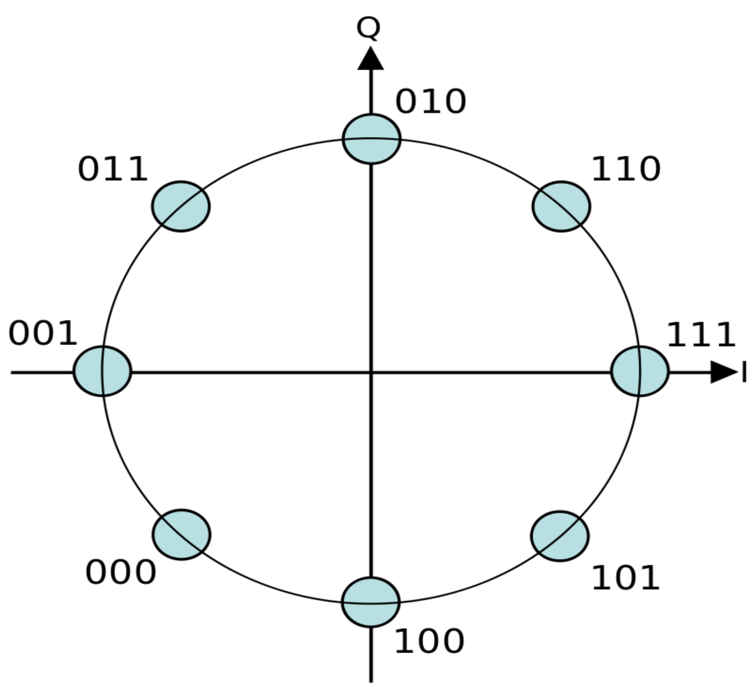


Figure 10- 8-PSK

An 8-PSK. The diagram shows information is transmitted as one of 8 "symbols", each representing 3 bits of data. Each symbol is encoded as a different phase shift of the carrier sine wave: 0°, 45°, 90°, 135°, 180°, 225°, 270°, 315°.

2. Sampling and reconstruction

2.1.Objective

To construct the sampling and reconstruction circuit and to observe its output waveforms.

2.2 Components and Apparatus

- OHM SMP Trainer Kit
- CRO (or DSO)
- Digital Multi meter (DMM)
- Set of Patch tips

2.3 Background

Sampling is defined as, “The process of measuring the instantaneous values of continuous-time signal in a discrete form."

Sampling Rate

To discretize the signals, the gap between the samples should be fixed. That gap can be termed as a sampling period Ts.

$$\text{Sampling Frequency (fs)} = \frac{1}{Ts}.$$

Equation 2 Sampling frequency

Ts-is the sampling time

fs-is the sampling frequency or the sampling rate

Sampling frequency is the reciprocal of the sampling period. This sampling frequency, can be simply called as Sampling rate. The sampling rate denotes the number of samples taken per second, or for a finite set of values. For an analog signal to be reconstructed from the digitized signal, the sampling rate should be highly considered.

Sampling Theorem

The sampling theorem, which is also called as Nyquist theorem, delivers the theory of sufficient sample rate in terms of bandwidth for the class of functions that are bandlimited.

The sampling theorem states that, “A signal can be exactly reproduced if it is sampled at the rate fs, which is greater than twice the maximum frequency W."

Sampling Techniques

There are three type of sampling techniques as follows:

- Impulse Sampling
- Natural Sampling
- Flat top Sampling

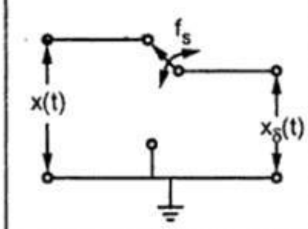
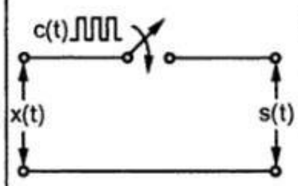
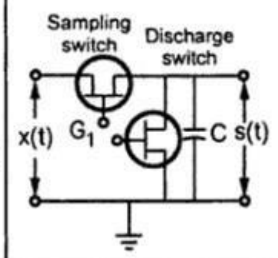
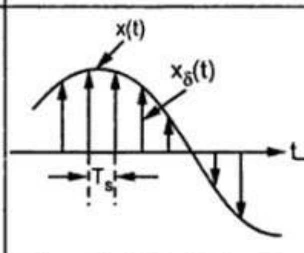
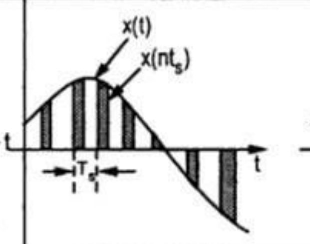
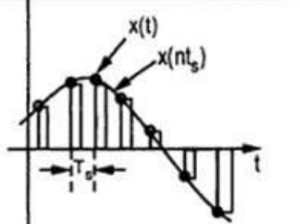
Sr. No.	Parameter of comparison	Ideal or instantaneous sampling	Natural sampling	Flat top sampling
1	Principle of sampling	It uses multiplication by an impulse function	It uses chopping principle	It uses sample and hold circuit
2	Circuit of sampler			
3	Waveforms			
4	Realizability	This is not practically possible method	This method is used practically	This method is used practically

Figure 11-Sampling Techniques

.

2.4 Procedure

1. Circuit was patched as the wiring diagram. (Operating Manual of the kit was referred.)
2. Circuit was switched on and checked the power supply to be + 15 V and – 15V and +5V.
3. With the help of DSO (Oscilloscope), the AF signal at the AF generator section was observed.
4. AF frequency and Amplitude were varied with the help of potentiometer provided.
5. Output of the sampling clock pulse and gate pulse signal was observed.
6. Frequency and the width of the gate pulse were varied with the help of potentiometer provided.
7. AF output was connected, Sampling clock pulse and the gate pulse to the input of the modulator section.
8. P1 was connected and NATURAL SAMPLING output was observed.
9. P2 and P3 was connected and FLAT TOP sampling output was observed.
10. P2 was connected and the SMPLE AND HOLD OUTPUT was observed.
11. Modulation output was connected to the demodulation input and observed the AF sine wave at the output terminal.

2.5 Observations

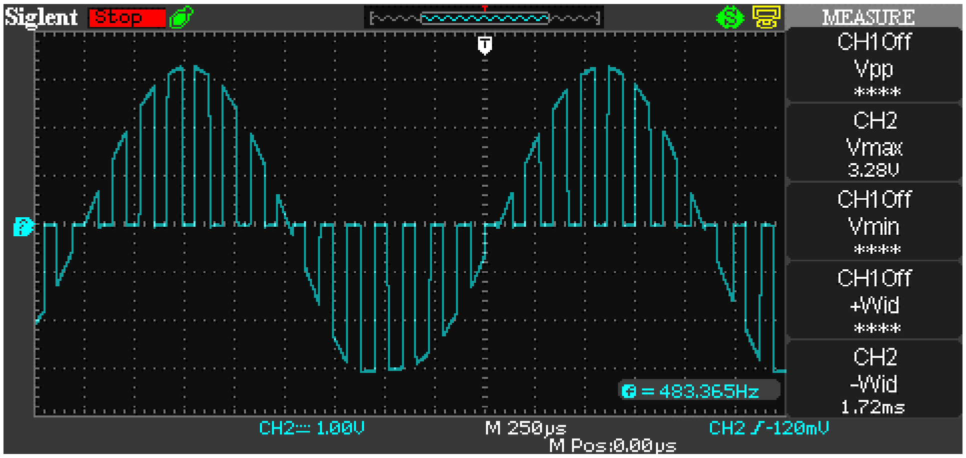


Figure 12-Output waveform

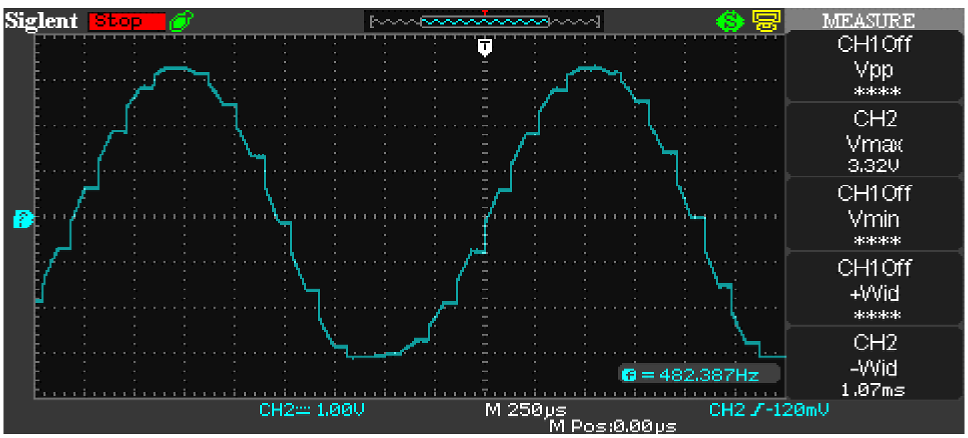


Figure 13- Sample and hold output

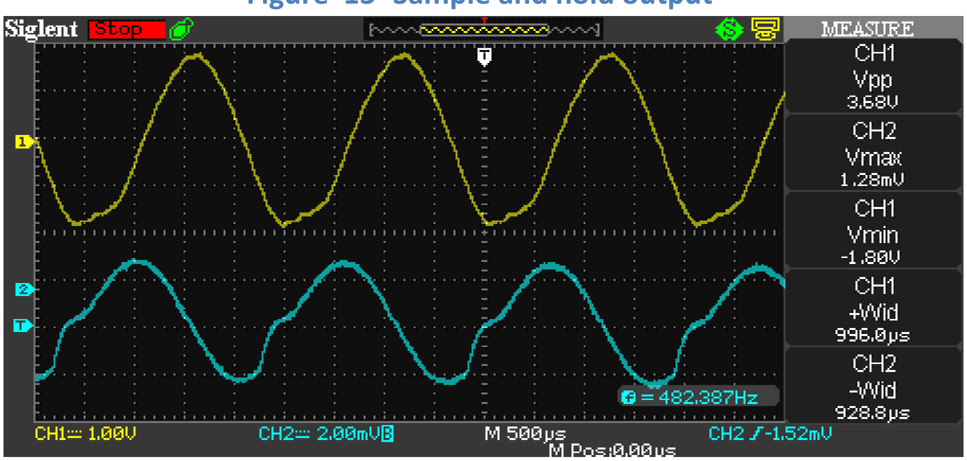


Figure 14- Demodulation output

2.6 Discussion

i. In FLAT TOP sampling output, it appears like peaks. Zoom in the output with time scale knob of DSO and observe the flat top nature. Is it biased to upper or lower side of the carrier wave? Give reasons.

   - It is biased towards the lower side of the carrier wave.

ii. In SAMPLE AND HOLD it doesn't appear like following. Explain the reasons that can be. Also discuss the difference between "Sample and Hold" and "Track and Hold".

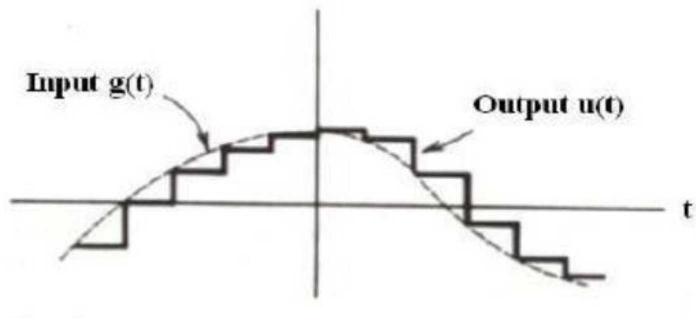


Figure 15-Sampling and Holding

   - Impulse functions are utilized for sampling in the Sampling and Holding method, which means Sampling and Holding will hold the same sampled value until it gets its next sampled value in next sampling. In Tracking and holding Complete tracking time itself be its sampling time so it will be in track of the input signal until it gets its next sampled value. In this practical Tracking and holding was observed for flat top sampling.

3.Amplitude modulation and demodulation

3.1 Objective

In this experiment you will be constructing amplitude modulator and you will be observing amplitude modulated wave and percentage of modulation.

3.2 Components and Apparatus

- OHM Amplitude Modulation Trainer Kit
- CRO (or DSO)
- Digital Multi meter
- Set of Patch tips

3.3 Background

3.3.1 AM modulation

In amplitude modulation, the amplitude of the carrier wave is varied in proportion to the waveform being transmitted. That waveform may, for instance, correspond to the sounds to be reproduced by a loudspeaker, or the light intensity of television pixels.

an amplitude modulated signal is created, the amplitude of the created signal represents the original baseband signal to be transmitted. This amplitude forms an envelope over the underlying high frequency carrier wave. Here, the overall envelope of the carrier is modulated to carry the audio signal. AM is the simplest way of modulating a signal

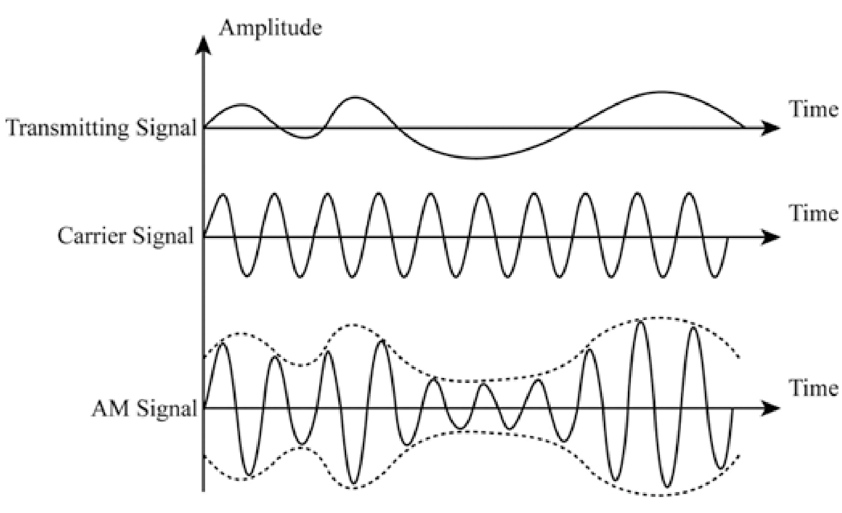


Figure 16-AM modulation

Looking at theory the carrier signal wave is express as follow

$$C\ (t)\ =\ C \sin\ (\omega c\ + \varphi);\ \text{Where: } \omega =\ 2\pi fc$$

C is the carrier amplitude ϕ is the phase of the signal at the start of the reference time. Both C and ϕ can be omitted to simplify the equation by changing C to "1" and ϕ to "0".

Message signal wave is express as follow

$$m\ (t)\ =\ M \sin\ (\omega m +\ \varphi);\ \text{Where: } \omega m\ =\ 2\pi f$$

M is the message signal amplitude
ϕ is the phase of the signal at the start of the reference time
modulated signal y(t) is obtained by
y (t) = [A + m (t)]. c (t); where A is required as it represents the amplitude of the waveform.
y (t) = * A + M cos (ω_m t + ϕ]. sin (ω_c t)
y (t) = A. sin (ω_c t) + M/2 * sin ((ω_c + ω_m) t + ϕ+ + M/2 * sin ((ω_c - ω_m) t

3.3.2 Modulation index

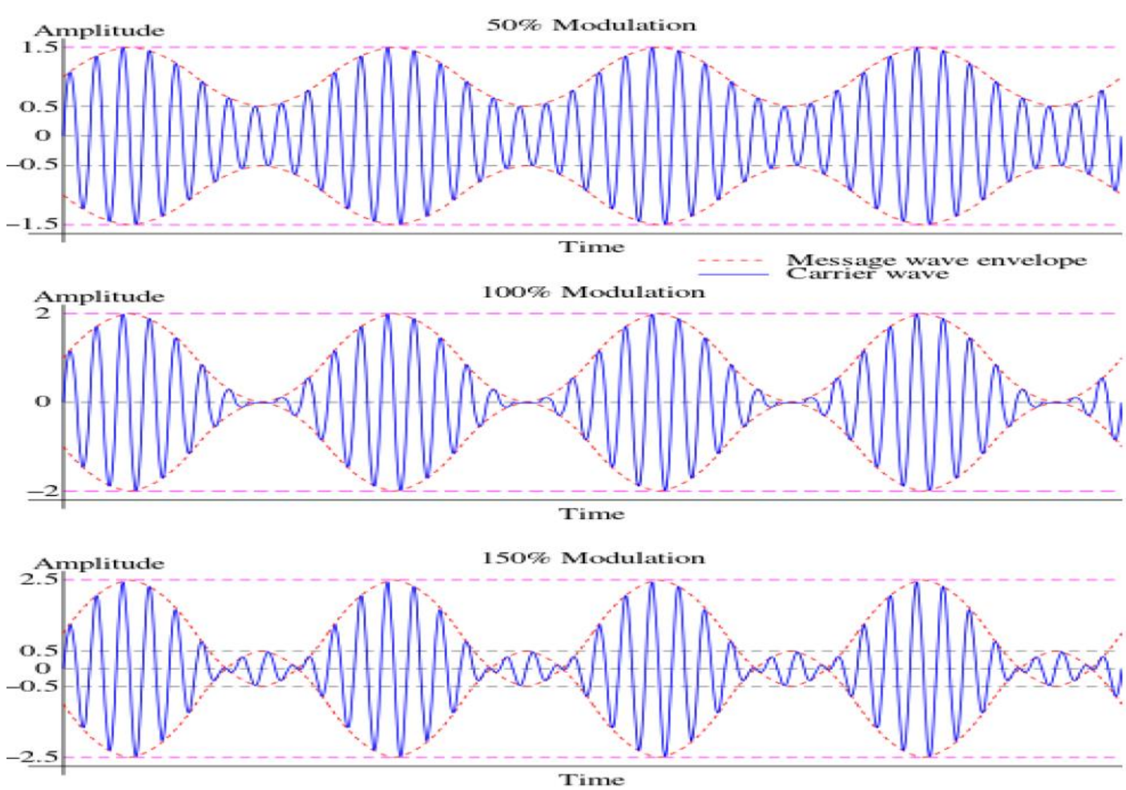


Figure 17-modulation index

$$\text{Modulation index h} = \text{M/C}\;;\;\text{Where: C is the carrier amplitude.}$$

M is the modulation amplitude.

