FM Communication System

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Introduction

Analog communication systems have contributed significantly to the advancement of modern telecommunications, acting as the foundation around which our worldwide society revolves. These systems work on the fundamental principle of delivering data in a way that accurately reproduces the original message using continuous signals. Frequency modulation (FM) is a well-known and adaptable technique for signal transmission among the many modulation techniques used in analogue communication.

Frequency Modulation (FM) is a modulation technique widely used in analog communication systems for transmitting information-rich signals such as audio and video. It provides many advantages including enhanced noise immunity, improved signal-to-noise ratio, high-quality audio reproduction and simplicity.

FM system

Frequency modulation system depends on the change of the frequency of carrier signal to transmit the information in the original modulating signal as shown in figure 1.

The main parts of FM system are modulating signal, carrier signal, modulator, and demodulator.

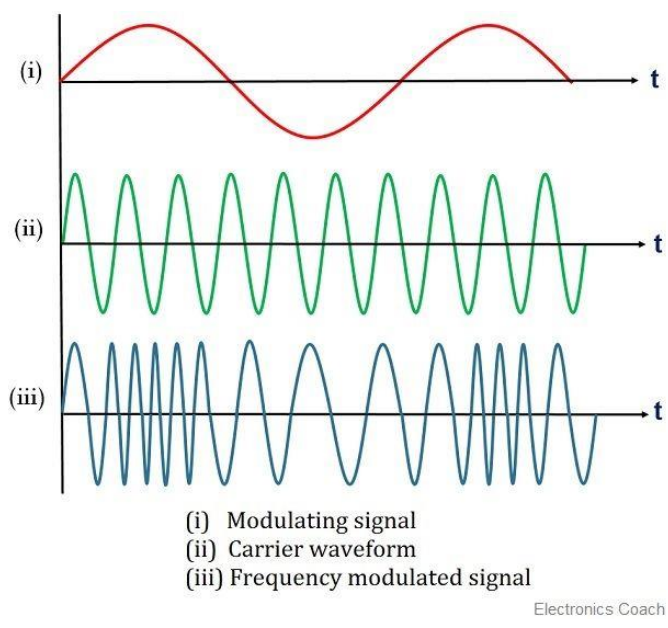

Figure 1 FM system.

Frequency Modulation

In frequency modulation step, the baseband signal's amplitude fluctuations cause the carrier signal's frequency to change proportionately, as the modulation procedure is accomplished by altering the carrier wave's instantaneous frequency.

Modulation process goes through these steps:

- The input signal (audio or data) is first passed through a pre-emphasis filter to boost the higher frequencies and attenuate the lower frequencies.
- The modulating signal then varies the frequency of the carrier wave. This is typically done using a voltage-controlled oscillator (VCO).
- The output of the VCO is combined with the carrier wave to produce the FM signal, which can then be transmitted over the air.

Mathematical representation:

Any Fm signal can be demonstrated as a wave equation as shown:

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

where **s(t)** is the FM signal, **Ac** is the amplitude of the carrier wave, **fc** is the carrier frequency, **kf** is the frequency sensitivity of the modulator (modulation index), **m(t)** is the modulating signal.

We can represent the expression for frequency-modulated wave by using a sine or cosine work for the vitality of the baseband signal.

$$m(t) = A_m \cos(\omega_m t + \Theta)$$

where **m(t)** is Balancing Signal, **A_m** is Amplitude of Balancing Signal, **ω_m** is Angular Recurrence of Tweaking Signal, **Θ** is is Period of the Balancing Signal.

Then we can reach that the frequency modulated wave as follows:

$$f_m(t) = f_c + k\, m(t)$$

Where **f_m(t)** is Frequency Modulated Wave, **fc** is Frequency of Carrier Wave

m(t) is Modulating Signal and **k** is Proportionality Constant.

Frequency demodulation

Frequency demodulation is the process of recovering back the information transmitted.

Mathematical Representation:

The demodulated signal can be obtained by taking the derivative of the FM signal. For a sinusoidal modulating signal, the demodulated signal can be represented as:

$$m(t) = \frac{d}{dt}\left[\phi(t)\right]$$

where $\boldsymbol{\phi(t)}$ is the phase of the FM signal.

MATLAB Representation

In this project we represented the FM modulating and demodulating system through a MATLAB code that take the signal once as sine wave and another time from a human sound and apply on it the process of modulation and then demodulation with These parameters:

- Sampling frequency of 100000 Hz.
- Carrier frequency of 10000 Hz.
- Kf of 0.1.
- Modulating frequency of 300 Hz.
- SNR_db = 20.

