FM Transmitter and Receiver

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***Abstract-* Frequency modulation is required to solve the noise interference which is encountered in AM modulation. The frequency of the FM signal is less vulnerable to noise than the amplitude. FM was originally introduced to reduce noise and improve the quality of radio reception. In order to accomplish this, FM signals have bandwidths that are several times higher than that of AM signals. We will construct the FM Transmitter using a VCO. The FM Transmitter and Receiver both will be implemented at the ground level using basic electronic components. Depending on the responses of the individual circuits, separate analysis for each circuit is done and improvements are suggested where necessary.**

Keywords- Frequency Modulation, Amplitude Modulation, Low Pass Filter, Voltage Controlled Oscillator, Comparator, Twin Pulse Generator, Capacitor, Zero Crossing Detector, Resistor, Inductor, 555 Timer IC, Multisim, MATLAB, Simulink

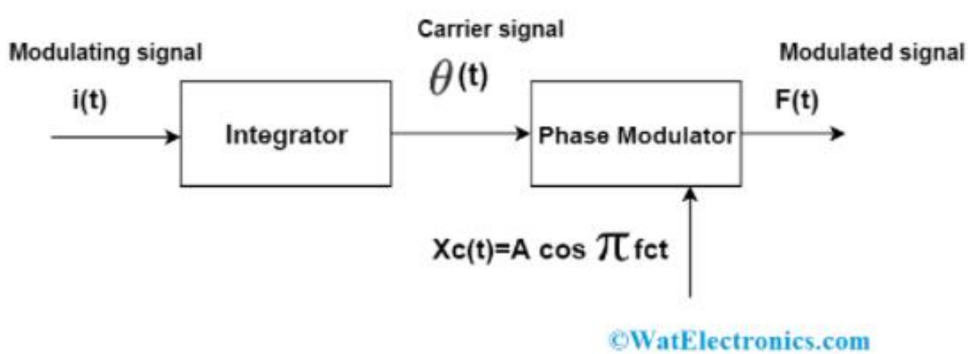
Software: Multisim, MATLAB

Discussion:

As its name implies, frequency modulation (FM) uses a message's amplitude to vary the frequency of a carrier instead of its amplitude. This means that the FM demodulator is designed to look for changes in frequency instead. As such, it is less affected by amplitude variations and so FM is less susceptible to noise. This makes FM a better communication system in this regard.

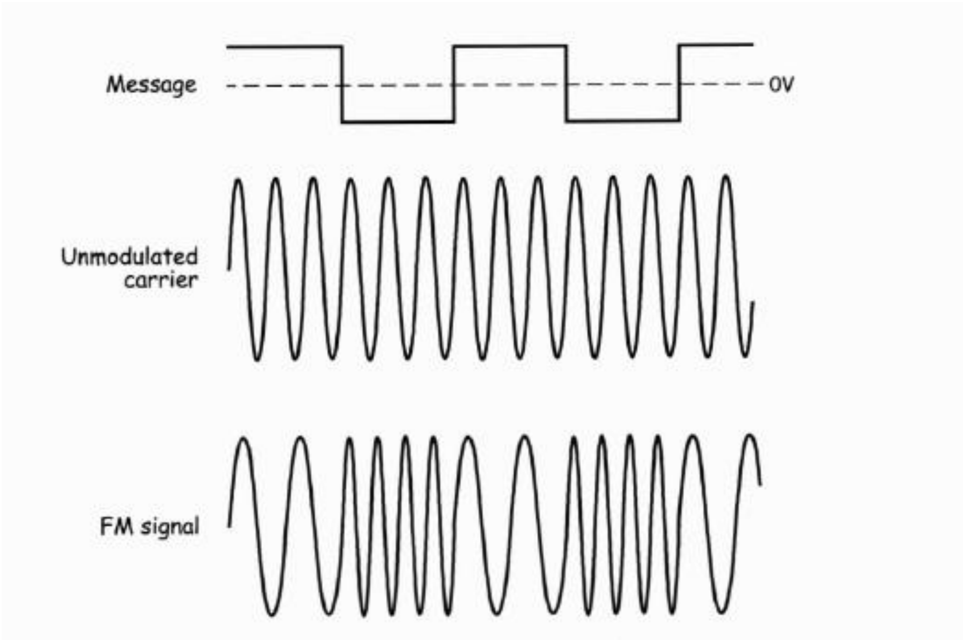
In FM modulation, the frequency of the carrier signal is changed by the message signal. Places with high amplitude of the message signal will result in high frequency of the carrier signal. Similarly, low amplitudes of message signal will result in low frequency of the carrier signal. There are a few things to notice about the FM signal. First, its envelopes are flat -FM doesn't vary the carrier's amplitude. Second, its period (and hence its frequency) changes when the amplitude of the message changes. Third, as the message alternates above and below 0V, the signal's frequency goes above and below the carrier's frequency.

For understanding the FM a block diagram is shown below. The carrier is a very high frequency signal and is multiplied with the message signal.

