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ECC-201
Short Notes

Message signal : Baseband (low frequency)
Transmitted Signal : Bandpass (High frequency)

Baseband $\longrightarrow$ $\boxed{Txr}$ - - - Bandpass - - - $\boxed{Rxr}$ $\longrightarrow$ Baseband

modulation ↓ demodulation

(suitable for transmission)

Amplitude Modulation (AM)

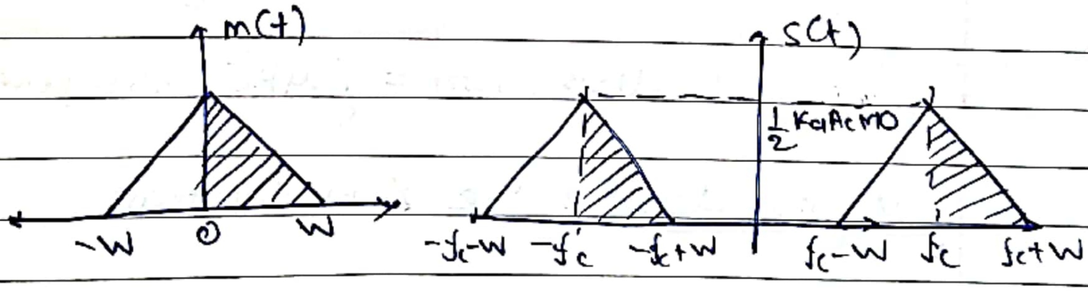
Carrier : $c(t) = A_c \cos(2\pi f_c t)$ $\qquad f_c >> W$

$$s(t) = A_c[1 + K_a m(t)]\cos(2\pi f_c t)$$

$|K_a m(t)| < 1$ for all $t \Rightarrow |K_a|\,|m(t)|_{max} < 1$

↳ ensures that $s(t) > 0$ to avoid phase reversal (overmodulation)

