Department of Communications Engineering

Communication Systems

Third Year Class

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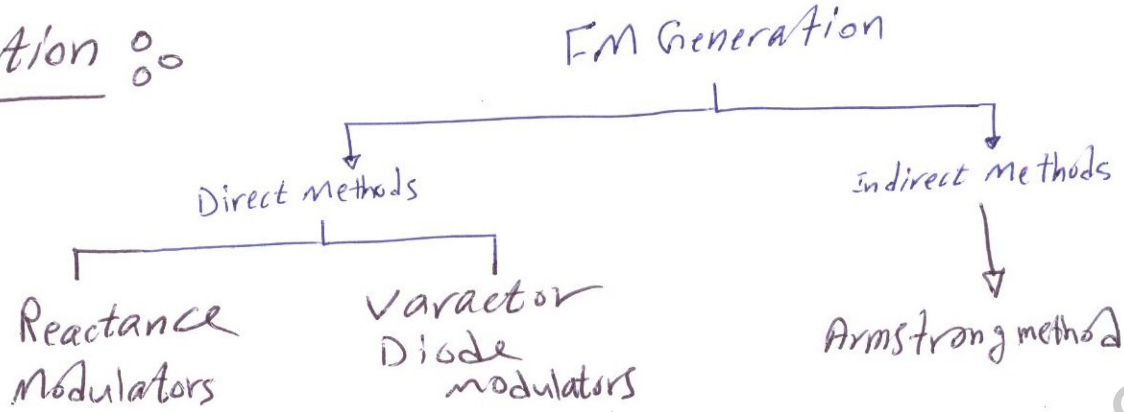
Lecture 9

FM Generation and Demodulation

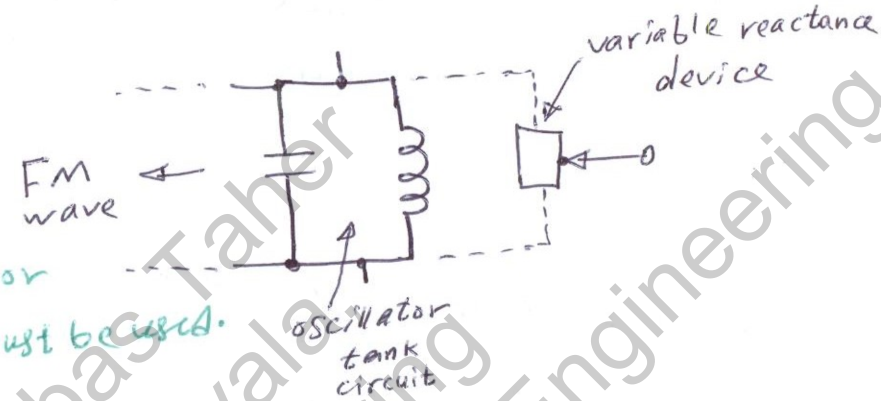
FM Generation :



* The direct method also called parameter variation method
* An LC parallel circuit oscillates the carrier frequency.
* The carrier frequency can be changed in accordance to the magnitude of the modulating signal $x(t)$.
* The circuit that changes the frequency according to the voltage is called voltage Controlled oscillator (VCO).
* The capacitor that changes its capacitance is called varactor or varicap capacitor.
* This capacitor can be found in the reversed biased diode,
* Also the capacitance of bipolar Junction Transistor (BJT) and the field Effect Transistor (FET) is varied by the miller-effect.
* Furthermore, the electron tube may also provide variable reactance (either inductive or capacitive), these tubes called reactance tubes.
* The inductance L of a tuned circuit may also varied in accordance to the modulating signal $x(t)$, this type of modulator is called saturable reactor modulator.

