Department of Communications Engineering

Communication Systems

Third Year Class

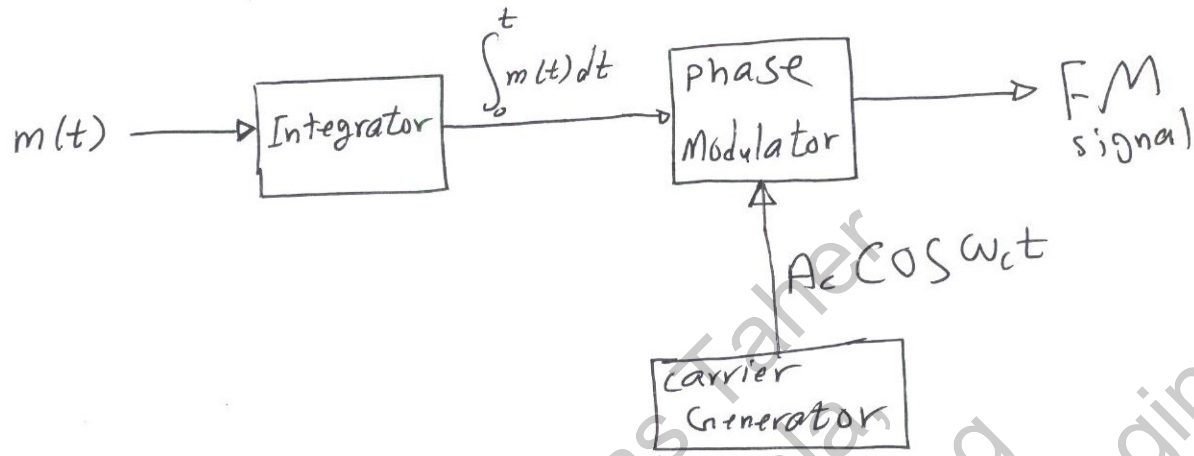
Dr. Montadar Abas Taher

montadar@ieee.org

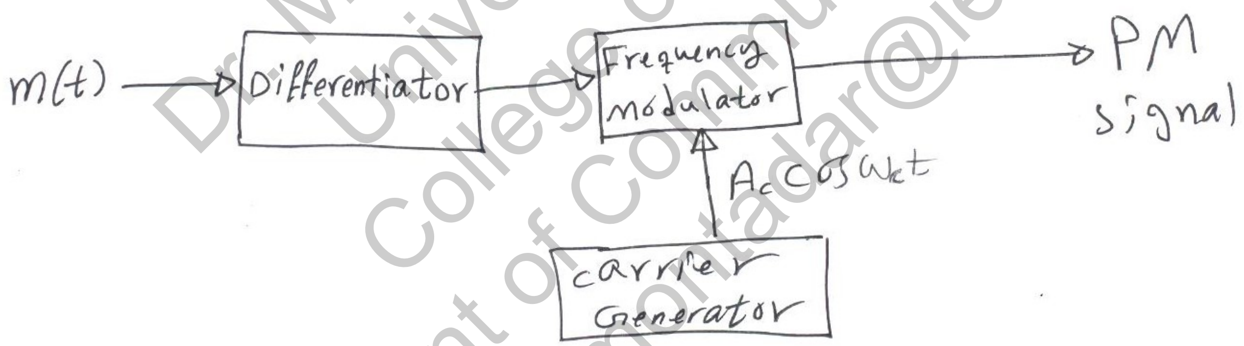
Lecture 6

FM and PM Generation, and Single Tone FM

Generating FM from PM



Generating PM from FM



Single Tone FM :

$$s(t)_{FM} = A_c \cos\left[\omega_c t + k_f \int_0^t m(t)\,dt\right]$$

Assuming the message signal is

$$m(t) = V_m \cos \omega_m t$$

$$\therefore \phi_i = \int \omega_i \, dt = \int \left[\omega_c + k_f V_m \cos \omega_m t\right] dt \longrightarrow (i)$$

But $\Delta\omega = |k_f\, m(t)|_{max} = k_f\, |m(t)|_{max}$

$$\therefore \Delta\omega = k_f V_m$$

$$\therefore \omega_i = \omega_c + \Delta\omega \cos \omega_m t$$

$$\therefore \phi_i = \int \left[\omega_c + \Delta\omega \cos \omega_m t\right] dt$$

$$= \omega_c t + \frac{\Delta\omega}{\omega_m} \sin \omega_m t$$

$\frac{\Delta\omega}{\omega_m} \rightarrow m_f$ = modulation index

$$= \omega_c t + m_f \sin \omega_m t$$

$$\therefore \boxed{S(t)_{FM} = A_c \cos\left[\omega_c t + m_f \sin \omega_m t\right]}$$

Single-Tone FM signal.