Some built-in functions are used for modulation and demodulating the signal and for adding white gaussian noise to the signal. Then the root-mean-square-error for the signal with noise and without noise is calculated.

Sine wave signal plots*

Figure 2 represents the original message, modulated and demodulated signals with noise and without noise.

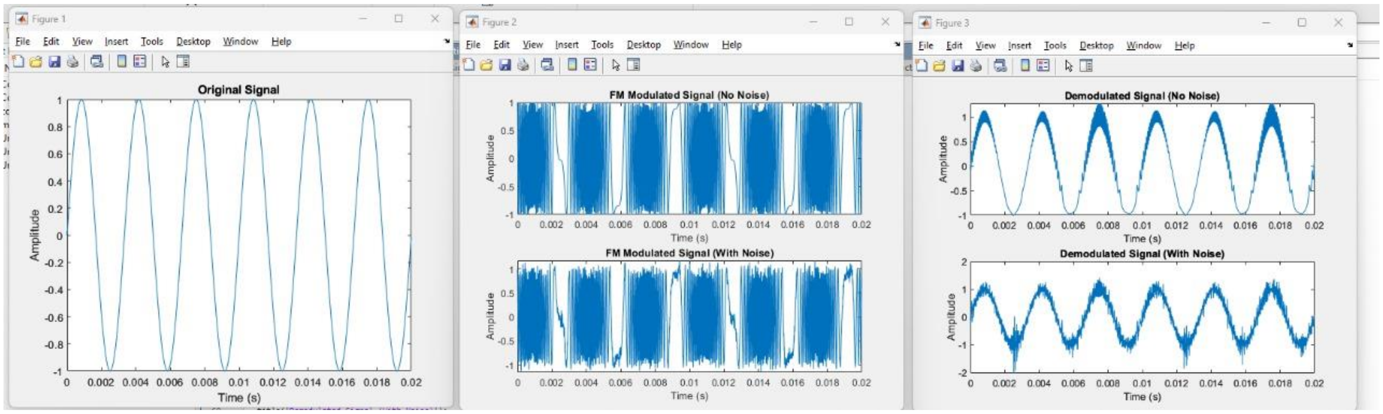

Figure 2 Sine message modulation and demodulation.

Figure 3 shows the RMSE with and without noise as they are very acceptable error values that gat the signal back with the least losses in its content.

```
>> Communications_Theory_Project
Error without noise: 0.090494
Error with noise: 0.17116
```

Figure 3 RMSE with and without noise.

Human Voice signal plots*

Figure 4 shows the original signal of the human sound record and figure 5 represents the plots of the mpdulated and demodulated signals with and without noise.

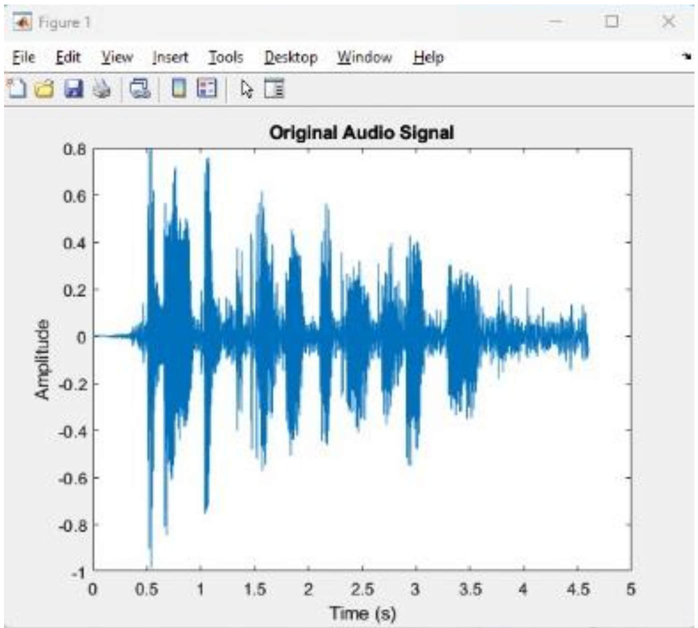

Figure 4 Human voice original signal.

