DSB-SC

COHERENT DEMODULATION.

LECTURE - (EEL-308)

~~Fr~~ March 12, 2014.

Another method for acquiring phase of the transmitted carrier is to transmit a pilot tone carrier and use a PLL (phase locked loop) at the receiver to track the unknown phase of the carrier signal received.

Let the transmitted carrier be $\cos 2\pi f_c t$ and the received carrier be $\cos(2\pi f_c t + \phi)$ (e.g. $\phi = -2\pi f_c \tau$ models a single delay of τ seconds).

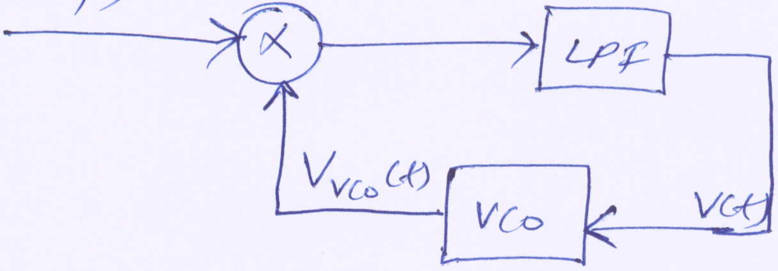
The PLL uses a VCO whose instantaneous frequency is

$$f_i(t) = f_c + k\,v(t)$$, where is the input to the VCO.

∴ The vco output signal is

$$V_{vco}(t) = A_{vco}\cos(2\pi f_c t + \phi_{vco}(0) + 2\pi k\int_0^t v(t)\,dt).$$

& received signal
$r(t) = A\cos(2\pi f_c t + \phi)$



Assuming an ideal LPF, band limited to $[-W, W]$,

$$v(t) \approx \frac{A A_{vco}}{2}\cos\phi_e(t)$$

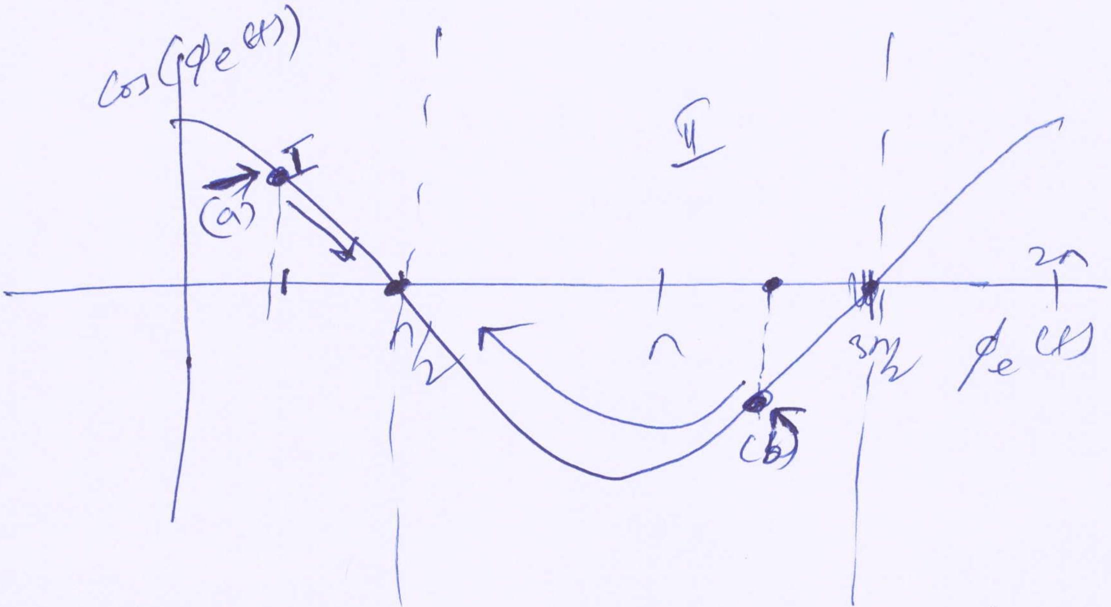
where $\phi_e(t) = \phi_{vco}(0) + 2\pi k\int_0^t v(t)\,dt - \phi$.

