EEEN 462 – ANALOGUE COMMUNICATION

ANALOGUE RADIO TRANSMITTERS - STUDY GUIDE/REVISION

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1. INTRODUCTION TO ANALOG RADIO TRANSMITTERS

- **Purpose:** Convert audio/data signals into electromagnetic waves for wireless transmission.
- **Key Applications:** AM/FM broadcasting, two-way radios (CB, aviation), emergency communication.
- **Core Principle:** Use **modulation** to imprint baseband signals onto high-frequency carriers.
- **Frequency Bands:**
    - **AM:** 530–1700 kHz (Medium Frequency)
    - **FM:** 88–108 MHz (Very High Frequency)

2. FUNDAMENTAL COMPONENTS

1. **Oscillator:**
    - Generates the **carrier wave** (e.g., 100 MHz for FM).
    - Crystal oscillators ensure frequency stability (±0.002%).
2. **Modulator:**
    - Alters carrier properties based on input signal:
        - **AM:** Varies carrier **amplitude** (e.g., ±50% modulation depth).
        - **FM:** Varies carrier **frequency** (e.g., ±75 kHz deviation).
3. **Amplifier Stages:**
    - **Pre-amplifier:** Boosts low-level audio signals.
    - **RF Power Amplifier (PA):** Increases modulated signal power (e.g., 1 kW for radio stations).
4. **Impedance Matching Network:**
    - Maximizes power transfer to the antenna (e.g., 50 Ω coaxial cable).
5. **Antenna:**
    - Radiates RF energy (e.g., dipole for FM, tower radiators for AM).

3. MODULATION TECHNIQUES

1. **Amplitude Modulation (AM):**
    - **Equation**

m = Modulation index ($0 \leq m \leq 1$), f_m = audio frequency, f_c = carrier frequency.

    - **Bandwidth:** $2 \times f_{m(max)}$ (e.g., 10 kHz for audio up to 5 kHz).
    - **Pros:** Simple circuitry, long-range propagation (ground/sky waves).
    - **Cons:** Susceptible to noise, inefficient power usage.
2. **Frequency Modulation (FM)**
    - **Equation**

$$s(t) = A_c \cos\left[2\pi f_c t + \beta \sin(2\pi f_m t)\right]$$

β = Modulation index (Δf/fm), Δf = frequency deviation.

    - **Bandwidth (Carson's Rule):**

2(Δf+fm(max)) (e.g., 200 kHz for commercial FM).

    - **Pros:** Noise immunity, constant amplitude (efficient PA use).
    - **Cons:** Larger bandwidth, line-of-sight propagation limits.

4. TRANSMITTER ARCHITECTURES

1. **Low-Level Modulation:**
    - Modulate at low power → amplify modulated signal.
    - Used in **FM** due to constant envelope (nonlinear PAs acceptable).

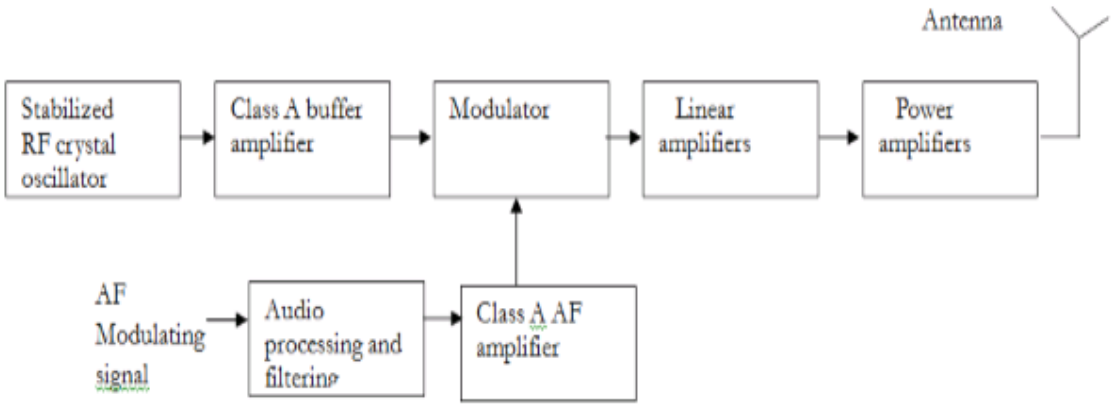

Figure 1. Low-level Modulator

2. **High-Level Modulation:**
    - Amplify carrier first → modulate at Power Amplifier (PA) stage.
    - Used in **AM** for efficiency (requires linear PA). Used in analogue TV transmitters.