This value of modulation index is less than 1 It is called as Under-modulation. Such a wave is called as an under-modulated wave. The value of the modulation index is greater than 1 then the wave will be an over-modulated wave. The value of modulation index is equal to one it is called perfect modulation.

3.3.3 AM Demodulation

Demodulation is the process by which the original information bearing signal, i.e. the modulation is extracted from the incoming overall received signal. There are a number of techniques that can be used to demodulate AM signals

1. Diode rectifier envelope detector: This form of detector is the simplest form, only requiring a single diode and a couple of other low-cost components.
2. Product detector: It is possible to demodulate amplitude modulated signals with a receiver that incorporates a product detector of mixer and a local beat frequency oscillator or carrier injection oscillator.
3. Synchronous detection: Synchronous detection provides the optimum performance. It uses a mixer or product detector with a local oscillator signal that is synchronized to the incoming signal carrier amplitude modulation applications.

- Broadcast transmissions
- Air band radio
- Single sideband
- Quadrature amplitude modulation

3.4 Procedure

1. The trainer kit is switched on and the digital multimeter was used to check whether the power supply was +12V and -12V DC.
2. The carrier and AF waveform with the corresponding generator section was observed with the help of a CRO
3. The trainer was patched as per the wiring diagram.
4. The AM modulation output was observed at the modulator section.
5. The AF amplitude was varied and changes in both the depth of the index and modulation index was observed.
6. The Modulation amplitude (M) and carrier amplitude (A) was calculated for different waveforms and corresponding modulation indices was calculated with the help of equation 01.
7. The demodulator components were connected and the output was compared with AF input.

3.5 Observations

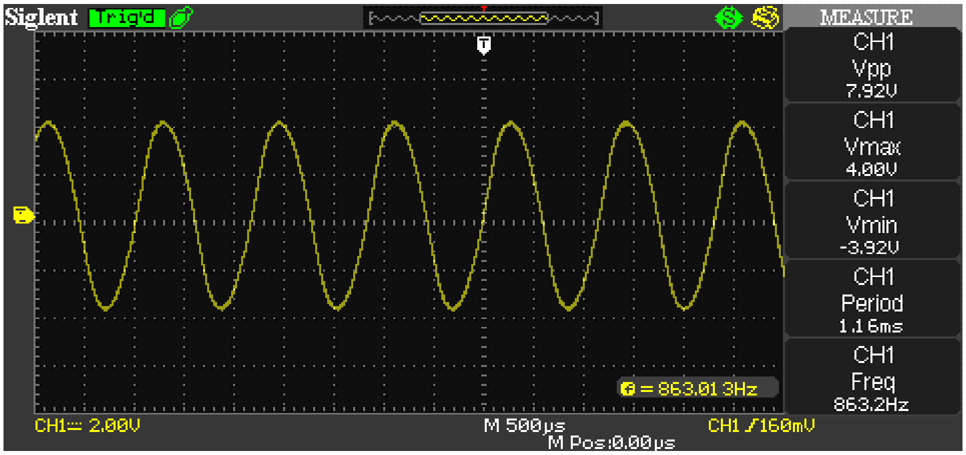


Figure 18- AF-Waveform

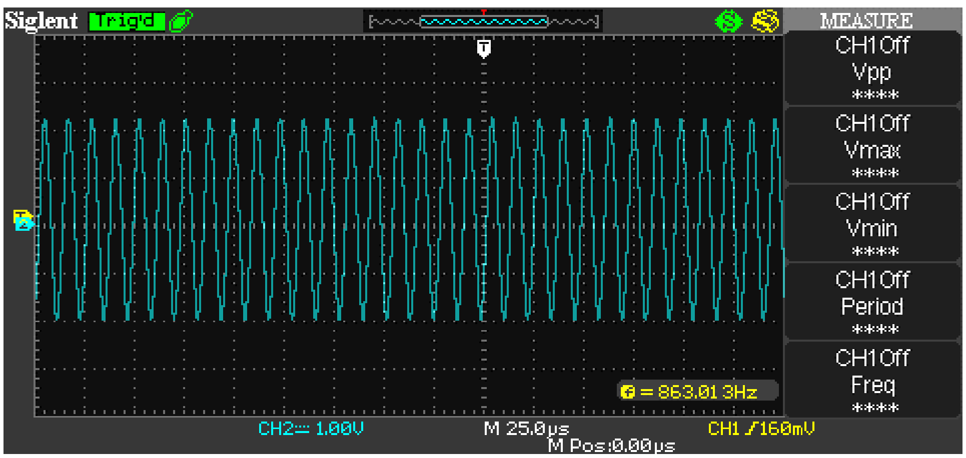


Figure 19- Carrier signal

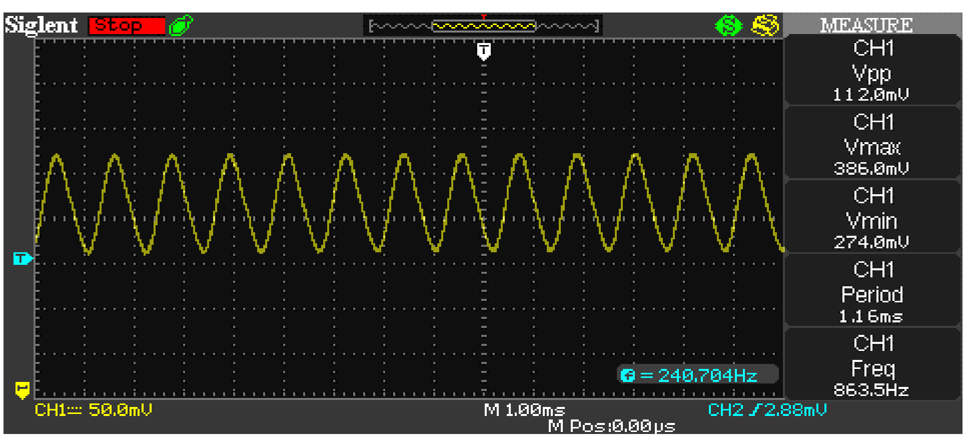


Figure 20- Demodulated (Not amplified) Signal

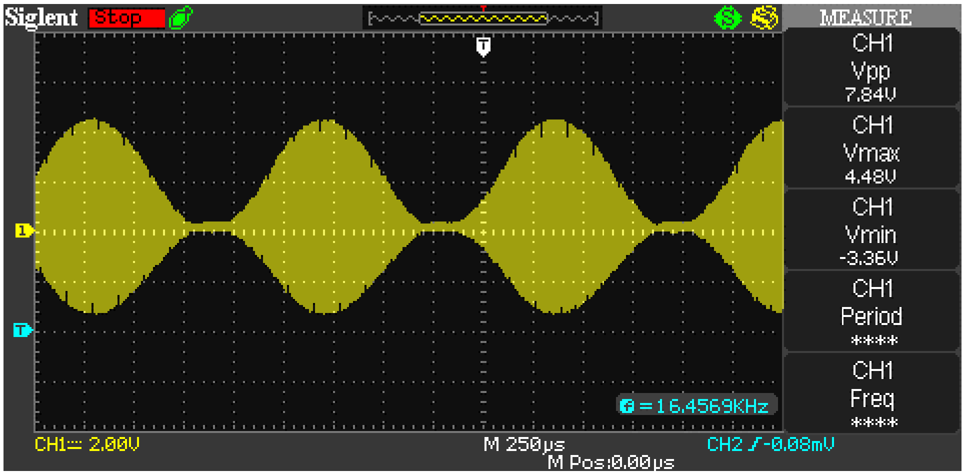


Figure 21- Modulated Signal

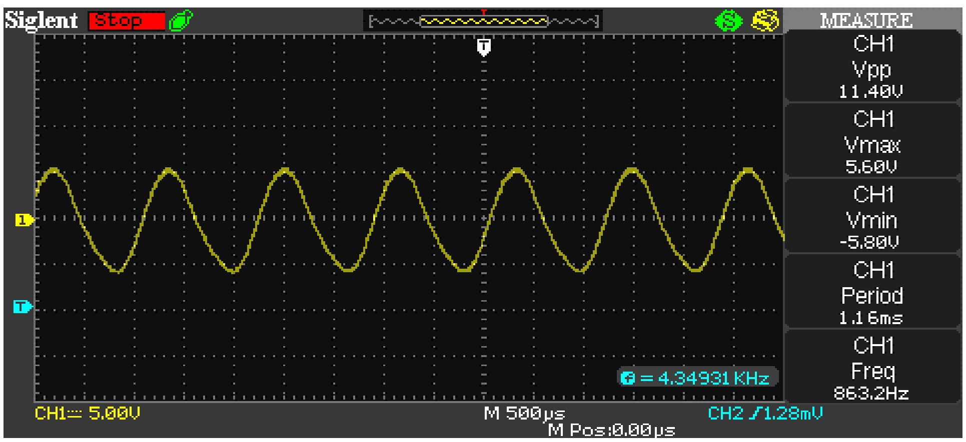


Figure 22- Demodulated output signal (Amplified)

3.6 Discussion

i. List some advantages and disadvantages of amplitude modulation, over the other modulation techniques.

- Advantages:
  - AM receivers are very cheap.
  - It can be demodulated using a simple circuit.
- Disadvantages:
  - Not efficient in power usage.
  - Not efficient in terms of bandwidth
  - Very sensitive to noise

ii. Discuss the impact of over modulation in an amplitude modulated transmission?

- In the image below a amplitude modulated sine wave:
  - 0% unmodulated, the sine envelope is not visible at all;
  - < 100% modulation depth is normal AM use;
  - 100% modulation depth, the sine envelope touch at y=0. Maximum modulation that can be retrieved with an envelope detector without distortion;
  - 100% modulation depth, "overmodulation", the original sine wave can no longer be detected with an envelope detector.

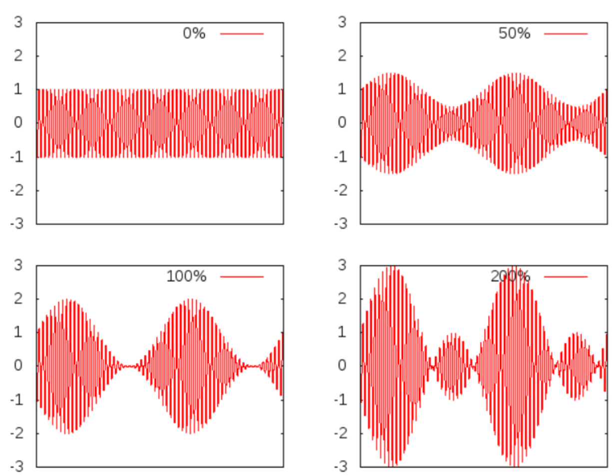


Figure 23-A still overview of the most important modulation depths (0, 50, 100 and 200%)

- If demodulate an over modulate signal it will get distortion

4.Amplitude Shift Keying Modulation and Demodulation

4.1.Objective

Studying the operation of ASK modulation & demodulation and to plot the ASK wave forms for binary data at different frequencies.

4.2 Components and Apparatus

- OHM QPSK Trainer KIT
- Set of Patch Tips
- A Digital Multimeter
- A Dual Chanel Oscilloscope

4.3 Background

4.3.1 ASK Modulation

Amplitude-shift keying (ASK) is a form of amplitude modulation used in digital to analog modulation that represents digital data as variations in the amplitude of a carrier wave. In an ASK system, 1 is represented by transmitting a fixed-amplitude carrier wave and fixed frequency for a bit duration of T seconds. If the signal value is 1 then the carrier signal will be transmitted; otherwise, a signal value of 0 will be transmitted.

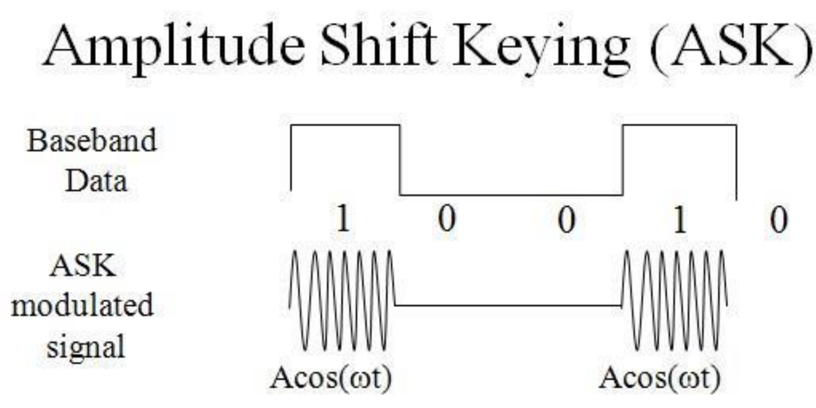


Figure 24-Amplitude shift keying modulation

Mathematically, amplitude-shift keying is

$_{(ask)}$=[1+$v_m(t)$][$\frac{A}{2}$cos$\boldsymbol{\omega}_c(t)$] ; where, $v_{(ask)}$= amplitude-shift keying wave

(t) = digital information (modulating) signal (volts)

$\frac{A}{2}$= un modulated carrier amplitude (volts)

$\boldsymbol{\omega}_c$ = analog carrier radian frequency (radians per second, 2πfct)

4.3.2 ASK Demodulation:

There are two types of ASK Demodulation techniques.

1. Asynchronous ASK Demodulation
2. Synchronous ASK Demodulation

The clock frequency at the transmitter when matches with the clock frequency at the receiver, it is known as a Synchronous method, as the frequency gets synchronized. Otherwise, it is known as Asynchronous.

4.4 Procedure

1. The trainer was switched on and the power supply was checked to see whether it was +5V and -5V.
2. The oscilloscope was connected to the output of the carrier signal generator and the frequency was noted down.
3. The oscilloscope was connected to the data signal output.
4. The carrier input of the ASK modulator was connected to the carrier signal and data input of ASK modulator.
5. The oscilloscope was connected to the output of the ASK modulator and the modulated output at the output terminal was observed.
6. The ASK modulator output was connected to the input of ASK demodulator.
7. The oscilloscope was connected to the output of the ASK demodulator section.
8. The data signal was observed at the ASK receiver.
9. The data signal was compared with original data signal.
10. The above steps were repeated for different frequencies of the data signals.

