EEP3010

Communication Systems Lab

To study the Frequency modulation (FM) and demodulation

Professor: Dr. Suraj Srivastava

By:

Name	Roll Number
Dhyey Findoriya	B22EE024

Abstract:

The primary objective was to understand how FM alters the frequency of a carrier wave in response to changes in the amplitude of a modulating signal, and how this modulation can be reversed through demodulation to retrieve the original signal. Through time-domain and frequency-domain analyses, the effects of varying modulation parameters on the modulated signal were explored. The experiment also involved observing the spectrum of the modulated signal using a signal analyzer.

The modulation process was characterized by the equation:

$$s(t) = A_c \cdot \cos(2\pi f_c t + 2\pi \Delta f \int_0^t m(\tau) d\tau)$$

Frequency Demodulation is a technique employed to extract the encoded information within an amplitude modulated (AM) signal. This method entails converting a high-frequency carrier signal into a lower frequency baseband signal, carrying the encoded information. The process involves multiplying the modulated signal with a locally generated carrier signal and filtering the resultant output to isolate the baseband signal.

The demodulated signal encompasses the original information content of the modulated signal, rendering it suitable for various applications, such as audio and data transmission. The fidelity of the demodulated signal is directly contingent upon the precision of the carrier signal utilized in the demodulation process.

Objective:

The objective of this experiment is to gain an understanding of Frequency Modulation (FM) and demodulation processes.

The main objective of experiment are:

- Investigate how FM alters a carrier wave's frequency in response to changes in the amplitude of a modulating signal.
- Explore the process of demodulation to retrieve the original signal from the modulated waveform.
- Analyze the effects of varying modulation parameters on the modulated signal through time- domain and frequency-domain analyses.
- Observe the spectrum of the modulated signal using a signal analyzer.

Experimental Procedure:

The necessary equipment required for this experiment is :

- N9010A Signal Analyzer/89601
- AFG3021B Function Generator (2 sets)
- DPO2024 Oscilloscope, 200 MHz
- FM trainer kit (Vinytics CT FM)
- BNC(m)-to-BNC(m) coaxial cable

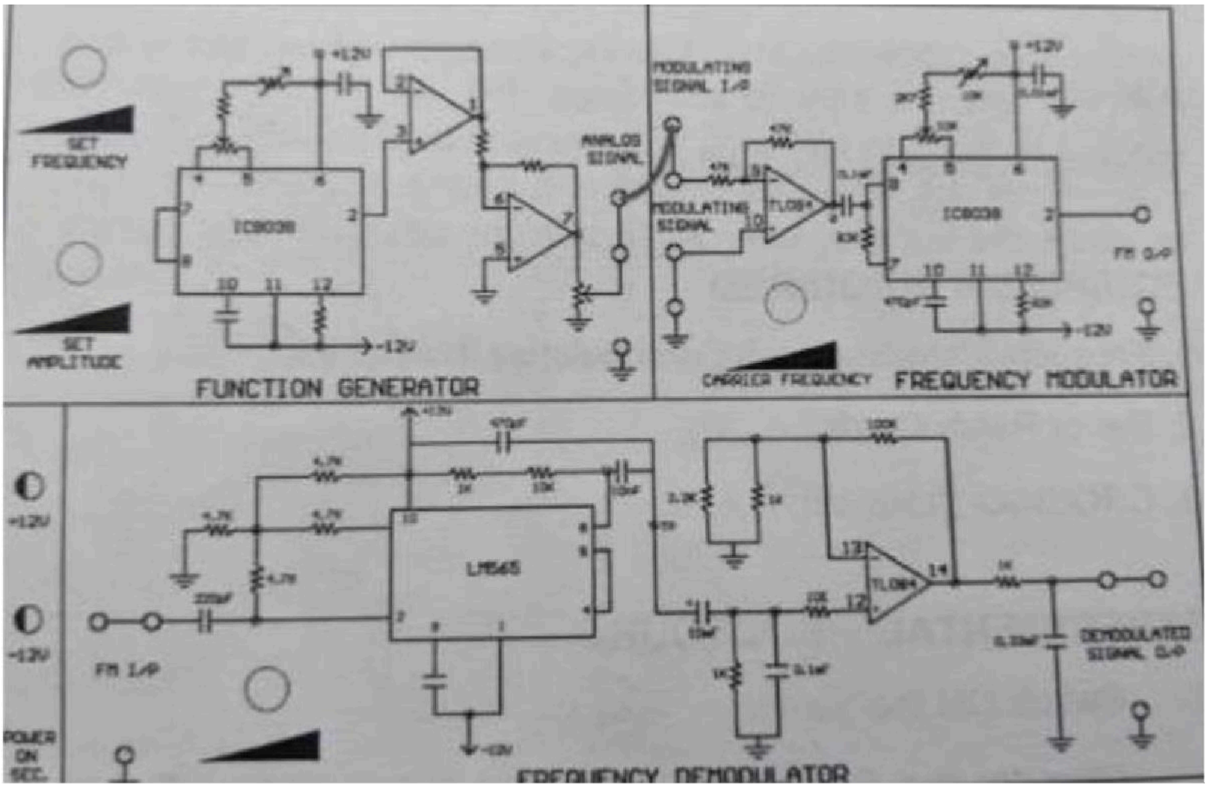
- SMA(m)-to-BNC(m) coaxial cable
- SMA(m)-to-SMA(m) coaxial cable
- Connecting

Chords FM Time Domain

Analysis:

The procedure of this part of experiment is :

- Connect the FM trainer kit according to the provided connection diagram below.
- Power on the FM trainer kit and the associated instruments.
- Generate a message signal with specified parameters (peak-to-peak amplitude = 10 volt and frequency = 4khz) using the Function Generator.
- Observe the output of the Function Generator Section on the oscilloscope.
- Examine the carrier output and FM modulated signal at designated sockets on the Frequency Modulation Section.
- Vary the parameters of the modulating signal and carrier frequency while observing their effects on the modulated signal.
- Properly tune the potentiometers for optimal modulation.
- Adjust oscilloscope settings and capture snapshots of the message signal and the FM signal.

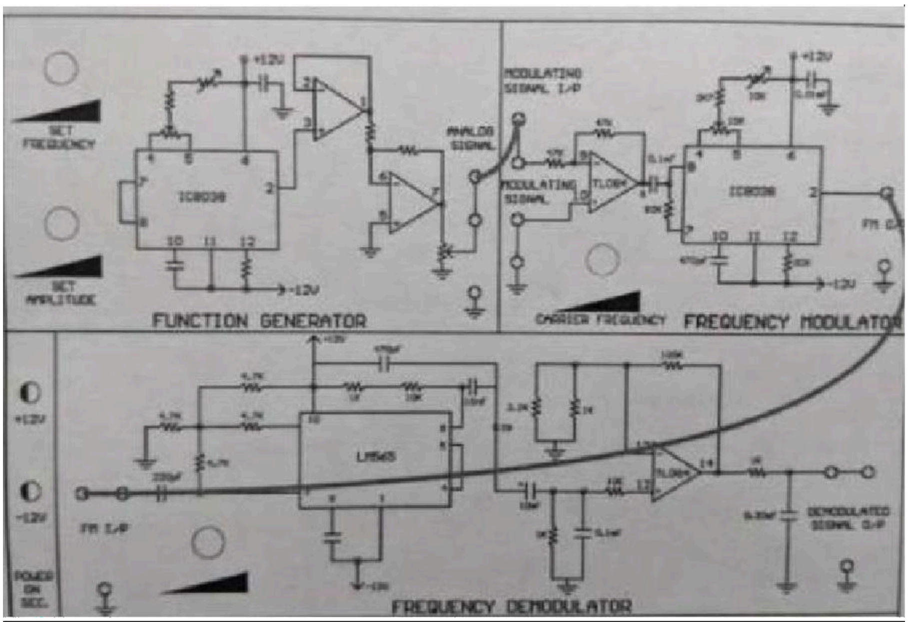


FM Demodulation:

The procedure of this part of experiment is:

- Follow the connection diagram as shown below to set up the FM demodulation section.