Envelope$\{s(t)\} = A_c[1 + K_a m(t)]$



$B_T = 2W$

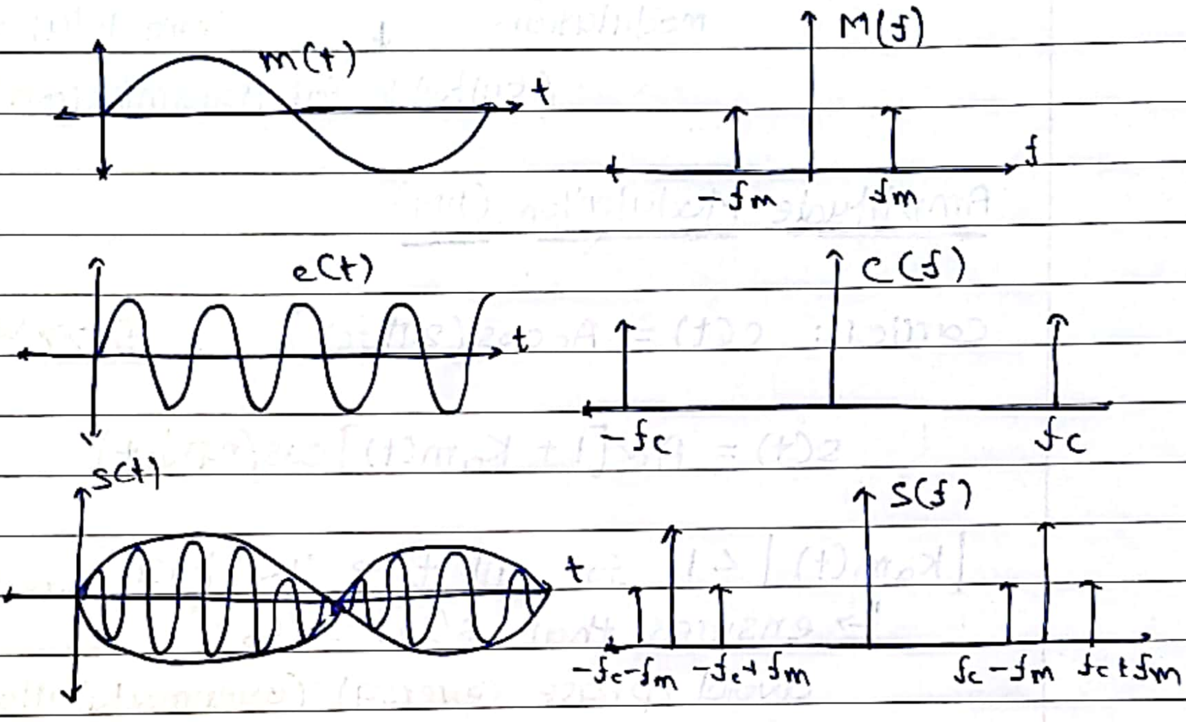
↳ transmission bandwidth

Single-Tone modulation: $m(t) = A_m \cos(2\pi f_m t)$

$$s(t) = A_c[1 + \mu \cos(2\pi f_m t)] \cos(2\pi f_c t)$$

$$\mu = K_a A_m \qquad \mu < 1$$

$$\frac{A_{max}}{A_{min}} = \frac{A_c(1+\mu)}{A_c(1-\mu)} \Rightarrow \mu = \frac{A_{max} - A_{min}}{A_{max} + A_{min}}$$

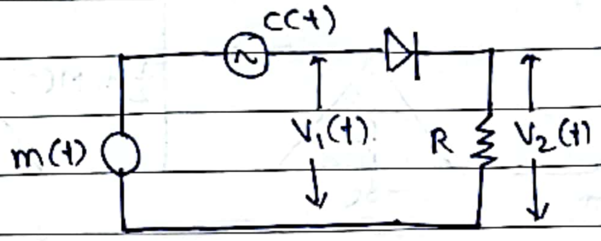


In $s(t) \Rightarrow$ carrier power $= \frac{1}{2} A_c^2$

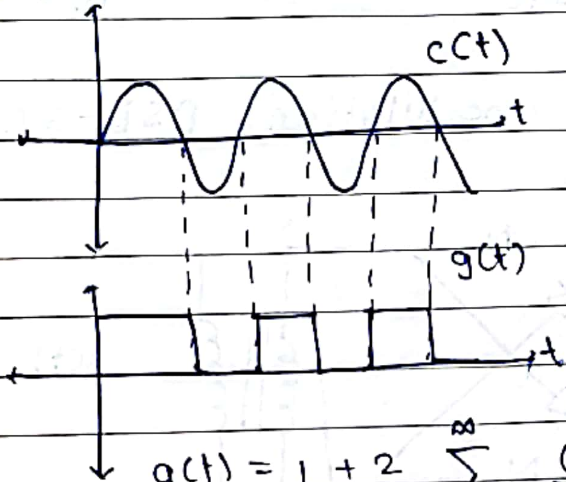
USB power $= \frac{1}{8} \mu A_c^2$ LSB power $= \frac{1}{8} \mu A_c^2$

μ also denotes the % modulation.

* Switching Modulator (modulation) DSB-FC



$$v_1(t) = m(t) + c(t)$$
$$= m(t) + A_c\cos(2\pi f_c t)$$
$$\approx A_c\cos(2\pi f_c t)$$
as $|m(t)| \ll A_c$

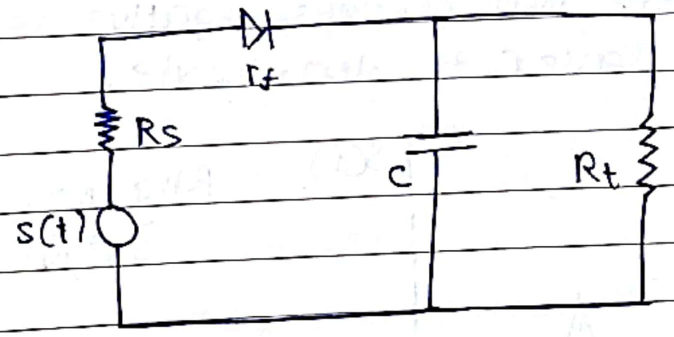


$$v_2(t) = v_1(t)\,g(t)$$
$$= g(t)\left[m(t) + A_c\cos(2\pi f_c t)\right]$$

$$\underbrace{BFF_{f_c}(v_2(t)) = \frac{A_c}{2}\left[1 + \frac{4\,m(t)}{\pi A_c}\right]\cos(\omega_c t)}_{s(t)}$$

$$g(t) = \frac{1}{2} + \frac{2}{\pi}\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{2n-1}\cos(2\pi f_c t(2n-1))$$