4.5 Observations

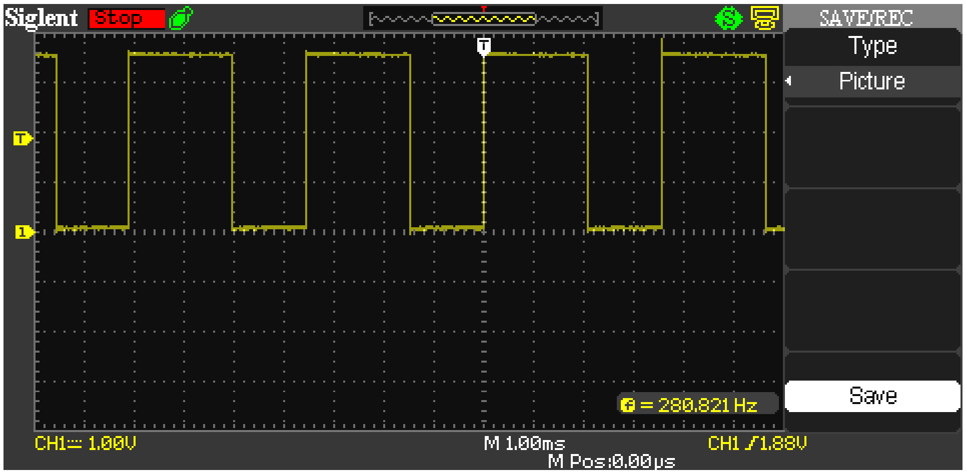


Figure 25- Message Signal

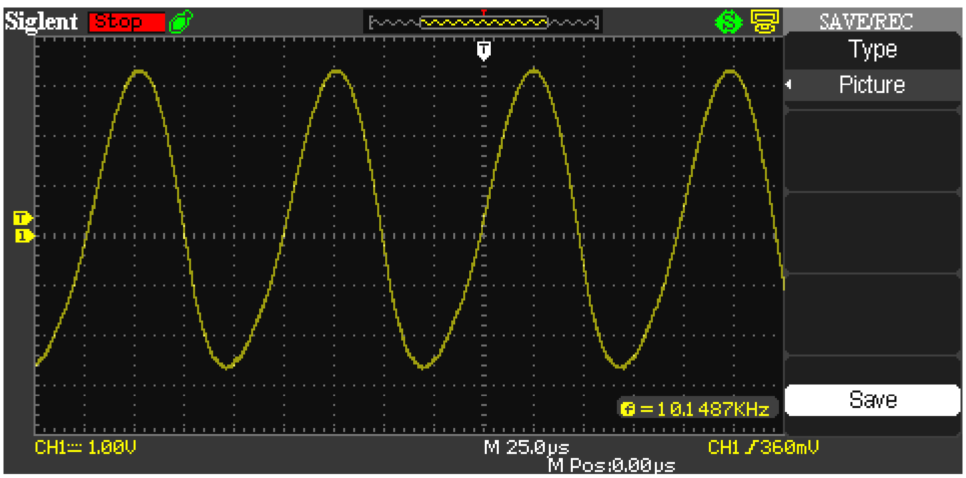


Figure 26- Carrier Signal

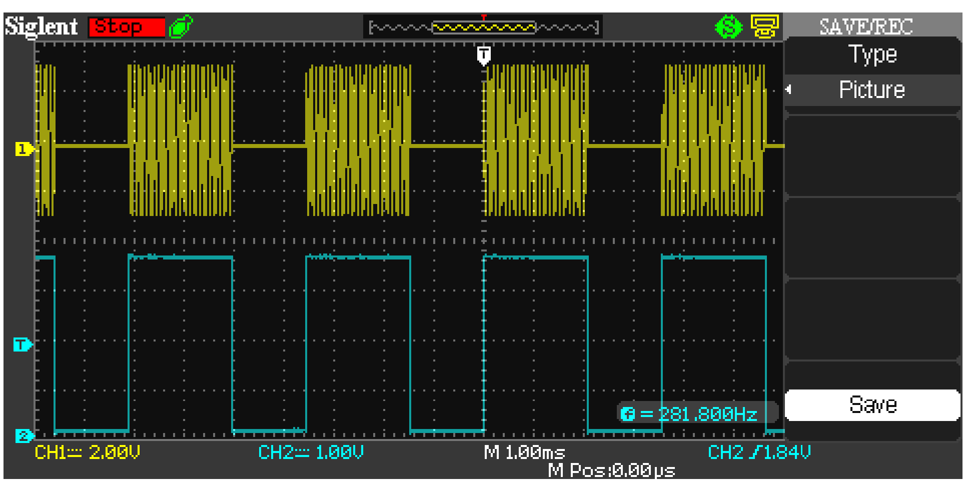


Figure 27-ASK Modulation signals

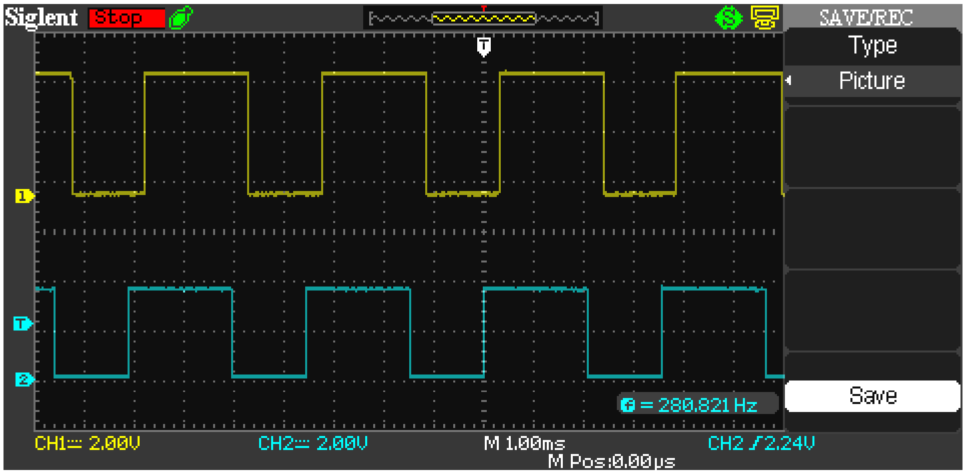


Figure 28-Demodulated signal

4.6 Discussion

i. Make a comparison between amplitude levels Between ASK and AM

- When the data to be sent is digitized (commonly in the form of zeros and ones), a digital modulation is used. More specifically in the case of ASK, different data are sent to digitize values by signals with different amplitudes. A simple example could be sending a Po(t)= 0 for a 0 bit and P1(t)=cos(2πfct) for a 1 (which is using the data bit as the amplitude of the pulse). However, in the case of analogue modulations, the data being sent is analogue and hence it could have any values in a continues manner (for example an unsampled recorded voice as a function of time from the output of a mic). An AM signal is in the form of m(t)=cos(2πfct), where m(t) is the message signal.

5.Balanced Modulator

5.1 Objective

Constructing the balanced modulator and observing modulated output

5.2 Components and Apparatus

- OHM balanced modulator trainer kits
- DMM
- Sets of patch tips
- Oscilloscope

5.3 Background

The balanced modulator is used to suppress the carrier in an AM wave. The carrier and modulating signals are applied to the inputs of the balanced modulator and obtained the DSB signal with suppressed carrier (DSB-SC) at the output of the balanced modulator. Thus, the output consists of the upper and lower side bands only.

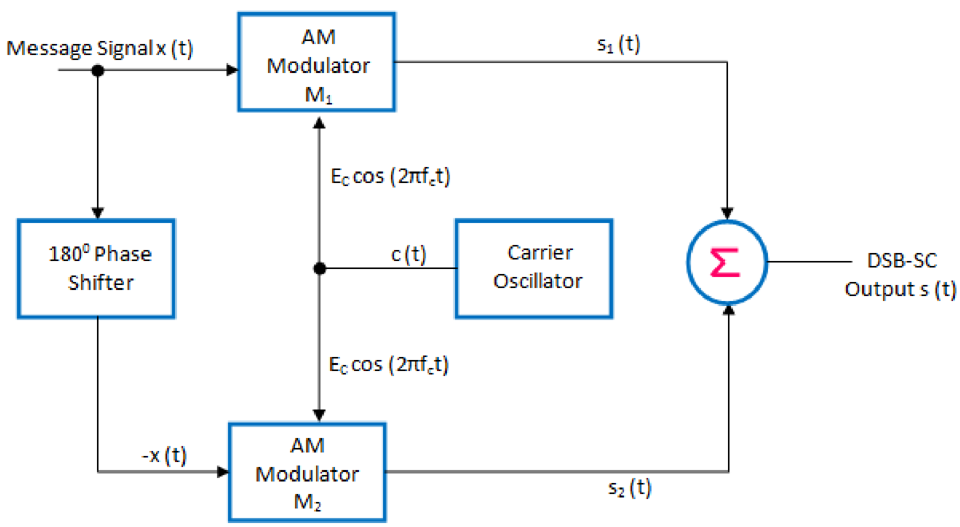


Figure 29- Balanced modulator

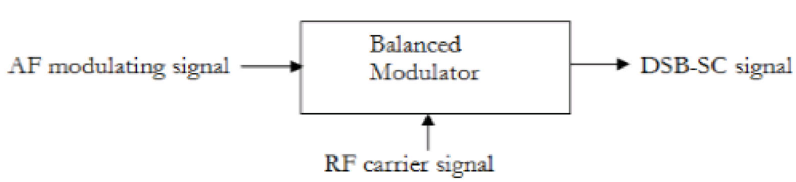


Figure 30- Block diagram of balanced modulator

In the balanced modulator two signals at different frequencies are passed through a "nonlinear resistance". Therefore, at the output, an AM signal with suppressed carrier is obtained. The device having a nonlinear resistance can be diode or a JFET or even a bipolar transistor.

Types of balanced modulator:

1. Using the diode ring modulator or lattice modulator.
2. Using the FET balanced modulator.

5.4 Procedure

1. OHM balanced modulator trainer kit was switched on and checked the power supply to be +12V.
2. Wiring diagram of the operating manual was referred to connect the OHM balanced modulator trainer kit.
3. 100 Hz (4V P-P) sine wave was connected at the input terminal.
4. 100 kHz (4V P-P) sine wave was connected at the carrier wave input terminal.
5. Modulated output at the output pin was observed in both time and frequency domain.
6. $Emin$ and $Emax$ values were measured and then calculated the percentage of efficiency.
7. While varying the frequency of input sine wave, variation of the output was observed.

5.5 Observations

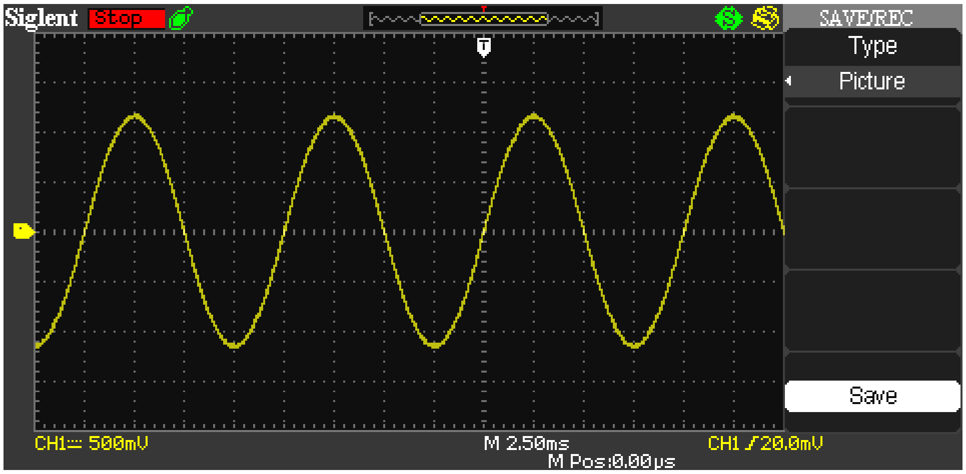


Figure 31- Message Signal

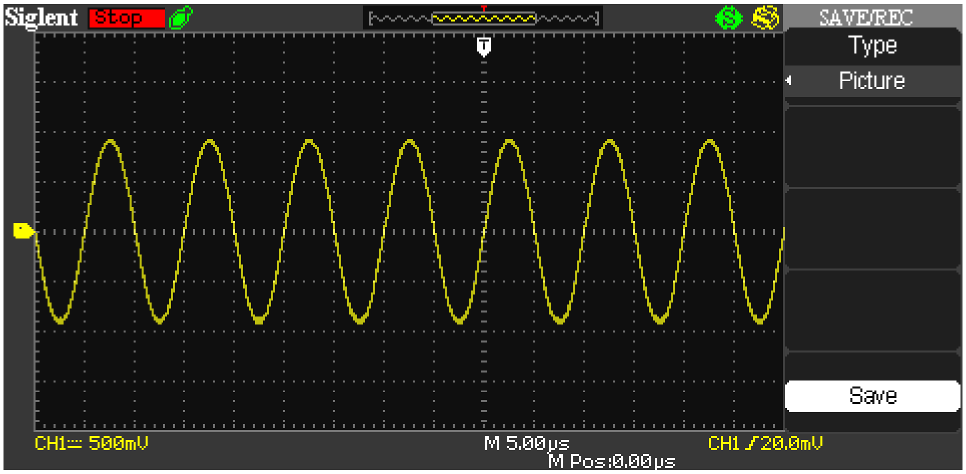


Figure 32- Carrier signal

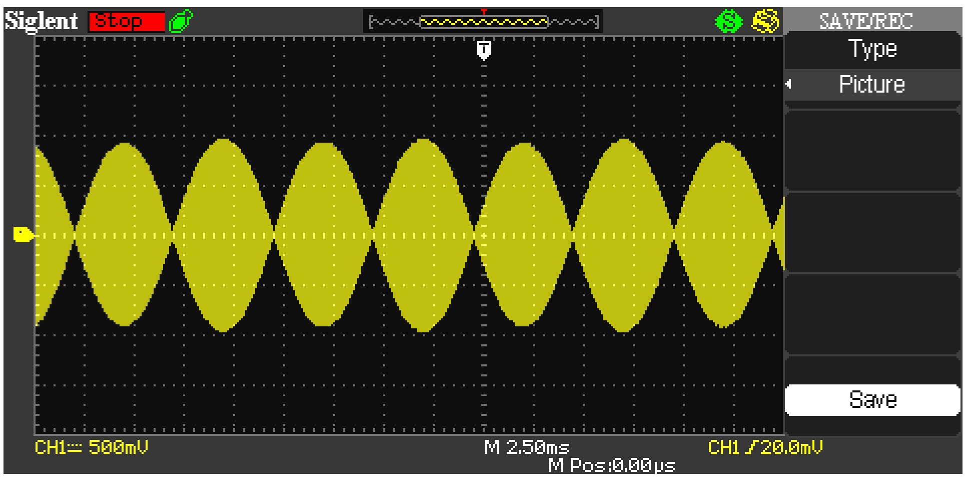


Figure 33- Modulated Signal

5.6 Discussion

i. Discuss the difference between DSB and DSB-CS by showing the waveforms in time domain and the frequency domain.

- DSB-SC (Double side band suppressed carrier), which produces the sum and difference frequencies but to cancel or balance out the carrier. Considerable power can be saved by eliminating the carrier and to put the power into the sidebands for stronger signals over long distances. This is the basic difference between DSB and DSB-SC where DSB suppresses the carrier where DSB is not.

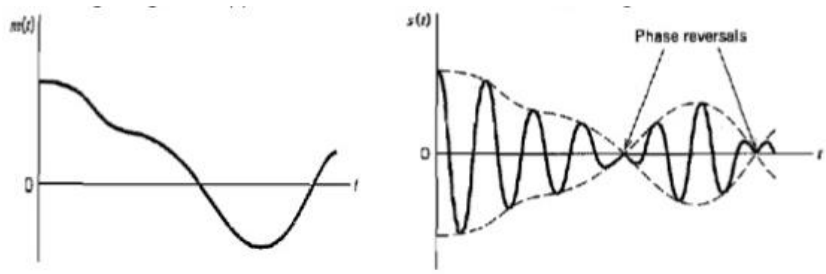


Figure 34-Time Domain

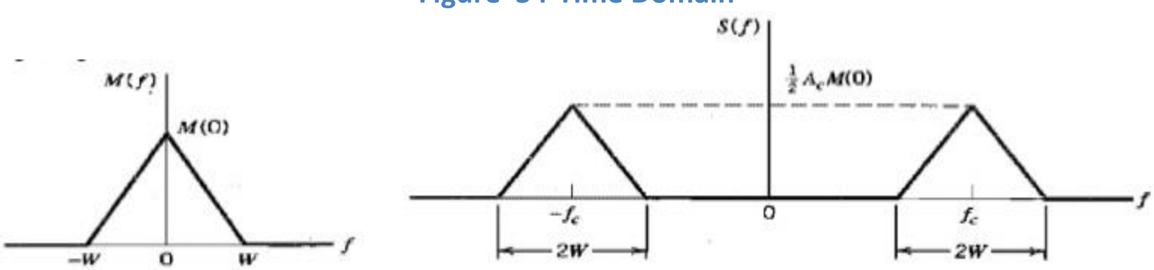


Figure 35-Frequency Domain

ii. When frequency of input sine wave is varying, what happened to the output?

- When frequency of the input sine wave varies it will be modulated perfectly until it satisfies the Nyquist theorem, if it dissatisfies, aliasing effect might occur and signal will get distorted.

6.DSPK Modulation and Demodulation

6.1 Objective

Familiarizing with the DPSK modulation and demodulation. Constructing the DPSK modulation and demodulation.

6.2 Components and Apparatus

- OHM DPSK trainer kits
- AFO
- Multimeter
- Sets of patch tips
- Oscilloscope

6.3 Background

Differential Phase Shift Keying (DPSK) is a digital modulation scheme where, the phase of the modulated signal is shifted relative to the previous signal element. The signal phase follows the high or low state of the previous element and the demodulator determines the changes in the phase of received signal. Hence, DPSK technique omits the need of a reference oscillator. DPSK is an alternative form of digital modulation where the binary input information is contained in the difference between two successive signaling elements rather than the absolute phase. With DPSK it is not necessary to recover a phase coherent carrier. Instead, a received signal element is delayed by one signaling element time slot and then compared the next received signal element. The difference in the phase of the two signaling elements determines the logic condition of the data.

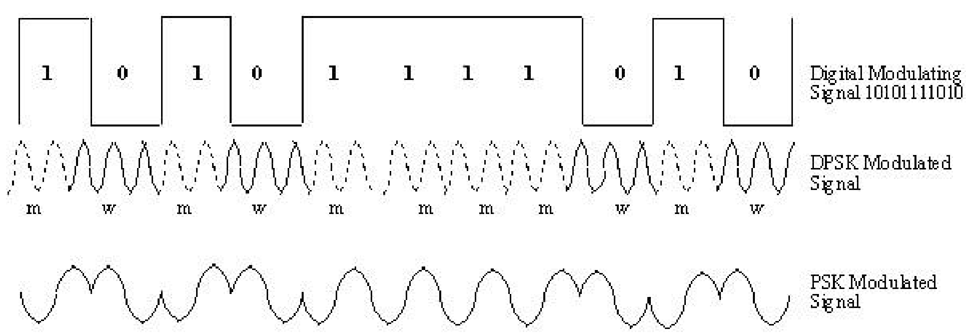


Figure 36- DPSK modulation

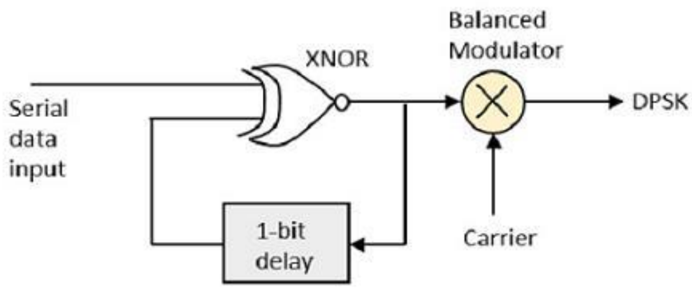


Figure 37- Block diagram of DPSK Modulator

6.4 Procedure

PART 1

1. The trainer kit was switched on and the power supply was checked to be +5V and -5V.
2. The patch tips were connected as per wiring diagram.
3. The carrier output at the pin 6 of TLO84 IC at the carrier generator section was observed.
4. The bit clock output at the pin 1 of TLO84 IC at the carrier generator section was observed.
5. The data output from D1 to D4 was observed. The frequencies of the observed waveforms were compared.
6. The output at the pin 3 of 4551 IC was observed.

PART 2

1. The patch tips were connected as per wiring diagram.
2. The demodulated output at the pin 11 of 7486 IC for the data input from D1 was observed.
3. Different data inputs from D1 to D4 was changed and corresponding demodulated outputs were observed.