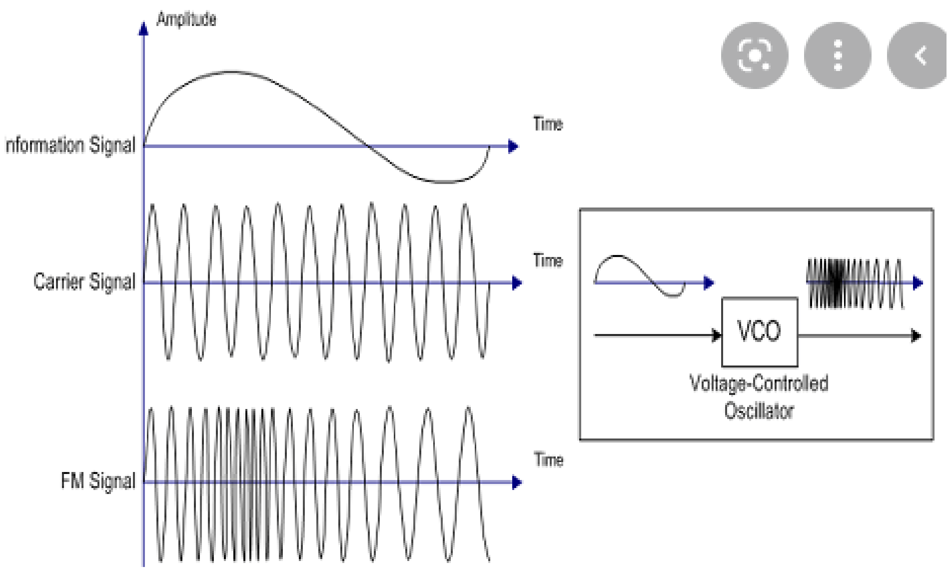


FM block diagram

A square wave message signal has been used in this discussion to help visualize how a FM carrier responds to its message.



But, to emulate real life scenario we will use a sin wave as out message signal.



There are several methods of generating FM signals. Most of these methods require an oscillator with an electrically adjustable frequency. We will use an VCO (Voltage Controlled Oscillator) to generate the FM signal, like the one shown in above figure and we are going to build every circuit from the ground level using common circuit elements.

Generating the message signal

Before making the VCO circuit for Frequency modulation we can use a Function Generator generating the message signal. But, as said before we will make every device that will be required from ground level. So, the first task is to create the circuit for message signal. Fig 1.1 shows the circuit for sine wave genrator. Experimentally it was seen that reducing the value of inductor at the output made an overlapping and unsmooth sine wave. Similarly, reducing the value of the capacitor resulted in the same issue. And, thus the L and C was set at 2 mH and 1 uF respectively. There are several ways to create a sin wave. For example- by using a IC8038 or using a 555 Timer IC which has been used here. The circuit implemented in Multisim is shown below. By varying the inductance and the capacitance of the LC Tank at the output the frequency of the sine wave can be changed.