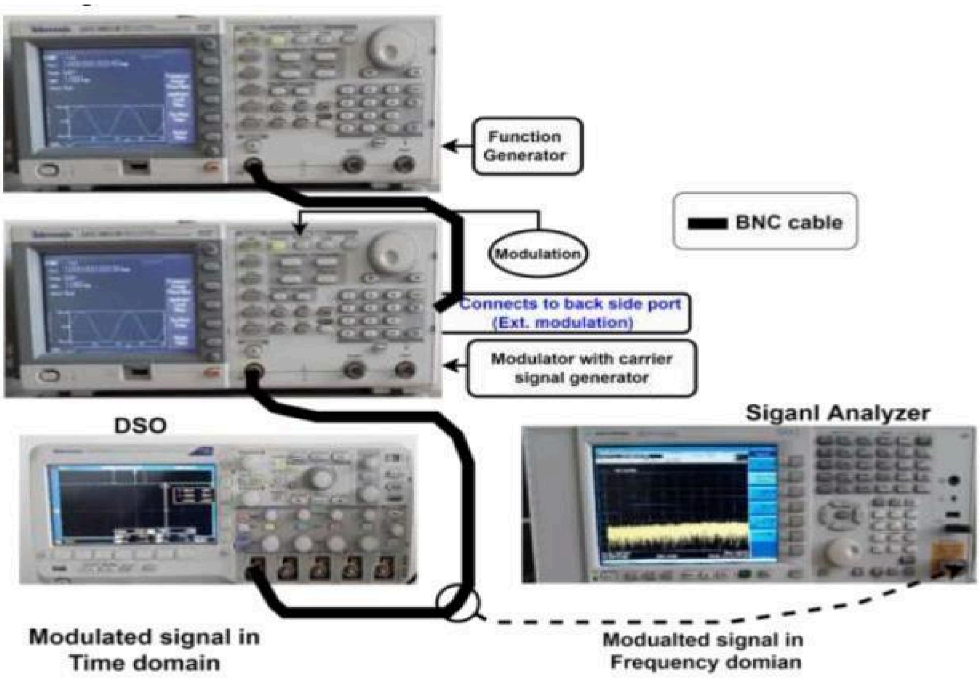
- Observe the FM demodulated signal simultaneously with the modulating signal on the oscilloscope.
- Vary the parameters of the modulating signal and observe their effects on the demodulated signal.
- Capture snapshots of the message signal and the demodulated signal.



Frequency Domain Analysis:

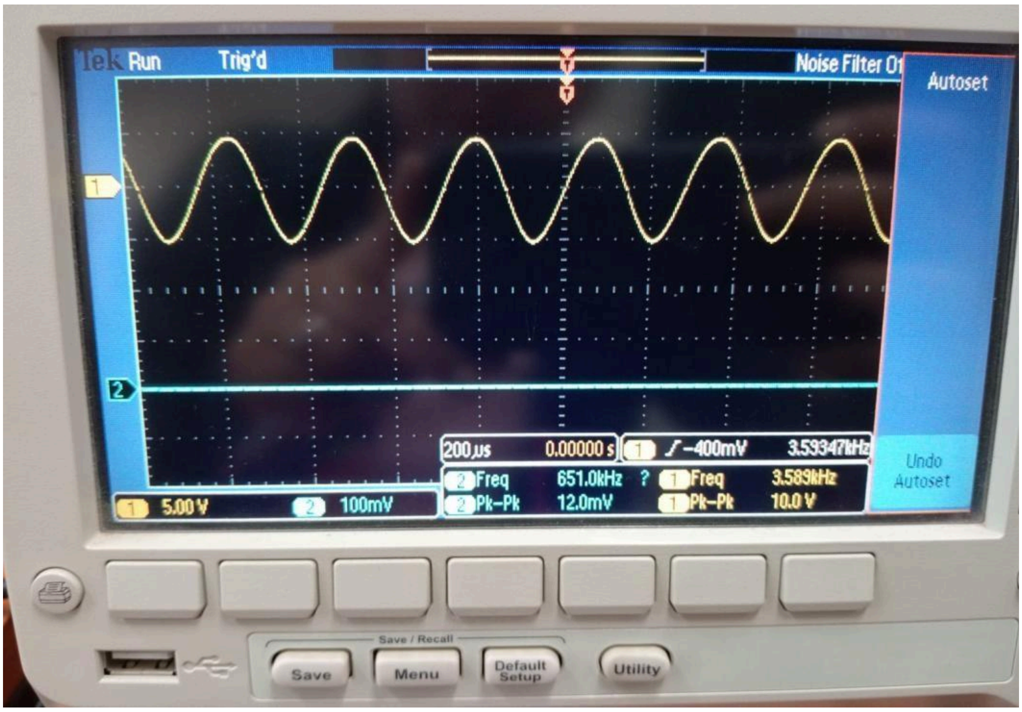
The procedure of this part of experiment is:

- In the Function Generator, select the continuous button and choose modulating signal type as sine. Further, set the amplitude and frequency of the modulating signal.
- Take the output of the function generator acting as the modulating signal and connect to the function generator as Modulator with Carrier Signal Generator in the backside port labeled as external modulation,
- Next, in the Modulator with Carrier Signal Generator (as shown below) select the Modulation button FM and select External input as Sine function (set cammer frequency and amplitude) and modulation depth (%).
- Further, connect the output (OUT) of the Modulator with Carrier Signal Generator to the DSO for time domain observation.
- For the frequency domain analysis connect the output of the block labeled as Modulator with carrier signal generator to the Signal Analyzer.
- Set all the parameters such as center frequency, span, resolution bandwidth, video bandwidth, marker, etc. of the Signal Analyzer and observe the modulated signal spectrum in the Signal Analyzer.

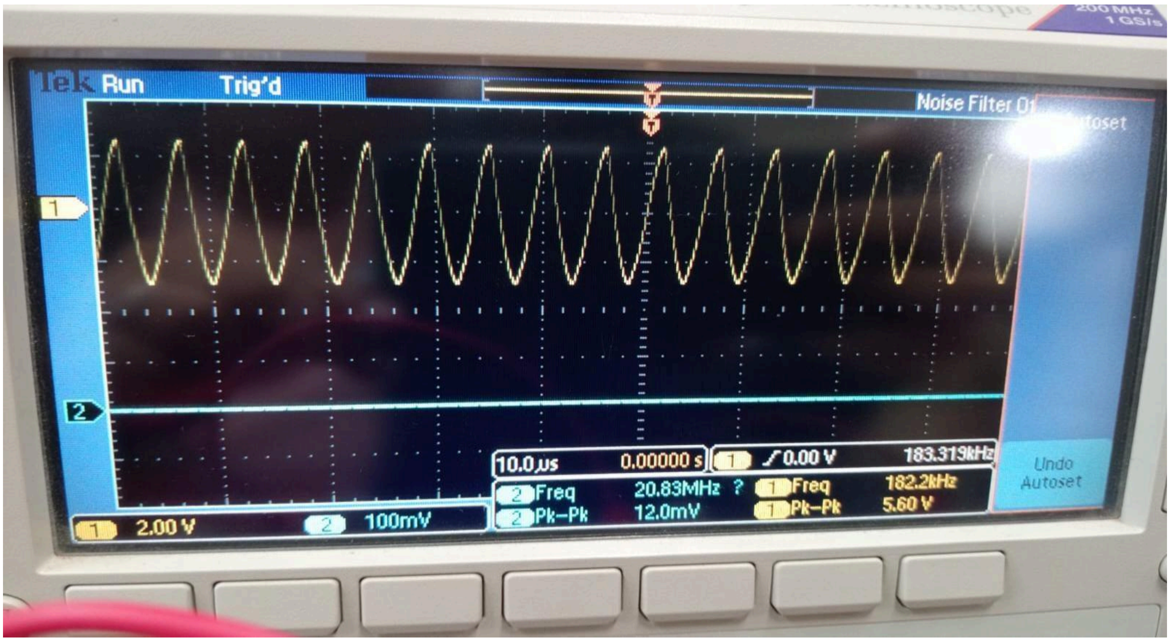


Test Results:

1. For the first part of performing Frequency Modulation, we were able to generate the message(modulating) signal and carrier signal as follows:

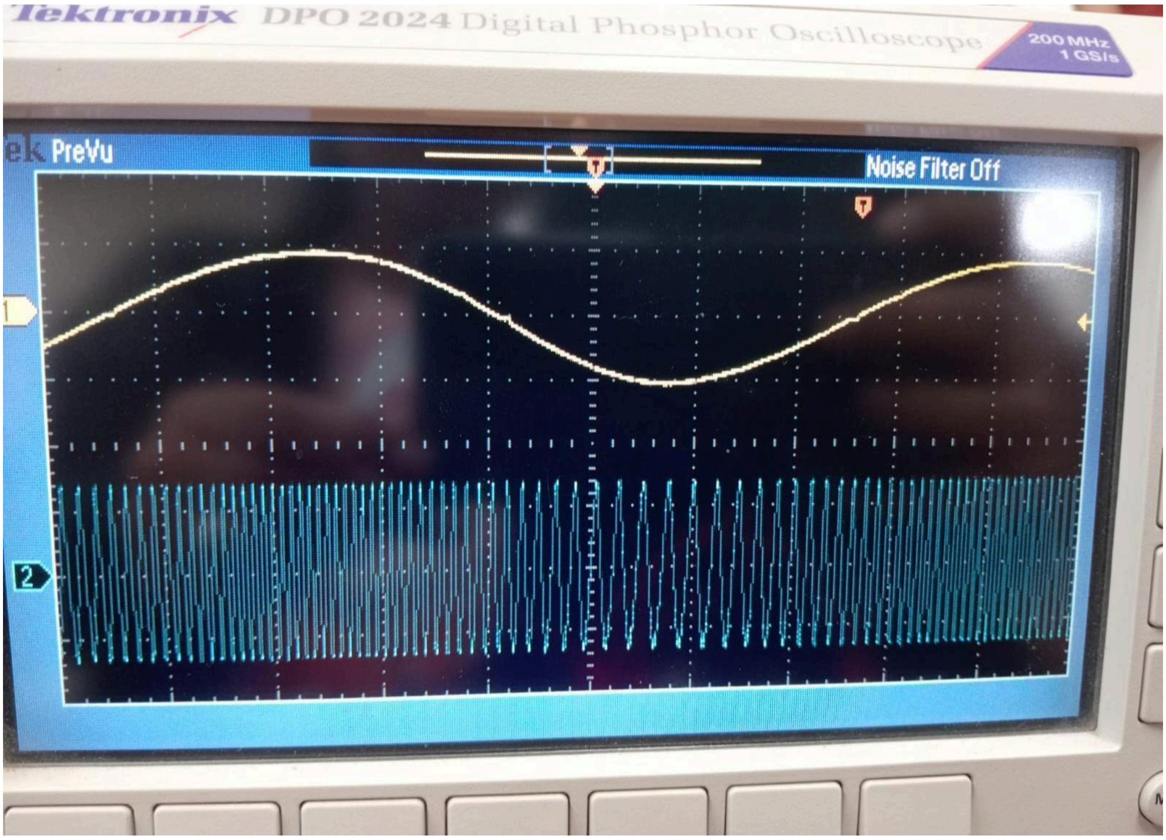
2. 

Message signal

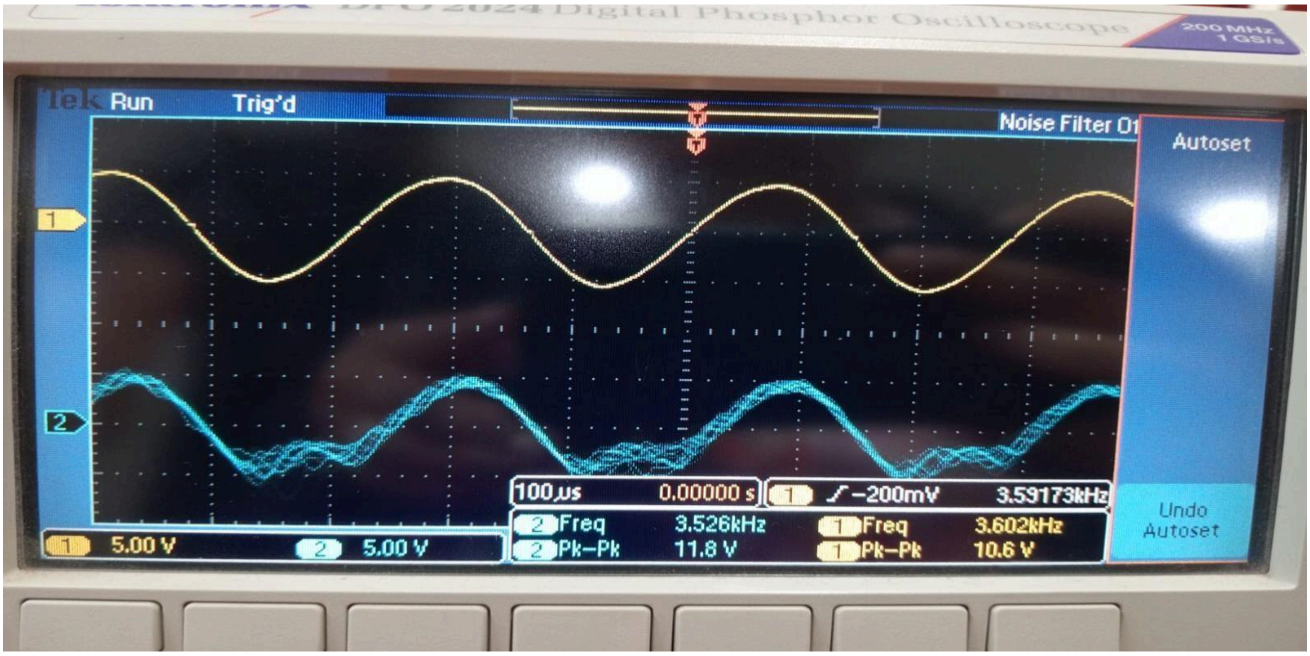


Carrier Signal

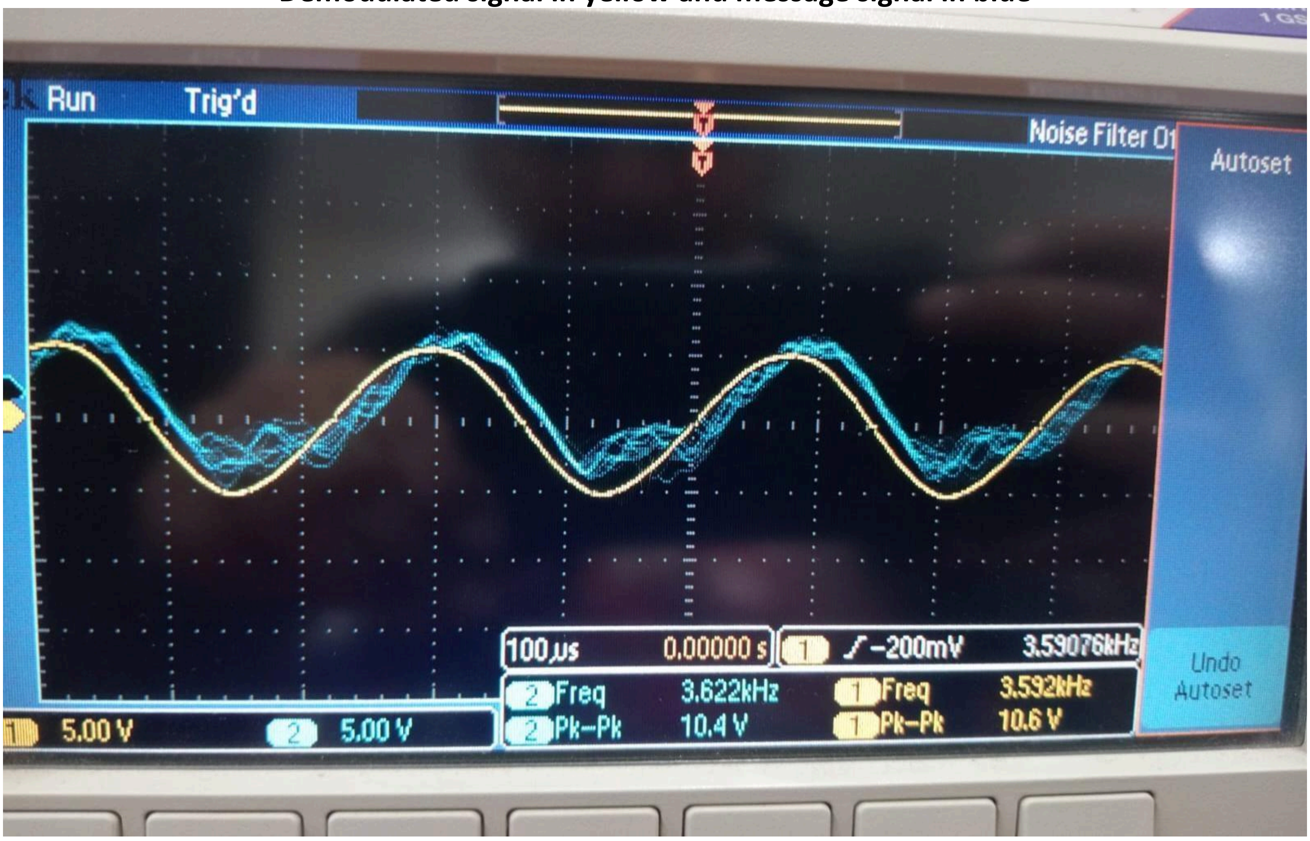
3. Next by using the FM generator kit we were able to produce frequency modulated wave as shown:



On increasing the amplitude of modulating signal, we observed that the percentage modulation is varied and on uncontrolled change distortion occurs in the signal. On tuning to a particular combination of frequency and amplitude we were able to
obtain a proper demodulated signal.
For the second part of Demodulation, we used the modulated wave output from FM OP port as input to the Demodulator section of the Kit and received
demodulated wave as shown:



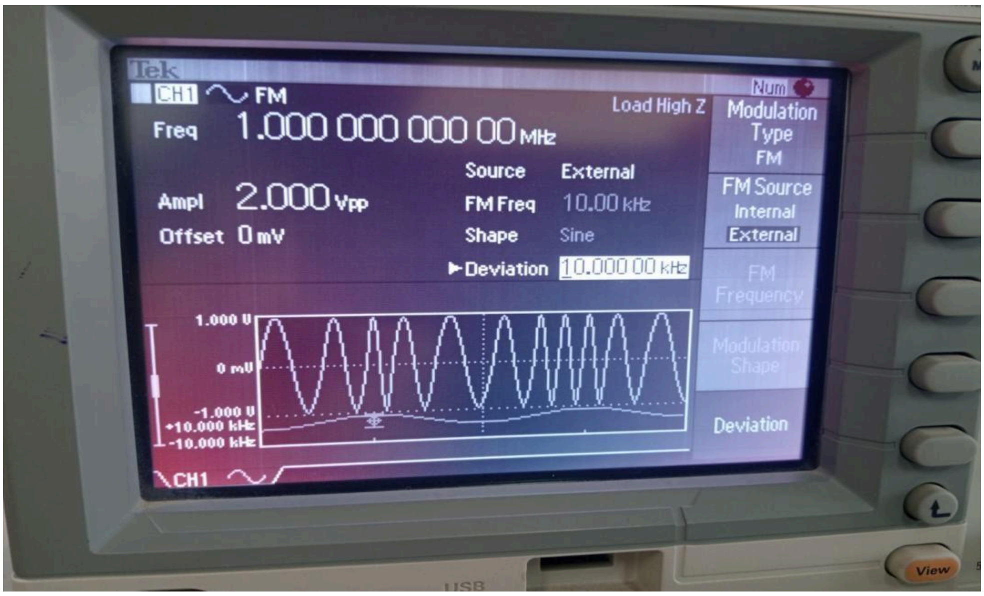
Demodulated signal in yellow and message signal in blue

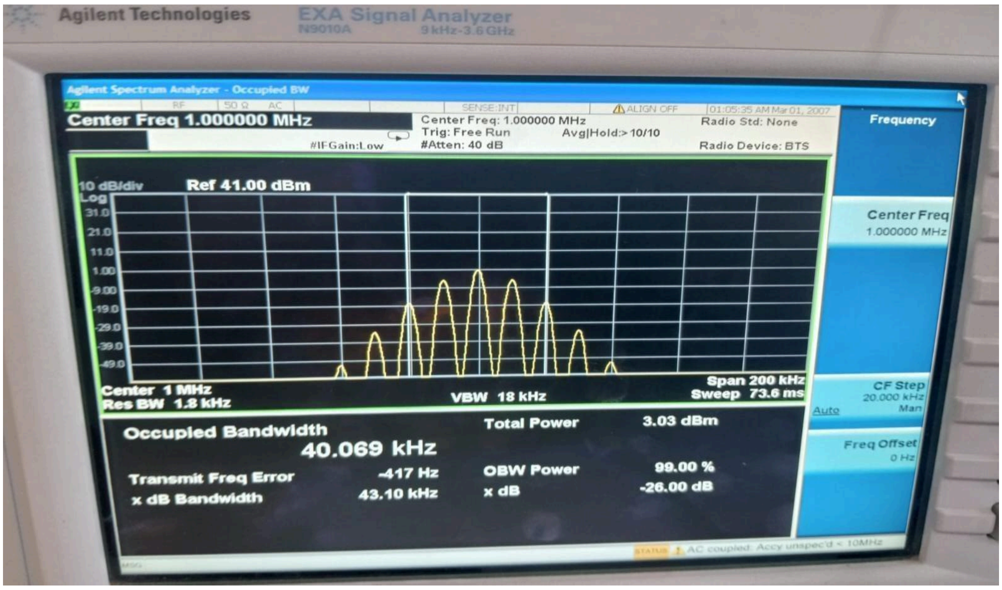


Demodulated signal in yellow and message signal in blue when there is demodulated locked and there is constant phase difference
For the Frequency domain Analysis, we set up the system as shown in the experimental procedure section.

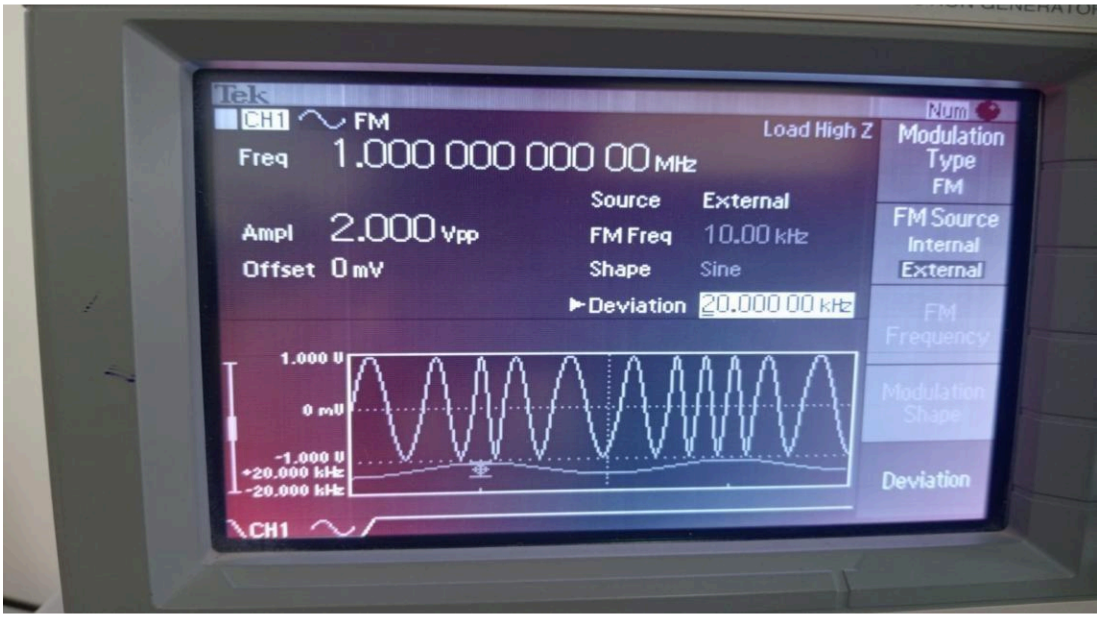
The function generator on the left acts as the modulating signal generator while the right function generator generates the modulated signal after modulating it with the carrier signal:

- **The spectrum of the modulated signal obtained was as shown in figure: Case 1: Frequency Deviation At 10 KHz**



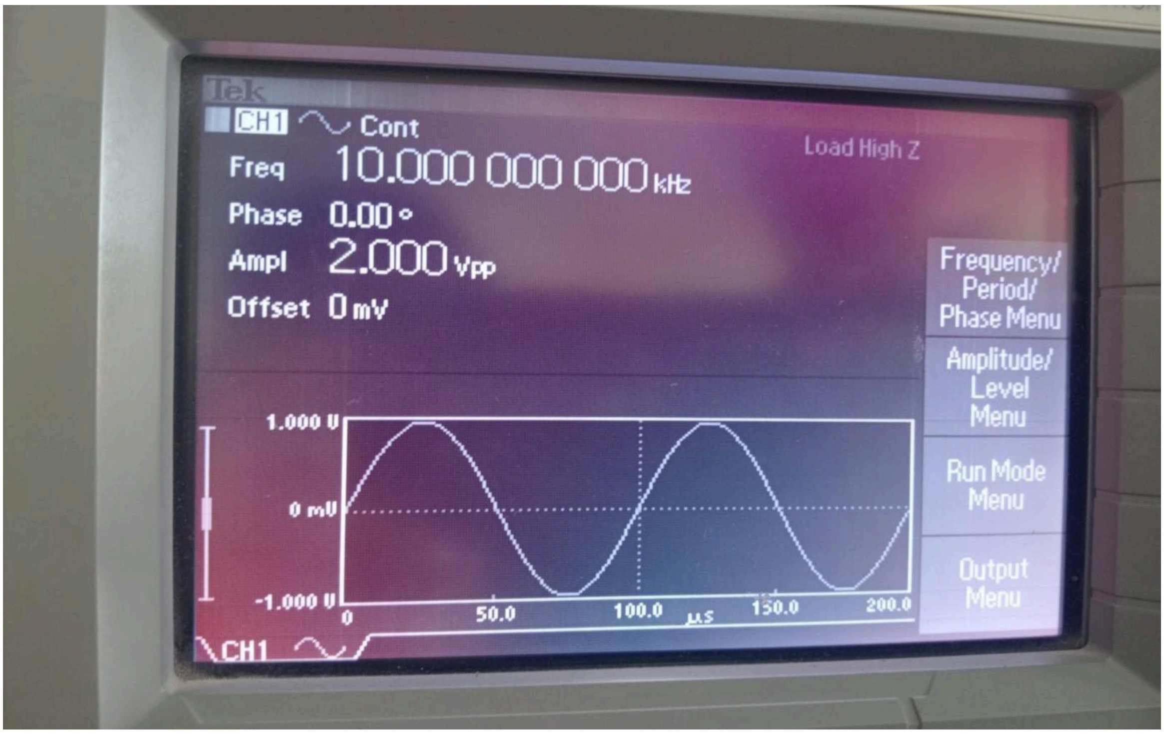


- **The spectrum of the modulated signal obtained was as shown in figure: Case 2: Frequency Deviation At 20 KHz**