$$\therefore \frac{d\phi_e(t)}{dt} = 2\pi k\, v(t).$$

Equilibrium values for $\phi_e(t)$ = odd multiples of $\pi/2$
$= (\pi/2, 3\pi/2)$ (modulo 2π)

For equilibrium, $\phi_e(t)$ and $v(t)$ should be such that $V_{vco}(t)$ and $\phi_e(t)$ donot change with time. The solution for equilibrium is therefore $\frac{d\phi_e(t)}{dt} = 0 \Rightarrow v(t) = 0$
$\Rightarrow \cos(\phi_e(t)) = 0$.

Out of these two points $(\pi/2, 3\pi/2)$ only $\pi/2$ is stable.

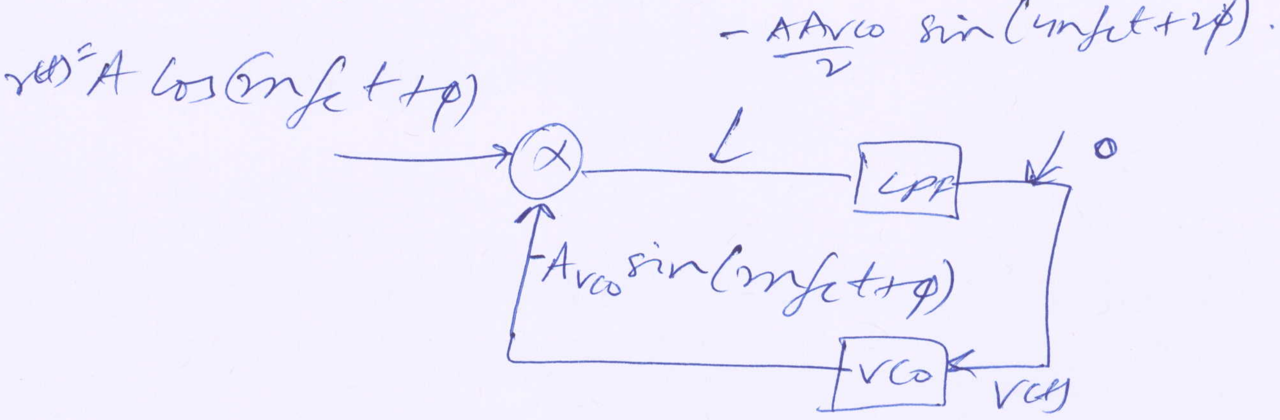


If we are at point (a) on the curve, then since $\cos\phi_e(t) > 0 \Rightarrow V(t) > 0$ and therefore the instantaneous phase of the VCO output increases and hence $\phi_e(t)$ increases till it reaches $\phi_e(t) = \pi/2$. Similarly if $\phi_e(t)$ is at point (b), $\cos(\phi_e(t)) < 0$ and hence the instantaneous phase ~~decreases~~ of VCO output decreases till $\phi_e(t)$ is $\pi/2$. Therefore the loop always converges to $\phi_e(t) = 2n\pi + \frac{\pi}{2}$ where n is any integer.