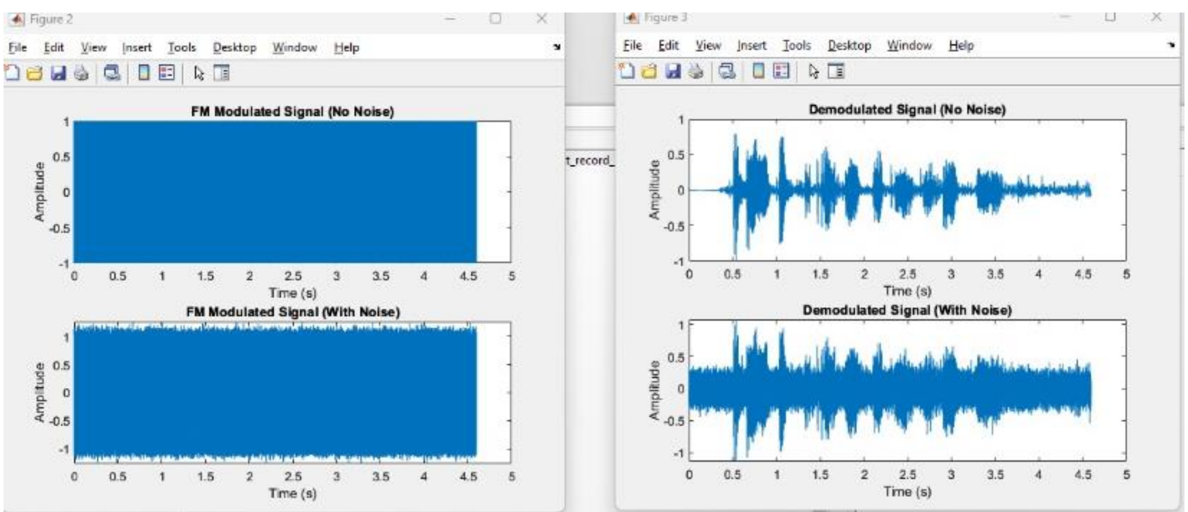

Figure 5 modulation and demodulation.

Figure 6 shows the RMSE with and without noise as they are very acceptable error values that gat the signal back with the least losses in its content.

```
>> Communications_Theory_Project_record_input
RMSE without noise: 0.0025855
RMSE with noise: 0.09914
```

Figure 6 RMSE with and without noise.

**The codes and the playing audio are attached.

LABVIEW Simulation

This schematic shown in figure7 is composed of the following blocks:

- Signal generation (Sine wave).
- Modulation.
- Spectral measurements.
- Waveform graphs.
- Demodulation.
- Playback.

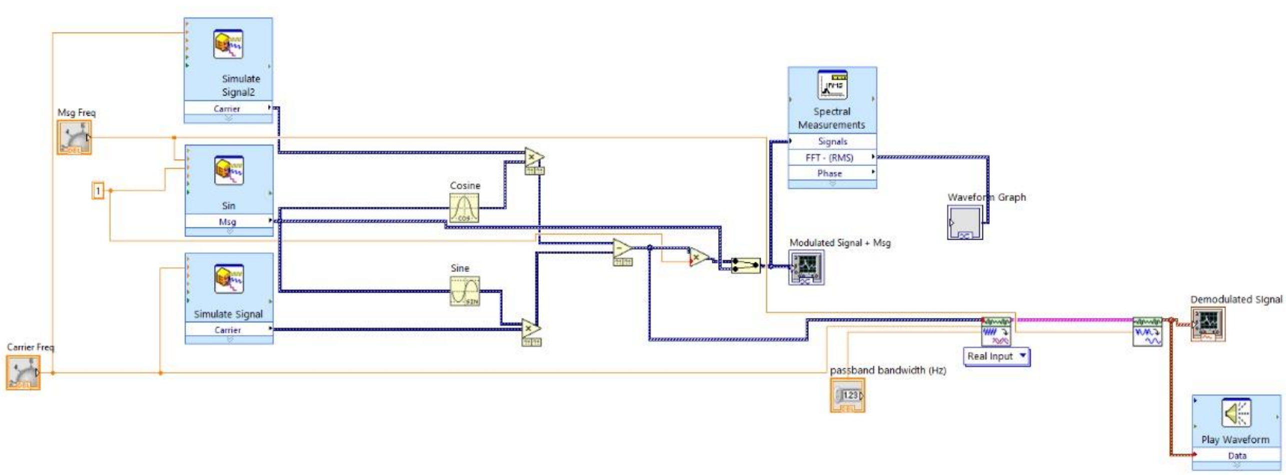

Figure 7 FM system in LABVIEW.

