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قسم هندسة تقنيات الاجهزة الطبية
College of Technnical Engineering

Medical Communication System

نظم اتصالات طبية

FM modulation

Third Stage

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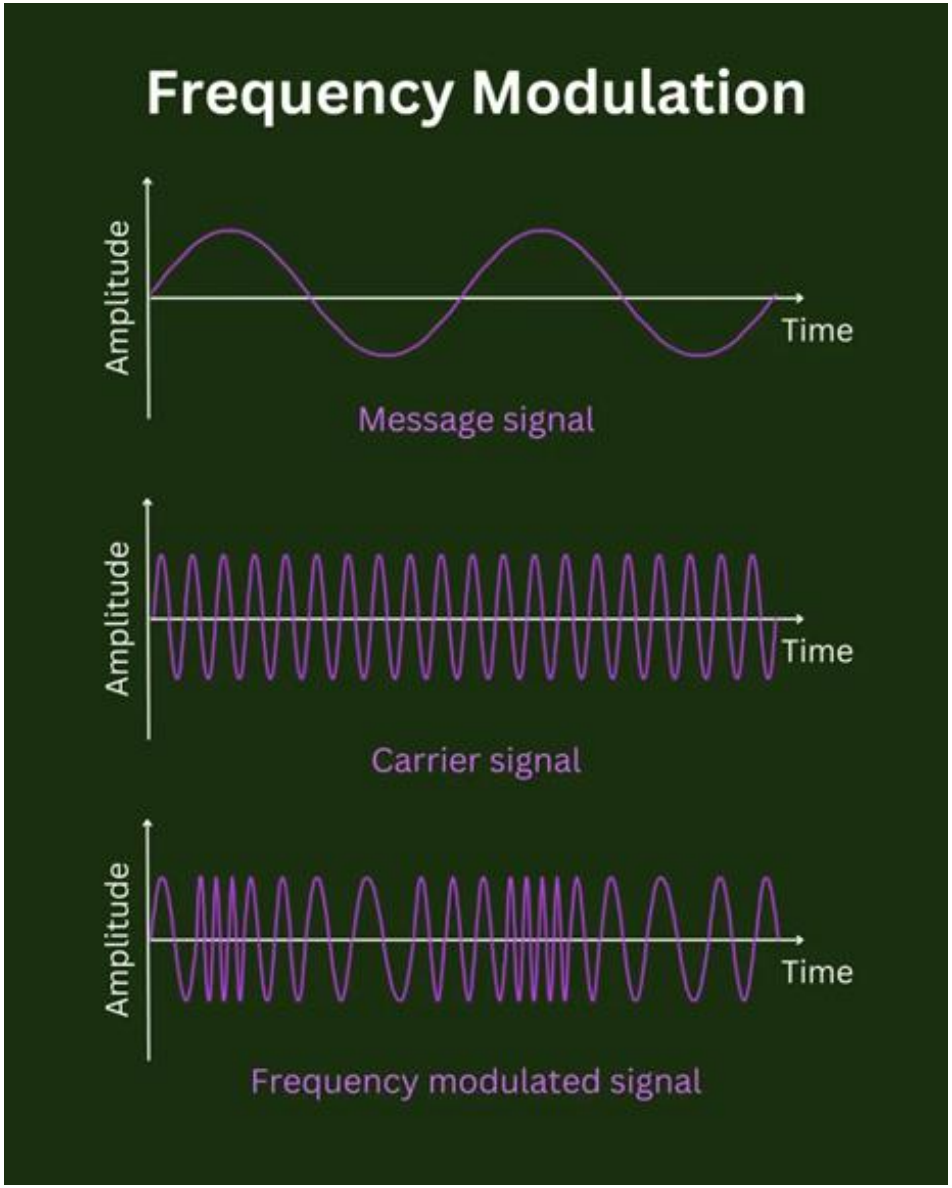
Frequency Modulation (FM)

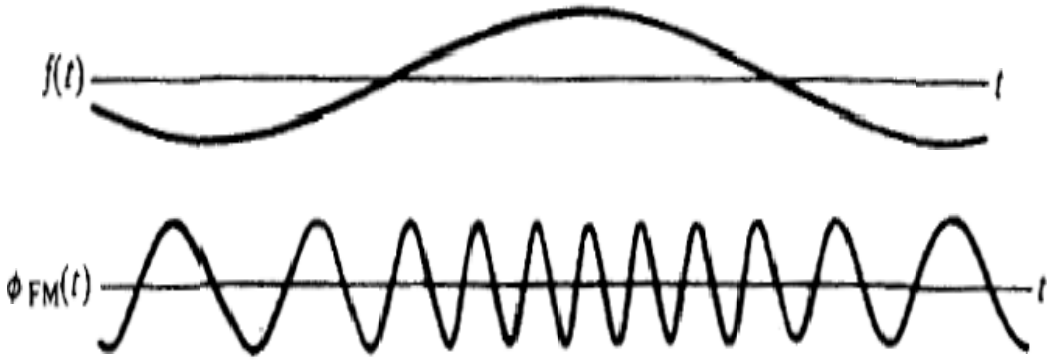
Frequency Modulation (FM) is a method of modulating a carrier signal in which the frequency of the carrier wave is varied in accordance with the amplitude of the message (modulating) signal, while the amplitude of the carrier wave remains constant. This modulation technique is widely used in telecommunications, audio broadcasting (FM radio), and many communication systems due to its resilience to noise and interference.

