EEEN 462 – ANALOGUE COMMUNICATION

FM BROADCASTING – STUDY GUIDE

I. FUNDAMENTAL CONCEPTS

1. **Definition of FM:**
   - Frequency Modulation: Carrier frequency (f_c) varies proportionally to the amplitude of the modulating signal (m(t).
   - **Equation:**

$$s_{\text{FM}}(t) = A_c \cos\left(2\pi f_c t + 2\pi k_f \int_0^t m(\tau)d\tau\right)$$

     - A_c: Carrier amplitude,
     - k_f: Frequency sensitivity (Hz/volt).

2. **Modulation Index (β):**
   - $\beta = \frac{\Delta f}{f_m}$
     - Δf: Peak frequency deviation (Hz),
     - f_m: Modulating signal frequency (Hz).
   - **Significance:**
     - β<1: Narrowband FM (NBFM),
     - β>1: Wideband FM (WBFM).

3. **Carson's Bandwidth Rule:**
   - Approximate RF bandwidth: $B \approx 2(\Delta f + f_m) = 2(\beta + 1)f_m$
   - **FM Broadcast Standard:**

     Δf=75 kHz (mono)

     f_m=15 kHz

B≈2(75+15)=180 kHz

II. FM BROADCASTING SYSTEM

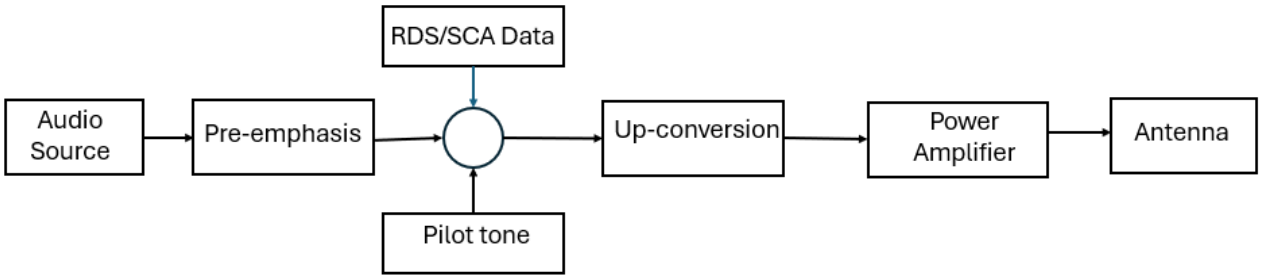

Figure 1. Block diagram of FM broadcasting system

1. **Pre-Emphasis & De-Emphasis:**
    - **Pre-Emphasis:** Boost high frequencies at transmitter
    - **De-Emphasis:** Attenuate high frequencies at receiver
    - **Purpose:** Reduce high-frequency noise (triangular noise spectrum).
2. **Stereo Multiplexing (MPX):**
    - **Composite Signal:**

$$m_{\text{MPX}}(t) = \underbrace{(L+R)}_{\text{Mono}} + \underbrace{(L-R)\cos(2\pi f_p t)}_{\text{DSB-SC}} + \underbrace{K\cos(\pi f_p t)}_{\text{Pilot}}$$

        - L,R: Left/Right audio channels,
        - f_p=19 kHz: Pilot tone,
        - DSB-SC subcarrier at kHz (suppressed carrier).
    - **Pilot Tone:** Synchronizes receiver's stereo decoder.
    - **Frequency spectrum:**
        - **Mono signal (0-15KHz)** serves mono receivers (backward compatibility)
        - **Stereo pilot (19 KHz)** is transmitted to:
            1. Notify the receiver that the transmission is stereo.

2. enable the receiver to reconstruct 38KHz which it uses to demodulate the stereo signal .

- **Radio Data Service (RDS)** transmits the Time and program details in digital form. Uses the frequency band 57±2KHz.