6.5 Observations

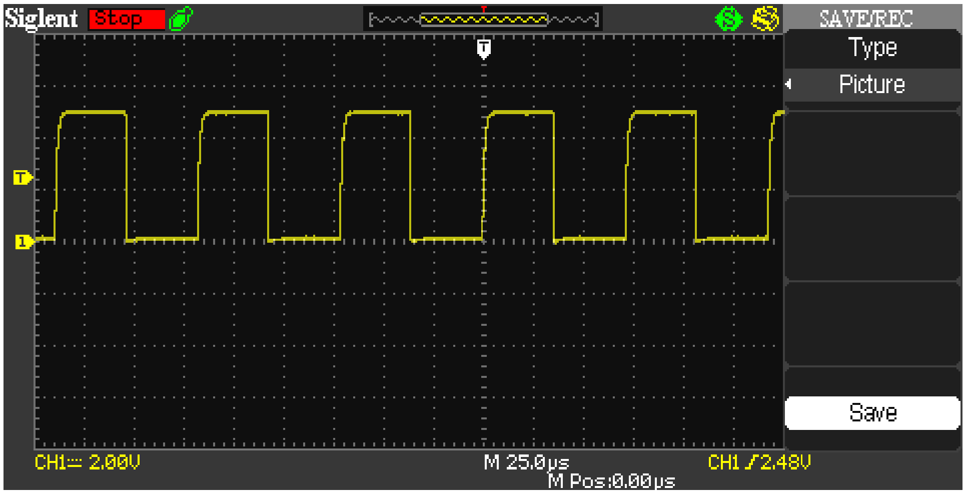


Figure 38- Clock Signal

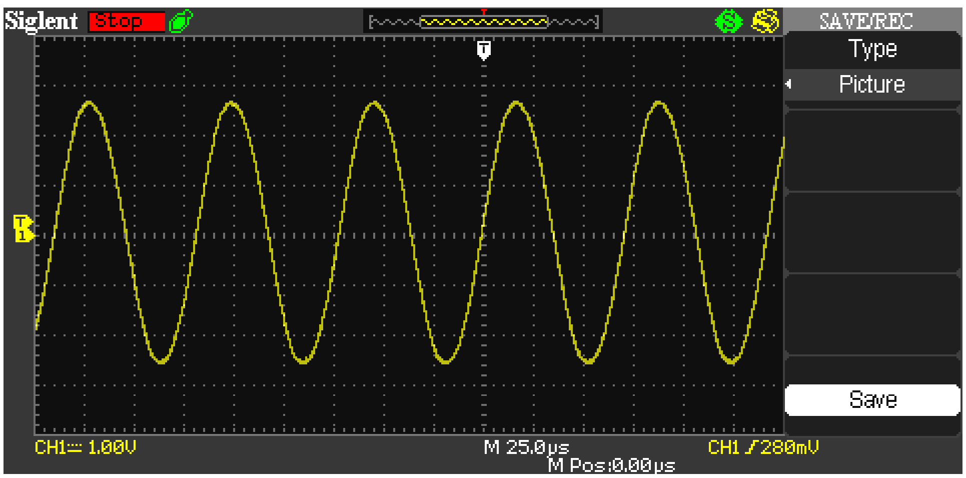


Figure 39- Carrier Signal

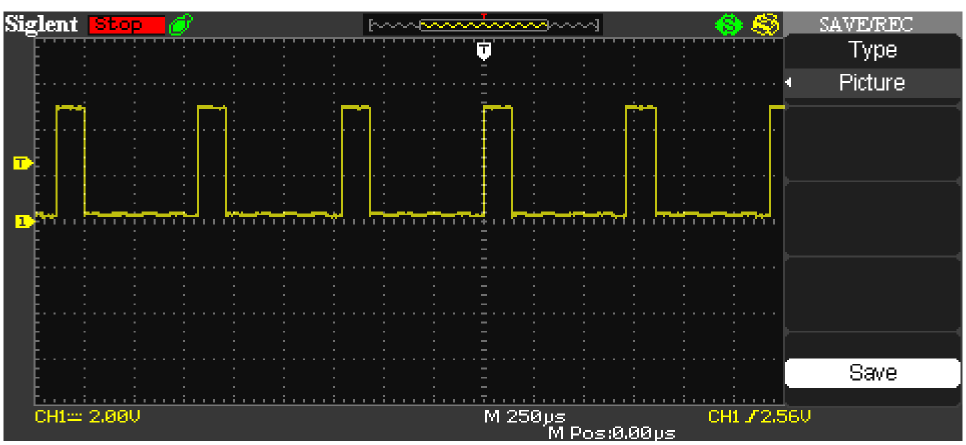


Figure 40- Message Signal

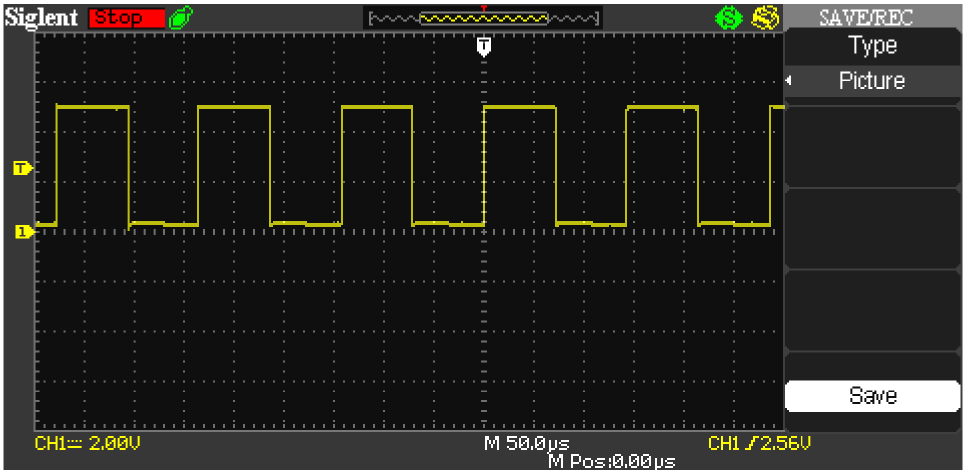


Figure 41- Message Signal

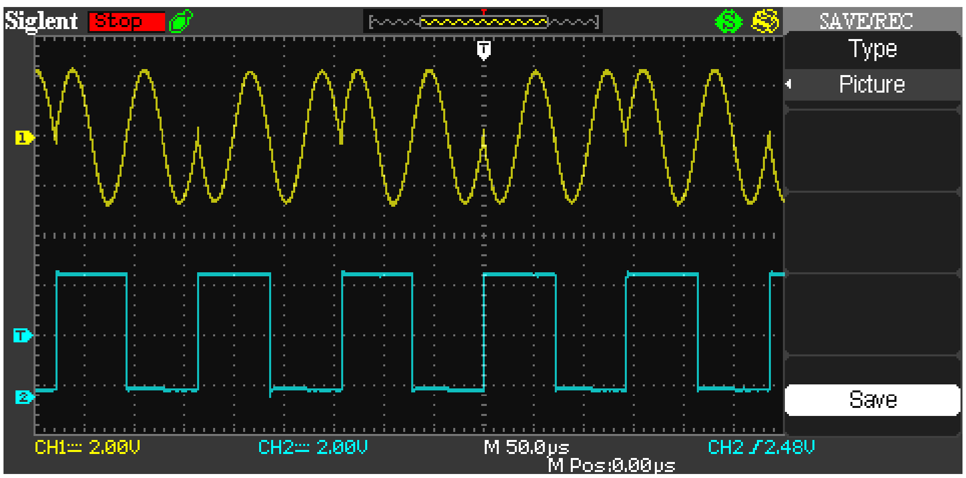


Figure 42- Modulated Signal with Message Signal

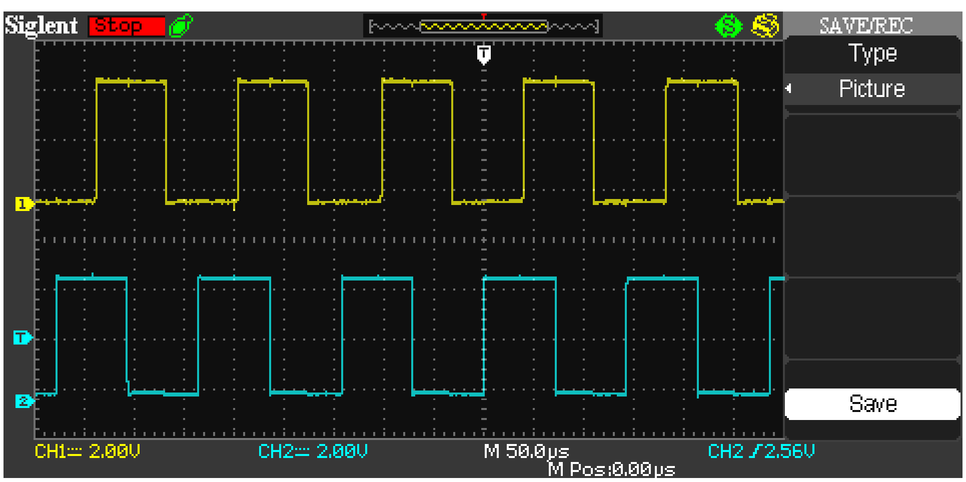


Figure 43- Demodulated Signal with Message Signal

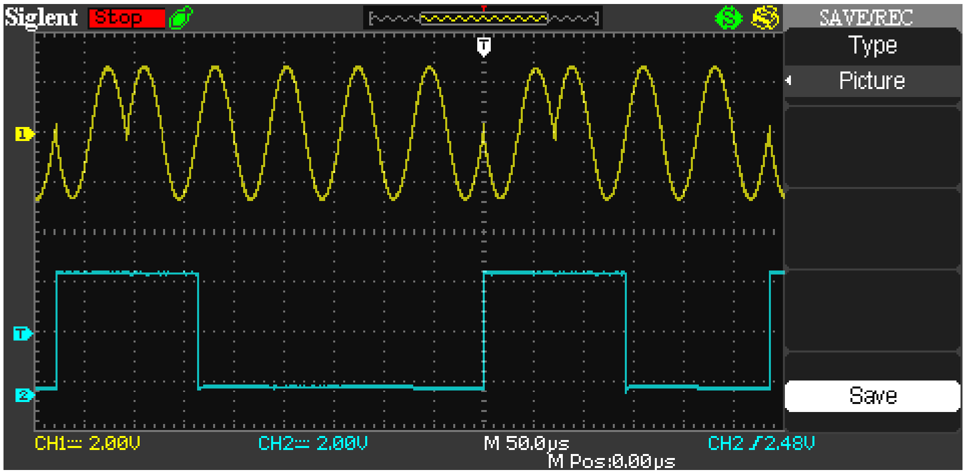


Figure 44- Modulated Signal with Message Signal

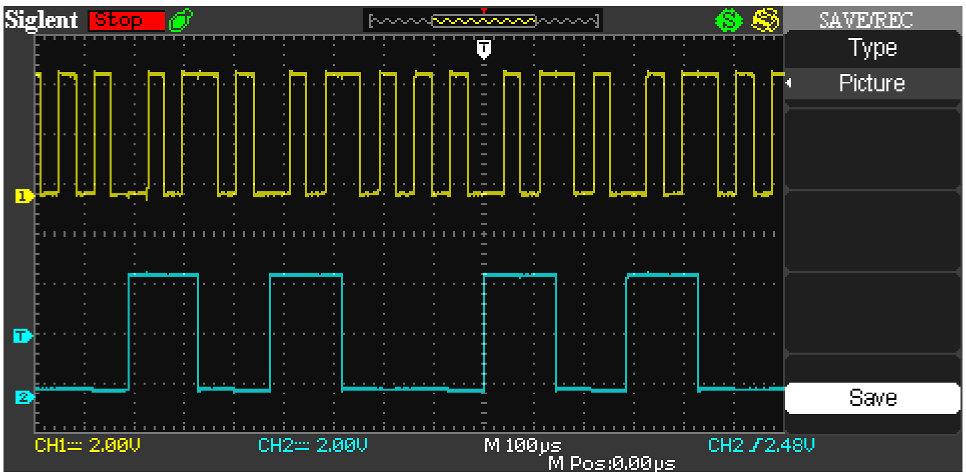


Figure 45- Demodulated Signal with Message Signal

6.6 Discussion

i. Discuss the difference between PSK and DPSK.

- DPSK has a shift of 1800 and it is a non-coherent form of PSK which avoids the need for a coherent reference signal at the receiver. PSK needs coherent detection due to its phase shift with reference signal. (No coherent receivers are easy and cheap to build)
- PSK is embedding info in the phase of transmitted signal. DPSK sends the phase difference between BPSK info symbol in order to allow for incoherent demodulation.

7.Principal of Modulation to the Real Signal

7.1 Objectives

To construct and verify the principle of the modulation to the real signal.

7.2 Components and Apparatus

- OHM CN7 trainer kits
- Function generator
- Multimeter
- Sets of patch tips
- Oscilloscope

7.3 Background

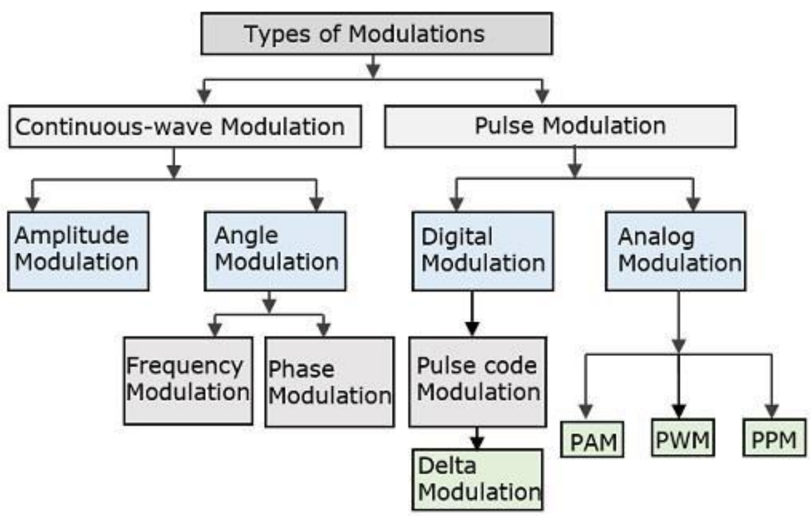


Figure 46- Types of modulations

Modulation

The process of superimposing the information contents of a modulating signal on a carrier signal by varying the characteristic of carrier signal according to the modulating signal is called as Modulation. The frequency of the carrier signal is much greater than the frequency of the modulating signal.

Pulse modulation

The process of transmitting the pulses from a transmitter to a receiver over a physical transmission medium with a special technique is called Pulse Modulation. Pulse modulation involves communication using a train of recurring pulses.

There are two main types of pulse modulation techniques.

1. Analog pulse modulation
2. Digital pulse modulation

- Analog pulse modulation is classified as;
  1. Pulse amplitude modulation (PAM)
  2. Pulse width modulation (PWM)
  3. Pulse position modulation (PPM)

- Digital pulse modulation is classified as;
  1. Pulse code modulation (PCM)
  2. Delta modulation (DM)

Pulse amplitude modulation (PAM)

In this modulation technique, the amplitude of the pulses is varying while keeping the width and position of the pulses are constant. There are two types of PAM and those are natural sampling and flat too sampling. The advantage of PAM is the generating and detection is comparably easy. The disadvantage is band width of the transmitted signal is very large.

Pulse width modulation (PWM)

In this modulation technique, the width of the pulses is varying while keeping the amplitude and position of the pulses are constant. It is sometimes called as pulse duration modulation (PDM) or pulse length modulation (PLM). PWM is very popular in digital circuits because of its easy generation.

Pulse position modulation (PPM)

In this modulation technique, the position of the pulses is varying while keeping the amplitude and width of the pulses are constant. PPM is widely used in communications over optic fibers as multipath fading is minimal. Moreover, PPM is also used in communications for RC equipment's because, demodulation is easy.

7.4 Procedure

1. The OHM CN7 trainer kit was switched on and the power supply was checked to be +5V.
2. A pulse input of 300 Hz was connected from a function generator to the pin 01 of 7404 inverter section.
3. The corresponding output at pin 2 and 4 of 7404 was observed. The output at pin 2 and 4 was compared with input pulse.
4. The setup was connected as per the wiring diagram.
5. The output at Q1 and Q2 were observed. Further the output at Q1 and Q2 were compared with input pulse.
6. The output of pulse modulator was observed and compared with the input pulse.
7. The setup was connected as per the wiring diagram 2 for analog modulator.
8. A pulse input of 300 Hz was connected from a function generator to the pin 01 of 7404 inverter section.
9. A sinusoidal input of 2.5 KHz was connected from a function generator to AF input pin.
10. The output of the analog modulator was observed and compared with the input pulse.