Reactance Modulator :-

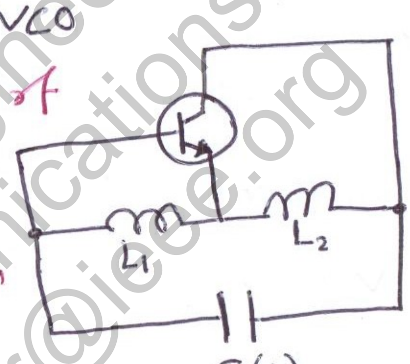
* one of the direct FM generation is by using the reactance modulator.



* In this modulator, VCO should be used.

* In VCO, the sinusoidal oscillator with high quality factor Q must be used.

* A Hartly oscillator can be used as a VCO where the capacitor C(t) is the capacitor of the varactor diode.

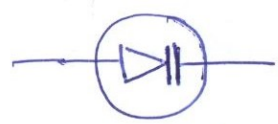


Hartly oscillator

* C(t) changes its value in accordance with the modulating signal x(t).

* The instantinuous frequency of the Hartley oscillator can be given as

$$f_i(t) = \frac{1}{2\pi\sqrt{(L_1+L_2)C(t)}} \quad \text{—— (1)}$$


varactor diode

where $C(t) = C + C_{varactor}$.

* The relationship between the modulating signal $x(t)$ and the capacitance $C(t)$ is

$$C(t) = C - k_c\, x(t) \quad \text{——— (2)}$$

where k_c is the sensitivity of the varactor capacitance.

Thus,

$$f_i(t) = f_0\left[1 + \frac{k_c}{C}\, x(t)\right] \quad \text{——— (3)}$$

where C = total capacitance

$f_0 = \dfrac{1}{2\pi\sqrt{(L_1+L_2)C}}$ ~~osill~~ is the oscillator frequency in absence of $x(t)$.

* if max change in capacitance is small compared to C then, approximately

$$f_i(t) \cong f_0 + \frac{f_0 k_c}{2C}\, x(t) \quad \text{——— (3)}$$

Hence :-

$$k_f = \frac{f_0 k_c}{2C} \quad \text{——— (4)}$$

$$f_i(t) = f_0 + k_f\, x(t) \quad \text{——— (5)}$$

k_f = frequency Sensitivity.

Indirect (Armstrong) FM Generation :

Armstrong method (indirect FM Generator) separates the generation of the carrier frequency from the modulating signal.

where in the previous methods (direct method), the message directly controls the FM carrier generation. Therefore, the frequency stability is not good, which is a requirement.

Furthermore, due to the harmonics generated of the modulating signal (which affect the varactor diode capacitor) the carrier will be distorted.

Therefore, Armstrong is more practical and a very stable frequency oscillators can be used (such as the crystal oscillator).

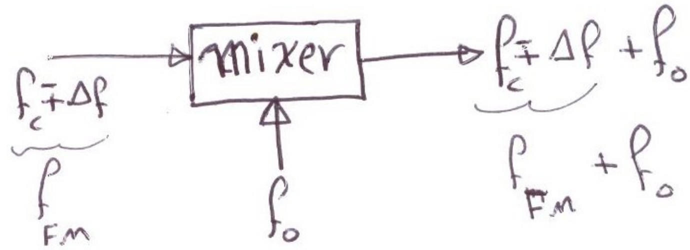
* The Armstrong method produces FM from ~~narrow~~ PM signal.

See the following diagram :-

Mixing:

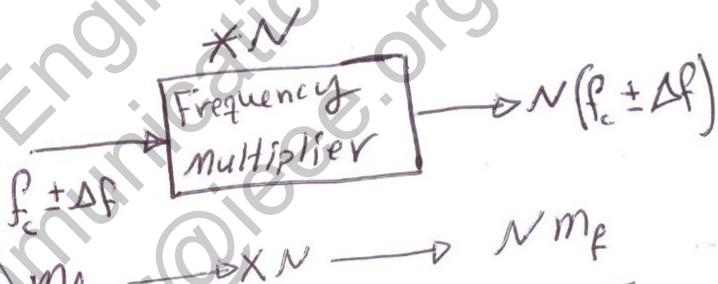
The mixer produces two outputs; if the input is f_1, the mixer frequency is f_2