In other words, the PLL converges such that it stabilizes with the VCO output having a phase lead of $\pi/2$ with respect to the phase of the received pilot tone carrier signal

$$r(t) = A\cos(2\pi f_c t + \phi).$$

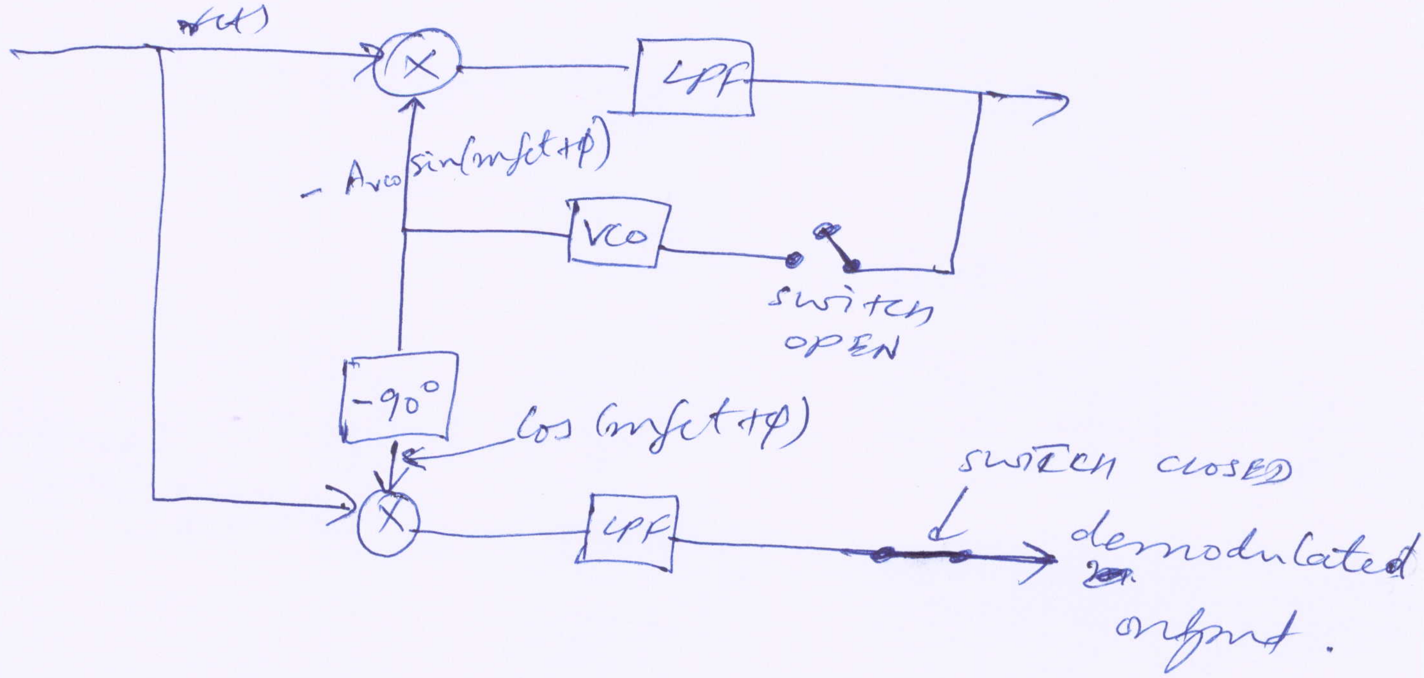
$\therefore$ Finally as $t \to \infty$, we have



For demodulation of DSB-SC, the transmit could first send a synchronization signal (i.e. a pilot tone carrier wave $A\cos 2\pi f_c t$) for a fixed duration. this will then be followed by transmission of the modulated DSB-SC signal.