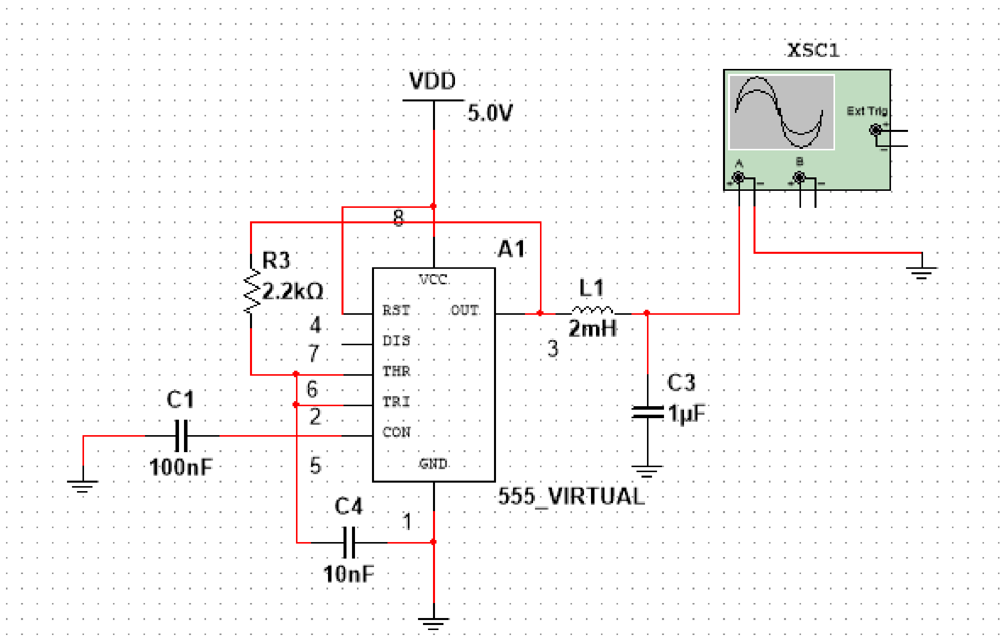


Fig 1.1: Sine Wave Generator using 555 Timer

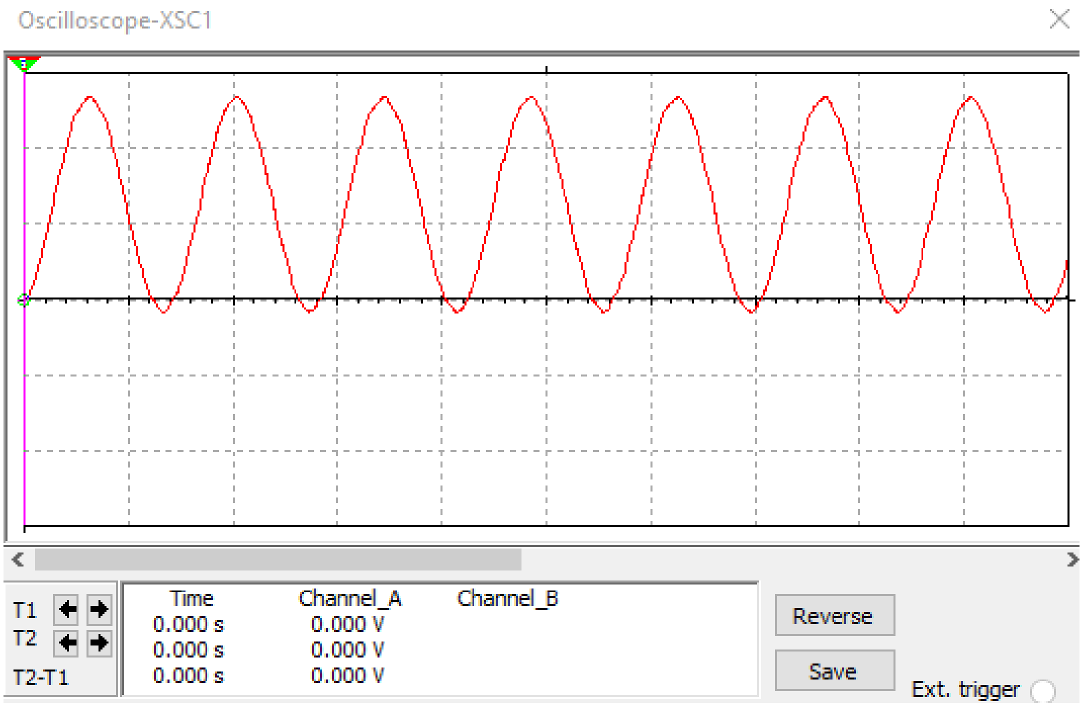


Fig 1.2: Sine Wave

Frequency Modulation using VCO

Since, our theory was developed from the Communication Laboratory where a VCO was used to generate the FM signal. Let's go through that explanation first for better understanding and analysis of the system that we are going to implement.

We performed Frequency Modulation using the Direct Method which involved a VCO. In direct FM modulation, the instantaneous frequency of the carrier is changed directly in proportion with the message signal. For this, a device called voltage controlled oscillator (VCO) is used. Let's get acquainted with the Voltage Controlled Oscillator (VCO). From the name it suggests that it controls the out AC signal depending on the input signal. As the DC input to the VCO increases the output signal's frequency also increases. And, this is exactly what happens in Frequency Modulation. The VCO performs the process of FM.

There are several ways to implement the VCO circuit for FM Transmitter. We used a 555 Timer IC. Fig. 2.1 shows the circuit and Fig: 2.2 shows the response. The red signal is the Output modulated signal and the green signal is the message signal. A 2 KHz sine wave is used a message signal from the Function Generator. This is the input of the VCO. For now, a Function Generator is used to generate the message signal instead of the circuit that was created for sin wave. The Function Generator settings are also shown in Fig: 2.3.