The function generator on the left acts as the modulating signal generator while the right function generator generates the modulated signal after modulating it with the carrier signal:

- **The spectrum of the modulated signal obtained was as shown in figure: Case 2: Frequency Deviation At 30 KHz**




Tektronix
AFG 3021B SINGLE CHANNEL ARBITRARY / FUNCTION GENERATOR
250 MS/s
25 MHz
Top Menu
CH1 FM
Load High Z
Freq 1.000 000 000 00 MHz
Ampl 2.000 Vpp
Offset 0 mV
Source External
FM Freq 10.00 kHz
Shape Sine
Deviation 30.000 00 kHz
Modulation Type FM
FM Source Internal External
FM Frequency
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Deviation
1.000 V
0 mV
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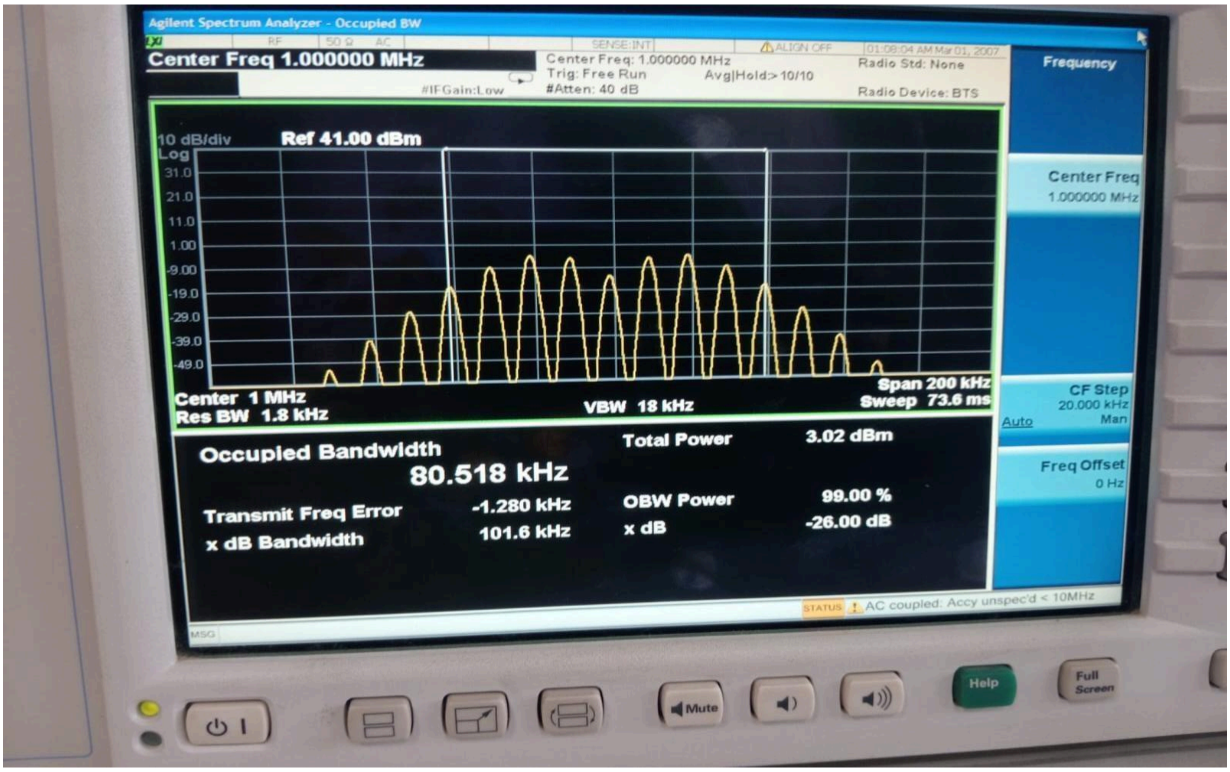
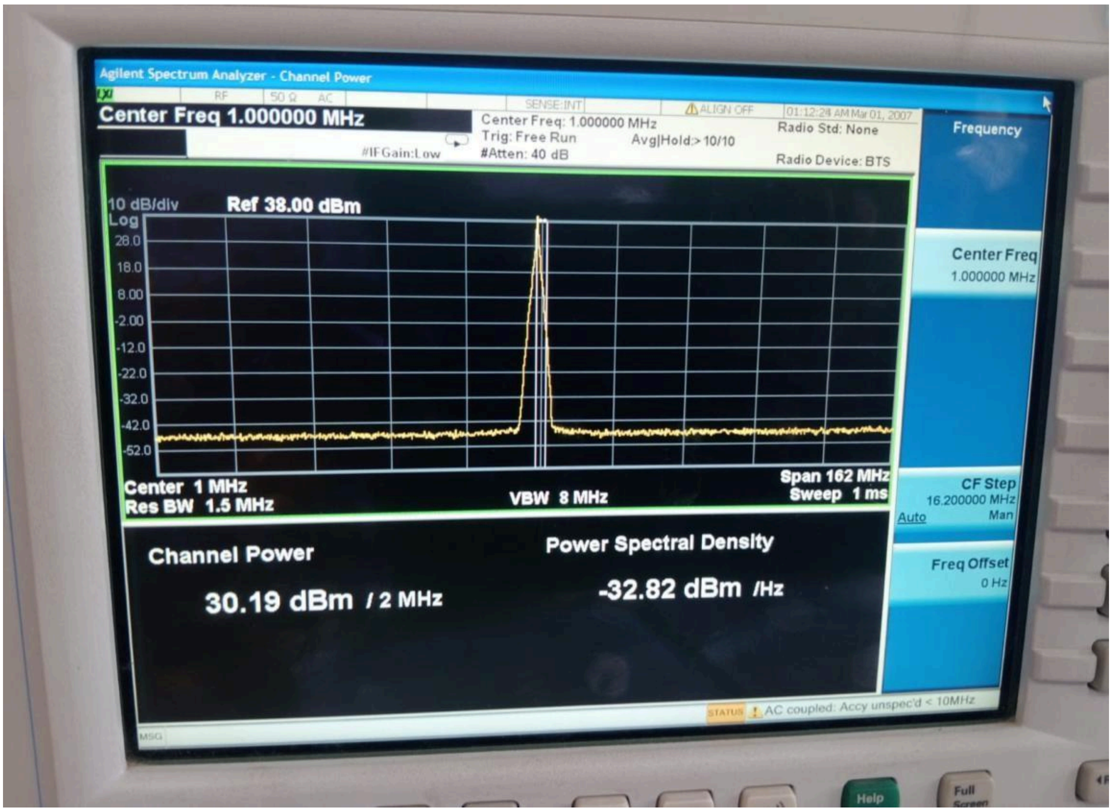
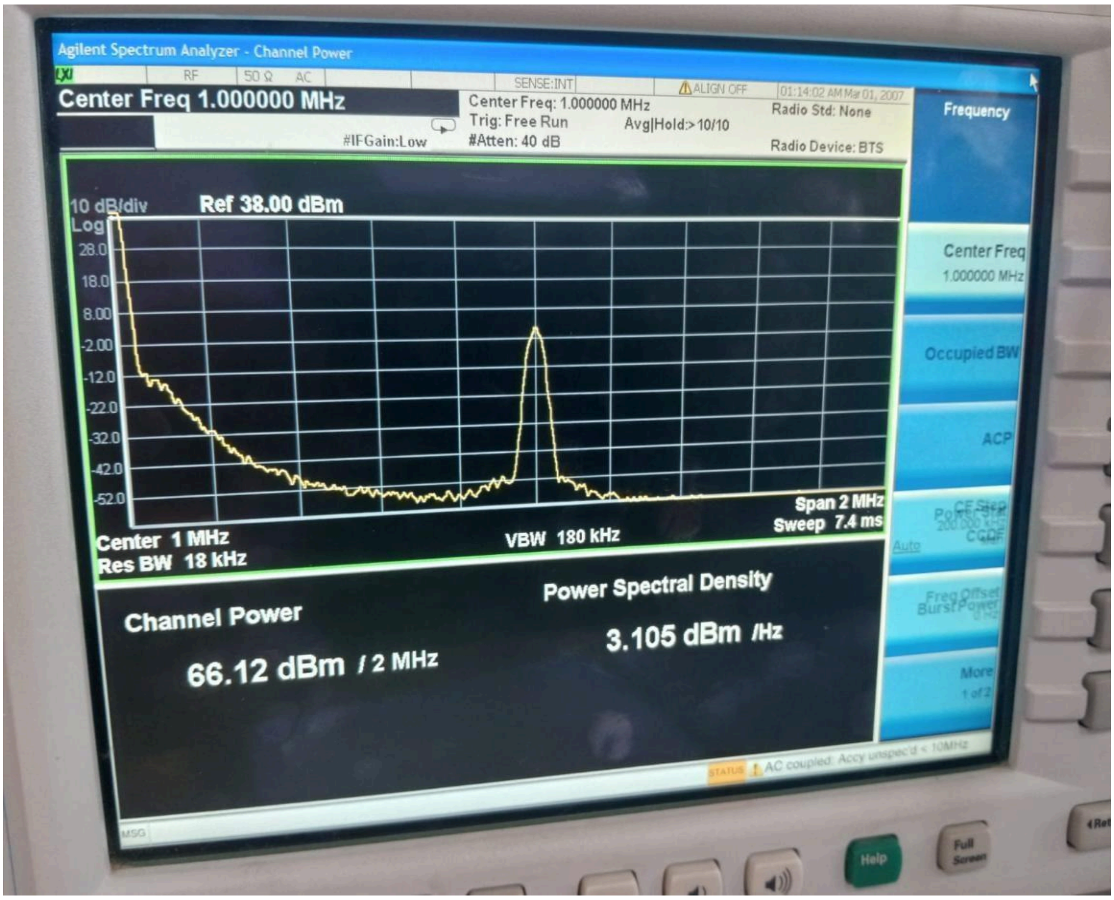
-30.000 kHz
View