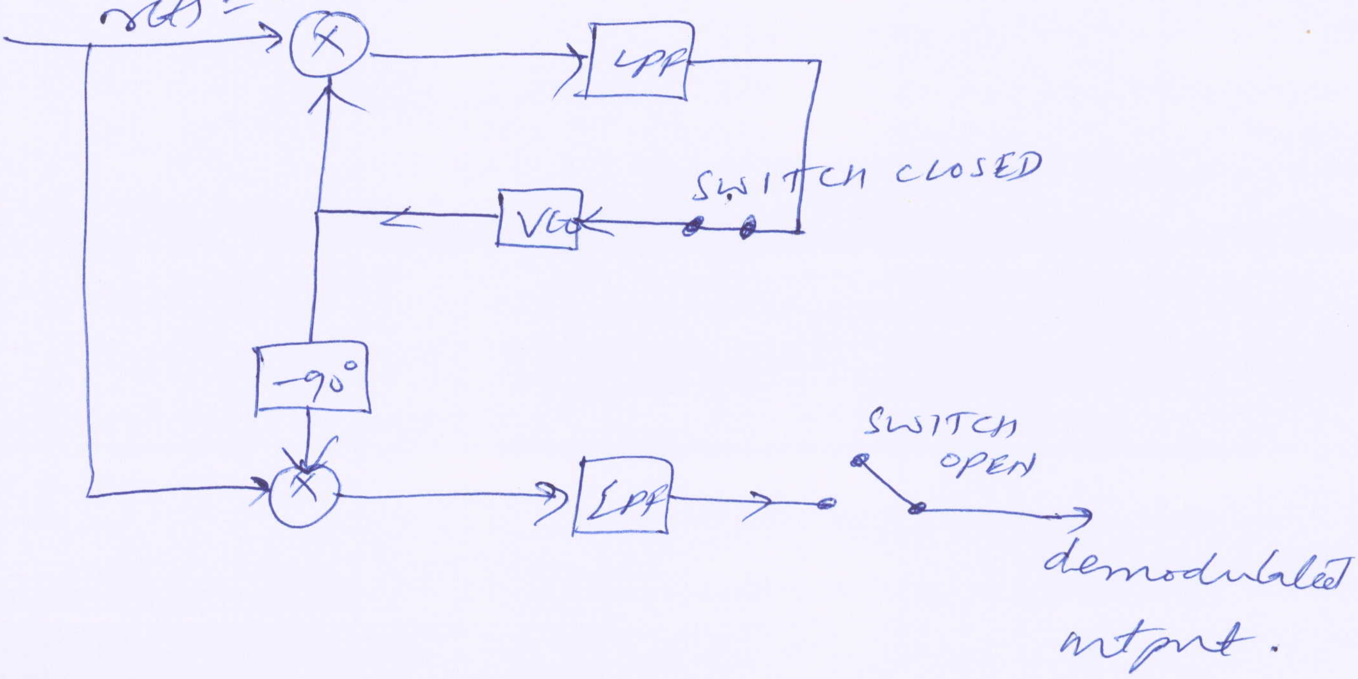
DURING COHERENT RECEPTION ③.

$r(t) = m(t)\cos(2\pi f_c t+\phi)$



DURING SYNCHRONIZATION

$r(t) = A\cos(2\pi f_c t+\phi)$



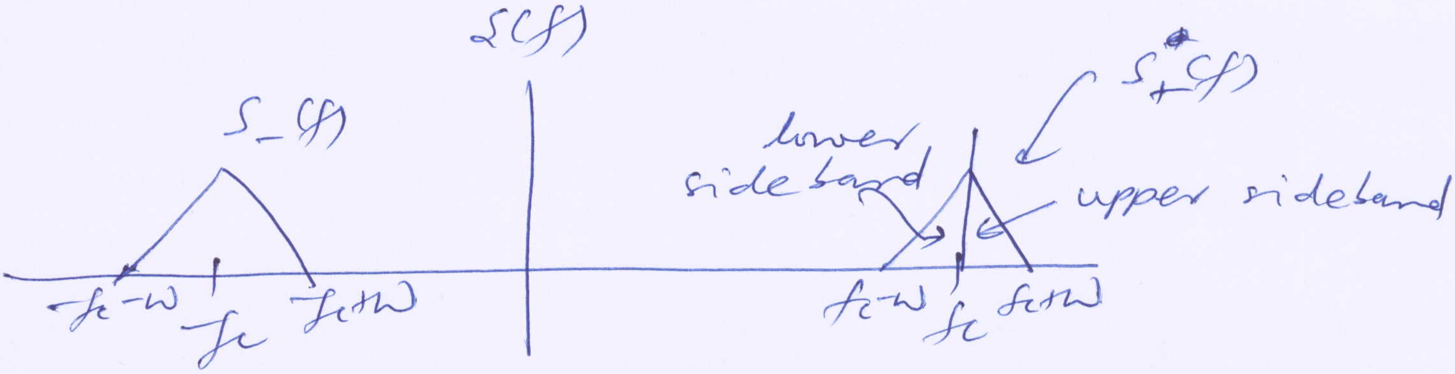
SINGLE SIDEBAND MODULATION (SSB).