Frequency Modulation (FM)



Principle of Operation

In FM, the instantaneous frequency of the carrier wave is directly proportional to the amplitude of the modulating signal. This means that when the input signal has a higher amplitude, the frequency deviation increases, and when the amplitude is lower, the deviation decreases.



Key Features of FM

1. **Better Noise Immunity:** FM signals are less susceptible to noise and interference compared to AM signals.
2. **Constant Amplitude:** Since only the frequency is modulated, FM signals maintain a consistent amplitude, reducing power fluctuations.
3. **Wider Bandwidth** : FM requires a larger bandwidth compared to AM, typically twice the sum of the maximum modulating frequency and the peak frequency deviation (Carson's rule).
4. **Improved Sound Quality :** Used in FM radio broadcasting (88–108 MHz), it provides superior audio quality compared to AM.
5. **Capture Effect :** When multiple FM signals are present, the strongest signal dominates, reducing interference.

Applications of FM:

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1. **Radio Broadcasting (FM Radio) :** Provides high-fidelity audio transmission.
2. **Television Sound Transmission :** Used in analog TV audio transmission.
3. **Two-Way Radio Communication :** Found in police radios, aviation, and marine communication.
4. **Wireless Communication :** Used in certain digital wireless systems.

Comparison Between AM and FM

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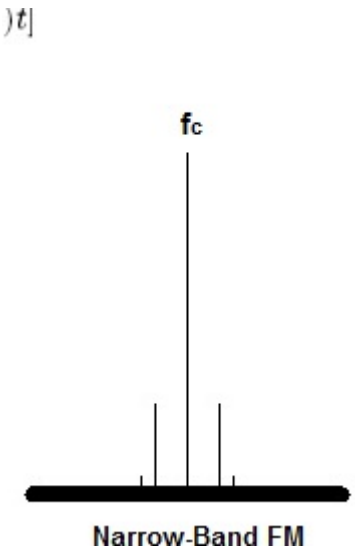
Feature	AM (Amplitude Modulation)	FM (Frequency Modulation)
Parameter Varied	Amplitude	Frequency
Bandwidth	Narrow (10 kHz for AM radio)	Wide (200 kHz for FM radio)
Noise Immunity	Low	High
Power Consumption	Lower	Higher
Audio Quality	Lower fidelity	Higher fidelity
Interference Resistance	Susceptible to amplitude noise	Less affected by noise

Main Parts of Communication Systems

Narrowband Frequency Modulation (NBFM) refers to a type of frequency modulation (FM) where the frequency deviation is small compared to the modulation frequency. In NBFM, the modulation index (β) is much less than 1, typically around 0.1 to 1.



Key Characteristics of NBFM:

- **Narrow Bandwidth:** Uses a smaller bandwidth compared to wideband FM (WBFM), making it more bandwidth-efficient.
- **Low Frequency Deviation:** The frequency deviation (Δf) is minimal, usually in the range of a few kHz.
- **Fewer Sidebands:** Since the modulation index is low, only a few significant sidebands are generated, reducing spectral occupancy.
- **Better Noise Performance than AM:** NBFM offers improved noise immunity compared to Amplitude Modulation (AM), though not as much as WBFM.

Transmission Bandwidth of FM signals

1. For Narrowband FM the modulation index ($Q < 0.2$) therefore the bandwidth is:

$$B.W = 2f_m$$

2. For Wideband FM the modulation index (Q is large) therefore the bandwidth is:

$$B.W = 2\Delta f \quad \text{for } Q \geq 100$$

Where:- $\Delta f = K_f A_m$

$$B.W = 2(1+\beta)f_m \text{ Carson's rule}$$

Where β: between small and large value.

Example 1

A 10 MHz carrier is frequency-modulated by a sinusoidal signal such that the peak frequency deviation is 50 kHz. Determine the approximate bandwidth of the FM signal if the frequency of the modulating sinusoid is:

(a) 500 kHz (b) 500 Hz (c) 10 kHz

$a)\ \beta = \frac{\Delta f}{f_m} = \frac{50}{500} = 0.10$

This is a narrowband FM signal;

$$B \approx 2f_m = 1\ MH_z$$

b) $\beta = 100$ this is the wideband case and

B $\approx 2\Delta f = 100KH_z$ (Carson's rule gives 101 kHz)

c) $\beta = 5$; use of Carson's rule gives

$$B \approx 2(\Delta f + f_{\mathrm{m}}) = 2(50 + 10) = 120\ kHz$$

Thank You
Q & A

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