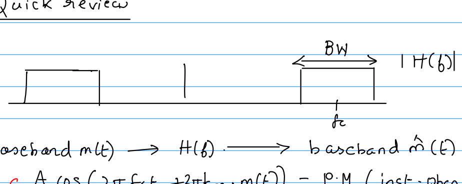
1) Please write question nos correctly in the margin 5)

2) Write the answer to one question completely in one part of the paper

3) Try to use good handwriting.

Frequency modulation & phase modulation

Quick review



channel assumptions

Baseband $m(t) \longrightarrow H(f) \longrightarrow$ baseband $\hat{m}(t)$ – the problem.

another technique

$A\cos(2\pi f_c t + 2\pi k_m \cdot m(t))$ – P.M (inst. phase $= k_m \cdot m(t)$)

k_m – P.M sensitivity (1 / V)

$\underbrace{A\cos\left(2\pi f_c t + 2\pi k_f \int_0^t m(u)\,du\right)}_{\text{inst freq} = f_c + (k_f \cdot m(t))}$ – F.M

k_f – FM sensitivity (Hz/V)

→ assuming that it is possible to recover m(t) from an FM signal from now on, we will look at FM systems

FM modulation – using VCOs.

FM demodulation – limiter discriminator circuit.

Spectrum of a FM signal? / B/W of a FM signal?

a) $m(t) = A_m\cos(2\pi f_m t)$; $f_m << f_c$

F.M signal? $= A\cos\left(2\pi f_c t + 2\pi k_f A_m \int_0^t \cos(2\pi f_m u)\,du\right)$

$= A\cos\left(2\pi f_c t + \frac{k_f A_m}{f_m}\sin(2\pi f_m t)\right)$

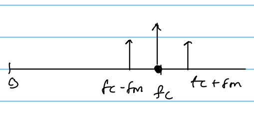
$= A\Big[\cos(2\pi f_c t)\cdot\underbrace{\cos\left(\frac{k_f A_m}{f_m}\sin(2\pi f_m t)\right)}_{\approx 1} -$

$\sin(2\pi f_c t)\cdot\underbrace{\sin\left(\frac{k_f \cdot A_m}{f_m}\sin(2\pi f_m t)\right)}_{\approx \frac{k_f A_m}{f_m}\sin(2\pi f_m t)}\Big]$

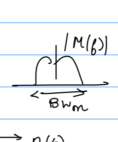
if $0 < \frac{k_f \cdot A_m}{f_m} << 1$

$FM = \underbrace{A\cos(2\pi f_c t)}_{\text{carrier}} - \underbrace{A\sin(2\pi f_c t)\cdot\frac{k_f A_m}{f_m}\overbrace{\sin(2\pi f_m t)}^{\int m(t)\cdot dt}}_{\text{DSBSC}}$

FM signal's one sided B/W = $(2f_m)$



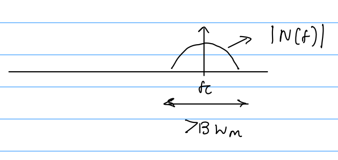
b) $m(t)$ is some baseband signal two sided B/W of BW_m



$\int_0^t m(u)\cdot du = n(t)$ $m(t) \longrightarrow \boxed{} \longrightarrow n(t)$

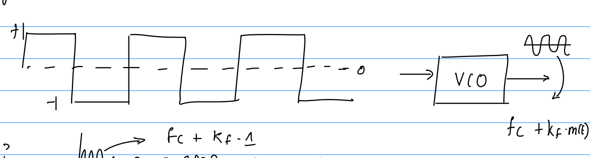
FM signal $= A\big[\cos(2\pi f_c t)\cdot\cos(k_f \cdot n(t)) - \sin(2\pi f_c t)\cdot\sin(k_f \cdot n(t))\big]$

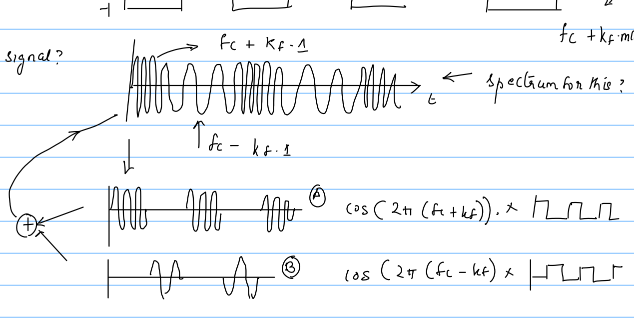
$\approx A\cos(2\pi f_c t) - k_f A\sin(2\pi f_c t)\cdot n(t)$



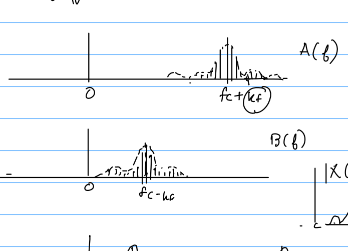
for FM if (k_f is small), then the one sided B/W of the FM signal ≈ two sided B/W of the modulating signal m(t).

c) k_f is large.



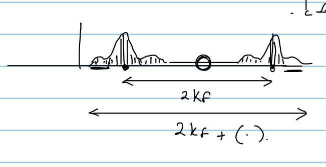


Ⓐ's spectrum?



Ⓑ's spectrum?

if k_f is large.



Carson's formula $= \left(\underset{\text{max. freq deviation}}{2k_f} + BW_m\right) \rightarrow$ refine