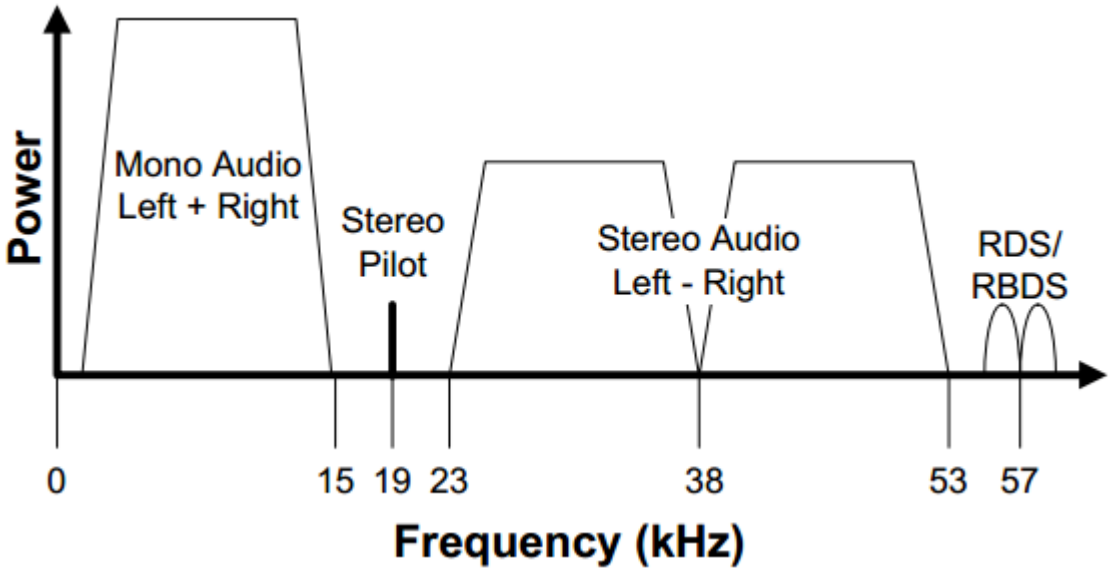

Figure2. Frequency spectrum of baseband FM signal

3. **Subsidiary Communications Authorization (SCA) & RDS:**
    - **SCA:** Subsidiary channels (e.g., background music) modulated at subcarriers (e.g., 67 kHz, 92 kHz).
    - **RDS (Radio Data System):** Digital data at 57 kHz57 kHz subcarrier (contains station ID, song info, traffic alerts).

3. FM TRANSMITTERS & RECEIVERS

3.1 Transmitter Block Diagram:

`Audio Input → Pre-Emphasis → Stereo Encoder → FM Modulator → Frequency Multipliers → Power Amplifier → Antenna`

- **Frequency Multiplication:** Increases Δf and fc simultaneously (e.g., ×72×72 for 75 kHz deviation).

2. **Receiver Block Diagram (Superheterodyne):**

`Antenna → RF Amp → Mixer → IF Amp → Limiter → FM Discriminator → De-Emphasis → Audio Amp → Speakers`

IF Frequency: 10.7 MHz (universal standard).

- **Limiter:** Removes amplitude noise (FM is amplitude-invariant).

3.2 FM Detection Methods:

- **Slope Detector:** Simple but distorted.
- **Foster-Seeley Discriminator:** Balanced slope detector.
- **Ratio Detector:** Insensitive to amplitude variations.
- **PLL Demodulator:** High fidelity, common in modern ICs.
- **Quadrature Detector:** Digital/analog implementations.

4. PERFORMANCE & ADVANTAGES

1. **Noise Immunity:**
   - **Capture Effect:** Stronger signal suppresses weaker co-channel signals.
   - **SNR Improvement:**

$$\text{SNR}_{\text{out}} = 3\beta^2(\beta + 1)\text{SNR}_{\text{in}} \text{ (for } \beta \gg 1\text{)}.$$

2. **Comparison with AM:**

Parameter	AM	FM
Bandwidth	2fm (10–30 kHz)	180–200 kHz
Noise Immunity	Poor	Excellent (capture)
Fidelity	Moderate	High (WBFM)
Transmitter Power	Inefficient (carrier)	Efficient (constant envelope)

3. **Trade-offs:**
   - **Bandwidth vs. Quality:** Higher $\beta\beta$ → better SNR but larger bandwidth.
   - **Threshold Effect:** SNR < 12 dB causes "cliff effect" (abrupt audio loss).

5. STANDARDS & REGULATIONS (ITU)

1. **Frequency Band:** 88–108 MHz (VHF Band II).
2. **Channel Spacing:** 200 kHz (ensures no overlap after modulation).
3. **Maximum Deviation:** ±75 kHz (mono), ±67.5 kHz (stereo pilot).
4. **Pilot Tone:** 19 kHz ± 2 Hz (for stereo synchronization).
5. **RDS Data Rate:** 1.1875 kbps (BPSK at 57 kHz subcarrier).

6. KEY FORMULAS & CALCULATIONS

1. Peak Deviation: $\Delta f = k_f \cdot |m(t)|_{\max}$
2. Modulation Index: $\beta = \frac{\Delta f}{f_m}$
3. Carson's Bandwidth: $B \approx 2(\Delta f + f_m)$
4. SNR Improvement: $\frac{S_o}{N_o} = 3\beta^2(\beta + 1)\frac{S_i}{N_i}$
5. Frequency Multiplier: $f_{\text{out}} = n \cdot f_{\text{in}}$, $\Delta f_{\text{out}} = n \cdot \Delta f_{\text{in}}$

7. SELF-ASSESSMENT QUESTIONS

1. Why is pre-emphasis used? Explain with a frequency response plot.
2. Derive the expression for an FM wave with a sinusoidal modulating signal.
3. How does a Foster-Seeley discriminator convert frequency to amplitude?
4. Calculate the bandwidth for Δf=75 kHz, f_m=15 kHz using Carson's rule.
5. Why does FM exhibit a "capture effect"?
6. Sketch the spectrum of a stereo FM signal labelling all components.

Last updated: Friday, 27 June 2025