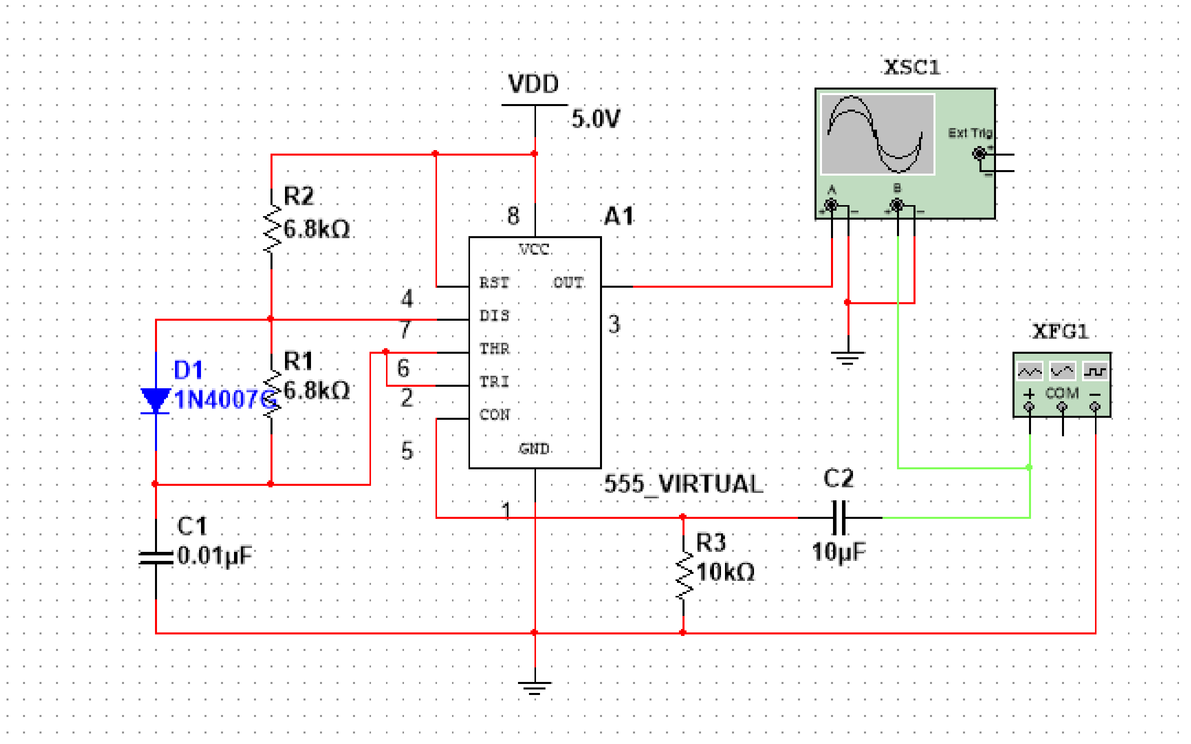


Fig 2.1: VCO Circuit

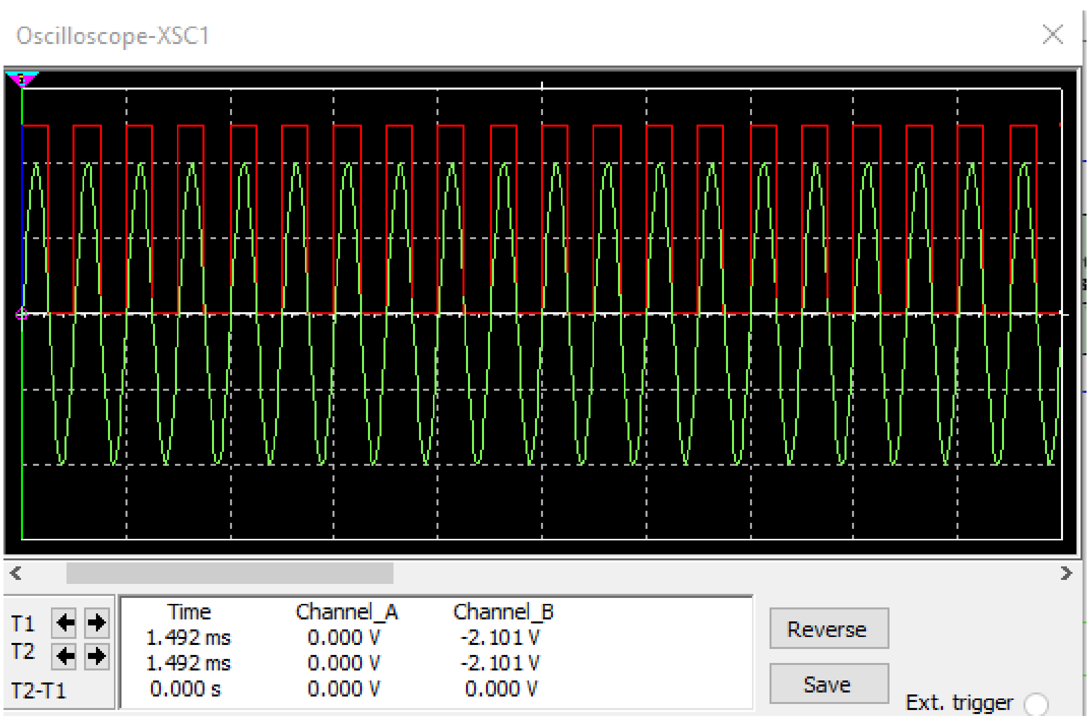


Fig 2.2: Modulated Sin Wave

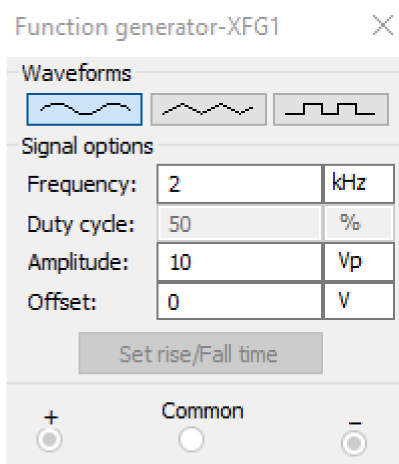


Fig 2.3: Function Generator Settings

But, Fig: 2.2 shows modulated signal which is a square wave which is not desirable. So, a LC Tank branch is used to transfer the square wave to a sin wave. Fig 2.4 shows the modified VCO with a LC Tank. The output is shown in Fig 2.5. The red signal is the demodulated signal and the green is the message signal. Although, the square wave output was satisfactory but this output is not. But, as simulation is performed further the original signal is recovered from this modulated signal at the receiver end.