* Envelope detector (demodulation) DSB-FC



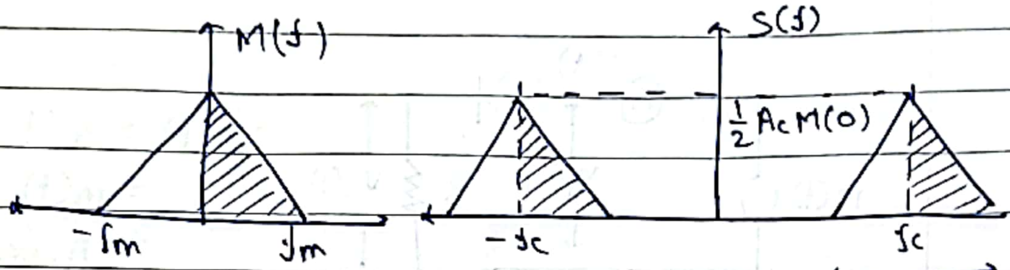
$$\underbrace{C(r_f + R_s)}_{\tau_{FB}} \ll \frac{1}{f_c}$$

$$\frac{1}{f_c} \ll \underbrace{R_t C}_{\tau_{RB}} \ll \frac{1}{f_m}$$

Constraints:

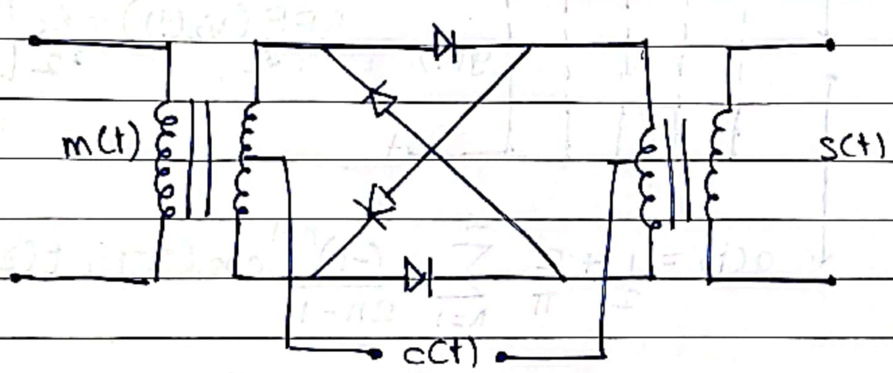
- $f_c \ggg f_m$ (signal should be narrowband)
- percentage modulation must be less than 100%. $(\mu < 1)$