7.5 Observations

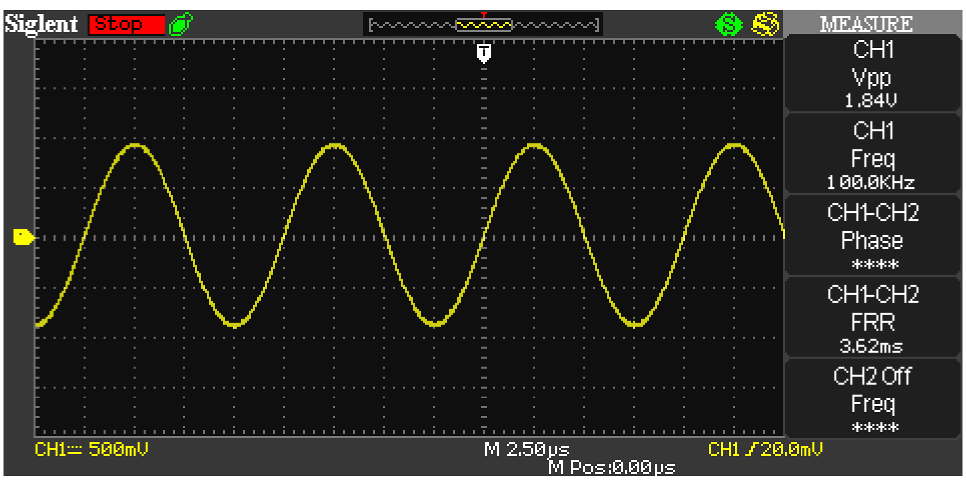


Figure 47- Carrier Signal

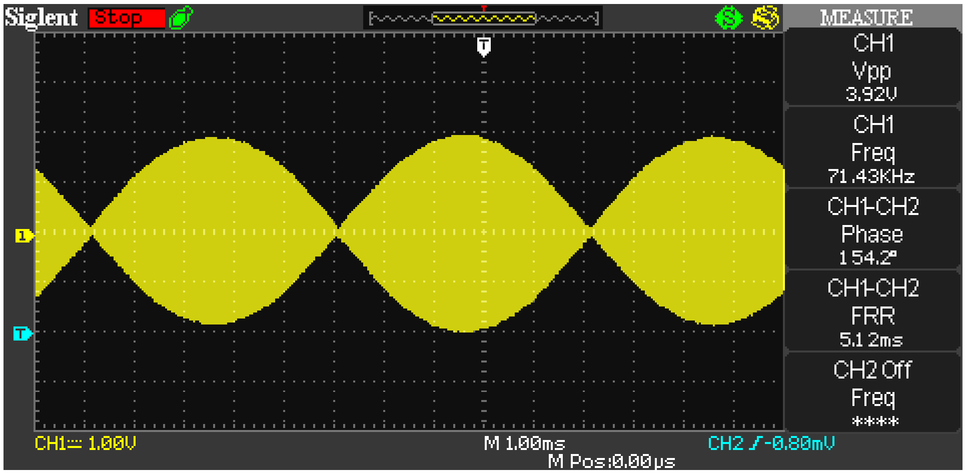


Figure 48- Modulated Signal

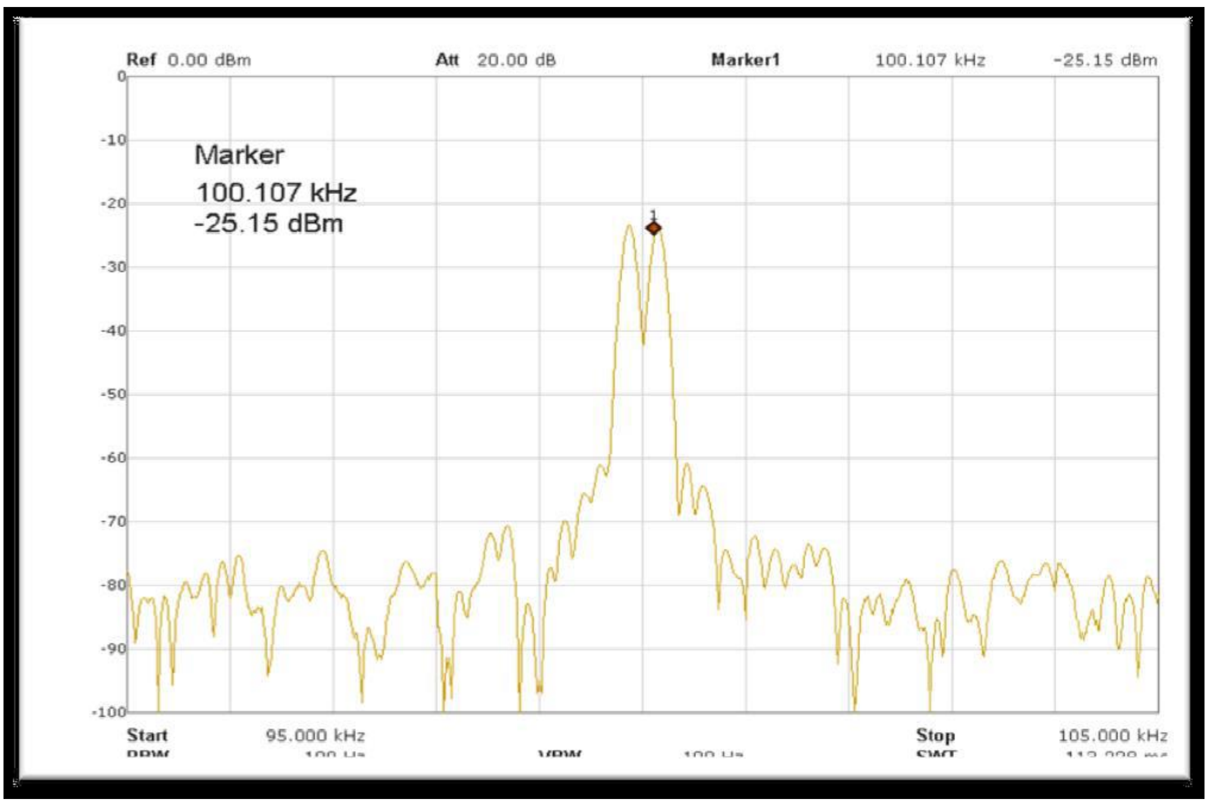


Figure 49- Modulated Signal in Frequency Domain

7.6 Discussion

i. Discuss the operation of the “divide by four circuit” section of the OHM CN7 trainer kit.

    - Divide by four circuit is normally a Dual Negative-Edge-Triggered Master-Slave J-K Flip-Flop which creates clock pulses to the circuit with pre-set and clear.

ii. List down the advantages and disadvantages of the digital transmission over analog transmission.

  - Advantages:
    - More secure
    - Error detection is easier than analog
    - Noise immunity
  - Disadvantages:
    - Sampling error
    - Require Synchronization
    - More bandwidth is required.

8.Frequency Shift Keying (FSK) Modulation and Demodulation

8.1 Objective

To study the operation of FSK modulation & demodulation and to differentiate the FSK wave forms for binary data at different frequencies.

8.2 Components and Apparatus

- An FSK trainer kit
- Set of patch tips
- A Digital multi meter
- A dual channel oscilloscope

8.3 Background

8.3.1 FSK Modulation

Frequency shift keying is a frequency modulation scheme which the digital information is transmitted through discrete frequency changes of a carrier signal the simplest FSK is called Binary FSK (BSFK) where a pair of discrete frequencies are used to transmit binary (0 and 1) information. With this scheme, the "1" is called the mark frequency and the "0" is called the space frequency.

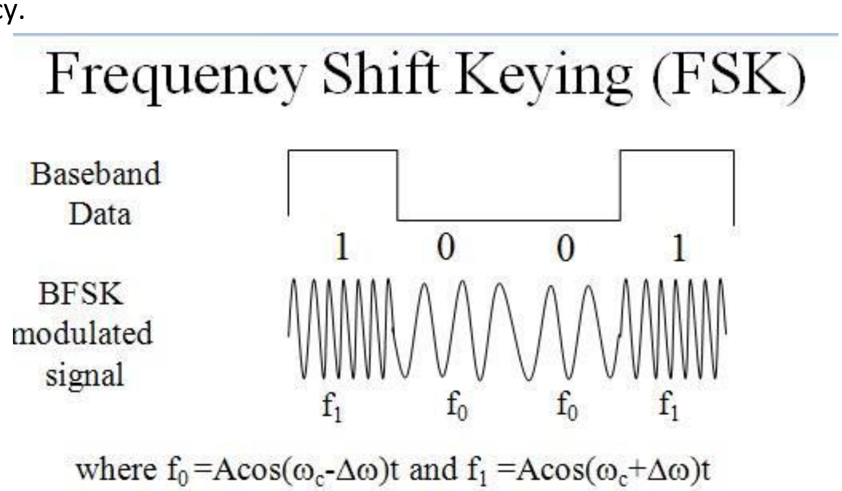


Figure 50- Frequency shift keying modulation

8.3.2 FSK Demodulation

FSK demodulator is a very beneficial application of the 565 PLL. In this, the frequency shift is generally proficient by motivating a VCO with the binary data signal. So that the two subsequent frequencies resemble the logic 0 & 1 states of the binary data signal. These frequencies corresponding to two states are generally called the mark and space frequencies. Numerous values are used to set the mark & space frequencies.

The demodulator gets a signal at one of the two separate carrier frequencies, representing the RS-232 C logic levels of mark or space, respectively. The capacitive connection is used as the i/p to eliminate a DC level.

The main methods of FSK detection

- Asynchronous detector The asynchronous detector is a non-coherent one. The block diagram of Asynchronous FSK detector consists of two band pass filters, two envelope detectors, and a decision circuit.
- Synchronous detector The synchronous detector is a coherent one. The block diagram of Synchronous FSK detector consists of two mixers with local oscillator circuits, two band pass filters and a decision circuit.

For both of the demodulators, the bandwidth of each of them depends on their bit rate. This synchronous demodulator is a bit complex than asynchronous type demodulators.

8.4 Procedure

1. The trainer was switched ON and power supply was checked to be +12V and -12V and -5V internally connected.
2. The clock generator output was observed which is at the 3rd pin of 555IC at the terminal provided with the oscilloscope.
3. Different data output at the output pins of the 7490IC was observed with oscilloscope.
4. Patch tips were connected as per wiring diagram and the FSK outputs for different data inputs were observed.
5. The clock generator output and FSK output was observed with spectrum analyzer.
6. The frequency spectrum of FSK was compared with frequency modulation.
7. The FSK modulator output was connected to the demodulator section and demodulator output was observed.
8. The FSK demodulator potentiometer was varied to obtain FSK demodulated output.

8.5 Observations

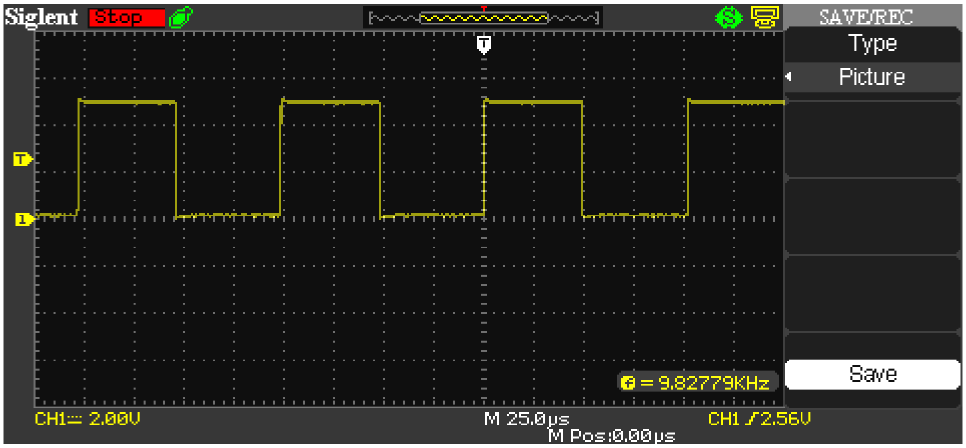


Figure 51- Clock Signal

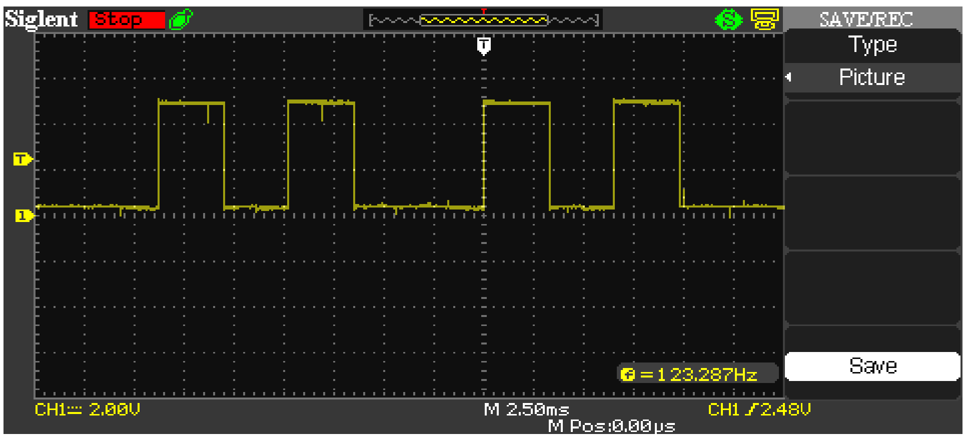


Figure 52- Message Signal

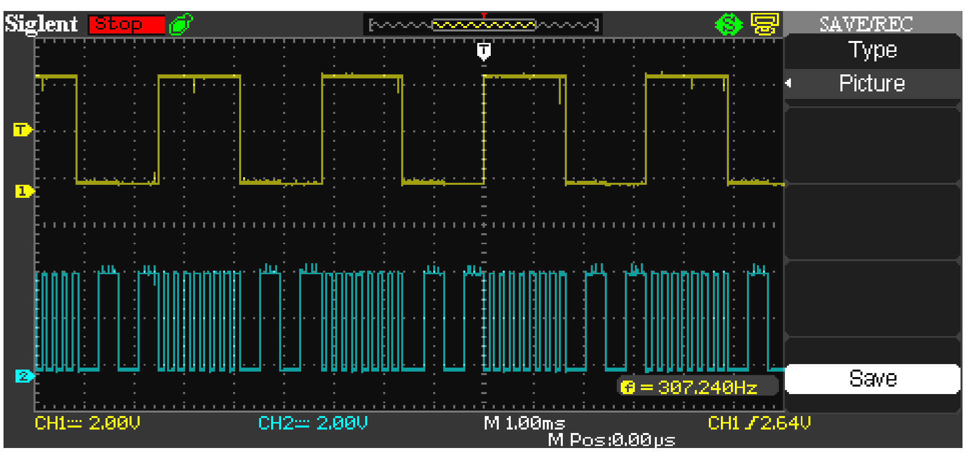


Figure 53- Message Signal with modulated Signal

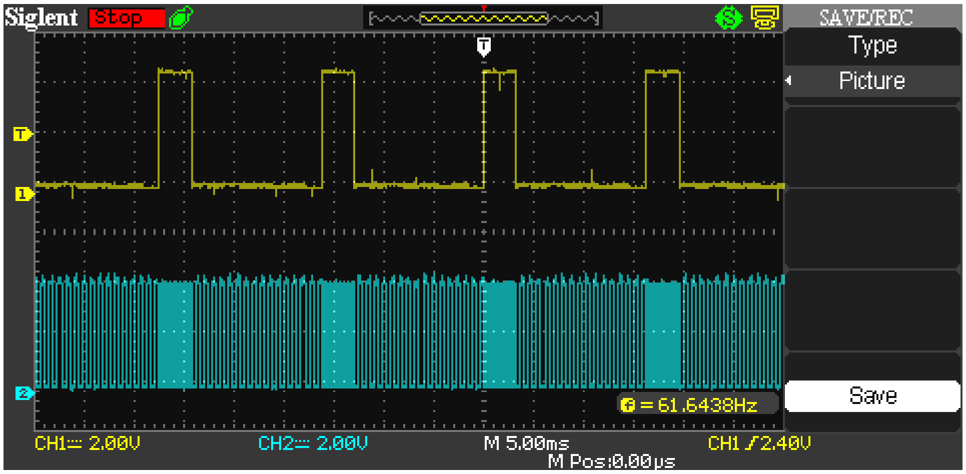


Figure 54- Modulated Signal with Message signal

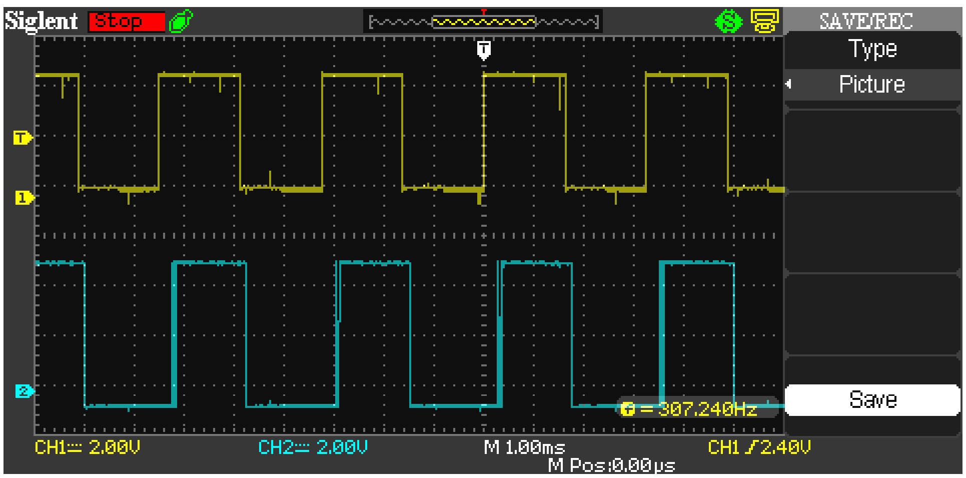


Figure 55- Demodulated output and message Signal

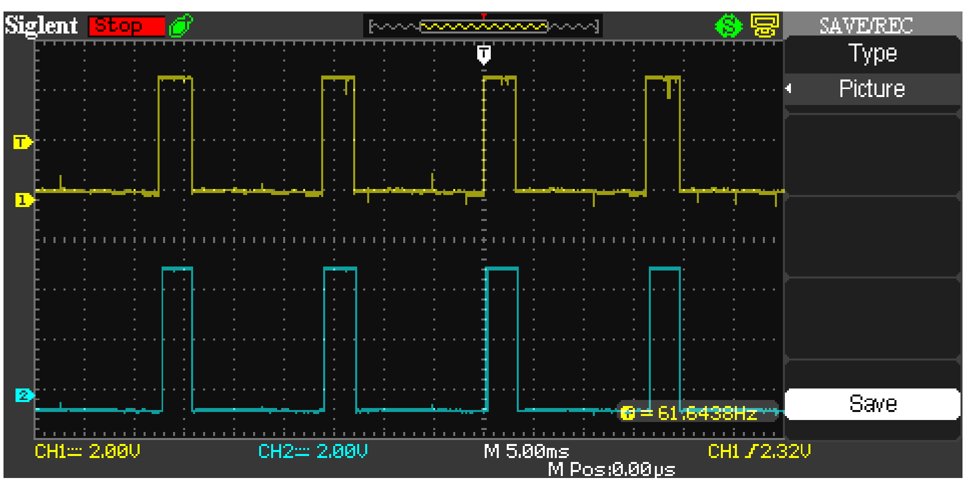


Figure 56- Demodulated output and message Signal

8.6 Discussion

i. What is the phase shift between waveforms in step 5?
    - Frequency Shift Keying Modulation and Frequency modulation has many differences in analyzing. FSK is used for digital data where there is discrete shifting from one frequency to another in accordance with the logic state being transmitted. In this case, basically two frequencies are used. FM is used for analog data and can have a continuous range of frequencies (within limits) output for a continuous analog signal (also within limits). Usually the frequency range is limited as is the modulation signal.

9.Frequency Modulation (FM) and Demodulation

9.1 Objective

To study the operation of frequency modulation & demodulation

9.2 Components and Apparatus

- A Frequency modulation trainer kit
- Set of patch tips
- A Digital multi meter
- A dual channel oscilloscope

9.3 Background

9.3.1 Frequency Modulation

Frequency modulation(FM) is the encoding of information in a carrier wave by varying the instantaneous frequency of the wave. In radio transmission, an advantage of frequency modulation is that it has a larger signal-to-noise ratio and therefore rejects radio frequency interference better than an equal power amplitude modulation (AM) signal. For this reason, most music is broadcast over FM radio. FM modulation index is equal to the ratio of the frequency deviation to the modulating frequency. The modulation index will vary according to the frequency that is modulating the transmitted carrier and the amount of deviation.

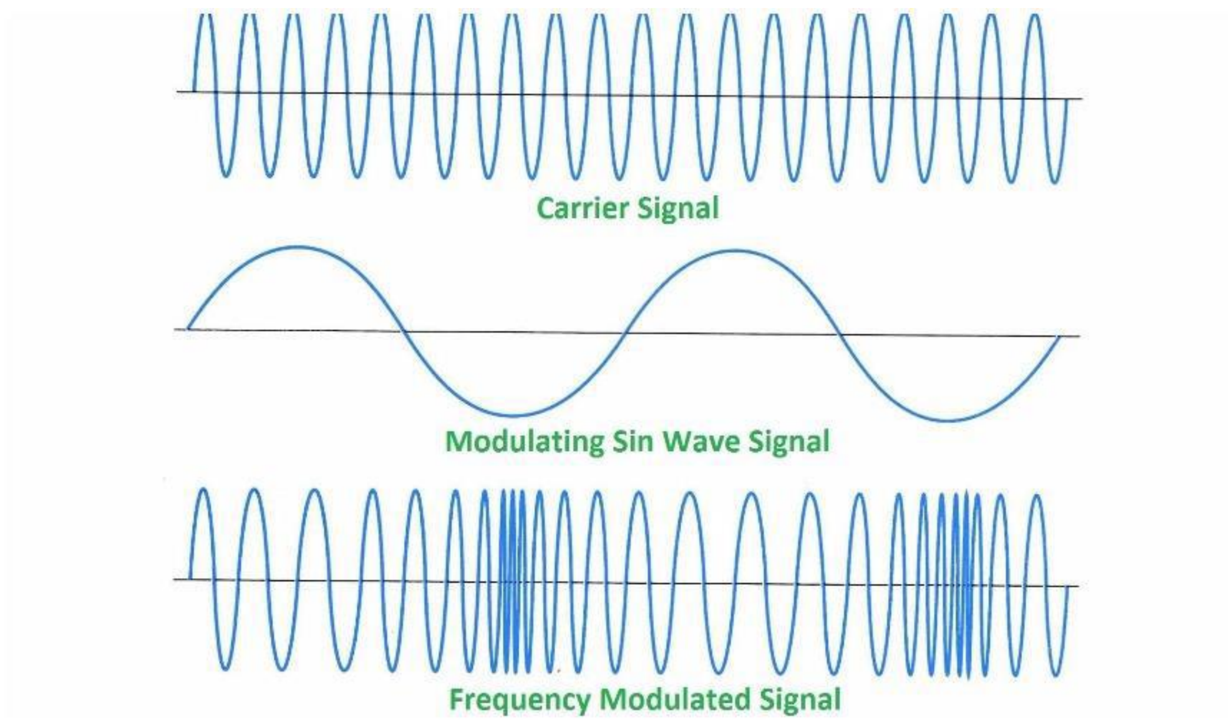


Figure 57- FM modulation

The spectrum of the frequency modulation modulated wave occurs above and below the carrier wave Fc, and the frequency is the integral multiple of the modulating signal Fm. In the spectrum, the modulation signal frequency FM, deviation Δf, and frequency modulation index m are related as follows the spectrum interval is the modulation signal frequency FM, and it spreads in an infinite frequency band. Deviation Δf is the difference in the center frequency Fc of the carrier wave and the frequency of the modulation index number from Fc.

$$\mathrm{M} = \frac{\text{Frequency deviation}(\Delta \mathrm{f})}{Modulating\ frequency(fm)}$$

9.3.2 Frequency Demodulation

As with any form of modulation, it is necessary to be able to successfully demodulate it and recover the original signal. The FM demodulator may be called a variety of names including FM demodulator, FM detector or an FM discriminator. There are a number of different types of FM demodulator, but all of them enable the frequency variations of the incoming signal to be converted into amplitude variations on the output. These are typically fed into an audio amplifier, or possibly a digital interface if data is being passed over the system.

9.4 Procedure

1. Trainer was switched on and the power supply was checked to be +12v and -12v.
2. AF (Data waveform) output was observed with oscilloscope at the TL084 IC with oscilloscope.
3. FM (Carrier waveform) output was observed with oscilloscope without connecting the AF input.
4. AF output was connected to the FM input and FM modulation was observed with oscilloscope.
5. FM output was observed for different modulation index by varying the AF amplitude.
6. Output was observed in above step 3 to 5 with spectrum analyzer. 7. The frequency spectrum of modulated FM signal was compared with the spectrum of FSK modulated signal. 8. The FM output was connected to the demodulator input section of 565 IC which is a PLL IC. 9. The demodulator output was observed.

9.5 Observations

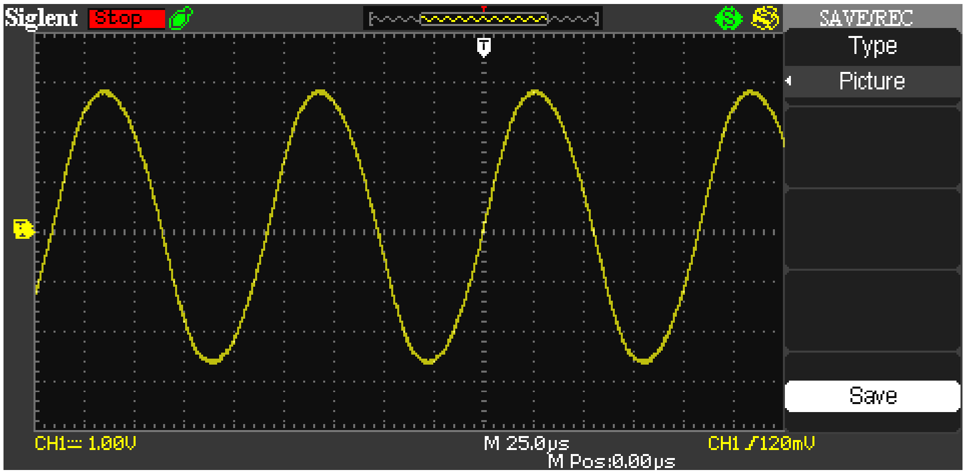


Figure 58- AF Signal

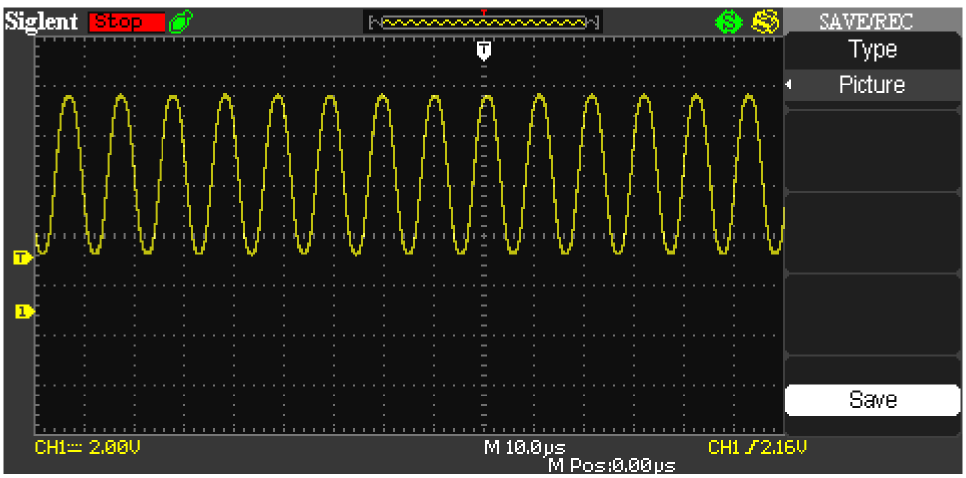


Figure 59- Carrier Signal

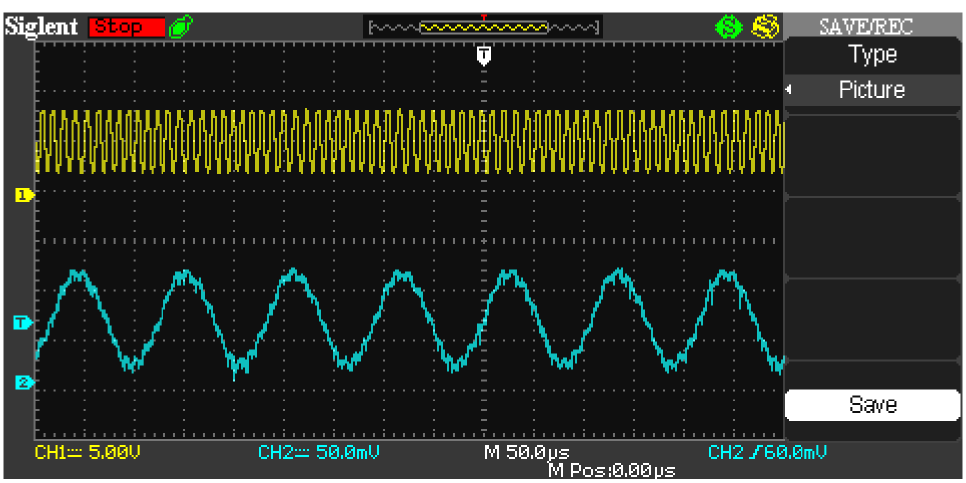


Figure 60- Modulated Signal With AF Signal

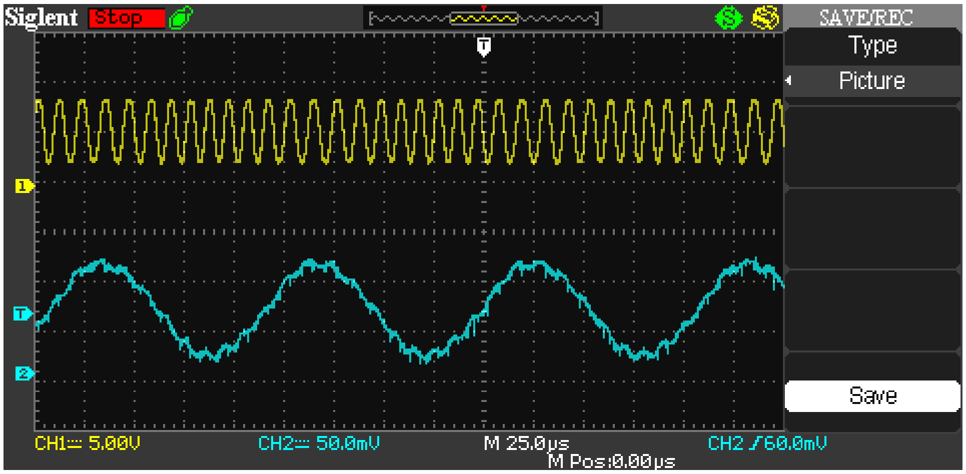


Figure 61- Modulated Signal With AF Signal

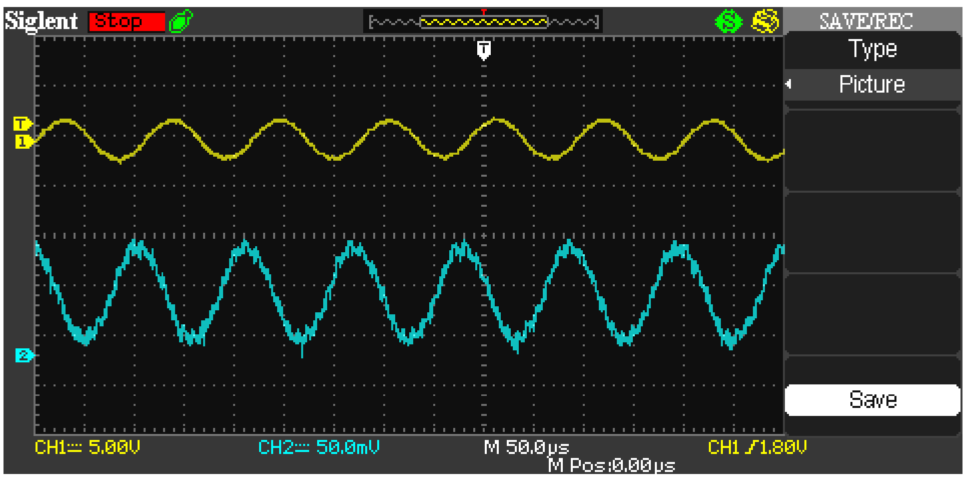
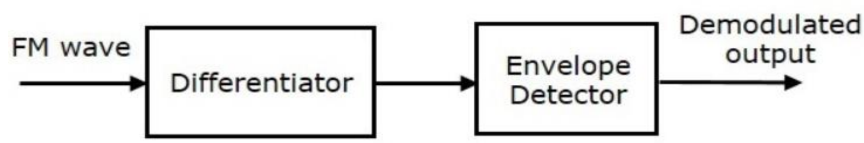


Figure 62- Modulated Signal with AF Signal

9.6 Discussion

i. Discuss the reasons for the difference in input signal (AF O/P) and the demodulated output (DEMOD O/P)

- FM signals can be generated using either direct or indirect frequency modulation.FM signal directly produce an output signal that is proportional to the message signal.



- Demodulation does not have disadvantages per say, but it does have a lot of complexities.There're some noise and distortion.There fore demodulated output quality desired.

ii. Let us assume we have a FM modulator with fixed modulation index. What is the impact on various message signal amplitudes in the FM modulated signal?

- Modulation index in FM Modulation becomes significant at lower values of it in both narrow-band FM, and wideband FM, by consisting the carrier and the two sidebands spaced at the modulation frequency either side of the carrier. Wideband FM is typically used for signals where the FM modulation index is above 0.5. For these signals the sidebands beyond the first two terms are not insignificant. Narrow band FM, is used for signals where the deviation is small enough that the terms in the Bessel function is small and the sidebands are negligible. For this the FM modulation index must be less than 0.5.

iii. Show the difference in frequency modulated signal and phase modulated signal by using a figure and compare the waveforms.

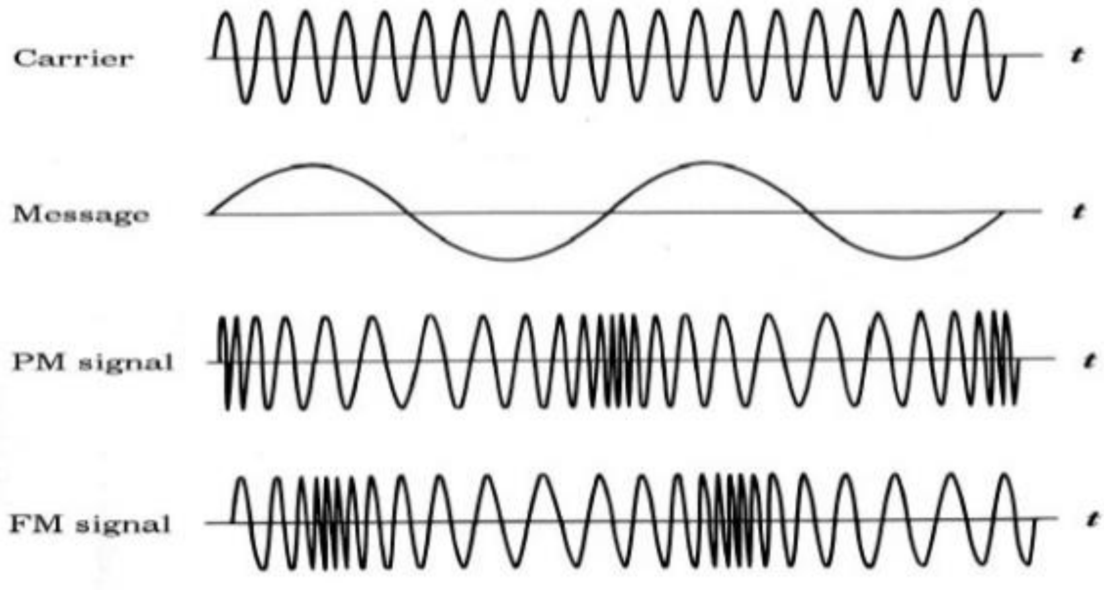


Figure 63- frequency modulated signal and phase modulated

10.Pulse Amplitude Modulation and Demodulation

10.1 Objective

To study the operation of Pulse Amplitude Modulation (PAM) & demodulation

10.2 Components and Apparatus

- A PCM trainer kit
- A Digital multi meter
- A dual channel oscilloscope
- Set of patch tips

10.3 Background

Pulse amplitude modulation (PAM) is the transmission of data by varying the amplitudes (voltage or power levels) of the individual pulses in a regularly timed sequence of electrical or electromagnetic pulses. The number of possible pulse amplitudes can be infinite (in the case of analog PAM), but it is usually some power of two so that the resulting output signal can be digital. For example, in 4-level PAM there are 22 possible discrete pulse amplitudes; in 8-level PAM there are 23 possible discrete pulse amplitudes; and in 16-level PAM there are 24 possible discrete pulse amplitudes.

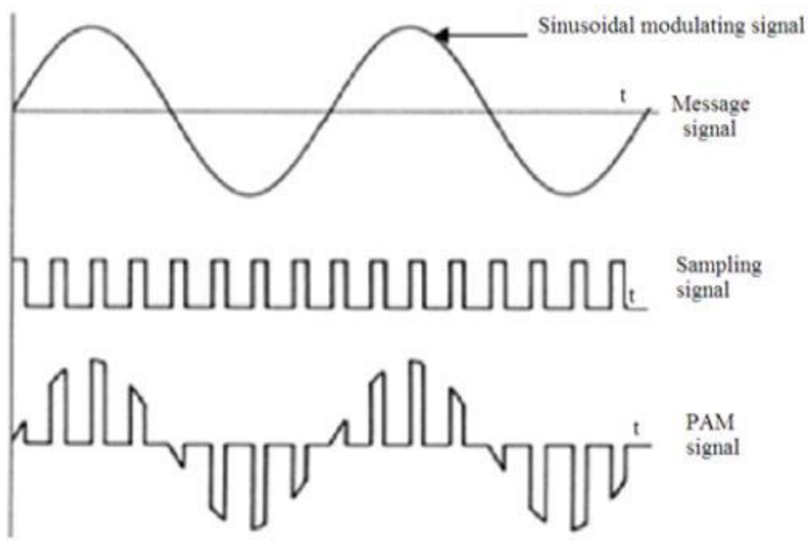


Figure 64-PAM signal

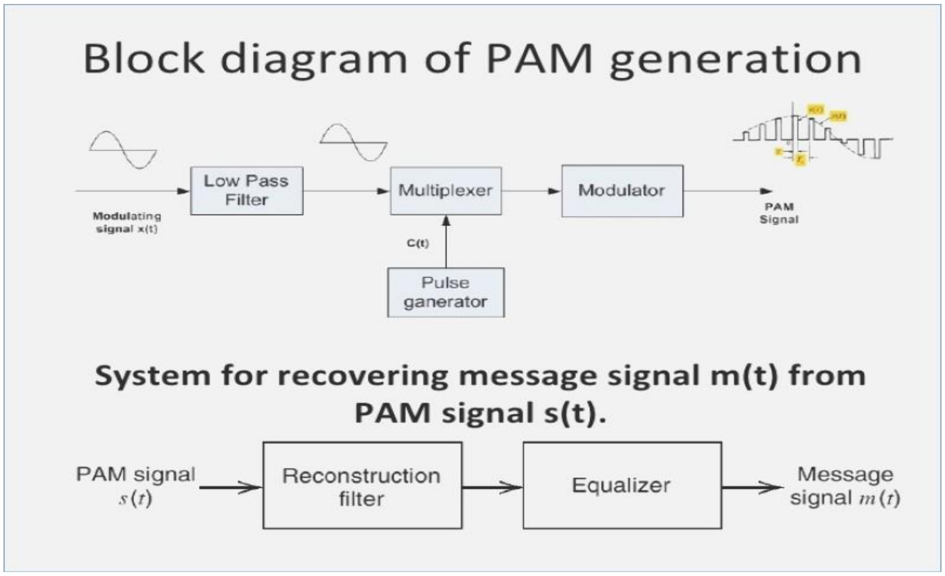


Figure 65-Block diagram of PAM signal

Pulse amplitude modulation is categorized into two types

1. Single Polarity PAM: A suitable fixed DC bias is added to the signal to ensure that all the pulses are positive
2. Double Polarity PAM: The pulses are both positive and negative.

10.4 Procedure

1. The trainer kit was switched on and power supply was checked to be +12V and -12V.
2. The circuit was patched as per the wiring diagram.
3. The pulse output which is the carrier signal was observed whose frequency or pulse can be varied with the help of the potentiometer.
4. Similarly, the AF output was observed.
5. The output of the PAM modulator was observed.
6. Next the patching wire from the 1st pin of 4016IC in the modulator section and The PAM modulated output was observed.
7. The Pam modulator was connected to the MOD I/P in demodulator and demodulated output was observed.
8. The demodulated output was observed by varying the pulse frequency

10.5 Observations

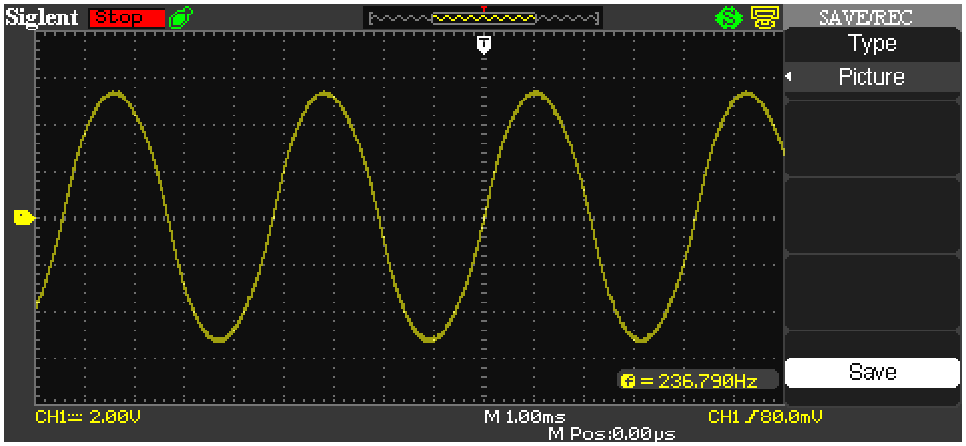


Figure 66- AF Signal

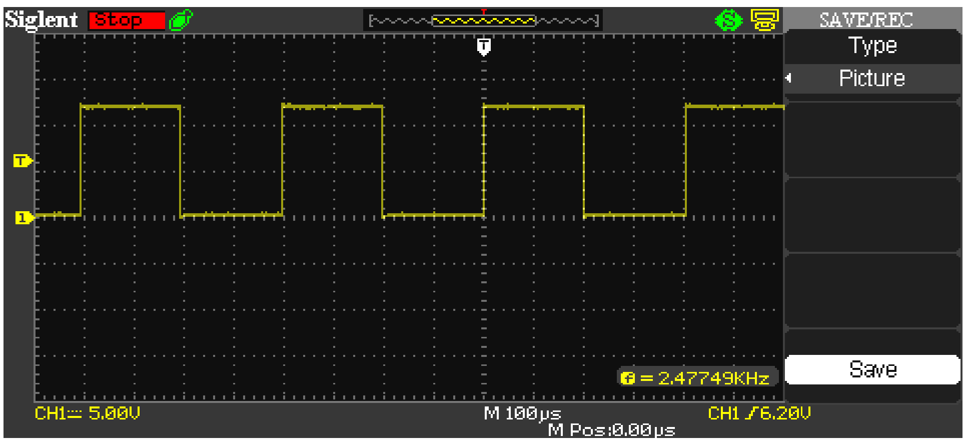


Figure 67- Pulse output

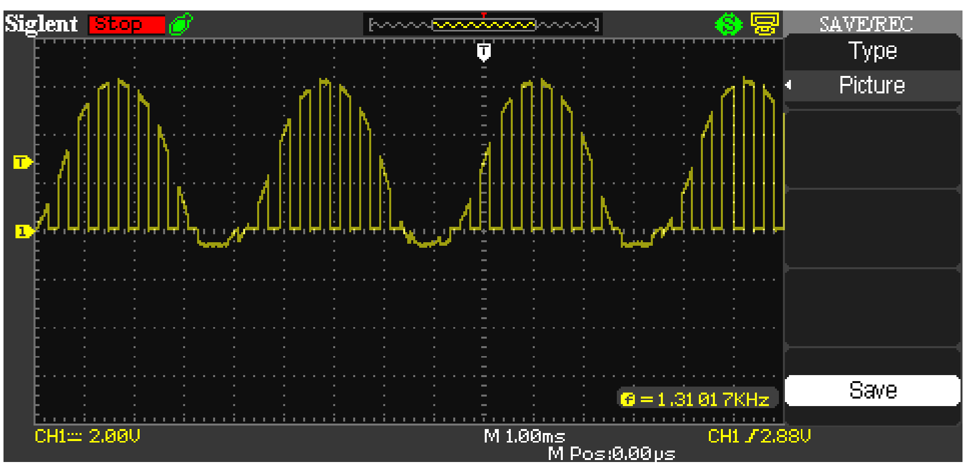


Figure 68- Modulated Signal

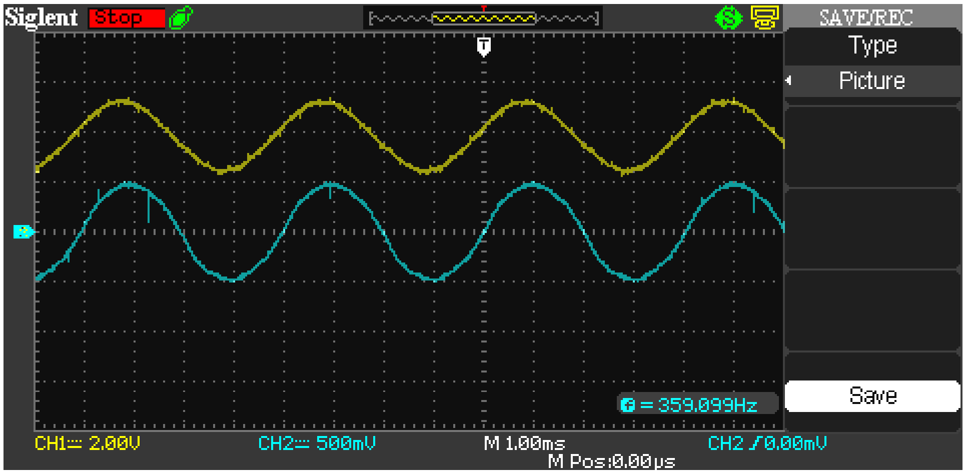


Figure 69- Demodulated Signal With AF Signal

10.6 Discussion

i. What type of PAM is used it in the above modulator?
   - Double polarity PAM(Pulses are both positive and negative)

PAM is an analog pulse modulation where analog data is converted as digital signal. here amplitude is varied where width and position remains constant. This has 2 varieties such as flat top pulse amplitude modulation and natural pulse amplitude modulation. System complexity is high. Noise interference is high. This is similar to amplitude modulation.

11.Quadrate phase shift keying modulation and demodulation

11.1 Objective

Studying the operation of QPSK modulation & demodulation and to plot the QPSK wave forms.

11.2 Components and Apparatus

- OHM QPSK Trainer KIT
- Set of Patch Tips
- A Digital Multimeter
- A Dual Chanel Oscilloscope

11.3 Background

For the transmission of digital signal over limited band width channel various methods of modulation techniques were developed from simple FSK, PSK system to complex DPSK, DASK and QPSK system. In simple PSK System, the phase of the carrier was modulated such that the carrier phase was reversed during the logic zero bit [fc = 180º] while the carrier without any phase shift [fc = 0] was transmitted during the logic 1 level or vice versa. This method is also known as BPSK or Bi phase shift keying. If fd is the data rate, then the band width required for transmitting BPSK signal would be 2*fd. In QPSK, the phase of the carrier depends upon the pair of successive bits in the data stream. Thus, there are four possible combinations of bit pair viz 00, 01, 10 and 11.

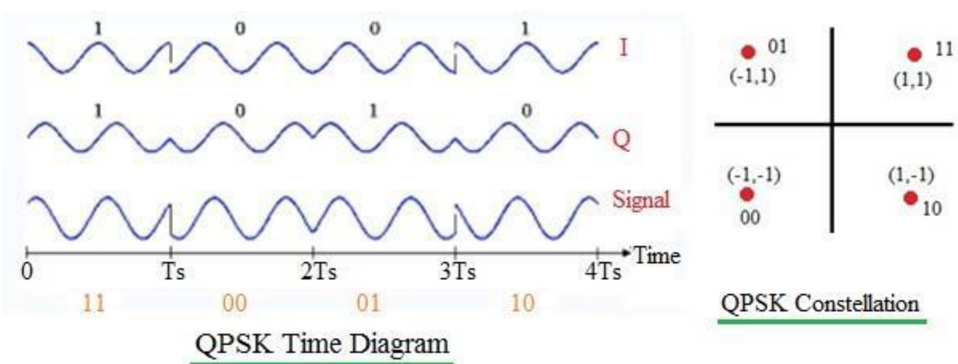


Figure 70-QPSK Time Diagram

11.4 Procedure

1. The trainer was switched on and power supply was checked to be +5V and -5V.
2. The carrier signal was observed with the help of oscilloscope at the CLK 0/p terminal.
3. Similarly, the carrier signal with phase difference of 1800 , 900 , 2700 with respect to 00 was observed.
4. The data CLK was approximately measured to 700Hz at the data CLK output terminal.
5. The DIP switch was kept as 11110000. The load switch was pressed, and observations were taken.
6. The data output was observed. It was approximately 100Hz.
7. The data CLK was connected to data CLK terminal in the modulator section and mono pulse at the pin 3 of 555 in data generator section was observed.
8. The circuit was patched as per the wiring diagram.
9. A square wave was observed at the QPSK O/P terminal.
10. The patching of DATA 1 and DATA 2 was removed from DATA O/P terminal and below table was followed to observe QPSK O/P with reference QPSK O/P with reference to 1800.

DATA 1	DATA 2	QPSK O/P (reference to 1800)
0	0	00
0	1	1800
1	0	900
1	1	2700

Table 1

i. Where 0=GND and 1=OPEN

11. The circuit was patched as per the wiring diagram. The modulation output was connected to phase and the bit pair detector section and demodulation section.
12. The phase discriminator output at T5 and pulses at T1 to T4 was observed. The demodulation output at the DEMOD.O/P was observed with respect to data output.

11.5 Observations

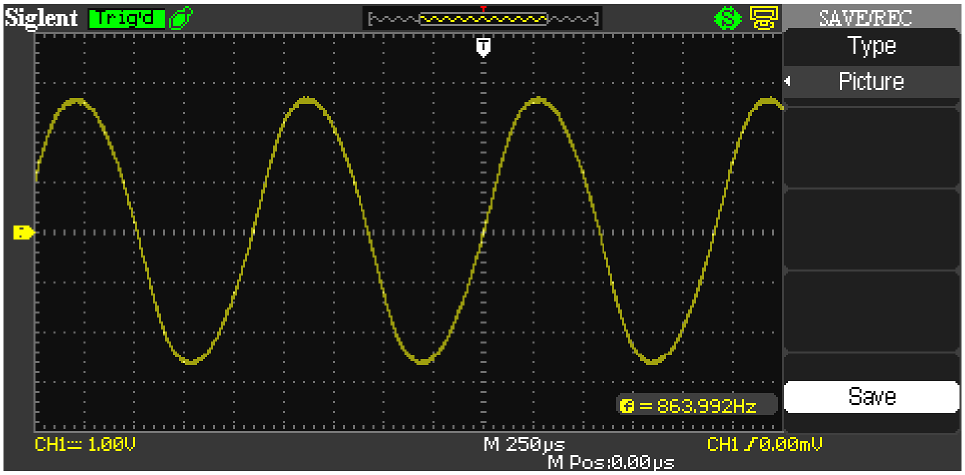


Figure 71- Message Signal

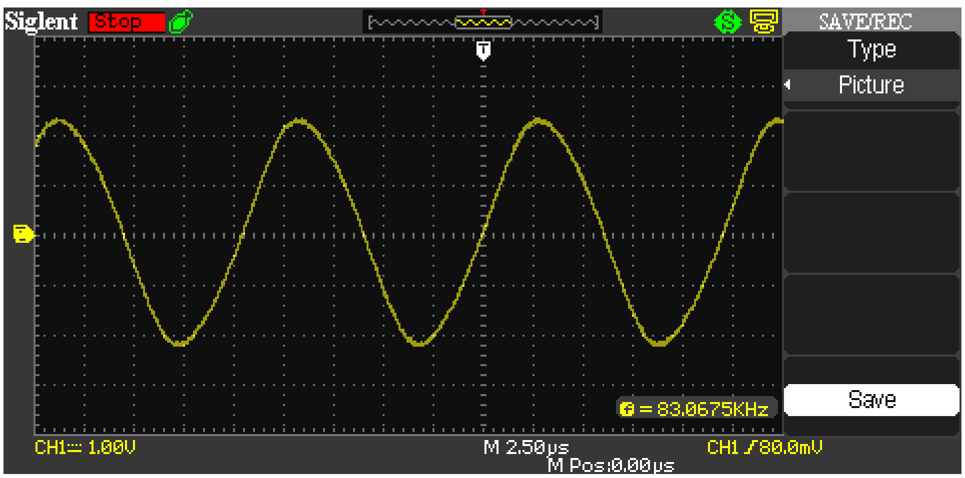


Figure 72- Carrier Signal

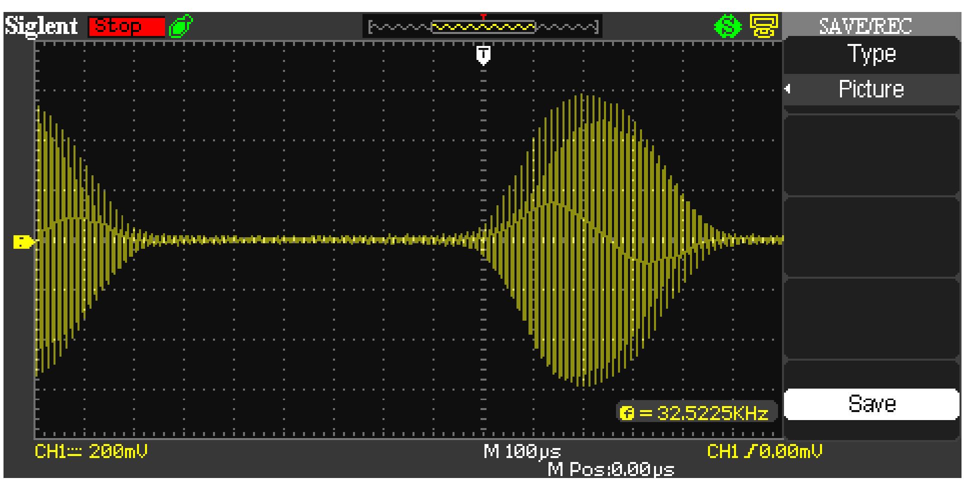


Figure 73- Modulated Signal

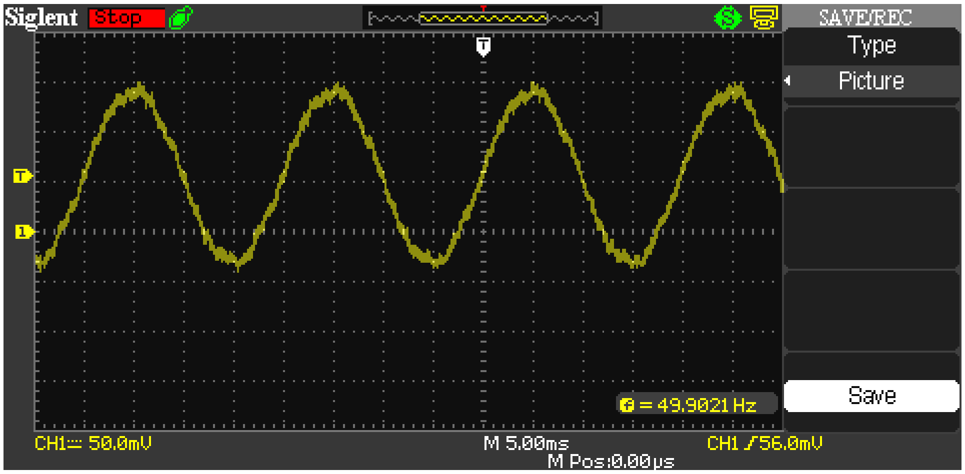


Figure 74- Demodulated Signal

11.6.Discussion

I. Draw a block diagram of QPSK modulator and explain how QPSK modulated waveforms are generated.

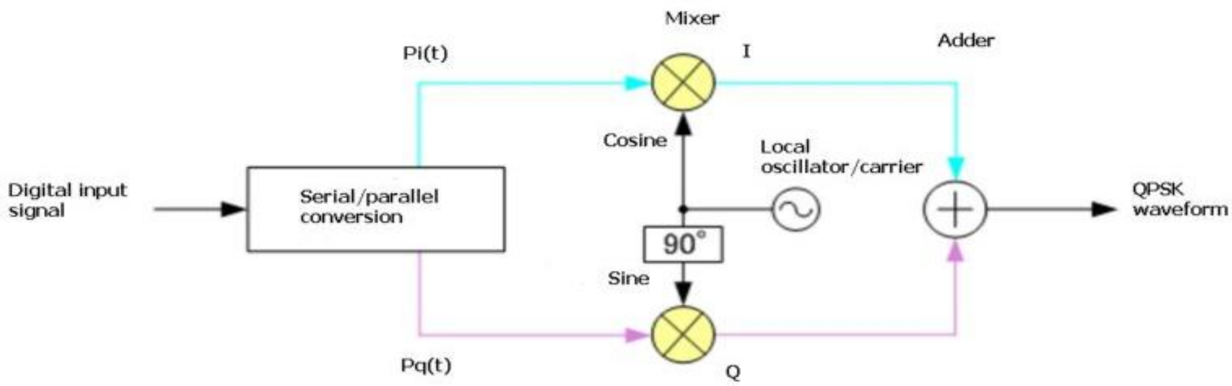


Figure 75-Block Diagram of QPSK

This process of modulation is generally called frequency-shift keying, FSK. There is a method similar to FSK called phase-shift keying. As you might suspect, FSK involves modulating the phase of the carrier rather than its frequency. The finite phase changes represent digital data. Using a digital signal to switch between two signals of equal frequency but opposing phase will generate a simple phase-modulated waveform.