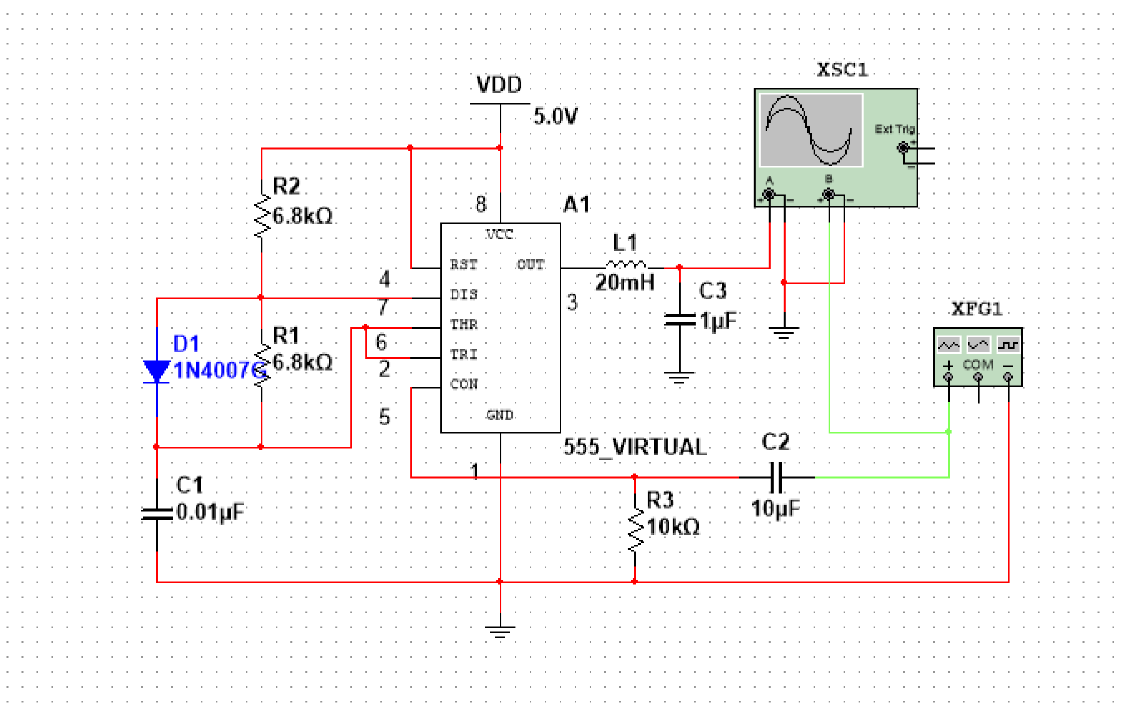


Fig 2.4: LC Tank VCO

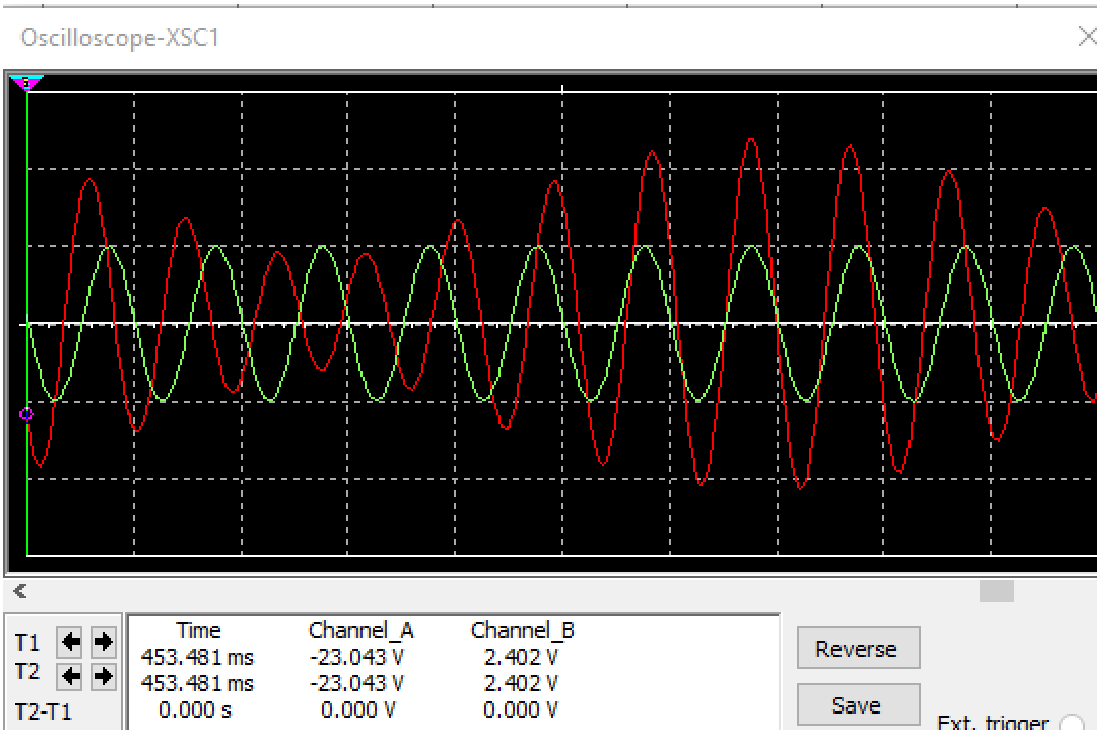


Fig 2.5: Frequency Modulated Signal

Problems faced during modulation

The function generator circuit implemented in Fig 1.1 works perfectly on its own and generates a proper sine wave. But, when given as input to the VCO circuit in Fig 2.1, the output is a completely distorted signal which is beyond interpretation. That is why, a Function Generator is used to generate the sin wave into the VCO circuit.

Although, the VCO circuit in Fig 2.1 showed perfect characteristics of FM transmitter but the output was a modulated square wave instead of a sine wave. This required the use of a LC tank to convert it to sine wave.

The modified circuit in Fig 2.4 did not show good response. There are places where the amplitude is modified. Although, the demodulation was carried out properly using the same modulated signal.

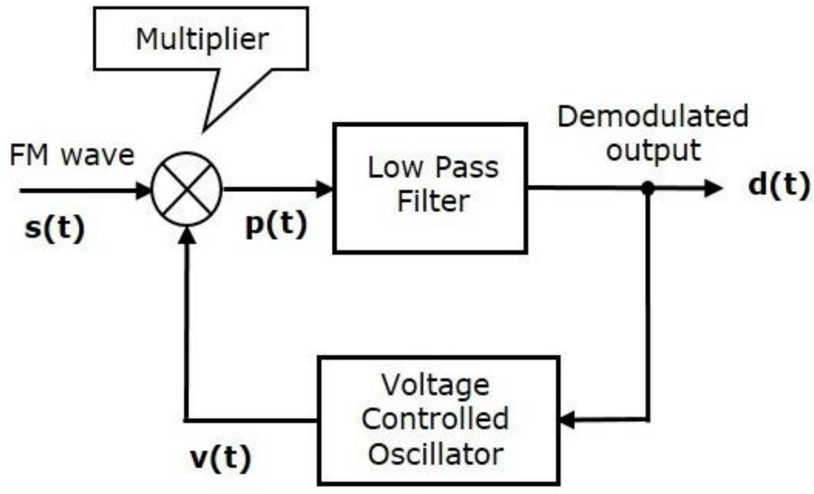
Suggested Solutions / Improvements

Replacing the 555 Timer IC could fix the problem as this is giving a squared modulated signal and not sine wave. Many papers were studied and seen that the 555 Timer IC's output is a squared wave that has to be converted to a sin wave.

