EC8491-Communiction Theory

UNIT-II Angle Modulation Systems

PRESENTED BY
S.SUDHAKAR B.E.,M.E.,MISTE.,
ASSISTANT PROFESSOR-ECE
NPRCET,DINDIGUL.

Introduction

- ***In angle modulation***, the timing parameters such as *phase or frequency* of the carrier are modulated according to amplitude of modulating signal.

- Frequency Modulation and Phase Modulation are also called ***angle modulation***.

- Angle modulation can provide better discrimination against ***noise and interference*** than amplitude modulation.

Angle modulation

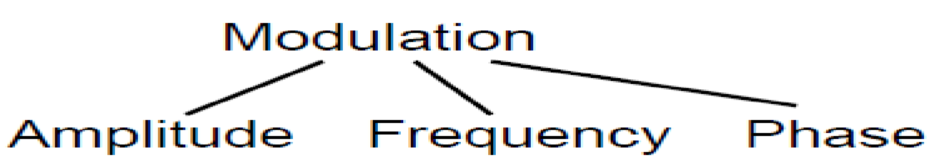
- ***Classified into two types***:

  1. Frequency Modulation
  2. Phase Modulation

Modulation of an RF Carrier

$$u(t) = A \cdot \cos(2\pi f t + \varphi);$$

A = amplitude
f = frequency
ϕ = phase



Expression for Angle Modulated Wave

- An angle modulated wave is expressed mathematically

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

s(t) - Angle modulated wave

Ac - Peak carrier amplitude (volts)

ω_c - Carrier radian frequency

$\theta(t)$ - Instantaneous phase deviation (radians)

Angle Modulation

Advantages

- Improving immunity to noise and interference.
- Improved system fidelity and more efficient use of power.

Disadvantages

- Wider bandwidth.
- Circuit complexity and cost.

Applications

- Commercial radio broadcasting
- Cellular radio & Microwave communication.

FM & PM Waveforms

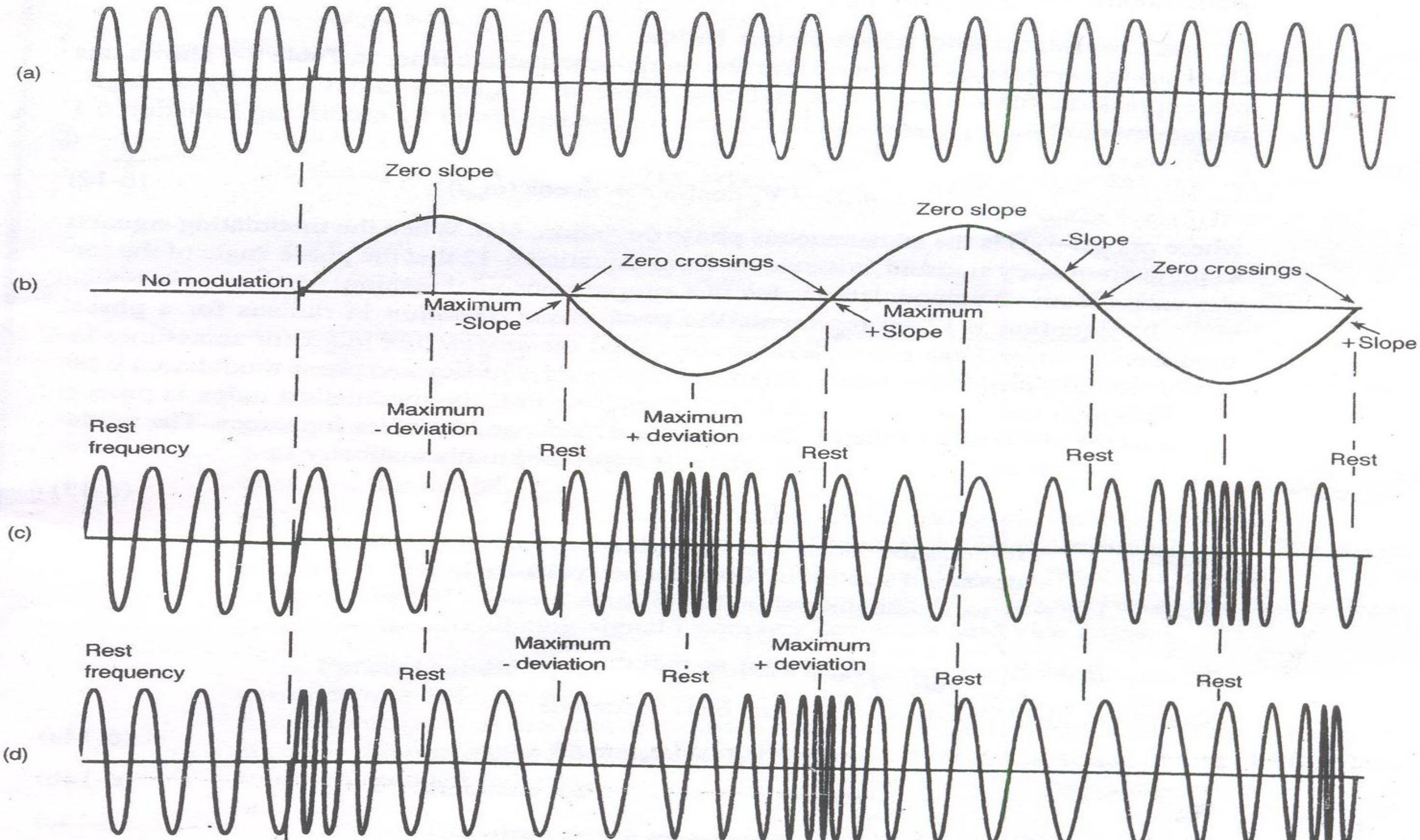


FIGURE 6-3 Phase and frequency modulation of a sine-wave carrier by a sine-wave signal: (a) unmodulated carrier; (b) modulating signal; (c) frequency-modulated wave; (d) phase-modulated wave.

FM & PM waveforms(Cont…)

- In FM, the maximum frequency deviation occurs during the ***maximum positive*** and ***negative peak*** of the modulating signal.

- In PM,the Maximum Phase deviation occurs during the ***zero crossing*** of the modulating signals.

Comparison of FM and PM

FM	PM
Frequency of the carrier is varied with respect to the modulating signal.	***Phase*** of the carrier is varied with respect to the modulating signal.
Modulation index is increased as modulating frequency is reduced.	Modulation index remain same if modulating frequency is changed.
Its signal to noise performance is not good.	It produces better signal to noise performance.
In FM, Maximum frequency deviation occurs during the maximum +ve and –ve peaks of the modulating signal.	***In PM,*** Maximum phase deviation occurs during the zero crossing of the modulating signal.

Angle Modulation

- ***Phase modulation (PM)*** is that form of angle modulation in which the instantaneous angle *θi(t)* is varied linearly with the message signal *m(t)*, then

$$\theta_i(t) = 2\pi f_c t + k_p m(t)$$

- The phase modulated signal is described by

$$s(t) = A_c \cos\left[2\pi f_c t + k_p m(t)\right]$$

Angle Modulation

Frequency Modulation (FM):

In frequency modulation the instantaneous frequency $f_i(t)$ is varied linearly with message signal, m(t) as:

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

where k_f is the frequency sensitivity of the modulator in hertz per volt.

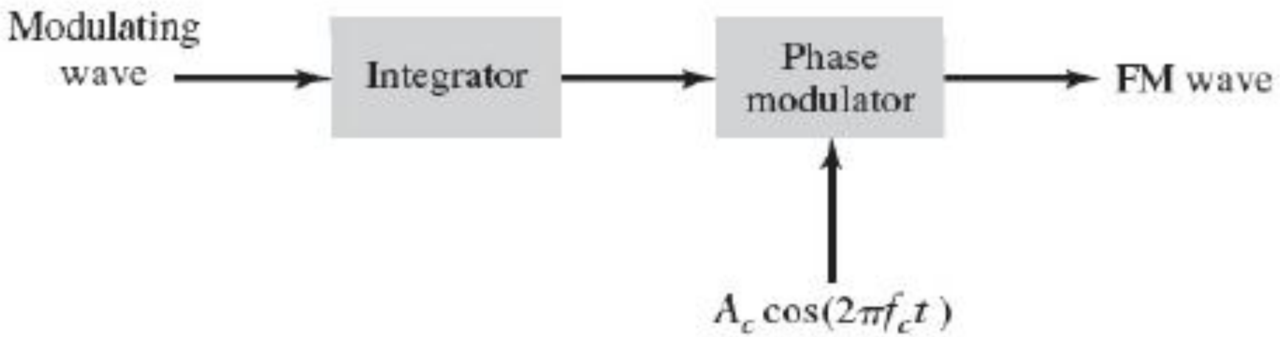
The instantaneous angle can now be defined as

$$\theta(t) = 2\pi f_c t + 2\pi k_f \int_0^t m(t)dt$$

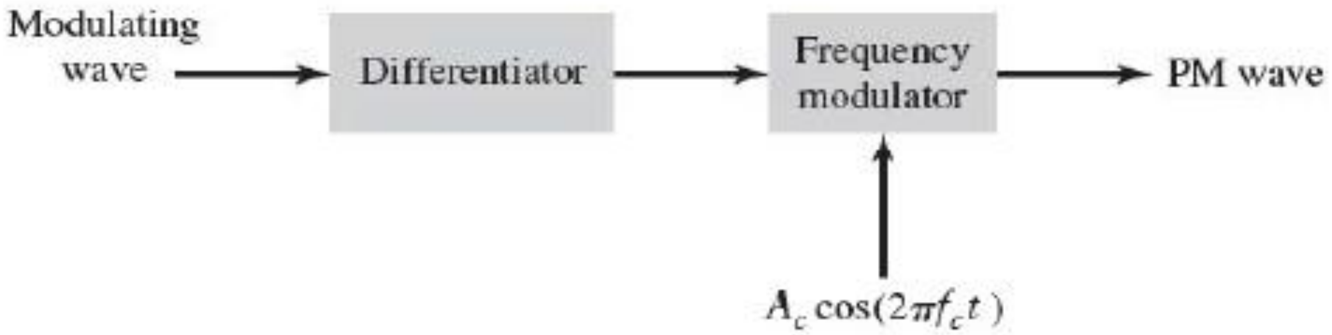
and thus the frequency modulated signal is given by

$$s(t) = A_c \cos\left[2\pi f_c t + 2\pi k_f \int_0^t m(t)dt\right]$$

Relations between FM and PM



(a)



(b)

Comparison of WBFM and NBFM

WBFM	***NBFM***
Modulation index is greater than 1	Modulation index is less than 1
Frequency deviation is 75 KHz	Frequency deviation is 5 KHz
Modulating frequency range from 30Hz-15KHz	Modulating frequency is 3KHz
Bandwidth 15 times NBFM	Bandwidth is 2fm
Noise is more suppressed	Less suppressing of noise
Use: Audio Broadcasting	Use: Mobile communication

Introduction

- The bandwidth of FM signal depends on the ***modulation index.***

- ***Two cases of FM***:

  1.Narrow band FM, for which β is ***small*** compared to one radian.

  2. Wideband FM, for which is ***large*** compared to one radian.

- **Narrow band FM:**
- When β is small ,then bandwidth of FM is narrow.
- Narrow band FM also called as ***low index FM***.
- Bandwidth of NBFM is same as that of AM.

Narrowband FM

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

With $\cos(A+B) = \cos A \cos B - \sin A \sin B$

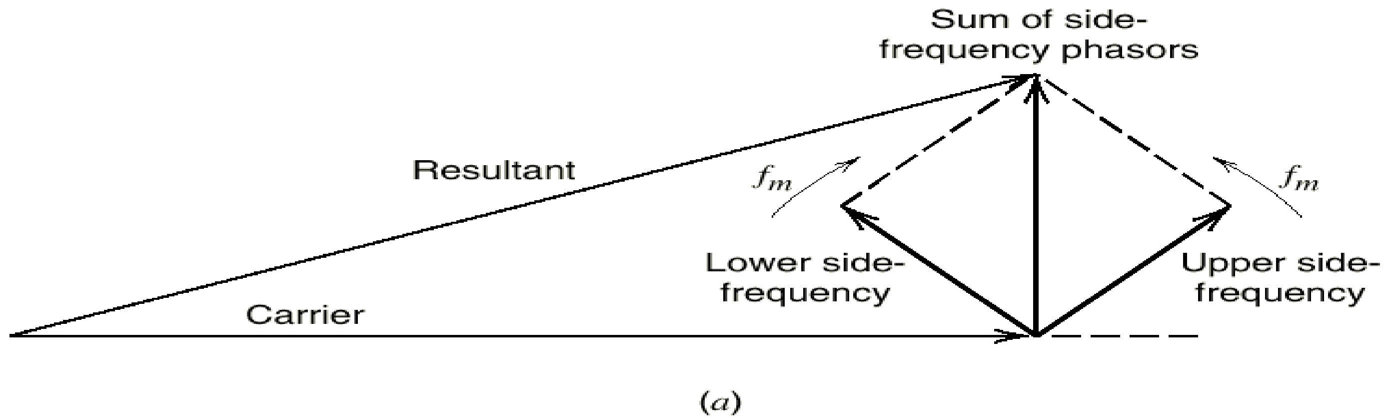
$$s(t) = A_c \cos(2\pi f_c t)\cos\left[\beta \sin(2\pi f_m t)\right] - A_c \sin(2\pi f_c t)\sin\left[\beta \sin(2\pi f_m t)\right]$$

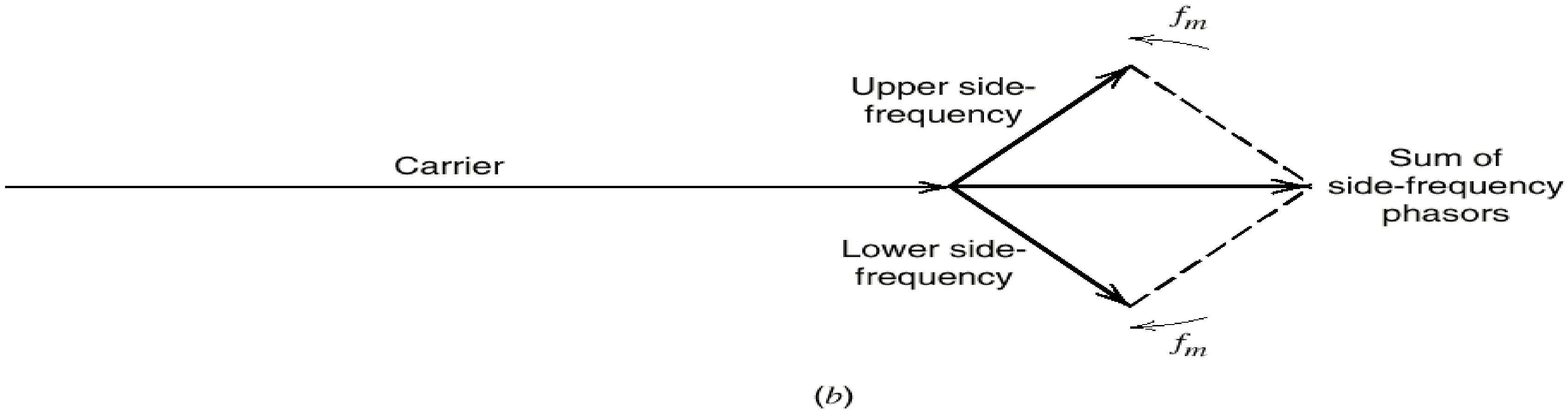
For NBFM: The modulation index, $\beta << 1$ radian.

$$\cos\left[\beta \sin(2\pi f_m t)\right] \approx 1 \quad \text{and} \quad \sin\left[\beta \sin(2\pi f_m t)\right] \approx \beta \sin(2\pi f_m t)$$

$$s(t) \approx A_c \cos(2\pi f_c t) - A_c \beta \sin(2\pi f_c t)\sin(2\pi f_m t)$$

A phasor comparison of narrowband FM and AM waves for sinusoidal modulation. (a) Narrowband FM wave.(b) AM wave.





Frequency Modulation

Advantages

- Improving immunity to noise and interference.
- Low power is required to transmit the signal.

Disadvantages

- Very large bandwidth is required.
- Compared to AM the area covered by FM is less.

Applications

- Radio broadcasting
- Sound broadcasting in TV .

Properties of Bessel Functions

1. $J_n(\beta)$ are real valued.
2. $J_n(\beta) = J_n(\beta)$ for n is even.
3. $J_n(\beta) = -J_{-n}(\beta)$ for n is odd.
4. $\sum_{n=-\infty}^{\infty} J_n^2(\beta) = 1$ Note: $|J_n(\beta)|$ diminish rapidly for $n > \beta$

Transmission Bandwidth of FM signals

1 Low-index modulation (***narrowband FM***)

$\beta < 1 \ (f_m >>> \Delta f) \quad B = 2f_m$ (Hz)

2 High-index modulation (***wideband FM***)

$\beta > 10 \ (\Delta f >>> f_m) \qquad B = 2\Delta f$

3 Actual bandwidth

$$B = 2nf_m$$

where n is the number of significant sidebands

4 Carson's rule (approx 98 % of power)

$$B = 2\left(\Delta f + f_m\right)$$

Transmission Bandwidth of FM signals

For large β: $\quad Bandwidth = 2nf_m \approx 2\beta f_m = 2 \times \dfrac{\Delta f}{f_m} \times f_m = 2(\Delta f)$

For very small values of β, $J_0(\beta)$ and $J_1(\beta)$ are the significant terms. Therefore the bandwidth for the narrowband case is:

For small β: $\quad Bandwidth \approx 2f_m$

In order to have a more general rule to take care of the intermediate cases, J.R. Carson proposed the following formula, Carson's Rule:

$$Bandwidth \approx 2(f_m + \Delta f) = 2f_m\left(1 + \frac{\Delta f}{f_m}\right) = 2f_m(\beta + 1)$$

Carson's rule approaches the correct limits for both very large and very small β.

Transmission Bandwidth of FM signals

- ***Deviation Ratio*** is a ratio of maximum peak frequency deviation divided by the maximum modulating signal frequency.

$$DR = \frac{\Delta f_{(\max)}}{f_{m(\max)}}$$

- Where
  - $\Delta f_{(max)}$ = max. peak frequency deviation
  - $f_{m(max)}$ = max. modulating signal frequency

FM Stereo Multiplexing

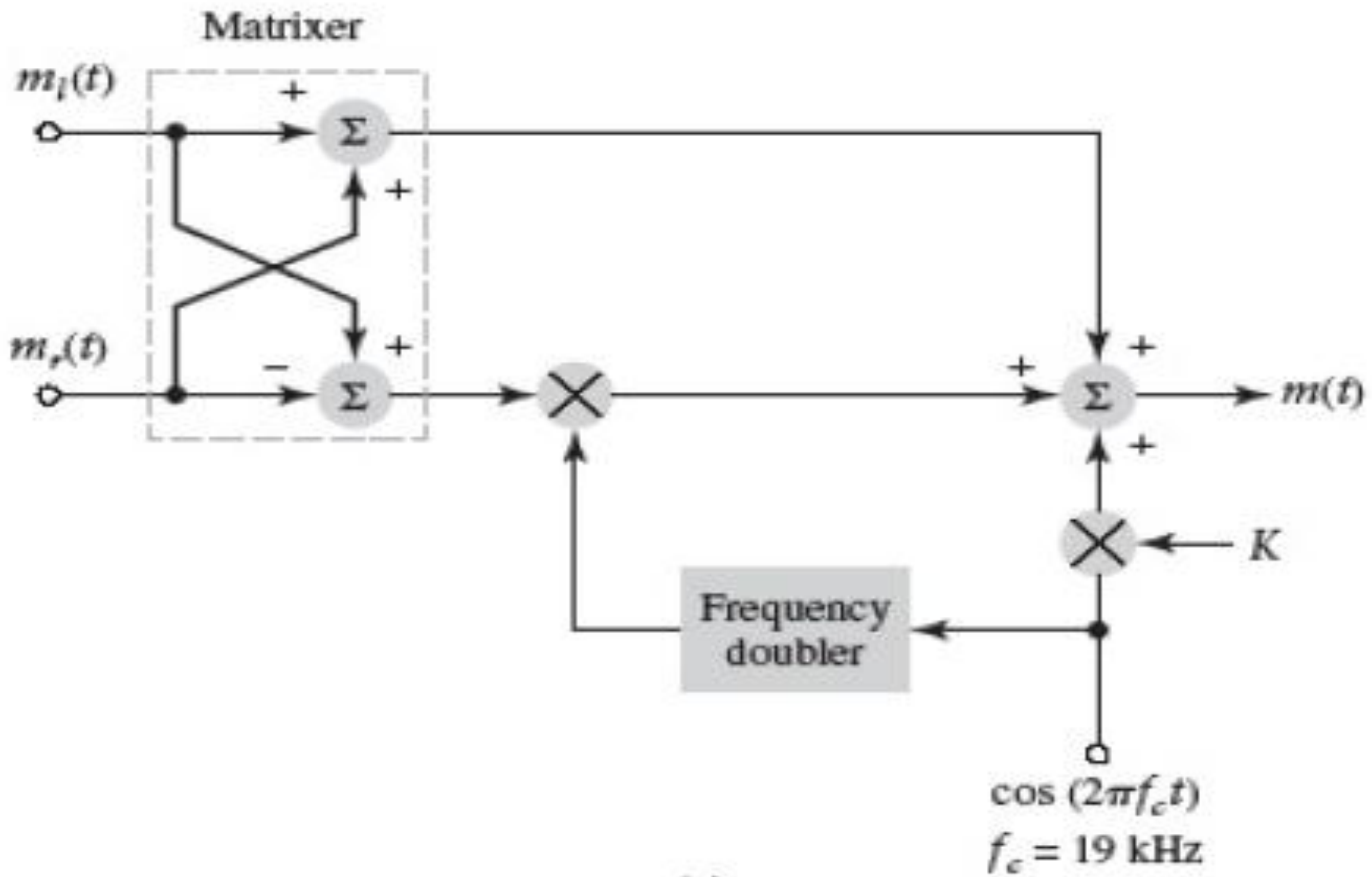
Introduction

- ***Stereo multiplexing*** is a form of frequency-division multiplexing (FDM) designed to transmit two separate signals via the same carrier.
- FM stereo multiplexing is used for stereo transmission.
- It is used for FM radio broadcasting.
- The specification for FM stereo is influenced by ***two factors:***

1. The transmission has to be within the allocated FM channels.

2. It has to be compatible with monophonic radio receivers.

FM Stereo Multiplexing



(a)

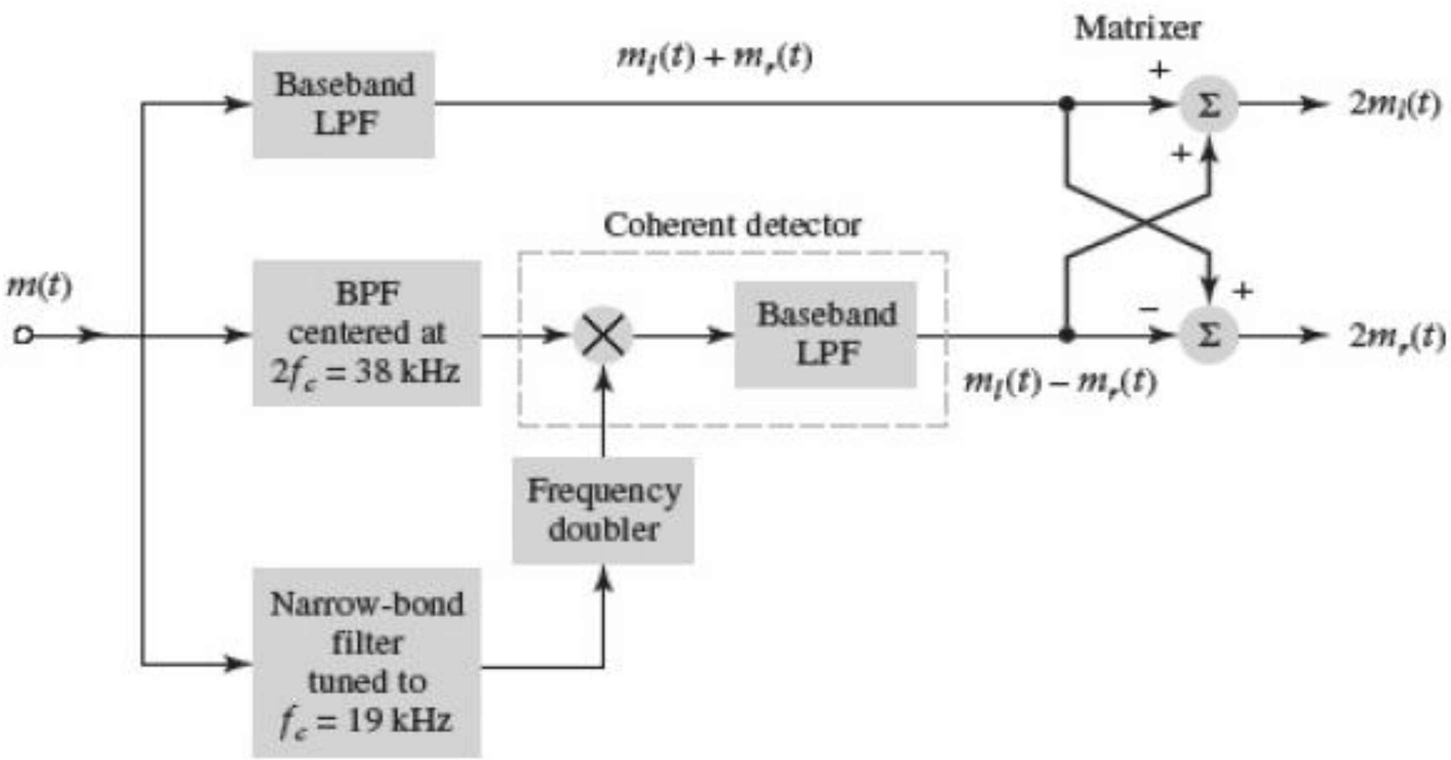
FM Stereo Multiplexing

Transmitter operation

- Here m_l (t) and m_r (t) are the two signals of left and right messages.
- The sum signal m_l (t) + m_r (t) and difference signal m_l (t) - m_r (t) are generated.
- The sum signal is directly given to output without any processing. It is used by monophonic receivers.
- The oscillator frequency of 19kHz is amplified by K times and given to output.
- The oscillator frequency is doubled and used by product modulator. The product modulator produces ***DSB-SC signal***.
- The multiplexed signal can be defined as:

$$m(t) = [\ m_l(t) + m_r(t)\ ]\ +[\ m_l(t) - m_r(t)\ ]\ cos(4\pi f_c t)\ + K\ cos(2\pi f_c t)$$

FM Stereo Multiplexing



(b)

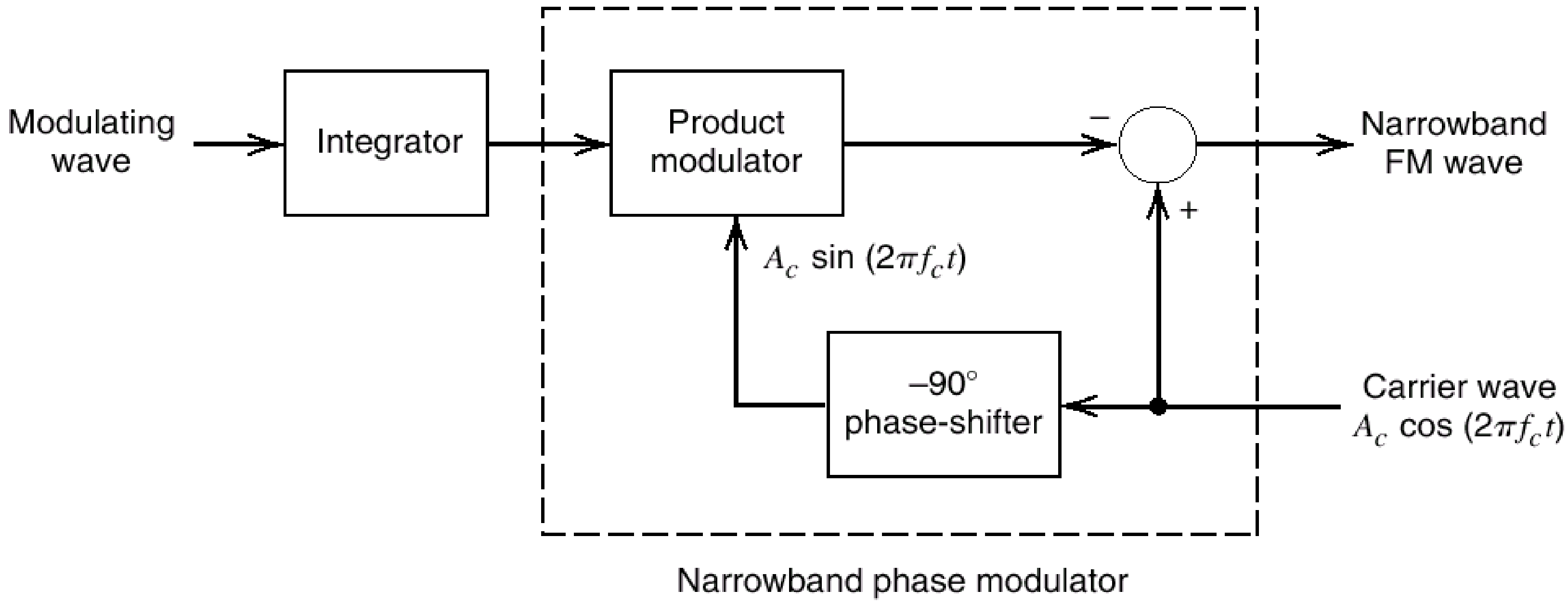
FIGURE 4.16 (*a*) Multiplexer in transmitter of FM stereo. (*b*) Demultiplexer in receiver of FM stereo.

FM Stereo Multiplexing

Receiver Operation

- The three multiplexed signals are separated by three ***appropriate filters.***
- Baseband LPF separates sum signal $m_l(t) + m_r(t)$
- BPF centered around 2fc separates the DSB-SC signal.
- NB filter tuned to fc separates reference carrier of cos(2πfct).
- This subcarrier enables the coherent detection of the DSB-SC modulated wave, there by the difference signal $m_l(t) - m_r(t)$ is recovered.
- The sum signal and difference signal is passed to the matrixes which reconstruct the $m_l(t)$ and $m_r(t)$ and then applied to their respective speakers.

Narrowband FM signal



- This modulator involves splitting the carrier wave into ***two paths***. One path is direct, and the other path contains a −90 degree phase-shifter and a product modulator (mixer), the combination of which generates a DSB-SC signal.
- The difference between these two signals produces a ***NBFM*** signal.

Generation of FM signals

- ***Two basic methods*** of generating FM signals:

    1. Direct method of FM

    2. Indirect method of FM

- ***Direct method***: Carrier frequency is directly varied in accordance with the input base-band signal.

- ***Indirect method:*** Modulating signal is first used to produce a NBFM signal , and frequency multiplication is next used to increase the frequency deviation to the desired level.

Indirect FM(Armstrong Method)

- ***Basic principle:*** Narrowband FM signal is generated using phase modulation method. Then the NBFM signal is converted to WBFM.

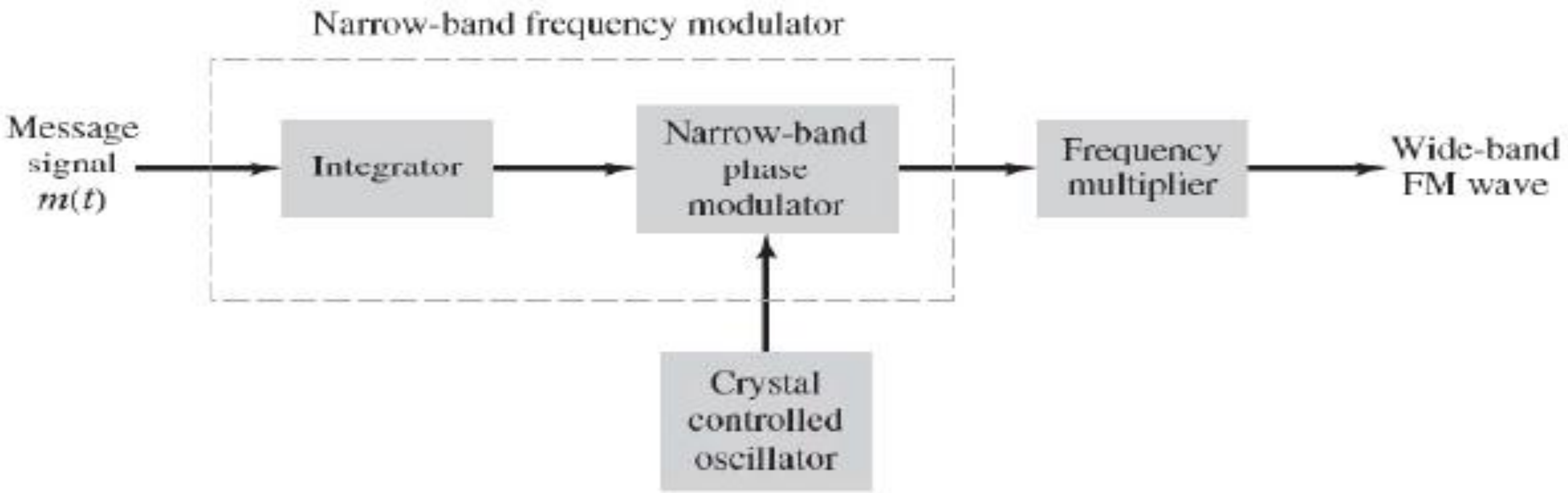


FIGURE 4.10 Block diagram of the indirect method of generating a wide-band FM wave.

Indirect FM

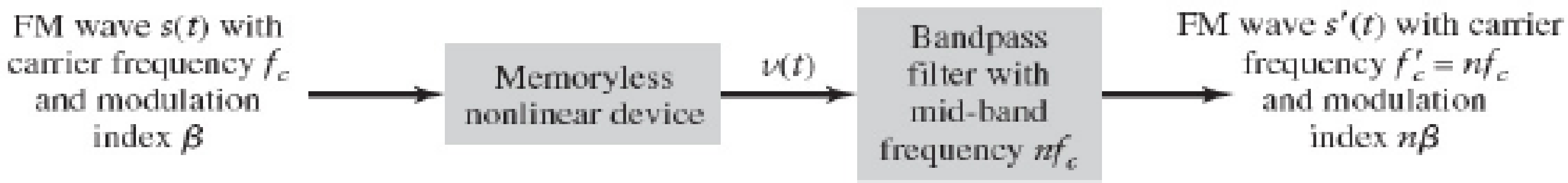


FIGURE 4.11 Block diagram of frequency multiplier.

A frequency multiplier consists of a memoryless non-linear device followed by a bandpass filter. The input-output relation of such a device may be expressed in the general form:

$$v(t) = a_1 s(t) + a_2 s^2(t) + \cdots\cdots + a_n s^n(t)$$

and

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

then

$$\begin{aligned} v(t) = {} & a_1 A_c \cos\left[2\pi f_c t + \beta \sin(2\pi f_m t)\right] \\ & + a_2 A_c^2 \cos^2\left[2\pi f_c t + \beta \sin(2\pi f_m t)\right] \\ & + \cdots\cdots \\ & + a_n A_c^n \cos^n\left[2\pi f_c t + \beta \sin(2\pi f_m t)\right] \end{aligned}$$

THANK YOU