CE387 – Final Lab Report

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# FM Radio Background and Theory

Frequency Modulation (FM) has played a groundbreaking role not only in audio broadcasting but also in fields such as telecommunications, radar systems, and medical imaging. The fundamental principle of FM—encoding information in frequency variations rather than amplitude—has made it an essential technology in modern communication. From enabling clearer radio transmissions to its application in two-way radios, satellite communications, and even MRI scanning in medical diagnostics, FM has profoundly influenced the way information is transmitted and received. The development of FM technology has revolutionized audio broadcasting, minimizing the noise and interference that plagued earlier amplitude-based systems, and laid the groundwork for many other communication technologies that shape our world today.

The origins of frequency modulation can be traced back to the early 20th century, with American electrical engineer Edwin Howard Armstrong making significant contributions to its development. In the 1920s and 1930s, Armstrong sought to improve radio transmission by reducing the static and interference issues inherent in Amplitude Modulation (AM). His transformative work and research led to the successful demonstration of FM radio, where he showcased its superior sound quality. Despite initial resistance from established AM broadcasters and regulatory hurdles, FM radio gained traction, and had widespread adoption in the 1940s.

The principles behind FM include how it operates within the Very High Frequency (VHF) range of the electromagnetic spectrum, specifically between 88 to 108 MHz for commercial radio broadcasting. In FM transmission, an audio signal modulates a high-frequency carrier wave by altering its frequency in direct proportion to the signal’s amplitude. This method allows FM to maintain a constant amplitude, reducing susceptibility to static and signal degradation.

The amount of frequency deviation in FM signals is controlled to ensure clarity and consistency. This deviation is directly linked to the amplitude of the audio signal; a higher amplitude corresponds to a greater frequency shift. This approach enables the transmission of stereo audio and additional subcarrier signals for supplementary data services, such as Radio Data System (RDS) functionality.

FM broadcasting relies on engineered transmission and reception processes. At a broadcasting station, the audio wave signal is encoded onto a carrier frequency. This is then amplified and transmitted via antennas. At the receiver (think FM radio) it captures the incoming signal through its antenna and processes it through several key stages. First, tuning and filtering take place, the receiver selects the desired station using a tuner finding the starting point. This is aided by a phase-locked loop (PLL) circuit for precise frequency control. A bandpass filter then isolates the intended signal while eliminating adjacent channel noise. Next demodulation takes place. The core function of an FM receiver is to extract the original audio signal from the modulated carrier wave. This is achieved using demodulators such as discriminators or PLL-based circuits, which convert frequency variations into corresponding voltage fluctuations, representing the audio waveform. Lastly, hearing the sound audio processing and output is needed. After demod, the signal undergoes low-pass filtering to remove high-frequency noise. The processed signal is then amplified and sent to speakers, converting electrical impulses into sound waves for human perception.

Beyond traditional radio broadcasting, FM has been instrumental in advancing numerous technological domains. Its noise-resistant properties make it ideal for two-way communication systems, including aviation, maritime, and military radio networks. In radar systems, FM is used for precise distance measurement and object detection. Moreover, Frequency Modulated Continuous Wave (FMCW) radar technology plays a vital role in automotive applications, such as adaptive cruise control and collision avoidance systems.

The invention and evolution of Frequency Modulation have greatly shaped the world, enhancing the quality and reliability of communication systems. FM's impact extends far beyond radio broadcasting, permeating fields such as defense, healthcare, and transportation. Its development by Edwin Armstrong marked a pivotal moment in technological history, proving that innovation in signal processing could revolutionize how we transmit and receive information. Today, FM remains a cornerstone of wireless communication, continuing to adapt and integrate into emerging technologies that define the modern age.

# System Architecture

Our system architecture is based on the top-level design presented in class and elaborated on by the C++ source code. See below for a top-level architecture comparison.

A diagram of a multi-tasking process

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In Class Top Level Architecture Design

A computer screen shot of a computer program

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Our Top-Level Architecture

Our design includes the use of FIFOs to separate the main components and ensure a proper streaming architecture.

# Design Process

# Optimizations

# Simulation and Performance

# Synthesis Results

A close-up of a document

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First Attempt Worst Slack Starting Points

A screenshot of a computer program

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First Attempt Worst Path Analysis Overview