Another one is replacing the LC branch.

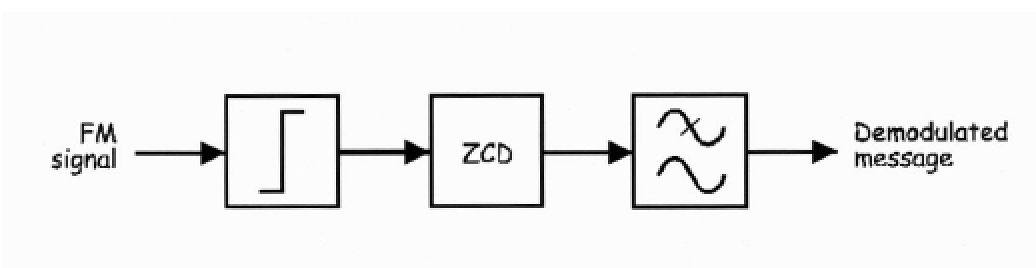
FM Receiver (Demodulation)

There are as many methods of demodulating FM signal as there are of generating one. Examples include- the slope detector, the Foster-Seeley discriminator, the ratio detector, the Phase Locked Loop (PLL), and the zero-crossing detector. A Frequency Demodulator could be as simple as the one shown in the block diagram below. This is the FM Demodulator using Phase Discrimination method.



Just like as FM lets go over the concepts of demodulation from the Communication Laboratory. There are two ways to demodulate the signal. And, we used Zero Crossing Detection (ZCD). The block of demodulation with ZCD method is shown below. Analyzing the ZCD method will help us understand the fundamentals of how demodulation works.

The Frequency Modulated signal goes through the Comparator. The squared up FM signal is continuously crossing zero. The ZCD converts the square wave to a rectangular wave. The Twin Pulse Generator generates the rectangular wave. When the FM signal's frequency change with response to the message signal so does the rectangular wave's frequency. A Low Pass Filter is used to block the high frequencies and the output is the original signal.



Now, the Comparator, LPF discussed above will be implemented in circuit level in Multisim and check if we can recover the message signal. The output from the Modulator circuit goes into the capacitor of the receiver circuit shown in Fig 3.1. Simple components are used rather than components like Comparator, Twin Pulse Generator which are readily available and are very costly.

In the implemented circuit shown in Fig 3.1 the diode gets rid of negative cycles of the modulated signal. The resistors with grounded capacitors gives the response of a Low Pass Filter and the high frequencies are all eliminated.

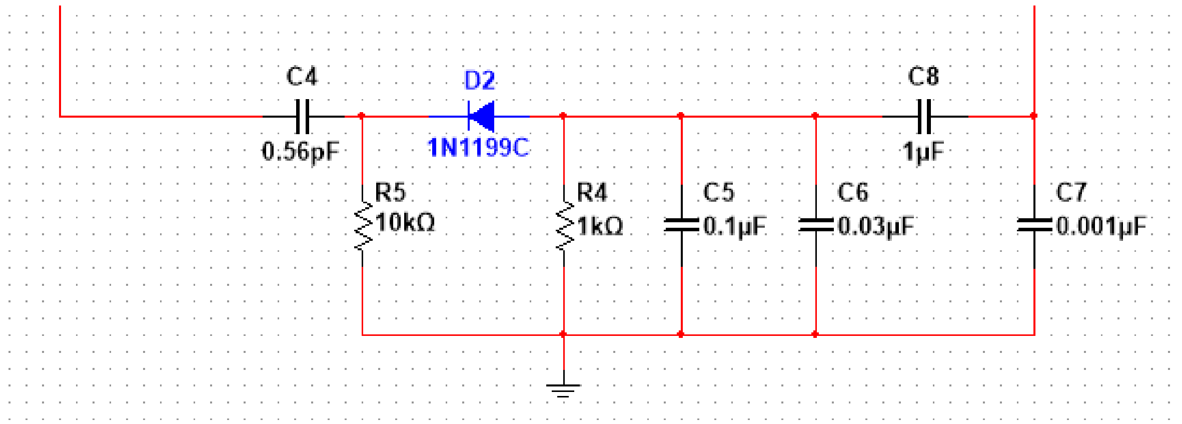


Fig 3.1: Demodulation circuit

The figure below Fig: 3.2 shows the whole FM transmitter and receiver circuit. The output is shown in Fig 3.3. The red signal is the demodulated signal and the green signal is the message signal. Although, slightly distorted, the demodulated signal follows the message signal's characteristics.

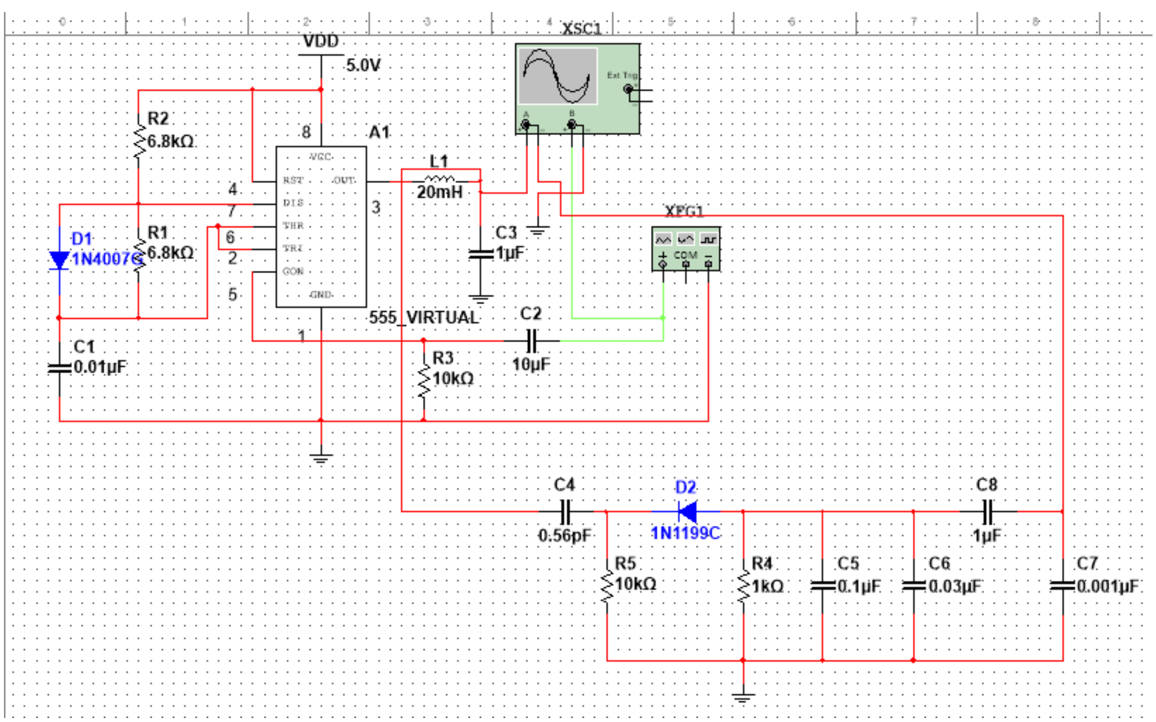


Fig 3.2: FM Transmitter and Receiver

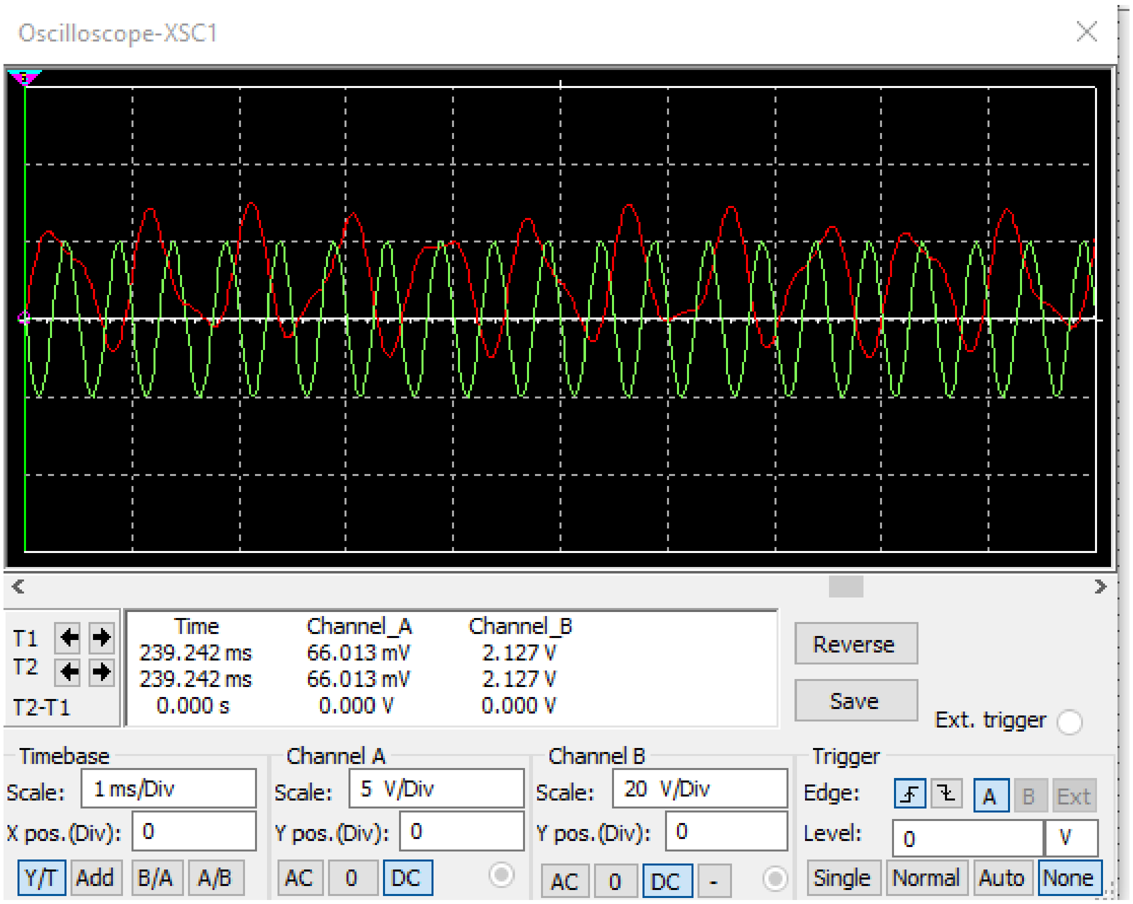


Fig 3.3: Demodulated Signal

Problems faced during demodulation

The demodulated signal was slightly distorted and had a phase shift which occurred due to the use of many analog passive elements in the circuit.