Agilent Spectrum Analyzer - Occupied BW
Center Freq 1.000000 MHz
Center Freq: 1.000000 MHz
Trig: Free Run
#Atten: 40 dB
Avg|Hold:> 10/10
Radio Std: None
Radio Device: BTS
#IFGain:Low
Frequency
10 dB/div
Log
Ref 41.00 dBm
31.0
21.0
11.0
1.00
-9.00
-19.0
-29.0
-39.0
-49.0
Center 1 MHz
Res BW 1.8 kHz
VBW 18 kHz
Span 200 kHz
Sweep 73.6 ms
Center Freq 1.000000 MHz
CF Step 20.000 kHz
Auto Man
Freq Offset 0 Hz
Occupied Bandwidth
80.518 kHz
Total Power 3.02 dBm
Transmit Freq Error -1.280 kHz
OBW Power 99.00 %
x dB Bandwidth 101.6 kHz
x dB -26.00 dB
AC coupled: Accy unspec'd < 10MHz
Mute
Help
Full Screen

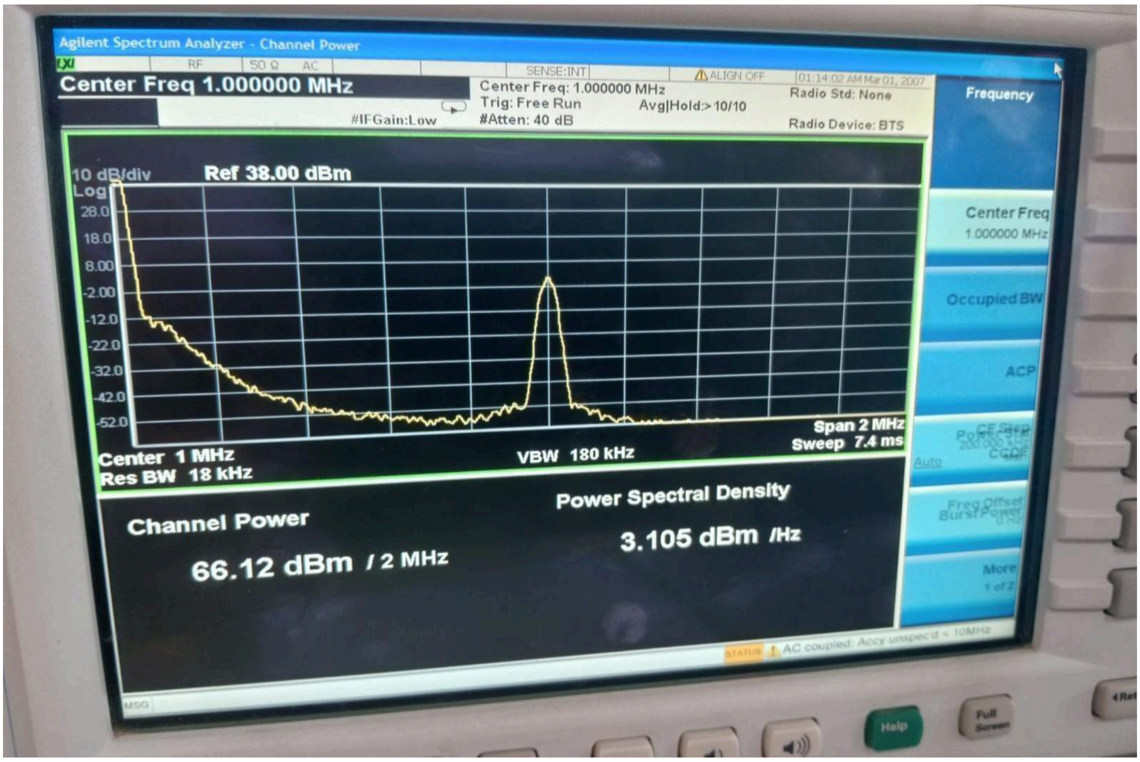
Case 1: At 30 KHz



Case 2: At 20 KHz

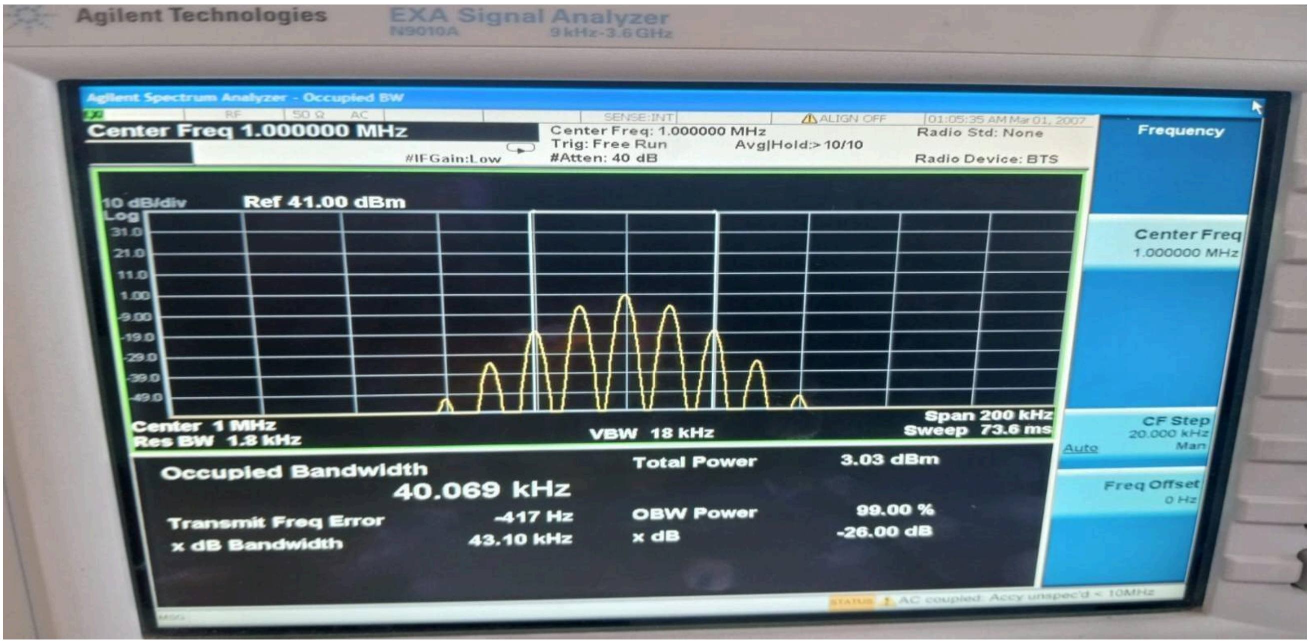


Case 3: At 30 KHz



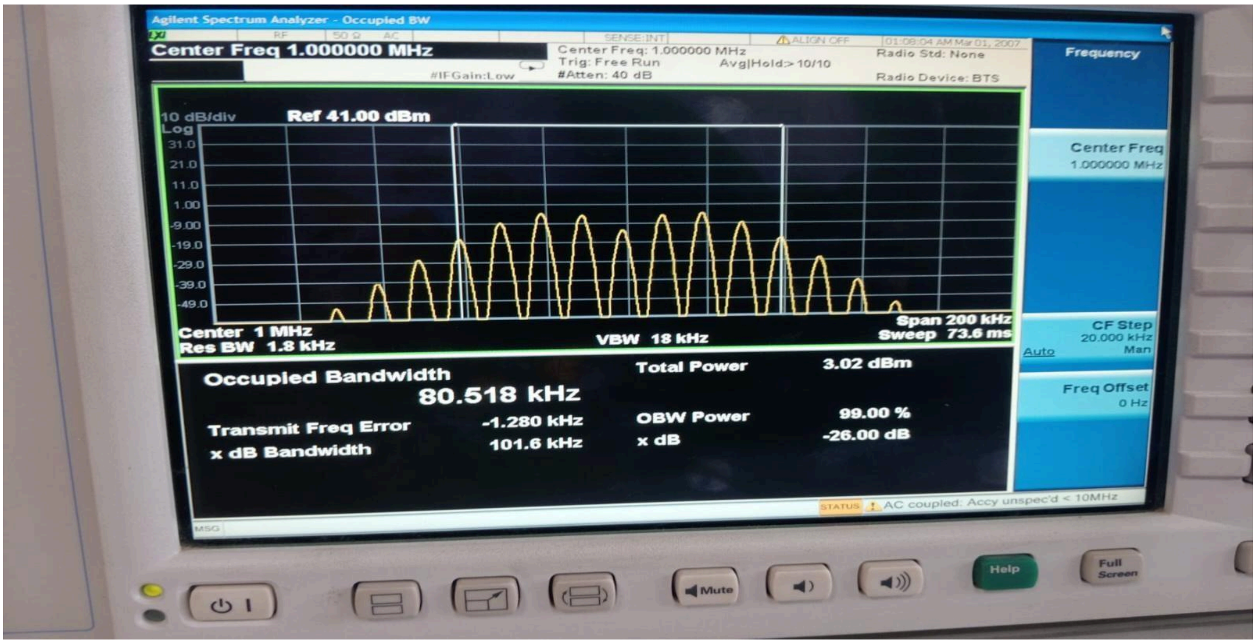
We can observe the 5 distinct peaks. The occupied bandwidth is 40kHz(approx), which verifies the Carson's inequality(bandwidth= $2(f_m + \delta f)$. The input to the spectrum analyzer was given using two function generators as shown earlier.

10 Khz Deviation:



Similarly for frequency deviation at 20 Khz and 30 Khz there are 7 and 9 peaks were observed and occupied bandwidth 60 Khz and 80 Khz respectively as shown below: For **20 Khz Deviation:**

For 30 Khz Deviation:



Observation table:

The observation table for experiment is:

Am	Ac	Fm	Fc	Frequency Deviation(del f)	Bandwidth(BW = 2(Fm + del f))	Modulation Depth(= del f/Fm)
2 Vpp	2 Vpp	10 Khz	1 MHZ	10KHZ	40.07 KHZ	1
2 Vpp	2 Vpp	10 Khz	1 MHZ	20KHZ	60.46KHZ	2
2 Vpp	2 Vpp	10 Khz	1 MHZ	30KHZ	80.51KHZ	3

We observed that the calculated bandwidth and the observed bandwidth are similar.

Discussion:

- Increasing the amplitude of the message signal led to a proportional increase in the deviation of the carrier frequency, resulting in a wider bandwidth. However, beyond a certain threshold, excessive deviation caused signal distortion.
- Altering the frequency of the carrier wave induced a shift in the center frequency of the FM signal. This shift could potentially cause spectral congestion and interfere with neighboring signals. Furthermore, carrier frequency variations could compromise the accuracy of the demodulation process, introducing errors in the recovered message signal.
