Communications Engineering Project

FM Stereo System

Project Overview

Design and implement a complete FM stereo broadcasting system. You will explore how different design parameters affect system performance through experimentation.

System Description

Transmitter: Stereo multiplexer (L+R baseband, 19 kHz pilot, L-R on 38 kHz) → Pre-emphasis → FM modulator

The (L-R) signal is DSB-SC modulated onto a 38 kHz subcarrier.

Receiver: FM demodulator → De-emphasis → Stereo decoder → L and R recovery

Your Task

Build a working FM stereo system using MATLAB or any other programming language and answer the questions below.

Requirements:

Audio: Use a 5-10 second stereo WAV file (your choice)

Composite signal bandwidth: 0-53 kHz

1. Frequency Deviation Effects

Implement your system with three different frequency deviations: Δf = 50 kHz, 75 kHz, and 100 kHz.

For each deviation:

i. Measure FM signal bandwidth (99% power)
ii. Calculate theoretical bandwidth using Carson's rule
iii. Measure output SNR when input SNR = 25 dB

Questions:

a) Create a table comparing theoretical vs. measured bandwidth for all three deviations

b) Plot: Δf (x-axis) vs. output SNR (y-axis)

c) Explain: What trade-off do you observe between bandwidth and SNR? Which deviation would you choose and why?

2. Noise Immunity Analysis

Fix your frequency deviation at 75 kHz. Add AWGN to the FM signal at five different input SNR levels: 5, 10, 15, 20, 25 dB.

For each input SNR:

i. Measure output SNR
ii. Measure channel separation (L→R and R→L)
iii. Measure THD (Total Harmonic Distortion)

Questions:

a) Plot: Input SNR (x-axis) vs. Output SNR (y-axis).

b) Plot: Input SNR (x-axis) vs. Channel Separation (y-axis)

c) Identify the "threshold SNR" where system performance degrades rapidly. What causes this threshold effect?

3. Channel Separation Analysis

Inject a 1 kHz tone only in the Left channel (Right = silence).

Questions:

a) Measure the separation: Separation_dB = $20 \times \log_{10}$ (|L_recovered| / |R_recovered|)

b) Identify which component in your system limits the separation (pilot extraction filter? synchronous demodulator? something else?)

c) Propose one specific modification to improve separation and estimate the expected improvement

4. Filter Design Impact

Your pilot extraction filter is critical for separation. Test three different filter orders for your pilot extraction bandpass filter (e.g., orders 4, 8, 12).

Questions:

a) Measure channel separation for each filter order

b) Plot filter frequency responses (all three on same plot)

c) Explain: Is higher order always better? What's the trade-off?

5. System Robustness Test

Real oscillators have frequency errors. Shift your pilot tone frequency within the range from -500 Hz to +500 Hz.

Questions**:**

a) Measure channel separation for each pilot frequency

b) Plot recovered audio spectrum for +500 Hz. What do you observe?

c) How much pilot frequency error can your system tolerate before separation drops below 20 dB?

Deliverables:

1. An **uncompressed pdf** project report containing:
    a. Explanation of your work.
    b. All the required results and answers to questions.
    c. All the required figures. Label your figures properly.
    d. All the codes, included at the end.
2. All the code and audio files as uncompressed separate files.

Instructions:

- **Team Size:** You may work individually or in teams of 2 members maximum.
- **Academic Integrity:** Any evidence of copying (from other teams, internet, …) will result in **zero grade** for all involved teams. All work must be your own.
- **Artificial Intelligence:** The use of AI tools is **strictly prohibited** for any part of this project.
- The code given in the report should be given as text, not as screenshots.
- You should cite any references or webpages that you use.

Due date: December 25, 2025, at 11:59 PM.