Suggested Solutions / Improvements

Improving the values of resistors and capacitors could result in a better demodulated signal.

Merits and Demerits

From the **Costs** perspective-

Mostly consisted of resistors, capacitors, diodes and 555 Timer IC the circuit can be implemented at a low cost of about TK 500. The price of each unit is given below to give an idea about the cost.

Component	Price (TK)
Resistor	8
Capacitor	6
NE 555 Timer IC	10
5 V Battery	30
Diode	5
Breadboard	20
Jumper Wires	40

From the **Analyzing** perspective-

Implementing the electronic circuits gave an idea about how these components work together in real life. Although, theoretically the circuits give accurate responses on paper but due to noise (although not in simulation) and many passive elements together, the results had to be often calibrated. This provides a better understanding of Analog Circuits.

The single demerit could be- since, many passive elements are used, it becomes harder to obtain the accurate responses.

FM Modulation & Demodulation in MATLAB

Block diagram of FM and Frequency Demodulation in Simulink MATLAB.

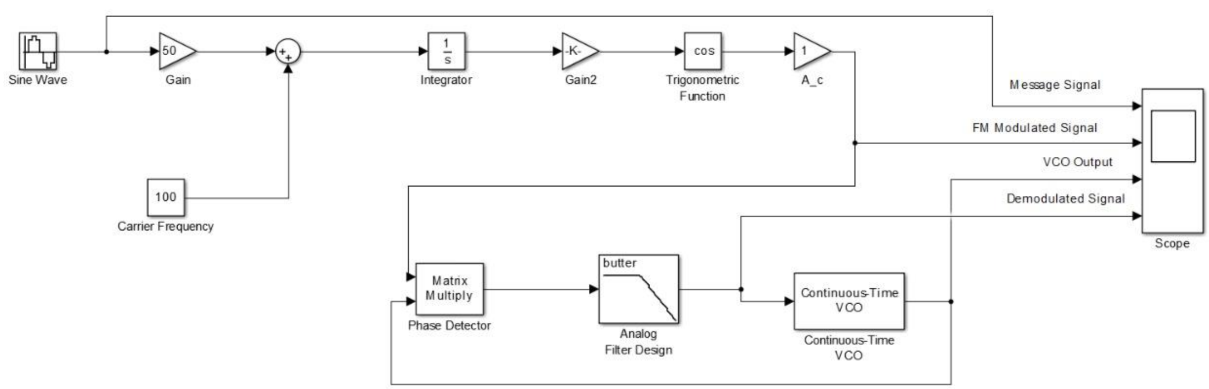


Fig 4.1: Block diagram of FM Modulator& Demodulator

The response of all the signals is shown below. It can be seen that a better response is obtained here compared to the Multisim experiment. The demodulated signal is very close to the message signal.

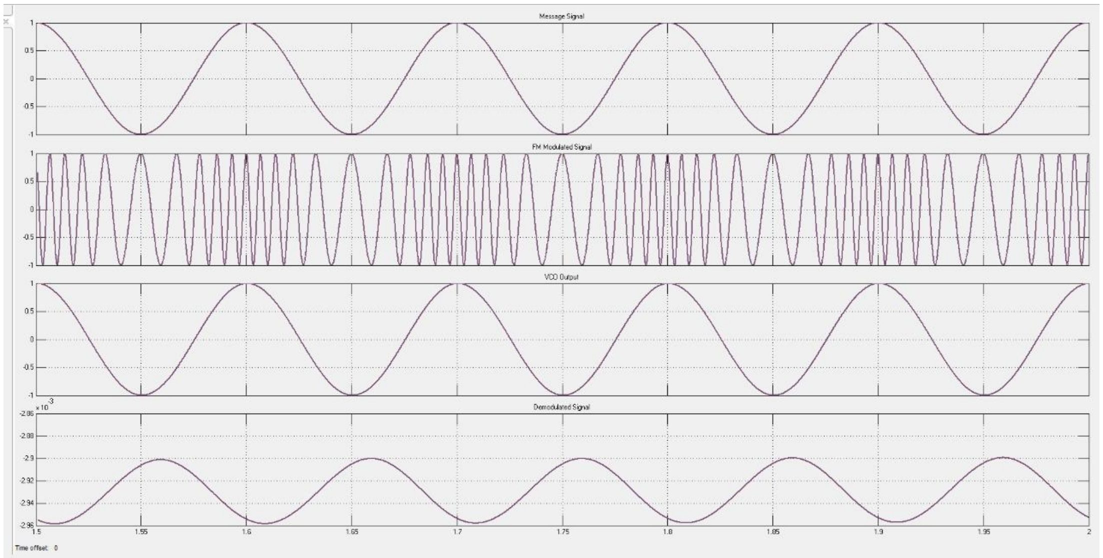


Fig 4.2: Response of all signals

Conclusion: In this lab experiment, we performed FM. Unlike AM, in FM we do not encounter noise interference. To accomplish the noise-reduction the bandwidth becomes several times higher than that of AM. Firstly, we used a VCO to generate the FM signal. The VCO is created at the electronic circuit level. We demodulated the FM signal using a diode which gets rid of the negative cycles and resistors and capacitors to create a LPF response for eliminating the high frequencies and finally to obtain the message signal.

References: FM lab sheet, AM lab sheet, EEE 310, eeeshopbd.com, watelectronics.com, tutorialspoint.com, mathworks.com