- Frequency demodulation, facilitated by the phase lock loop (PLL) method within the kit, ensures accurate signal recovery. This technique involves locking the phase of a locally generated carrier signal to that of the incoming FM signal. By comparing and adjusting the frequencies, the PLL circuit enables precise demodulation, yielding a smooth baseband signal after mixing and filtering.
- FM demodulation using phase locking is commonly used in applications where a high degree of accuracy is required, such as in radio communication systems, The PLL circuit ensures that the locally generated carrier signal tracks the incoming signal, resulting in a demodulated signal that accurately represents the original message signal.
- In the frequency domain analysis we were able to verify that Carson's rule holds as calculated bandwidth $2(f_m + \delta f)$ which came out to be 40kHz for the chosen inputs as shown in the appendices and figures above is almost the same as that found by the analyzer.

Conclusions:

- In conclusion, Frequency Modulation (FM) serves as a method for encoding information by modulating the frequency of a carrier wave in response to changes in the amplitude of a message signal.

- This modulation process results in an FM wave that can be demodulated to retrieve the original message signal. Demodulation is achieved by multiplying the FM wave with a locally generated carrier wave, filtering the resulting signal through a low-pass filter, and integrating the output. The accuracy of the demodulated signal is contingent upon the stability of the locally generated carrier wave and the precision of the detector and low-pass filter.

- The results of the experiment confirmed the effectiveness of FM demodulation in extracting the original information from a modulated signal. The demodulated signal closely resembled the original message signal, indicating the success of the demodulation process.

- To improve the design and execution of the experiment, it is recommended to ensure meticulous calibration of instruments, minimize noise interference, and optimize tuning parameters for accurate results.

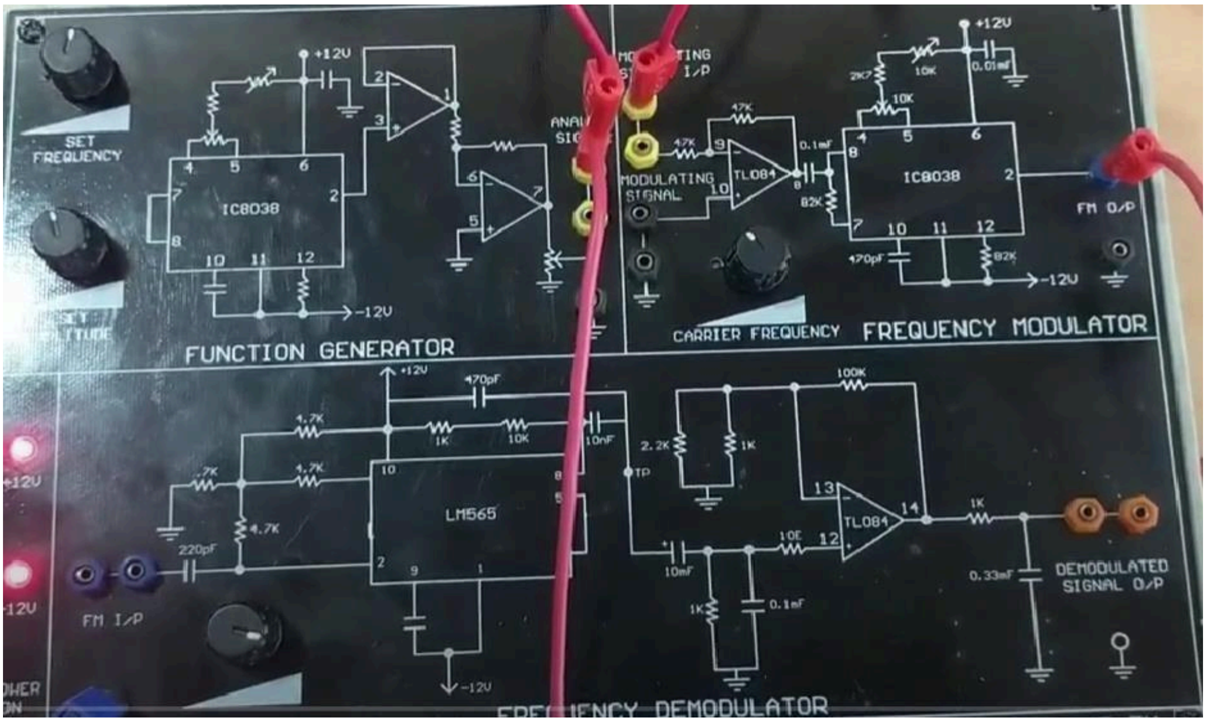
- Overall, FM wave modulation and demodulation are important techniques used in various applications, such as radio communication systems, where high quality signal transmission and reception is required. Through the experiment, it was demonstrated how the process of FM modulation and demodulation can be implemented in a laboratory setting.