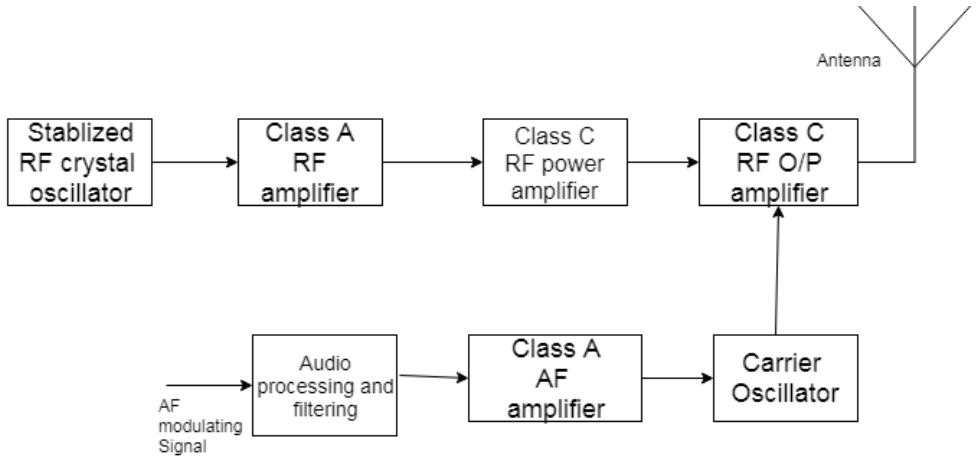

Figure 2. High-level Modulator

3. **Class C Amplifier:**
    - High-efficiency (~80%) PA for FM transmitters.
    - Operates in nonlinear mode (conducts <180° of cycle).

5. KEY PERFORMANCE METRICS

1. **Output Power:**
    - Measured in **dBW** or **dBm** (e.g., 10 kW AM station = 70 dBm).
    - Impacts coverage area.
2. **Efficiency:**
    - $$\text{Efficiency} = \frac{\text{RF Output Power}}{\text{DC Input Power}} \times 100\%$$
    - FM transmitters: 70–80%; AM transmitters: 30–50%.
3. **Frequency Stability:**
    - Drift tolerance (e.g., ±20 ppm for FM).
4. **Harmonic Distortion:**
    - Must be <1% (CA regulations) to avoid interference.

6. DESIGN CHALLENGES & SOLUTIONS

1. **Challenge: Nonlinear Distortion (AM)**
    - **Solution:** Class A/B PAs for linearity.
2. **Challenge: Frequency Drift**
    - **Solution:** Phase-Locked Loops (PLLs) for stable carriers.
3. **Challenge: Spurious Emissions**
    - **Solution:** Output filters (e.g., bandpass filters at PA stage).

4. **Challenge: Thermal Management**
    - **Solution:** Heat sinks, forced-air cooling for high-power PAs.

7. EXAMPLE SYSTEMS

1. **AM Broadcast Transmitter:**
    - Audio input → Pre-emphasis → High-level AM modulator → Class B PA → Antenna.
2. **FM Stereo Transmitter:**
    - Stereo encoder → Pre-emphasis → VCO modulator → Class C PA → Antenna.
    - **Pilot tone:** 19 kHz for stereo synchronization.

8. PRACTICAL CONSIDERATIONS

1. **Regulatory Compliance:**
    - CA/ITU standards for power, bandwidth, and spectral purity.
2. **Antenna Matching:**
    - VSWR <1.5:1 to minimize reflected power.
3. **Testing Instruments:**
    - Spectrum analyzer (modulation depth, harmonics), RF power meter.

9. PRACTICE PROBLEMS

1. An AM transmitter operates at 1 MHz with 80% modulation. Calculate bandwidth for a 4 kHz audio signal.
2. An FM transmitter has a carrier frequency of 98.5 MHz and frequency deviation of 75 kHz. For a 15 kHz audio tone, compute modulation index (ββ) and bandwidth.
3. A 5 kW FM transmitter is 75% efficient. What is its DC input power?
4. Calculate the wavelength for a 100 MHz FM signal and design a quarter-wave monopole antenna.