then $f_{output} = f_1 \mp f_2$

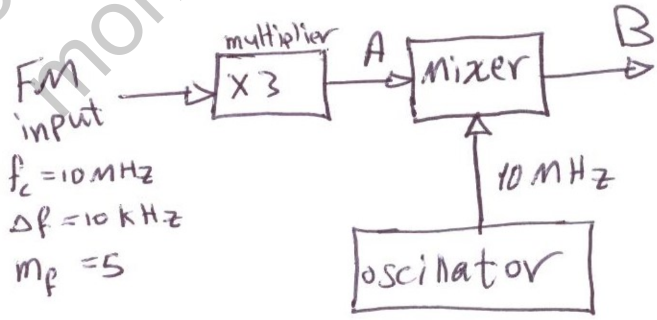


Multiplier:

Frequency Multiplier multiplies the input by N.



EX. in the block diagram shown below, determine the carrier frequency, frequency deviation and the modulation index at points A & B, assume that the output of the mixer is the additive mode.



solution

* At point A we have

$f_c = 10\,MHz \times 3 = 30\,MHz$

$\Delta f = 10\,kHz \times 3 = 30\,kHz$

$m_f = 5 \times 3 = 15$

* At point B we have

$f_c = 30\,MHz + 10\,MHz = 40\,MHz$.

Δf = not changed = 30 kHz

m_f = not changed = 15

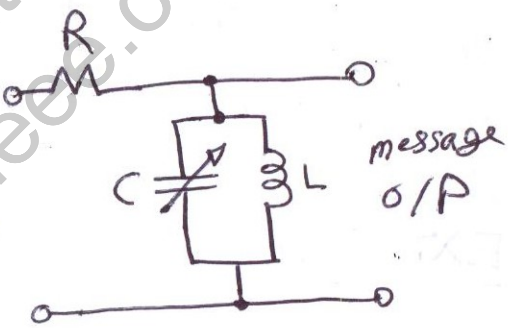
FM Demodulation

There are two branches for FM demodulation :-

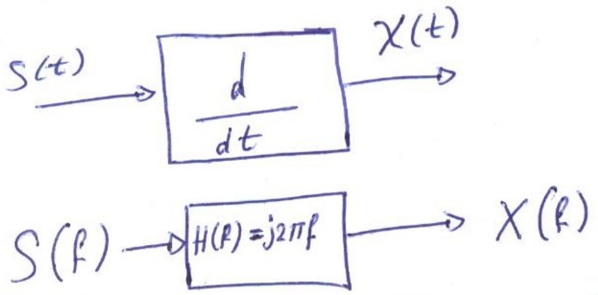
1. Direct methods :-
   - (a) Frequency Discriminator
   - (b) Zero crossing detector
2. Indirect methods; such as Phase Locked Loop (PLL).

1) Direct methods :- Frequency Discriminator

* It is simply a differentiator $\frac{d}{dt}$.
* The resonant frequency of the tuned circuit is deliberately adjusted to $f_c + \Delta f$.

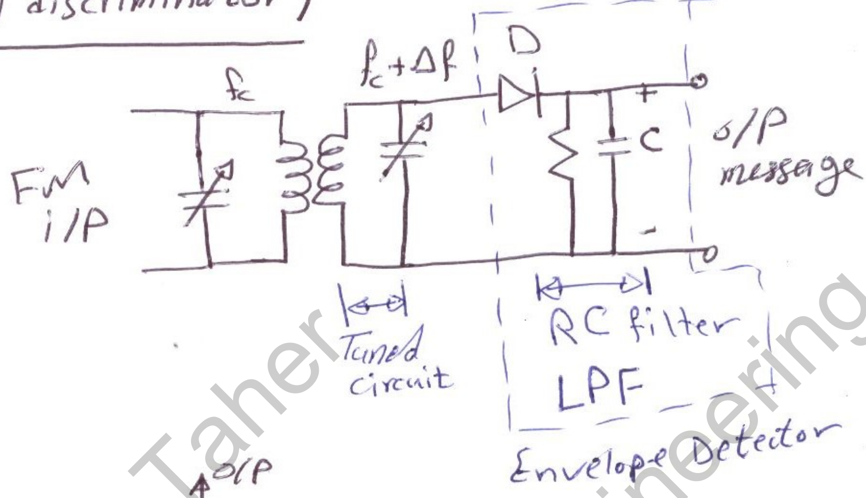


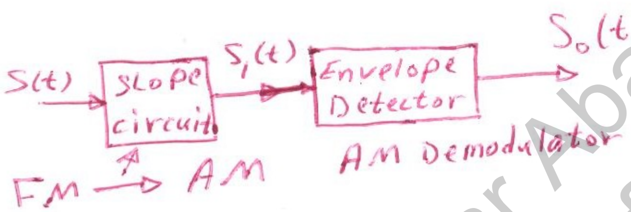
* The amplitude of the output voltage of the tuned circuit depends on the frequency deviation Δf of the input signal.
* Hence, the output is a variation of voltage which is the message signal.



Slope Detector (frequency discriminator)

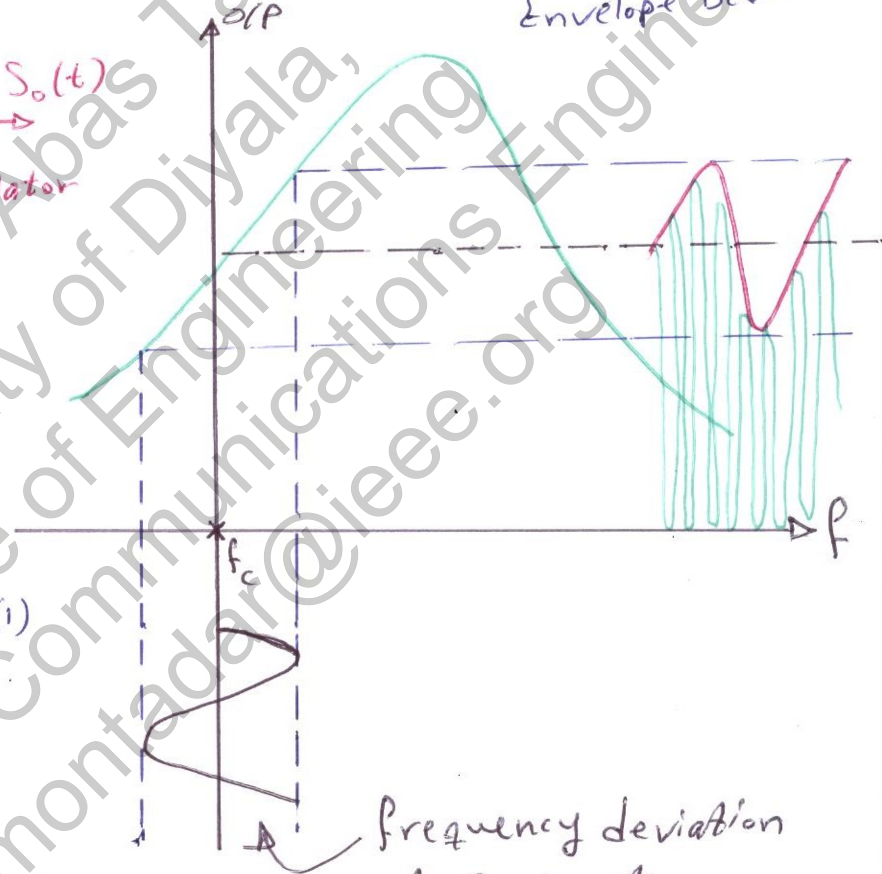
* Slope detector consists of two parts :-
  1. Slope circuit
  2. Envelope detector





Frequency controlled voltage

FCV



* consider FM signal

$$s(t) = A_c \cos\left[2\pi f_c t + 2\pi k_f \int_0^t m(\tau)\,d\tau\right] \quad (1)$$

where

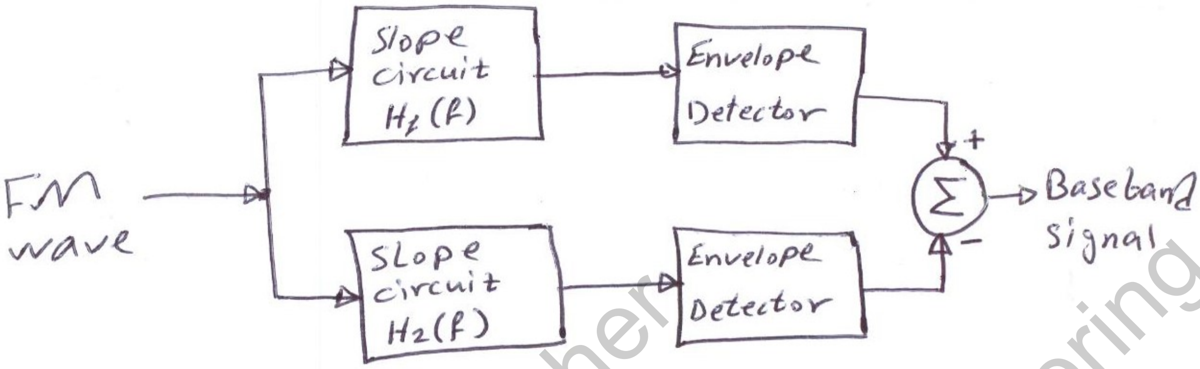
$$f_i(t) = f_c + k_f\, m(t)$$

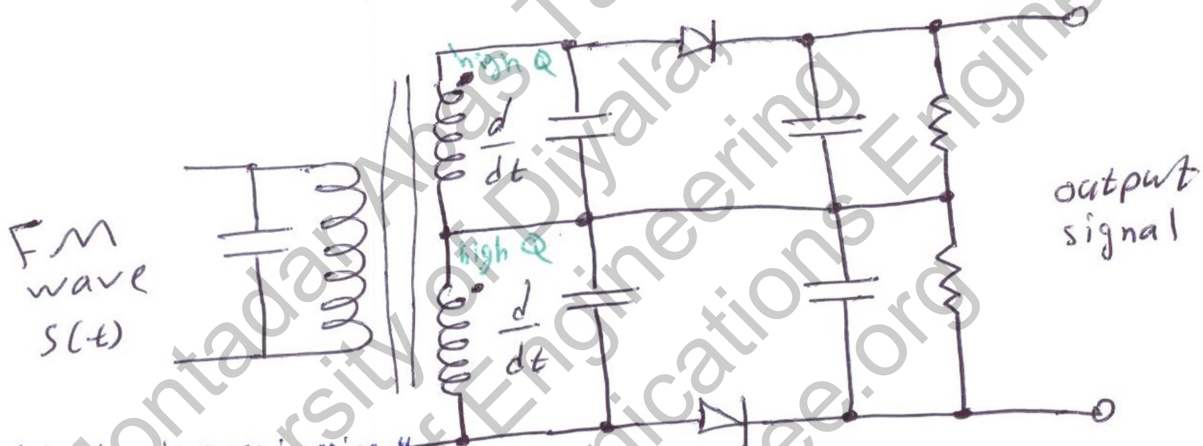
* since the slope circuit is a differentiator,

$$s_1(t) = -A_c\left[2\pi f_c + 2\pi k_f\, m(t)\right] \sin\left[2\pi f_c t + 2\pi k_f \int_0^t m(\tau)\,d\tau\right]$$

$$\therefore\; S_o(t) \cong -A_c\left[2\pi f_c + 2\pi k_f\, m(t)\right]$$

Balanced Frequency Discriminator :





* The ideal slope detector is pure imaginary

$$H_1(f) = \begin{cases} j2\pi a\left(f - f_c + \frac{B_T}{2}\right) & \text{for } f_c - \frac{B_T}{2} \leq f \leq f_c + \frac{B_T}{2} \\ j2\pi a\left(f + f_c - \frac{B_T}{2}\right) & \text{for } -f_c - \frac{B_T}{2} \leq f \leq -f_c + \frac{B_T}{2} \\ 0 & \text{otherwise} \end{cases}$$

$$|H_2(f+f_c)| = |H_1(-f+f_c)|$$

$$\therefore S_o(t) = 4\pi k_f a A_c m(t)$$

where (a) is the slope

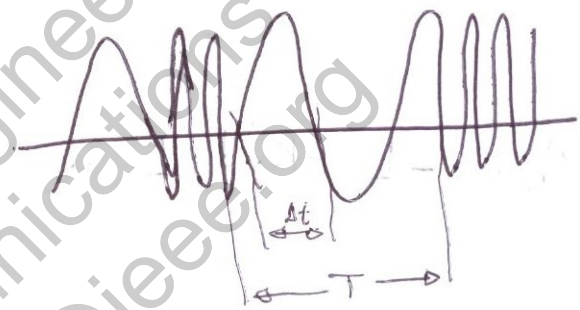
* overall performance is good only when both the filters have high Q-factor and proper frequency separation between the tuning frequencies of the two filters.

* But there is a distortion at the output ↘

The Distortion due to the following reasons :-

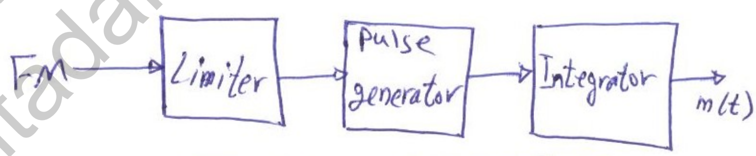
1. spectrum of FM is not exactly zero for the frequecies outside the range.
2. Tuned circuits filters are not strictly Band-Limited.
3. RC filters in the Envelope detector introduces distortion.
4. Tuned filter characteristics are not Linear over the whole frequency band.

Zero Crossing Detector



$$f_i(t) = \frac{1}{2\pi}\frac{d\theta_i(t)}{dt} = \frac{1}{2\Delta t}$$

Δt : is the time difference between adjacent zero crossing of the FM signal.



ZERO CROSSING DETECTOR

* If there is n_o crossing times in an interval T, then

$$\Delta t = \frac{T}{n_o} \longrightarrow f_i(t) = \frac{1}{2\Delta t} = \frac{n_o}{2T}$$

Hence, the instantaneous frequency is linearly related to m(t).

→ principle of operation.

* The Limiter :- produces a square wave version of the FM signal.

* The pulse generator :- produces pulses at the positive going edges and negative going edges.

* The integrator :- performs the averaging over the interval T and hence produces the message signal.

In Conclusion:- The Discriminator is:

$$v_i(t) = A(t)\cos[\omega_c t + \theta(t)]$$

$$\theta(t) = k_f \int_{-\infty}^{t} m(\tau)\,d\tau$$

$$v_1(t) = V_L \cos(\omega_c t + \theta(t))$$

$$v_2(t) = -V_L\left[\omega_c + \frac{d\theta(t)}{dt}\right]\sin(\omega_c t + \theta(t))$$

$$v_o(t) = \left|-V_L\left[\omega_c + \frac{d\theta(t)}{dt}\right]\right|$$

$$\therefore\ v_o(t) = V_L\left[\omega_c + \frac{d\theta(t)}{dt}\right]$$

$$\therefore\ \boxed{v_o(t) = V_L\omega_c + V_L k_f m(t)}$$

where $V_L\omega_c$ is a DC component can be blocked using AC coupling circuit.