References:

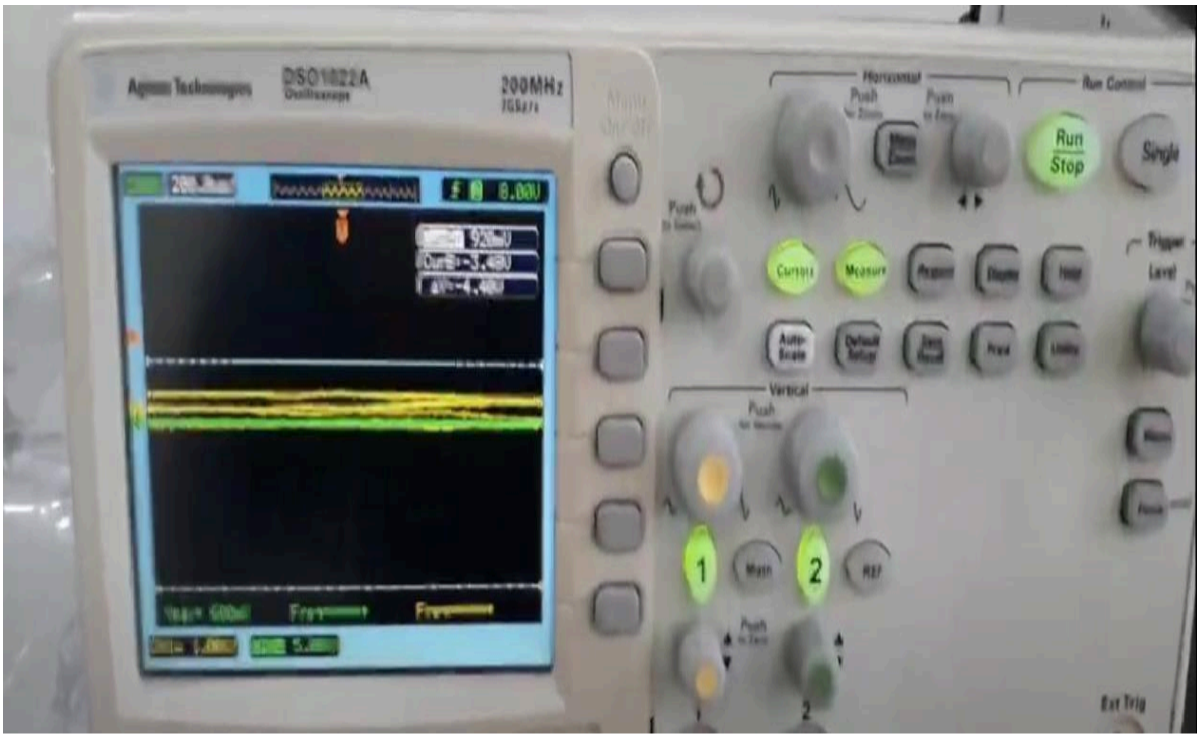
- Lab Manual For Experiment #2.
- Principles of communication systems – S.Haykin.
- Communication system Notes.

Appendices:

FM trainer kit (Vinytics CT FM)



DSO:

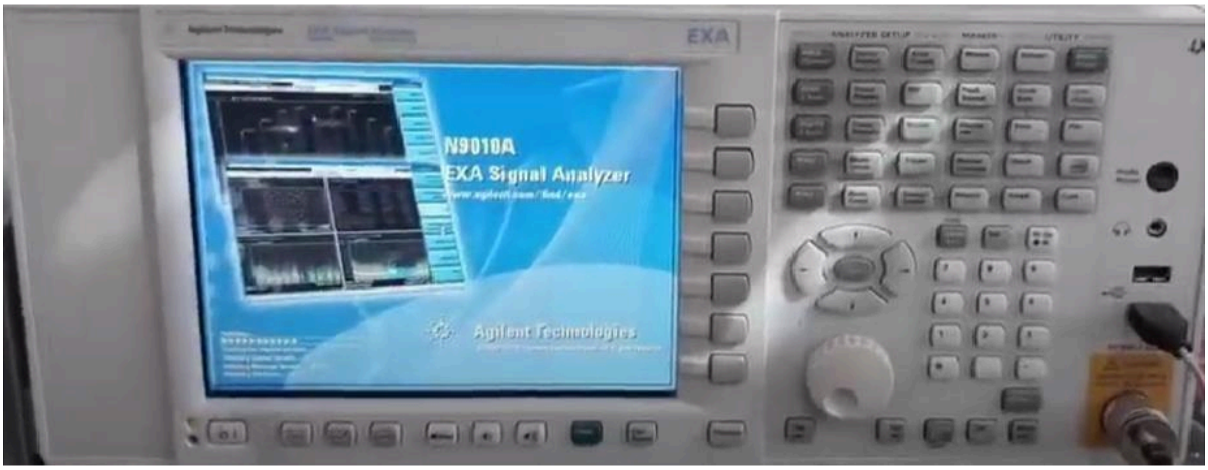


Patch Cords:

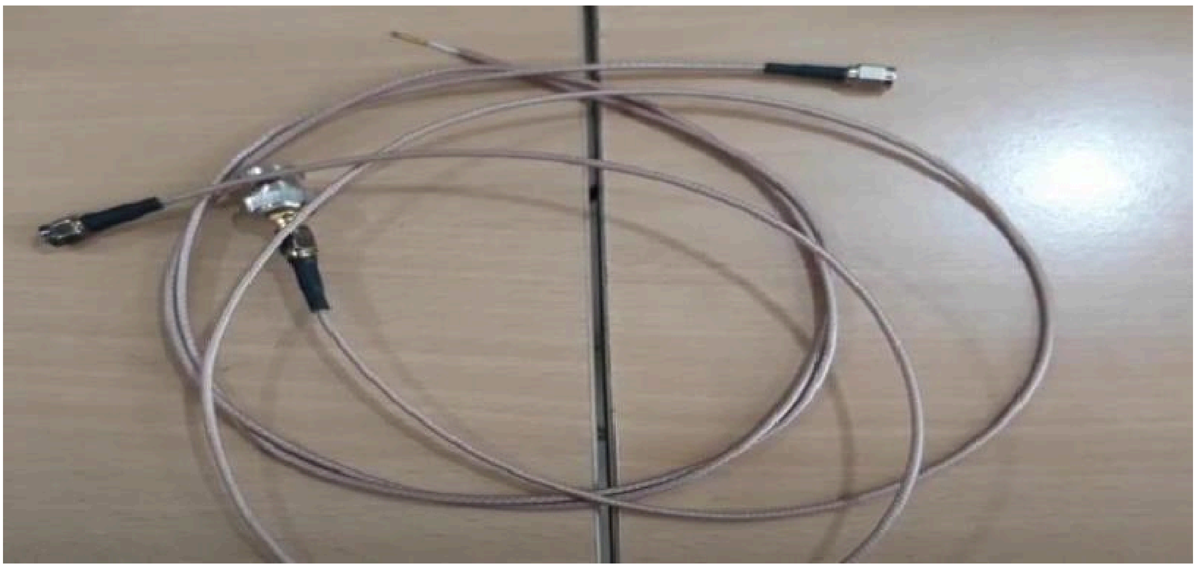
Probe Cable:

Function Generator :

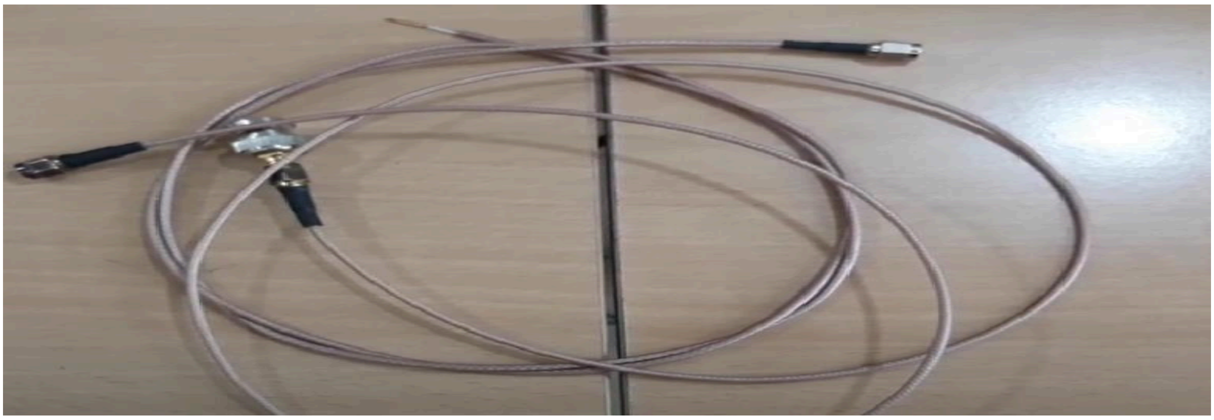
Signal Analyser:



Bnc to Bnc Coaxial Cable:



Sma to Bnc Coaxial Cable:



Sma to Sma coaxial Cable: