$$= \frac{2\eta\omega_1^2}{A_c^2}\int_0^B \frac{4\pi^2 f^2}{4\pi^2 f^2+\omega_1^2}df$$

$$N_o' = \frac{\eta\omega_1^2}{A_c^2}\left[2B - 2f_1 tan^{-1}\frac{B}{f_1}\right], \quad f_1 = \frac{\omega_1}{2\pi} \qquad \ldots (5\text{-}45)$$

The noise power N_o without PDE is found from

$$N_0 = \frac{8\pi^2\eta B^3}{3A_c^2} \qquad \ldots (5\text{-}46)$$

Hence the improvement factor $\frac{N_o}{N_o'}$ is

$$\frac{N_o}{N_o'} = \frac{1}{3\left[1-\frac{f_1}{B}tan^{-1}\left(\frac{B}{f_1}\right)\right]}\left(\frac{B}{f_1}\right)^2 \qquad \ldots (5\text{-}47)$$

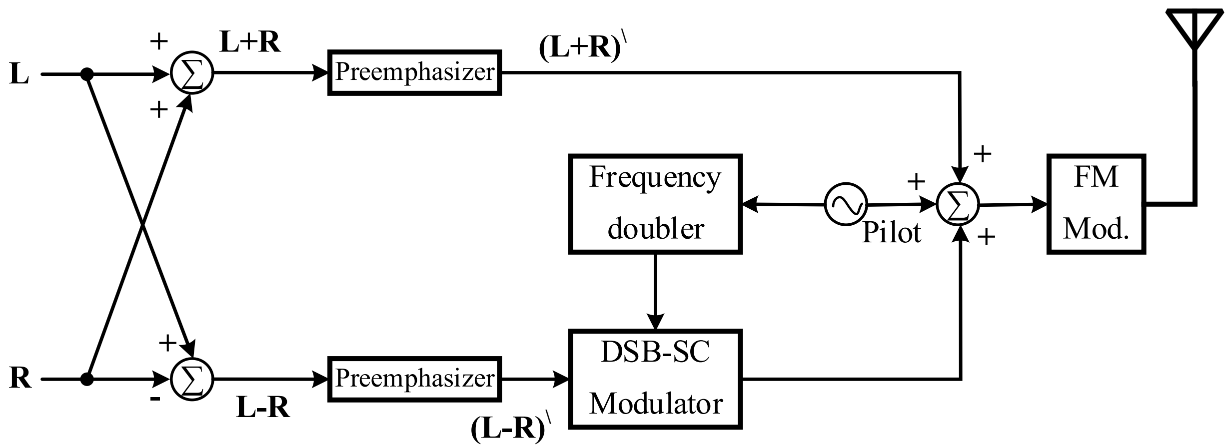
Subsituting B=15 kHz and f_1=2.1 kHz, we get $\frac{N_o}{N_o'} = 21.25 = 13.27\ dB$

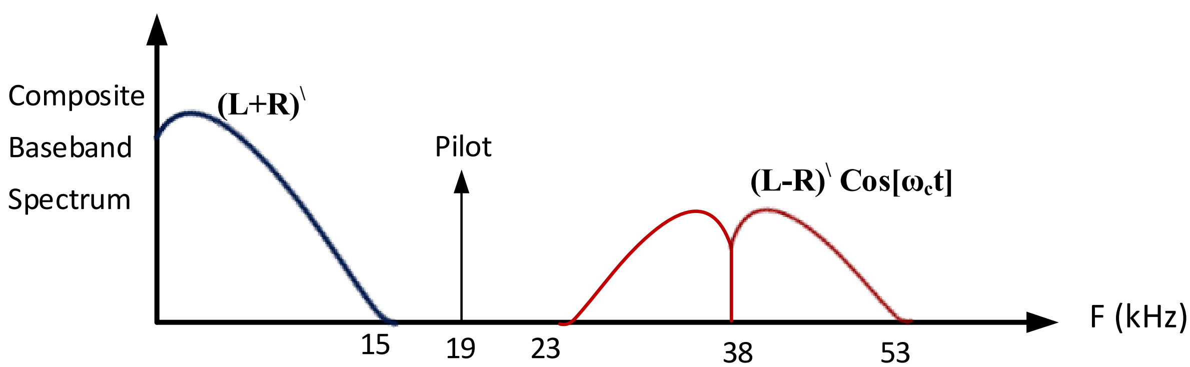
We could also use preemphasis- deemphasis in AM broadcasting to improve the output SNR. In practice, however, this is not done for several reasons:

1- The o/p noise PSD in AM is flat, and is not parabolic as in FM, hence the deemphasis does not yield a dramatic improvement.
2- Introduction of PDE would necessitate modifications in receivers already in use.
3- Increasing high frequency component amplitudes (deemphasis) would increase interference with adjacent stations (no such problem arises in FM).

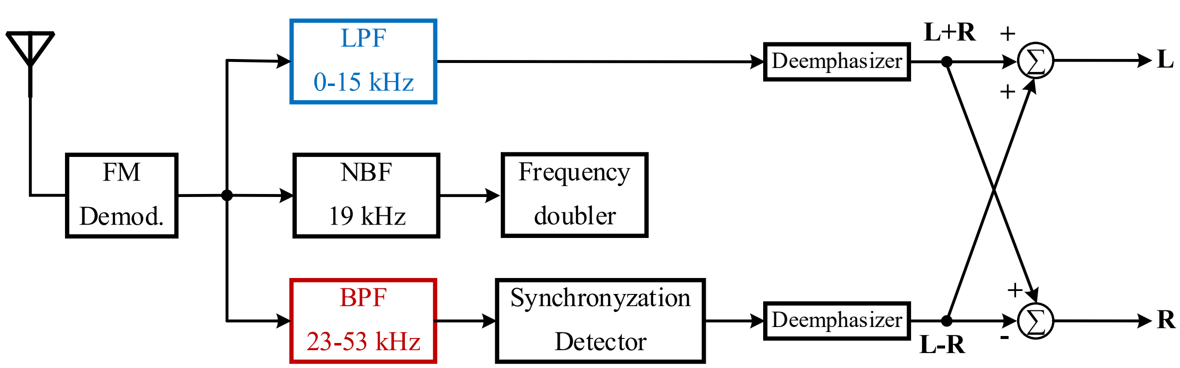
Stereo FM Transmission:

Earlier FM were monophonic. Stereophonic FM broadcasting, in which two audio signals L (left microphone) and R (right microphone) are used for more natural effect was proposed later. The FCC (Federal Communication Commission) ruled that the stereophonic system had to be compatible with original monophonic system (L+R signal with total transmission BW of 200 kHz and Δf=75 kHz) to ensure that the old receivers could continue to receive monophonic as well as stereophonic broadcast.





Reception:

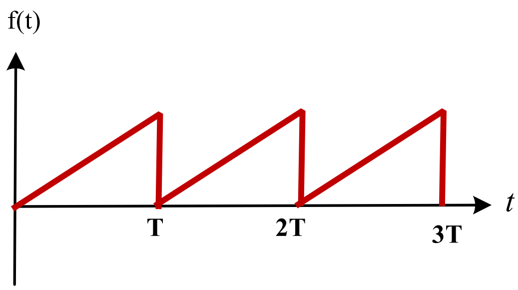


H.W

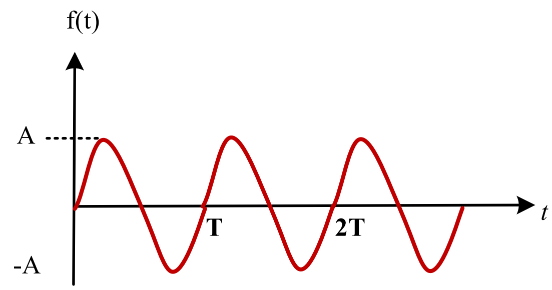
For a certain FM system with β=5, $\frac{\overline{f^2(t)}}{f_p^2}$= 0.05, the output SNR is found to be 20 dB, if β is increased to 6 (keeping all other parameters unchanged), would the output SNR increase or decrease?

Problem Sheet for Angle Modulation

Q1: Sketch roughly the AM, FM and PM waveforms for the modulating singals shown in fig. below:



(a)



(b)

Q2: Determine the instantaneous frequency of the signal:

$$\emptyset(t) = A\cos(10\pi t + \pi t^2) \quad at \quad t = 0$$

Ans: 5Hz.

Q3: The equation of an angle modulated voltage

$$\emptyset(t) = 10\cos(10^8 t + 3\sin 10^4\, t)$$

(a)What form of angle modulation is this?

(b) Calculate the carrier and modulating frequencies.

(c)Calculate the modulation index, deviation and the power dissipated in a 100 Ω resistor.

Ans: (a) FM or PM (b) 15.9MHz, 1.59 kHz.

(c) 3, 4.77 kHz, 0.5 watt.

Q4: When the modulating frequency in an FM system is 400Hz and the modulating voltage is 2.4 v, the modulation index is 60. Calculate the maximum deviation. What is the modulation index when the modulating frequency is reduced to 250 Hz and modulating voltage simultaneously raised to 3.2 v?

Ans: 24 kHz, 128.

Q5: A 1 MHz carrier of 10 v amplitude, when frequency modulated by a 400 Hz 1-volt modulating signal, undergoes 1 kHz deviation. If the modulating signal frequency is changed to kHz, with 2 v amplitude, determine the bandwidth of this signal.

Ans: 6 KHz.

Q6: A 50 MHz carrier delivers 100 watt power to a load. The carrier is now frequency modulated by a 1KHz modulating signal causing a maximum deviation of 6 KHz. This frequency-modulated signal is now coupled to a load through an ideal BPF filter with a 50 MHz center frequency and a variable bandwidth. Determine the power delivered to the load when the filter bandwidth is:

(i) 1 kHz	Ans: 2.268 w
(ii)2.1 kHz	17.6 w
(iii) 12.5 kHz	95 w
(iv) 14.5 kHz	98.4 w
(v) 20.2 kHz	99.2 w

Q7: A given FM transmitter is modulated with a single sinusoid. The output for no modulation is 200 watt into a 50 Ω resistive load. The peak frequency deviation of the transmitter is carefully increased from zero until the second sideband amplitude in the output is zero. Under these conditions determine:

(a) The average power at carrier frequency.
(b) The average power in all the remaining sidebands.
(c) The average power in the third – order sidebands.

Ans: (a) 6.48 w (b) 193.52 w (c) 51.84 w.

Q8: For the previous question (Q7), determine the peak amplitude of:

(a) The total waveform.
(b) The upper first – order sideband.

Ans: (a) 141.42 v (b) -43.37 v.

Q9: 1 GHz carrier is frequency modulated by a 10 kHz sinusoid, so that the peak frequency deviation is 1 kHz determine:

(a)The approximate bandwidth of the FM signal.
(b) The bandwidth if the modulating signal amplitude were doubled.

(c) The bandwidth if the modulating signal frequency were doubled.

(d) The bandwidth if the amplitude and the frequency of the modulating signal were doubled.

Ans: (a) 20 kHz, (b) 20 kHz, (c) 40 kHz, (d) 40 kHz.

Q10: The FM signal (in volts): $\emptyset(t) = 20cos(2\pi 10^7 t + 10\sin 2\pi 10^3\, t)$ is present across a $50\,\Omega$ resistive load.

(a)What is the total average power?

(b) What percentage of this power is at $10\ MHz$?

(c) Find the peak frequency deviation.

(d) Determine the approximate bandwidth of $\phi(t)$ using Carson's rule.

(e) Can you determine from $\phi(t)$ wether this is FM or PM? Explain.

Ans: (a) 4 watt (b) 6.25% (c) 10 kHz (d) 22 kHz.

Q11: A given FM transmitter is modulated with sinusoid input (in volts),$f(t) = 10cos200\pi t$, and the modulation index is 5. the modulated carrier power is 10 watt across $50\,\Omega$ resistive load, Determine:

(a)The modulation constantk_f.

(b) The peak amplitude of the first-order lower sideband and its phase relative to the unmodulated carrier.

(c) The ratio of the average power in the sum of the third and fourth order sidebands to the power in all remaining sidebands excluding carrier.

(d) The bandwidth reduction factor if the input sinusoid peak amplitude is reduced to 2 v (use Carson's rule).

Ans: (a) 50 Hz/ v, (b) 10.4 0^0, (c) 0.582, (d) 3.

Q12: A certain sinusoid at a frequency of $\mathbf{f_m}$ Hz is used at the modulating signal in both an AM (DSB – LC) and an FM system. The unmodulated carrier powers are equal in both systems. When modulated, the peak frequency deviation of FM system is set to four times the bandwidth of the AM system. The magnitude of those sidebands spaced $\mp fm$ Hz from carrier in both systems are equal, determine:

(a)The modulation index of FM system.

(b) The modulation index of AM system.

Ans: (a) 8 (b) 0.46.

Q13: A 200 KHz carrier signal is frequency – modulated by a 1inusoid such that the peak frequency deviation is 150 Hz.

(a)What is the bandwidth?

(b) The above FM signal is applied to a * 16 freq. multiplier. By what factor is the bandwidth increased? (Use Carson's rule).

(c) The FM signal of (b) is applied to a second * 16 frequency multiplier. By what factor is the bandwidth increased over parts (a) and (b).

(d) Estimate the number of significant sidebands possible in the FM signal of part (c) above.

Ans: (a) 2.3 KHz, (b) 2.96, (c) 34.4, 11.6, (d) 39.

Q14: A carrier is phase modulated by a sinusoidal signal. The peak phase deviation is 1 radian when the peak input amplitude is 1 volt. Find the ratio of the average power in the carrier to that in all sidebands excluding carrier for each of the following cases, and the bandwidth in each case using Carson's rule [f (t) is given in volts].

(a) $f(t) = 2\cos 2500\, t$
(b) $f(t) = 3.8\cos 200\pi\, t$
(c) $f(t) = 5.5\cos 300\pi\, t$
(d) $f(t) = 7\cos 8000\pi\, t$

Ans: (a) 2387 Hz, (b) 960 Hz, (c) 1950 Hz, (d) 64 kHz.

Q15: A carrier is phase modulated by a sinusoidal signal of 5 kHz and unit amplitude and the peak phase deviation is one radian. Calculate the bandwidth of the PM signal.

(a)Using Carson's rule.

(b) Using the definition of significant sidebands.

Ans: (a) 20 kHz (b) 30 kHz.

Q16: The bandwidth of the two angle modulated transmitting systems are compared, using the sinusoidal test signal $f(t) = a\cos\omega_m t$. The resulting approximate bandwidth are tabulated below:

Test	System A	System B