Plotting

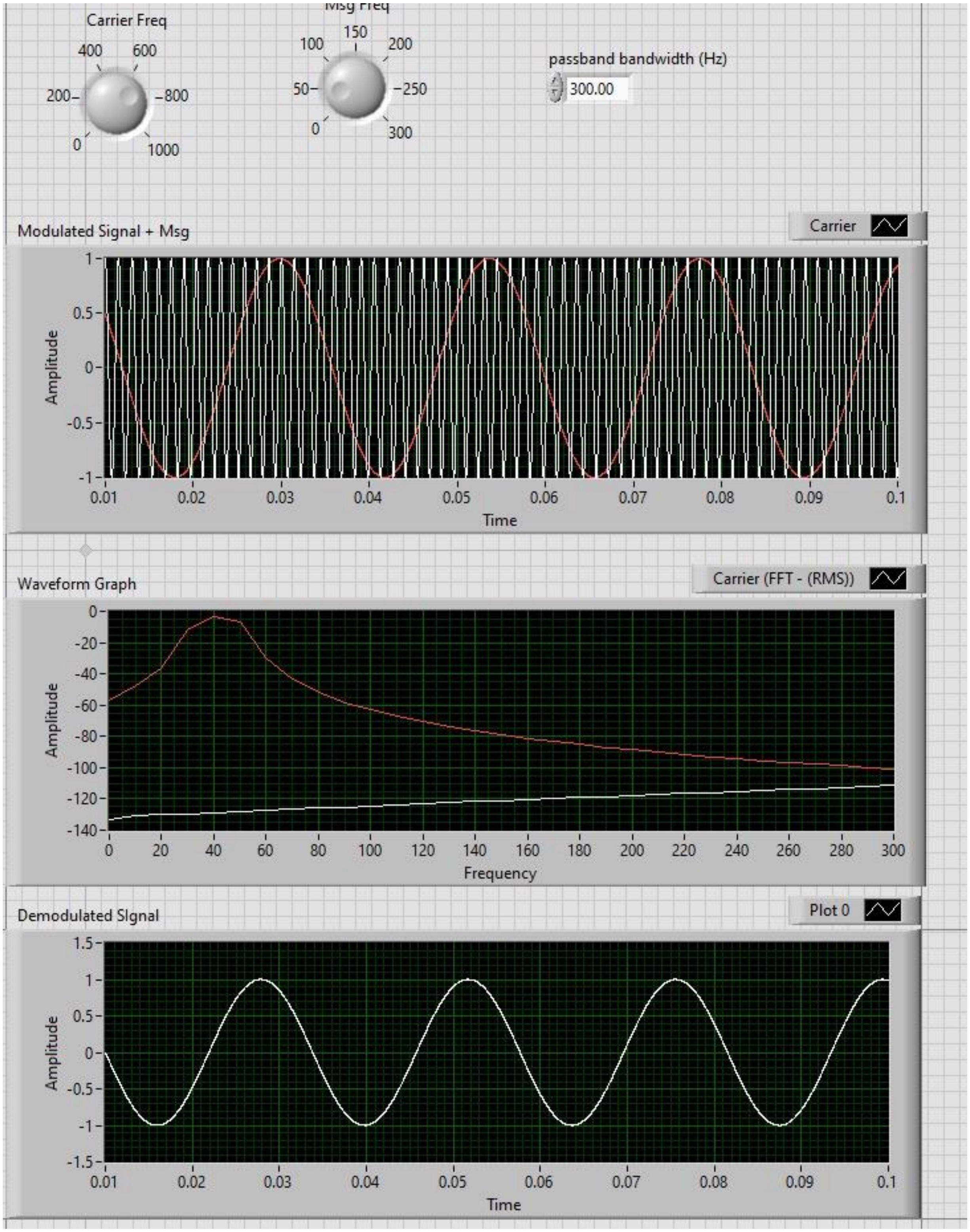

Figure 8 Modulation and Demodulation.

Each part of this system is crucial for the successful implementation of FM modulation and demodulation in a simulated environment. The system allows for testing and optimization of FM techniques without the need for physical hardware.

Applications

FM is used in radio broadcasting and telecommunications due to its clear voice transmission, better resistance to noise, and the ability to operate over long distances.

Also, it's used in medical applications as wireless assistive hearing devices that enhance the use of hearing aids, cochlear implants and assist people who are hard of hearing but do not wear hearing aids, in particular over distance and in noisy environments.

Conclusion

Frequency Modulation (FM) and demodulation are fundamental techniques in telecommunications and broadcasting. FM allows for high-quality audio transmission with reduced susceptibility to noise, while demodulation techniques like the phase-locked loop (PLL) enable the extraction of the original signal from the FM carrier. Understanding these principles is crucial for designing and implementing efficient communication systems.

References

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