MOTIVATION:

DSB-SC is wasteful of bandwidth

$s(t) = m(t) \cos 2\pi f_c t$.

$M(f) = M^*(-f)$.



$$S_+(f) = \frac{1}{2} M(f-f_c) = \underset{\substack{\uparrow \\ \text{lower sideband}}}{S_+^L(f)} + \underset{\substack{\uparrow \\ \text{upper sideband}}}{S_+^U(f)}$$

$$S_+^L(f) = \begin{cases} S_+(f), & f_c - W < f < f_c \\ 0, & \text{otherwise} \end{cases}$$

$$S_+^U(f) = \begin{cases} S_+(f), & f_c < f < f_c + W \\ 0, & \text{otherwise} \end{cases}$$

$\therefore$,

$$s_+^U(f) = M_+(f-f_c) \text{ and}$$

$$s_+^L(f) = M_-(f-f_c)$$

also, $M_+(f) = M_-^*(-f)$ (since $M(f) = M^*(-f)$)

$$\therefore \quad s_+^U(f) = M_+(f-f_c)$$

$$= M_-^*(f_c-f)$$

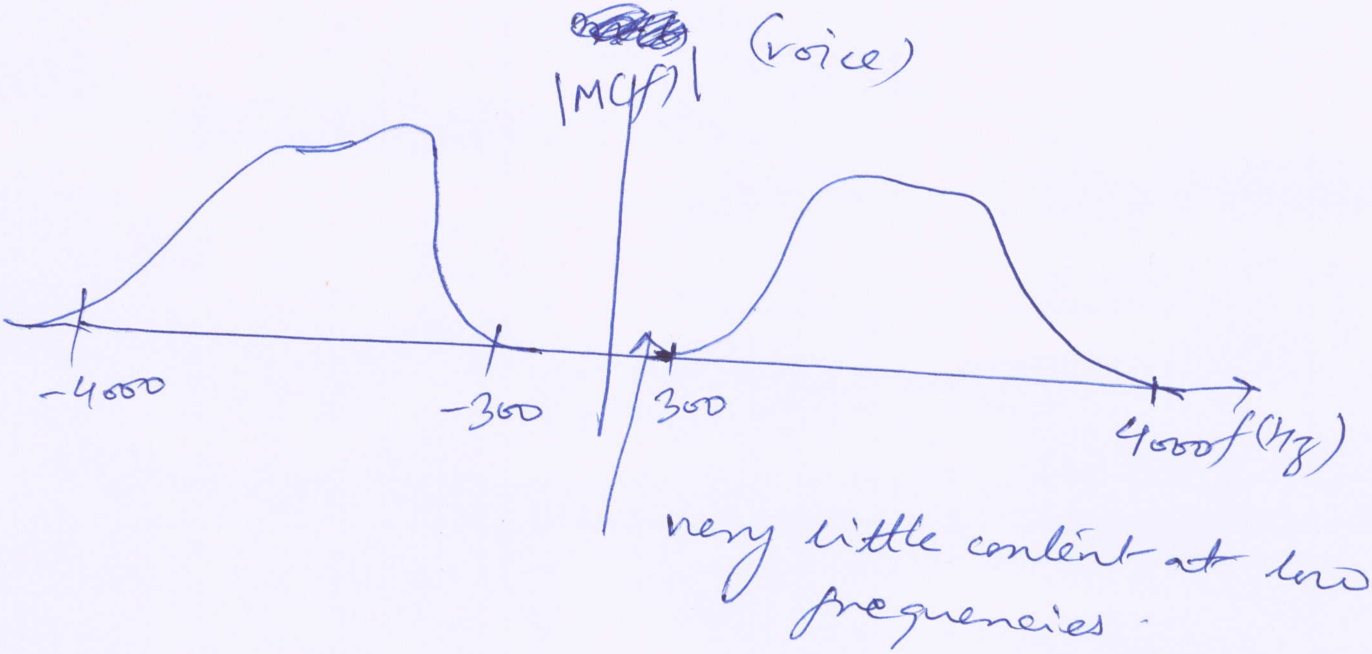
$$= \left[s_+^L(2f_c-f)\right]^* \leftarrow \text{complex conjugation.}$$