~~Third Year EXAM 2015/2016~~

~~31/1/2016~~

EX. 1 A single-tone FM is represented by the voltage equation as:

$$v(t) = 12\cos(6\times10^8 t + 5\sin 1250t)$$

Determine the following :-

(i) carrier frequency (ii) modulating frequency (iii) modulation index (iv) maximum deviation (v) what power will this FM wave dissipate in 10 Ω resistor?

solution :- The standard expression for a single-tone FM is

$$v(t) = A\cos(\omega_c t + m_f \sin\omega_m t)$$

we have given

$$v(t) = 12\cos(6\times10^8 t + 5\sin 1250t)$$

$\therefore \omega_c = 6\times10^8$ rad/sec.

(1) $\therefore f_c = 95.5$ MHz.

$\omega_m = 1250$ rad/sec

(2) $f_m = 199$ Hz

(3) $m_f = 5$

(4) $m_f = \frac{\Delta\omega}{\omega_m} = \frac{\Delta f}{f_m}$

$$\Delta f = m_f f_m = 995 \text{ Hz}$$

(5) The power dissipated is $P = \frac{V_{rms}^2}{R} = \frac{\left(\frac{12}{\sqrt{2}}\right)^2}{10} = \frac{72}{10} = 7.2$ W.

EX.2 A 107.6 MHz carrier signal is frequency modulated by a 7 KHz sine wave. The resultant F.M signal has a frequency deviation of 50 KHz. Determine the following:

(1) The carrier swing of the FM signal. (2) The highest & Lowest frequencies attained by the modulated signal. (3) modu. index of the FM wave.

Solution

$f_c = 107.6 \text{ MHz}$.

$f_m = 7 \text{ KHz}$.

$\Delta f = 50 \text{ KHz}$.

(1) Carrier swing $= 2 *$ frequency deviation $= 2 \times 50 = 100 \text{ KHz}$.

(2)

$$f_H = f_c + \Delta f = 107.6 \text{ MHz} + 50 \text{ KHz}$$

$$f_H = 107.65 \text{ MHz}$$

$$f_L = f_c - \Delta f = 107.6 \text{ MHz} - 50 \text{ KHz}$$

$$f_L = 107.55 \text{ MHz}$$

(3) Modulation index

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

EX.3 Determine Δf and carrier swing of FM signal which has a resting frequency of 105 MHz and upper frequency of 105.007 MHz. Also find the lowest frequency reached.

solution

$f_c = 105 \ MHz$

$f_H = 105.007 \ MHz$

$\Delta f = f_H - f_c = 105.007 - 105 = 7 \ kHz.$

carrier swing $= 2 \times \Delta f = 14 \ kHz.$

$f_L = f_c - \Delta f = 104.993 \ MHz.$

EX.4 what is m_f of FM signal of carrier swing = 100 kHz when the modulating signal has frequency = 8 kHz?

Solution

+ carrier swing = 100 kHz $= 2\Delta f \rightarrow \Delta f = 50 \ kHz$
+ $f_m = 8 \ kHz$

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

Technical Considerations for FM Stations :

* The amount of Δf depends on amplitude (loudness) of the message.

Louder sound ⟶ greater deviation

Lower Sound ⟶ Lower deviation

* But it is agreed internationally that maximum $\Delta f = 75$ kHz for FM broadcast stations and 25 kHz for TV sound.

* The commercial FM broadcasting in 88–108 MHz.
* Since maximum deviation is 75 kHz, hence the channel width is $75 \times 2 = 150$ kHz, allowing 25 kHz guardband on either sides, the channel width becomes 200 kHz.

* In FM, the highest audio frequency transmitted is 15 kHz.
* The percent modulation : in FM it refers to the ratio of actual frequency deviation $\Delta f_{actu.}$ to the maximum allowable frequency deviation. Thus, 100% modulation corresponds to 75 kHz in FM broadcast band OR 100% modulation corresponds to 25 kHz for TV sound.

Percent Modulation $M = \dfrac{\Delta f_{actual}}{\Delta f_{max}}$

Ex. 4 An FM transmission has a frequency deviation of 20 KHz.

① Determine the percent modulation of this signal if it is broadcasted in the 88-108 MHz band.

② calculate the percent modulation if this signal is broadcasted as the audio portion of a television broadcast.

Solution we have given $\Delta f = 20\ kHz$.

① percent modulation for an FM wave is

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

the maximum Δf in FM is 75 KHz

$$\therefore \quad M = \frac{20}{75} * 100\% = 26.67\%$$

② the maximum Δf for the FM audio portion of a TV broadcast is 25 KHz

$$\therefore \quad M = \frac{20 * 10^3}{25 * 10^3} * 100\%$$

$$M = 80\%$$