Now consider multiplying the resulting phase-modulated waveform by a sine wave of equal frequency. This generates two component waveforms. One is a cosine waveform of double the received frequency. The other is a frequency-dependent term having an amplitude proportional to the cosine of the phase shift. Now, filtering out the doubled frequency term produces the original data used for modulating the transmission.

The concept of quadrature phase shifting arises from the idea that there can be more than two states of phase shifting. The carrier can experience numerous phase changes. Then multiplying the received signal by a sine wave of equal frequency will demodulate the phase shifts into voltage levels that are independent of frequency. Thus in QPSK, the carrier undergoes four changes in phase. Each phase change can represent two binary bits of data. The point of this approach is that the carrier can transmit two bits of data instead of one, so the bandwidth of the transmission has effectively doubled.

12.Pulse Code Modulation and Demodulation

12.1 Objective

To study the operation of Pulse Code Modulation (PCM) & demodulation

12.2 Components and Apparatus

- A PCM trainer kit
- A Digital multi meter
- A dual channel oscilloscope
- Set of patch tips

12.3 Background

Pulse code modulation is a method that is used to convert an analog signal into a digital signal, so that modified analog signal can be transmitted through the digital communication network. PCM is in binary form, so there will be only two possible states high and low (0 and 1). The Pulse Code Modulation process is done in three steps Sampling, Quantization, and Encoding. The low pass filter prior to sampling prevents aliasing of the message signal. Regenerative repeaters increase the signal strength throughout the transmission. The output of the channel also has one regenerative repeater circuit, to compensate the signal loss and reconstruct the signal, and also to increase its strength. The basic operations in the receiver section are regeneration of impaired signals, decoding, and reconstruction of the quantized pulse train.

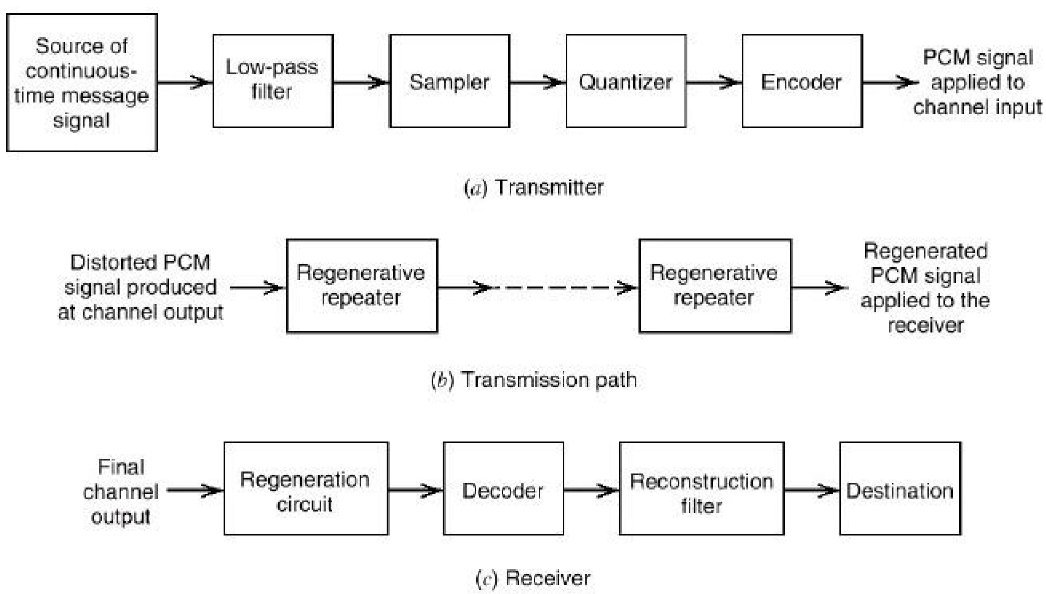


Figure 76-PCM block diagram

12.4 Procedure

1. The trainer kit was switched on and the power supply was set to +5V, -5V and +12V.
2. The AF output was observed at the AF output terminal.
3. The AF output was connected to the sample and hold circuit section and the corresponding output was observed.
4. CLK1 and CLK3 was observed for circuit operation.
5. The A to D output was observed with the help of LED.
6. The PCM output of the terminal was observed with the help of oscilloscope.
7. The output of the D to an output of the demodulator section was observed via LED.
8. At the low pass filter section, a SPDT is provided for AC and DC operation.
9. Switch condition was not considered for sine [AC] input.
10. The DC input was connected as per the wiring diagram in the manual.
11. The above steps 6-8 was repeated with DC input.
12. For DC input the demodulation output was observed before amplifier.

12.5 Observations

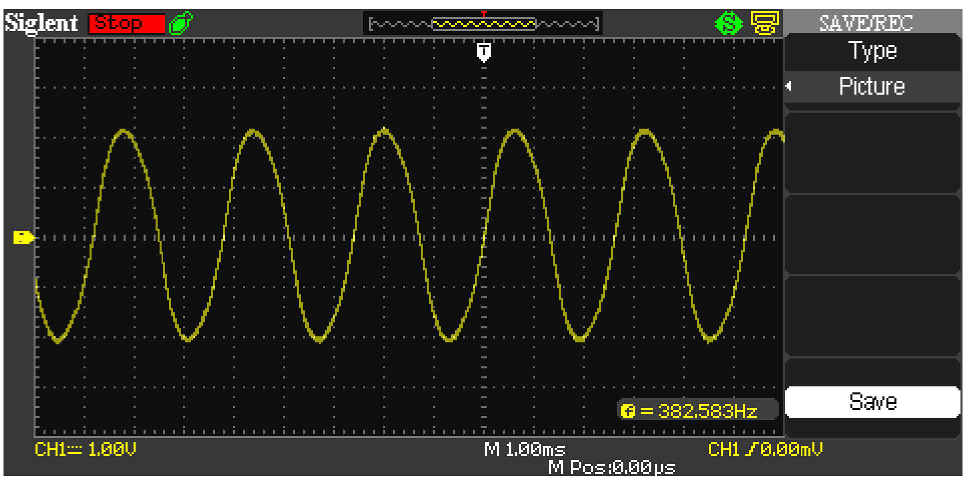


Figure 77- AF Signal

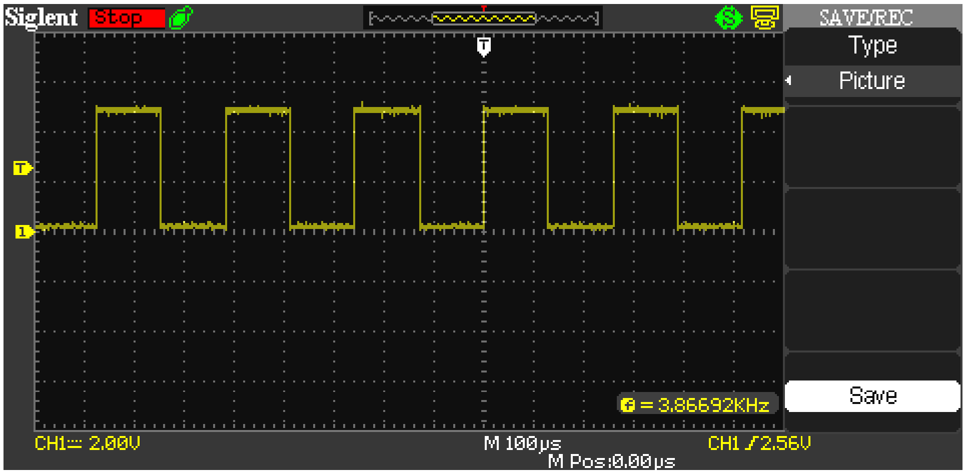


Figure 78- Clock Signal

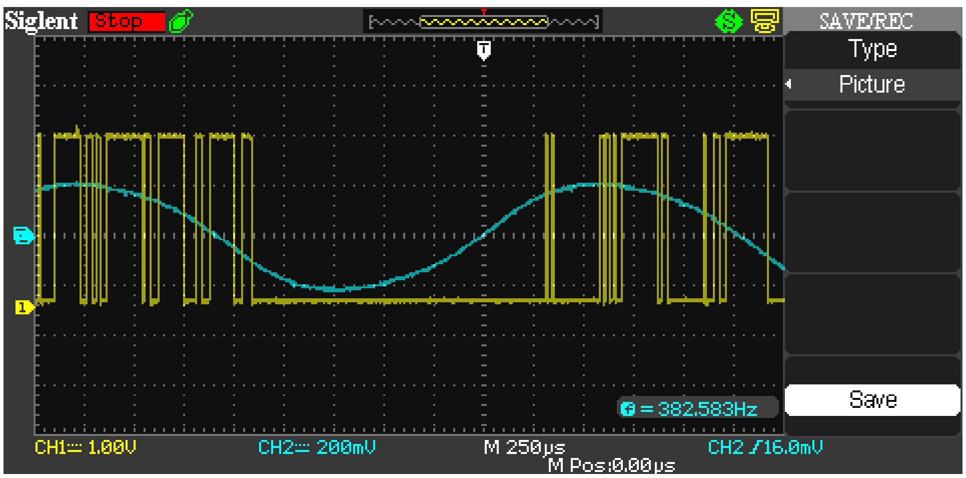


Figure 79- Output of Sample and hold circuit

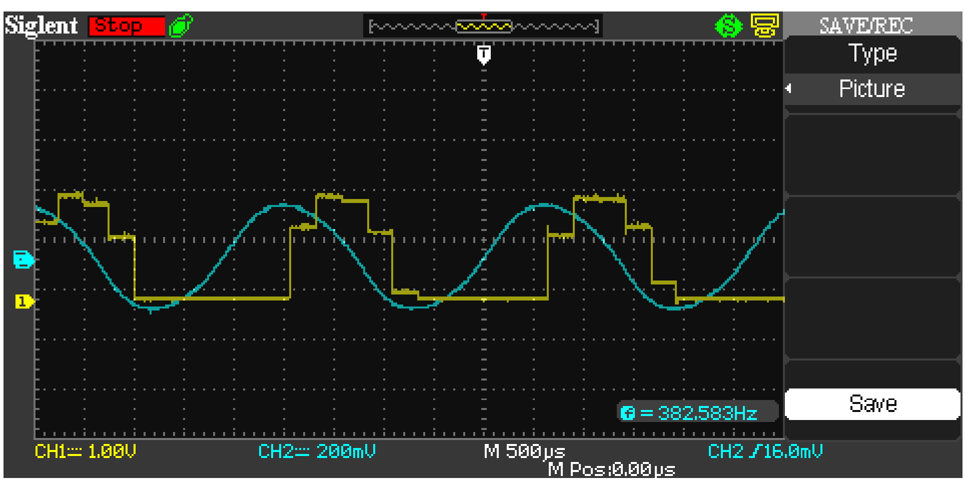


Figure 80- Wave Output

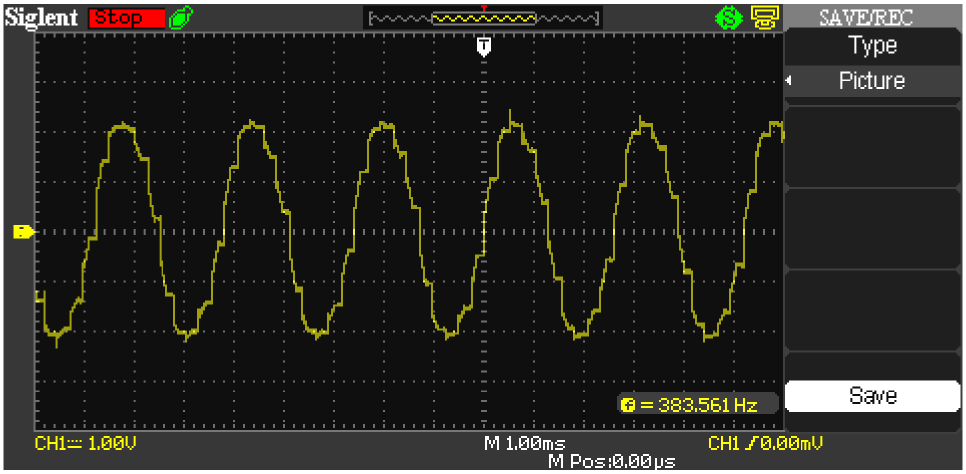


Figure 81- Sample and hold output

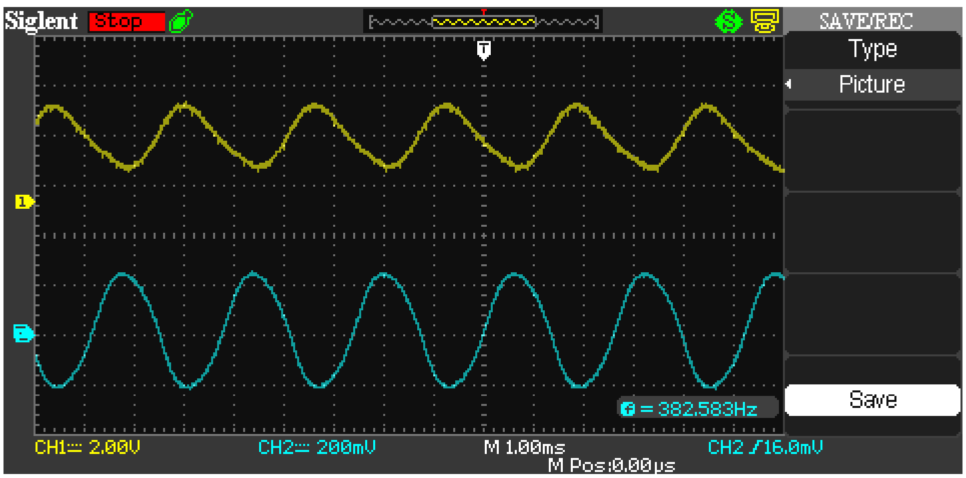


Figure 82- Demodulated output with message signal

12.6 Discussion

This is an analog modulation where analog data is converted as analog signal. Here amplitude and frequency remains constant where phase differs according to the message signal. This has lower bandwidth compared to FM.

13. Conclusion

Different types of analogue and digital modulations were observed. Factors like modulating index, carrier amplitude, carrier phase, frequencies, frequency modulation index etc. were found during the practical sessions and their influences on the modulation and demodulation processes were well understood. Although the process of modulation in a communication system increases its complexity and cost but it is a definite need for communication.

14.References

1. "WIKIPEDIA," 2 Jan 2019. [Online]. Available: https://en.wikipedia.org/wiki/Impedance_matching.
2. "Totalecer," [Online]. Available: https://totalecer.blogspot.com/2016/10/comparison-of-various-sampling.html.
3. "SAMPLING AND RECONSTRUCTION - ADVANCED," Sri Lanka Technological, Campus, Meepa, 2018.
4. Akira, "WIKIPEDIA," 24 March 2010. [Online]. Available: https://en.m.wikipedia.org/wiki/File:Illustration_of_Amplitude_Modulation.png.
5. Ramnath, 2016. [Online]. Available: http://www.ques10.com/p/3542/explain-balanced-modulator/.
6. "Just Science," [Online]. Available: http://www.justscience.in/articles/what-are-the-applications-of-frequency-modulation/.
7. T. Agarwal, "El-PRO-CUS," [Online]. Available: https://www.elprocus.com/pulse-code-modulation-and-demodulation/.
8. "Ques10," December 2014. [Online]. Available: http://www.ques10.com/p/11460/explain-generation-and-demodulation-of-pam-ppm-and/.
9. "cathology.info," 26th July 2017. [Online]. Available: http://cathology.info/block-diagram-of-pulse-amplitude-modulation/.
10. "TutorialsPoint," [Online]. Available: https://www.tutorialspoint.com/digital_communication/digital_communication_amplitude_shift_keying.htm.
11. "WIKIPEDIA," 2016. [Online]. Available: https://en.wikipedia.org/wiki/Frequency-shift_keying.

12. "RF Wireless World," [Online]. Available: http://www.rfwireless-world.com/Terminology/QPSK-vs-DP-QPSK.html.
13. Soper, Jon A., “Electrical Engineering Basics” in Principals and Practice of Electrical Engineering, Merle C. Potter, ed., Great Lakes Press, Inc., Ann Arbor, Michigan, 1998.
14. Sunde, E. (1969). Communication systems engineering theory [by] Erling D. Sunde. New York: J. Wiley.