$\therefore$ $s_+^L(f)$ and $s_+^U(f)$ are ~~dependent~~ related to each other. Given $s_+^U(f)$ we can find out $s_+^L(f)$ and viceversa. There is therefore the same information communicated in both the bands (upper and lower). This is a waste of useful bandwidth. Why not simply transmit only the upper sideband or only the lower side band.

By doing so we can save both power and bandwidth.

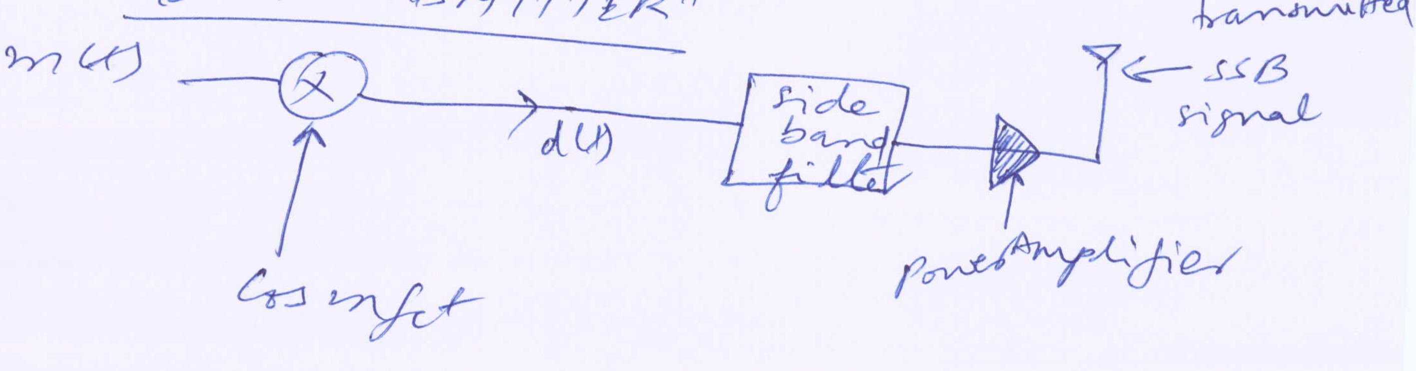
Since we propose to transmit only a single side band (either upper or lower), this scheme is called SSB.

One simple way of generating the SSB signal is to first generate a DSB-SC and ~~fil~~ then filter out one of the sidebands. This technique however suffers from the drawback that realizing perfectly brickwall filter is not practical. This scheme is however suited for those message signals which have less content near 0 Hz. The absence of significant energy/power at low frequencies allows us to use these low frequencies as the transition band between the pass band and the stop band of the filter (one Example is that of voice signals which have very little content below 300 Hz).

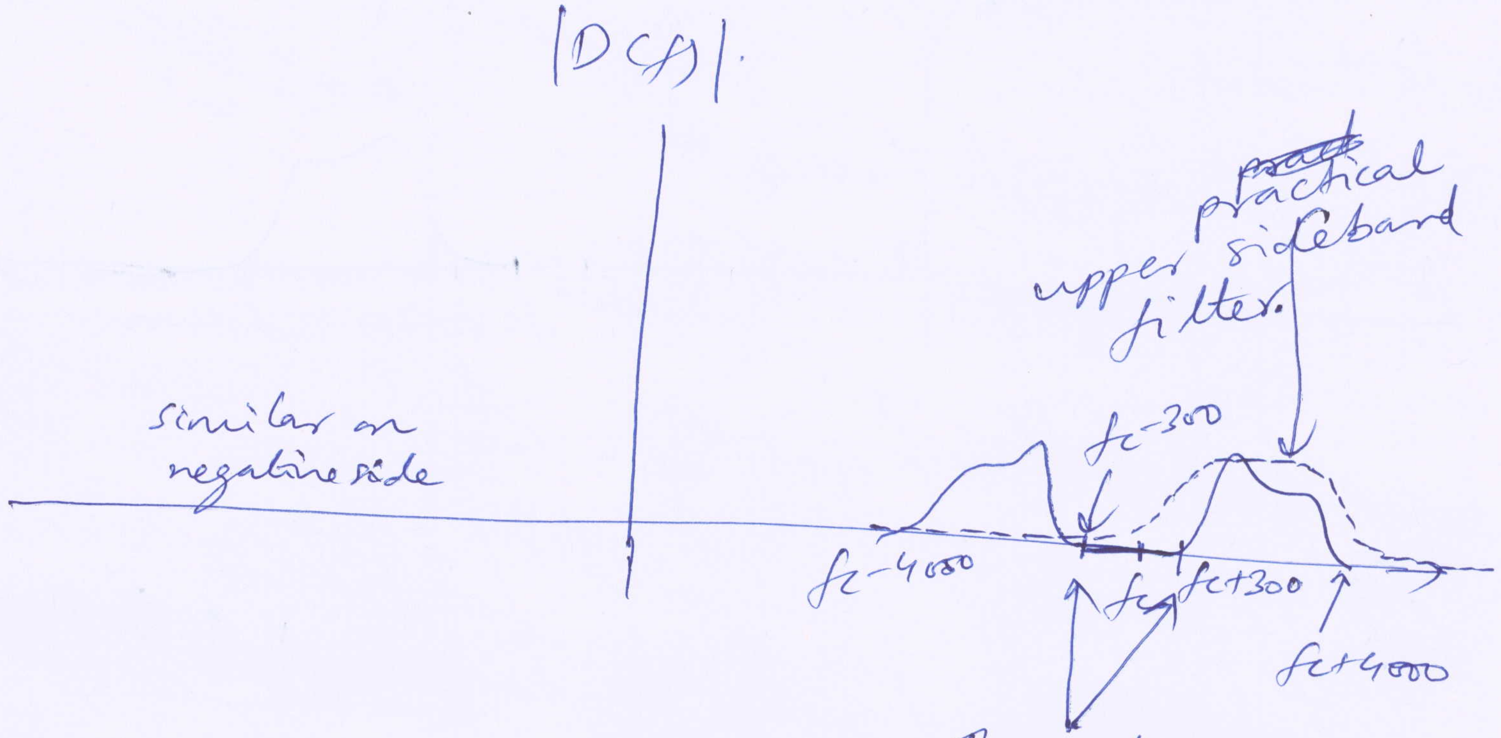


~~$s(t) = m(t)\cos \omega_c t$~~

"SSB TRANSMITTER"



$d(t) = m(t) \cos 2\pi f_c t$



The absence of message content in the frequency range $[f_c-300, f_c+300]$ allows us to practically design filter to select the required sideband, since we can now have a filter with a 600 Hz transition band between the passband of the filter (f_c+300, f_c+4000) and the stop band of the filter $(0, ~~0~~ f_c-300)$.