DSB-SC : $s(t) = A_c \cos(2\pi f_c t)\, m(t)$

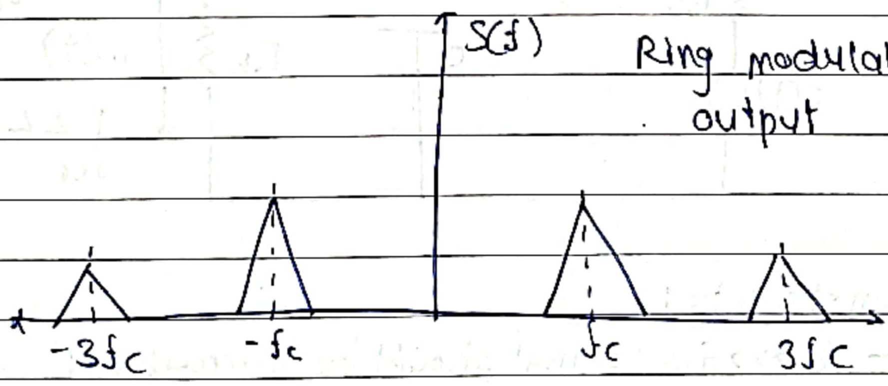


"Phase reversal issue" $B_T = 2W$

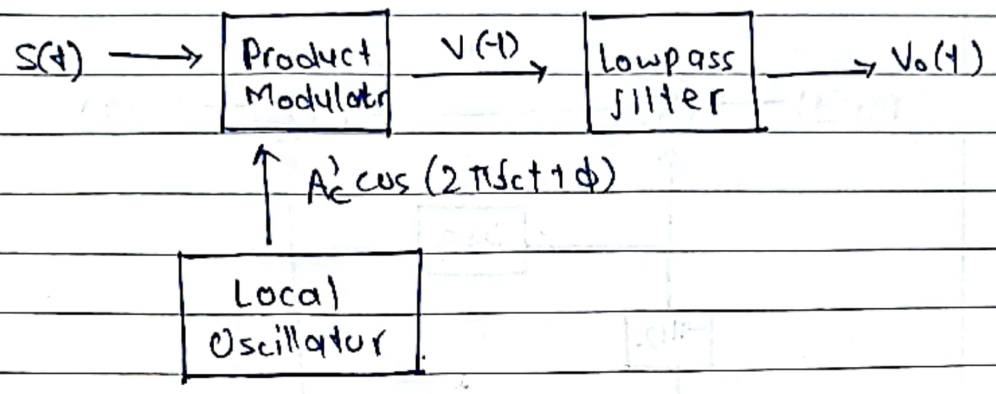
✳ Ring Modulator (modulation) DSB-SC



The diode ring causes a phase reversal of c(t) where m(t) becomes negative so it becomes easier to demodulate.



* Coherent Detector (demodulation) DSB-SC

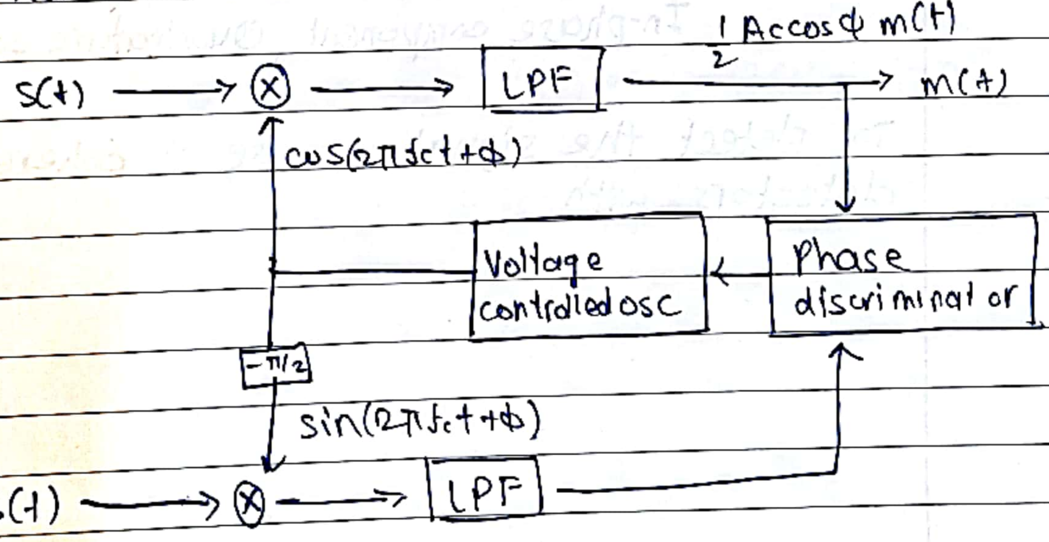


$$v(t) = s(t) \cdot A_c' \cos(2\pi f_c t + \phi)$$
$$= A_c A_c' \cos(2\pi f_c t) \cos(2\pi f_c t + \phi) m(t)$$
$$= \frac{A_c A_c'}{2} \cos(4\pi f_c t + \phi) m(t) + \frac{A_c A_c' \cos\phi \, m(t)}{2}$$

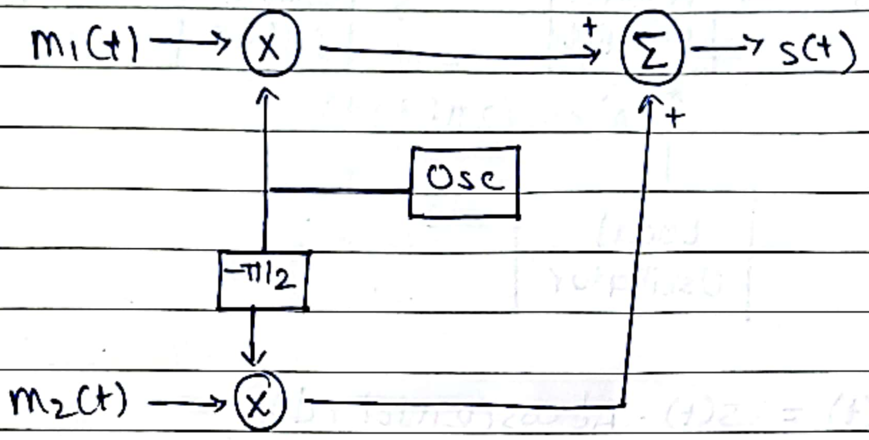
$$V_o(t) = \frac{1}{2} A_c A_c' \cos(\phi) m(t)$$ If $\phi = \pm \pi/2$, $V_o(t) = 0$ "Quadrature null effect"

* Costas Receiver

Uses negative feedback loop to counter problems caused by time varying $\phi(t)$ in coherent detector



Quadrature Carrier Multiplexing



$$s(t) = A_c m_1(t) \cos(2\pi f_c t) + A_c m_2(t) \sin(2\pi f_c t)$$

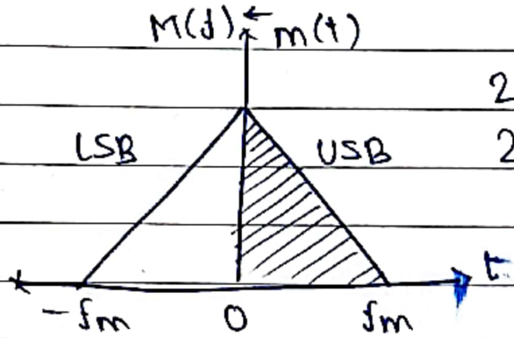
We can use the quadrature null effect at coherent detector to multiplex 2 signals on the same bandwidth.

$$s(t) = \underbrace{g_I \cos(2\pi f_c t)}_{\text{In-phase component}} - \underbrace{g_Q \sin(2\pi f_c t)}_{\text{Quadrature component}}$$

To detect the signal we use 2 coherent detectors with

$$s(t) = A_c \cos(\theta_i) = A_c \cos(2\pi f_i t) \qquad f_i = \frac{1}{2\pi}\frac{d\theta_i}{dt}$$

Phase Modulation	Frequency Modulation
$\theta_i = 2\pi f_c t + K m(t)$	$\theta_i = 2\pi f_c t + K 2\pi \int_{-\infty}^{\infty} m(\tau) d\tau$
$f_i = f_c + \frac{K}{2\pi}\frac{d\,m(t)}{dt}$	$f_i = \cancel{2\pi} f_c + K m(t)$

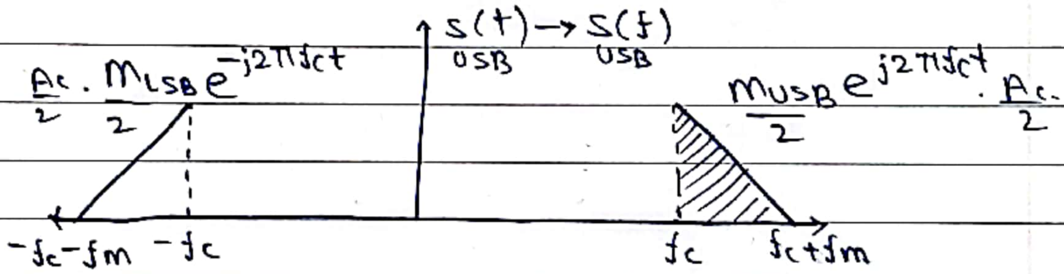


$$2 m_{USB}(t) = m(t) + j\hat{m}(t)$$

$$2 m_{LSB}(t) = m(t) - j\hat{m}(t)$$

$$\hat{m}(t) = m(t) * \left(\frac{1}{\pi t}\right)$$

$$\hat{M}(f) = (-j\,\mathrm{sgn} f) M(f)$$



$$S_{USB}(t) = \tfrac{1}{2}(m(t) + j\hat{m}(t)) e^{j2\pi f_c t} + \tfrac{1}{2}(m(t) - j\hat{m}(t)) e^{-j2\pi f_c t}$$

$$= m(t)\left[\frac{e^{j2\pi f_c t} + e^{-j2\pi f_c t}}{2}\right] + j\hat{m}(t)\left[\frac{e^{j2\pi f t} - e^{-j2\pi f t}}{2}\right]$$

$$= \frac{A_c}{2} m(t)\cos(2\pi f t) - \frac{A_c}{2}\hat{m}(t)\sin(2\pi f_c t)$$

$$S_{LSB}(t) = \frac{A_c}{2} m(t)\cos(2\pi f t) + \frac{A_c}{2}\hat{m}(t)\sin(2\pi f t)$$