Communication Fundamentals

FM Modulation

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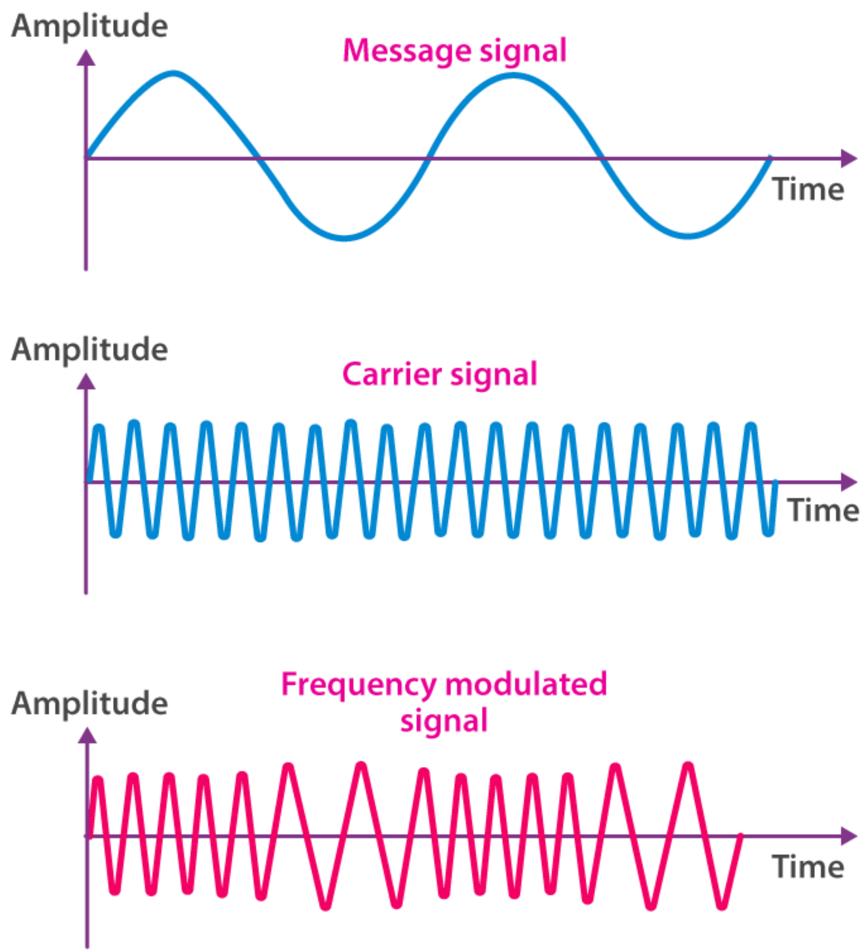
Content

- Define the FM.
- Explain the FM Spectrum.
- Explain the FM bandwidth calculation.
- Compare between AM & FM
- Explain FM Generation
- Explain the FM detection.

Frequency Modulation (FM)

1. Why we develop Frequency Modulation FM?

In order to reduce the noise effect on the AM required signal, because noise is AM unwanted signal.



Frequency Modulation (FM)

2. Frequency Modulation (FM) Process

The carrier frequency is modulated (varying) by the modulating signal (information Vm), while amplitude keep fixed.

$$v_c = A\sin(2\pi f_c t)$$
$$v_m = B\sin(2\pi f_m t)$$

After modulation, f_c is changed, to f_{FM}

$$f_{FM} = f_c + \Delta f \sin(2\pi f_m t)$$
$$V_{FM} = A\sin[2\pi(f_c + \Delta f \sin(2\pi f_m t))t]$$

Where Δf called frequency deviation

Frequency Modulation (FM)

3.Frequency Deviation : It represents the maximum change in frequency of the modulated wave.

4.Carrier Swing :The total variation in frequency from the lowest to highest.

$\therefore$ For sine wave used as modulating signal

If $\Delta f = \textit{frequency deviation}$,, $\therefore$ $\textit{carrier swing} = 2\,\Delta f$

So we can write V_{FM} as : $V_{FM} = A\sin\left(2\pi f_c t + \frac{\Delta f}{f_m}\cos(2\pi f_m t)\right)$

Where $\frac{\Delta f}{f_m}$ is the modulation index m_f

Frequency Modulation (FM)

Note: FM broad-cast band from 88 MHz-108 MHz and maximum Δf is 75 KHz, Δf is 25 KHz for audio part of TV signal, fm (max)=15KHz.

5. Present Modulation

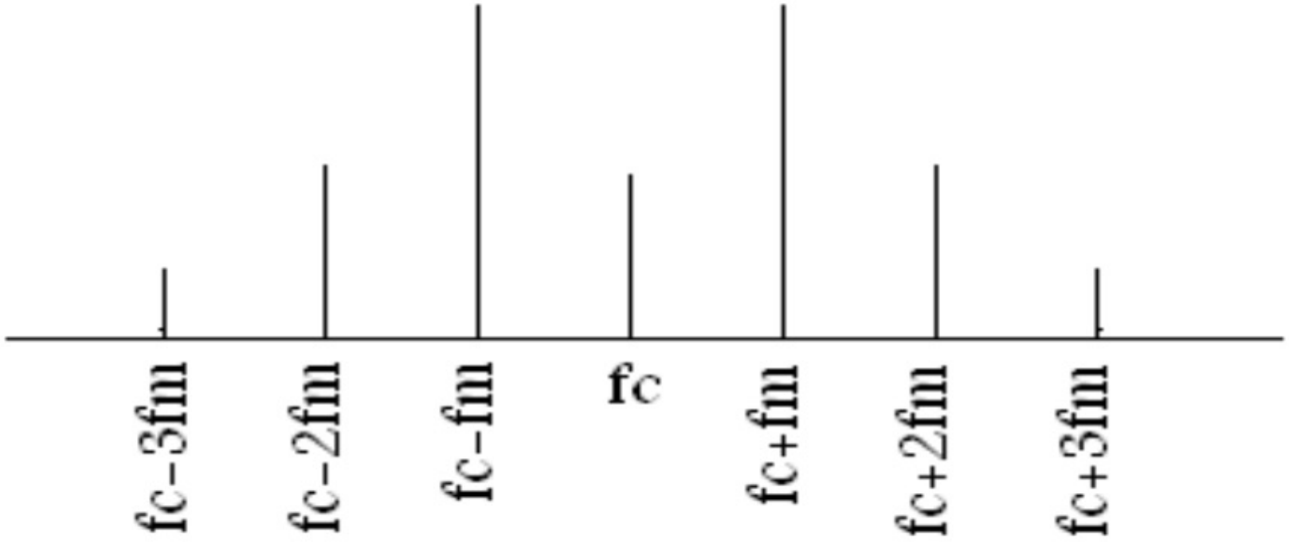
It is the ratio of actual frequency deviation to maximum allowable frequency deviation.

$$M = \frac{\Delta f_{actual}}{\Delta f_{\max}} \times 100$$

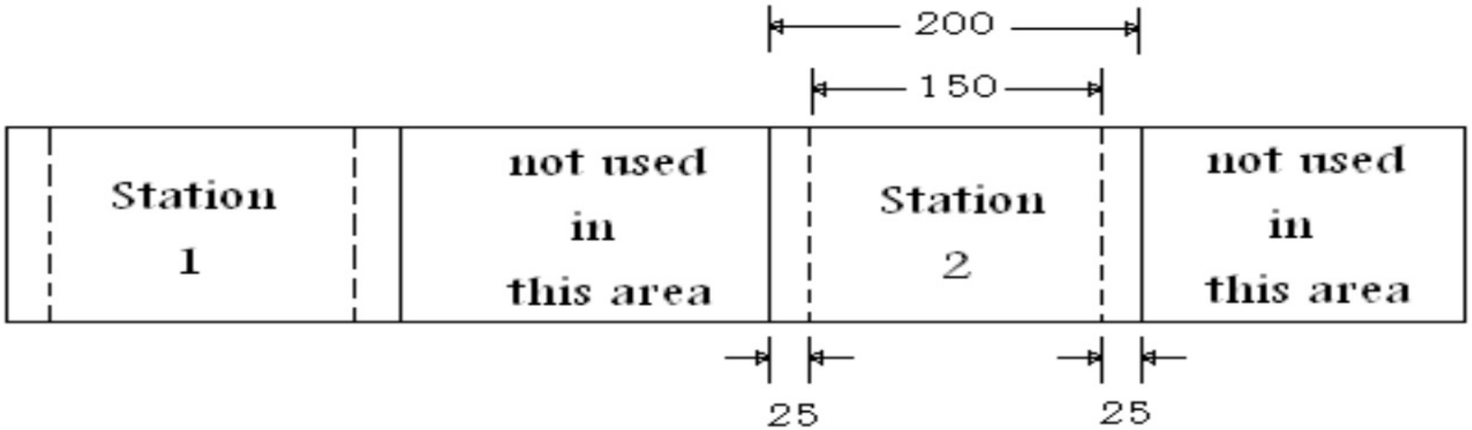
Frequency Modulation (FM)

6. FM Spectrum

FM as in figure below has many side bands, but not all of them have significant power. Number of sidebands (BW of FM) depends on modulation index m_f.



Frequency Modulation (FM)



The figure above shows the distribution of stations using FM

Frequency Modulation (FM)

7. FM Channel Bandwidth

$$BW_{FM} = (2\times\Delta f_{\max}) + (2\times gaurd\ band)$$
$$= (2\times 75) + (2\times 50) = 200 \quad KHz$$

1. large BW
2. Not all stations are used in the same area.
3. Reception is limited to distances only slightly farther than the horizon.

Types of Bandwidth in FM

According to value of m_f (modulation index) we have two types of FM BW

1. Narrow band FM:

$$BW = 2 f_m \quad , \quad for \quad m_f < \frac{\pi}{2}$$

∴ N.B FM BW = AM BW\

2. Wideband FM: if mf> π/2.

Notes that even the BW of AM and narrow band FM are equal, but we preferred to use FM, why?

Because in N.B FM the carrier power content reduce when increasing the modulation, that good, modulation signal has the information

EX1

A 107.6 MHz carrier is modulated by 7 KHz sin wave, the FM signal produced has frequency deviation of 50 KHz.

1. find the carrier Swing of the FM signal
2. What are the heights and the lowest modulated signal frequencies?
3. Modulation index.

Sol

$\therefore$ F_c =107.6 MHz, f_m=7 KHz, Δf =50 KHz

1. $S.C = 2\,\Delta f = 2\times 50 = 100\ KHz$

2. $f_H = f_c + \Delta f = 107.6\times 10^6 + 50\times 10^3 = 107650 \quad KHz$
   $f_L = f_c - \Delta f = 107.6\times 10^6 - 50\times 10^3 = 107550 \quad KHz$

3. $m_f = \dfrac{\Delta f}{f_m} = \dfrac{50\times 10^3}{7\times 10^3} = 7.143$

EX2

Determine Δf, C.S, f_L if f_c =105 MHz and f_H = 105.007 MHz

Sol

1. $f_H = f_c + \Delta f \quad \Rightarrow \quad \Delta f = f_H - f_c = 105.007 - 105 = 7 \quad KHz$
2. $C.S = 2 \times \Delta f = 2 \times 7 = 14 \quad KHz$
3. $f_L = f_c - \Delta f = 105 \times 10^3 - 7 = 104993 \quad KHz$

EX3

Find the modulation index if C.S =100 KHz and f_m = 8 KHz

Sol

$$\because \quad C.S = 2\Delta f \quad \Rightarrow \quad \Delta f = \frac{C.S}{2} = \frac{100}{2} = 50 \quad KHz$$

$$\therefore \quad m_f = \frac{\Delta f}{f_m} = \frac{50 \quad KHz}{8 \quad KHz} = 6.25$$

EX4

FM signal is modulated by 3 KHz sine wave reaches maximum frequency of 100.02 MHz and minimum frequency of 99.98 MHz, find: C.S, f_c, Δf, m_f.

Sol

1. C.S = $f_{max} - f_{min}$ =100.02 - 99.98 = 0.04 MHz =40 KHz.
2. carrier frequency is the midway between max & min frequency reached by FM wave

$$f_c = \frac{f_{\max} + f_{\min}}{2} = \frac{100.02 + 99.98}{2} = 100 \quad MHz$$

3. $$\Delta f = \frac{C.S}{2} = \frac{40\times10^3}{2} = 20 \quad KHz$$
4. $$m_f = \frac{\Delta f}{f_m} = \frac{20}{3} = 6.667\ KHz$$

FM Bandwidth Calculation from Bessel Function

<u>Note</u>

The number of important side-bands can be found from a known (Bessel table)

In general, from Bessel function; FM BW can be calculated as follows:

1. for $m_f < 1$ Narrowband FM

   $BW = 2\ f_m$

2. for $m_f > 20$ Wideband FM

   $BW = 2\ \Delta f$

3. for $1 < m_f < 20$ (approximatly)

   $BW = 2(\Delta f + f_m)$

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EX.5

10 MHz carrier frequency is modulated by a sine wave, to give frequency divation of 50 KHz, determine the approximate BW, if the modulating frequency is: 500 KHz, 500 Hz, 10 KHz

Sol

1. $\because \quad m_f = \dfrac{\Delta f}{f_m} = \dfrac{50\times10^3}{500\times10^3} = 0.1$

   $\therefore \quad BW = 2\, f_m = 2\times500\times10^3 = 1 \quad MHz$

2. $m_f = \dfrac{50\times10^3}{500} = 100$

   $BW = 2\,\Delta f = 2\times50 = 100 \quad KHz$

3. $m_f = \dfrac{50}{10} = 5$

   $BW = 2\left(\Delta f + f_m\right) = 2\left(50\times10^3 + 10\times10^3\right) = 120 \quad KHz$

Comparison between AM & FM

Similarities:

1.In both systems, a carrier wave is modulated by an audio signal to produce a carrier and sidebands, used in various communication systems, such as TV, Telephony.

2.Both systems are receivers based on the superheterodyne principle.

3.Special techniques like AGC can be used for both.

Comparison between AM & FM

Contrast

	AM		FM
1	Vary carrier amplitude	1	Vary carrier frequency
2	Has two sidebands, Narrow band systems	2	Large number of sidebands, wideband systems
3	Has lower S/N	3	Has better S/N
4	Difference in T_x & R_x	4	Differ in T_x & R_x
5	Simple and cheap	5	More complex and expensive

FM Generation

There are two types for circuits, used to generate FM signal:

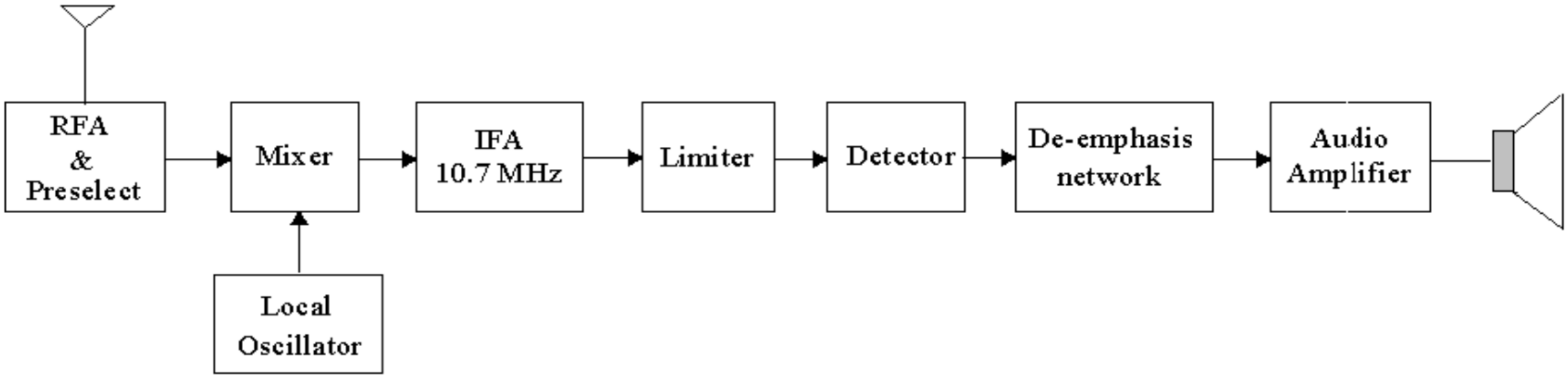
1. Direct Method:

In this method the carrier frequency is directly varied in accordance with the incoming message signal. In which the carrier frequency is varying by means of modulating signal, this can be done by using non-linear device such as a valve or transistor to vary the capacitance across the tuned circuit of an oscillator.

2. InDirect Method :

This method was first proposed by Armstrong. In this method the modulating wave is first used to produce a narrow-band FM wave, and frequency multiplication is next used to increase the frequency deviation to the desired level.To over come the problem of oscillator stability in the FM generation, of the direct method, we use to generate FM indirectly, using phase modulation (PM) (Armstrong system).

FM Receiver



Similar to AM super hetrodyne receiver, but it has 10.7 MHz IF frequency, this receiver differ from AM one in:

1. Demodulation ways
2. Limiter Block
3. De-emphasis block.

FM Receiver

Limiter

It's used to clip any unwanted AM variations that could be exist in this part of R_x. this clipping doesn't effect the information signal because it contained in frequency variations.

DE-emphasis Network

It represents the other half of the pre-emphasis that was in Transmitter, which used to amplify the higher content of the information (audio) signal more than the lower frequency information. The de-emphasis network will reduce the frequency by reducing the gain. This operation is made to reduce the FM noise from affecting the signal.

Detection of FM waves

To perform frequency demodulation we require 2-port device that produces an output signal with amplitude directly proportional to the instantaneous frequency of a FM wave used as the input signal.

Type of FM detectors:

a. Slope detector
b. Balanced Slope detector(Travis detector, Triple-tuned-discriminator)
c. Phase discriminator (Foster seeley discriminator or center-tuned discriminator)
d. Ratio detector
e. PLL demodulator and
f. Quadrature detector

FM Discriminator

It represents circuits that change the frequency variation to amplitude variation and detect it.

There are two types:

1. Foster- Seeley discriminator

   Advantage of Foster-seeley discriminator: Output voltage-vs-frequency deviation curve is more linear than that of a slope detector, is easier to tune.

   Disadvantage of Foster-seeley discriminator: a separate limiter circuit must precede it.

2. Ratio Detector

   Advantage of Ratio detector over Foster seeley discriminator: it is relatively immune to amplitude variations in its input signal.

Thank you …