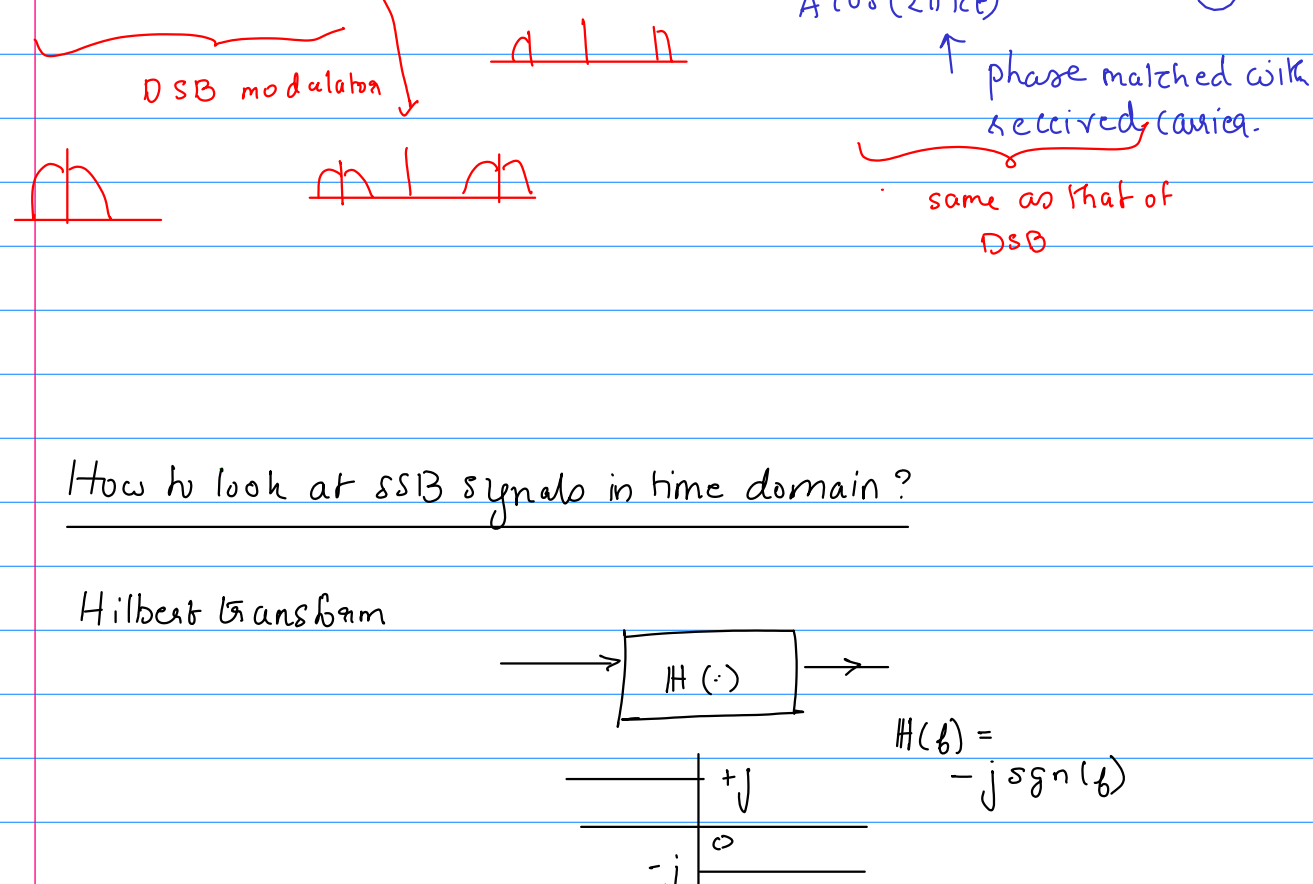
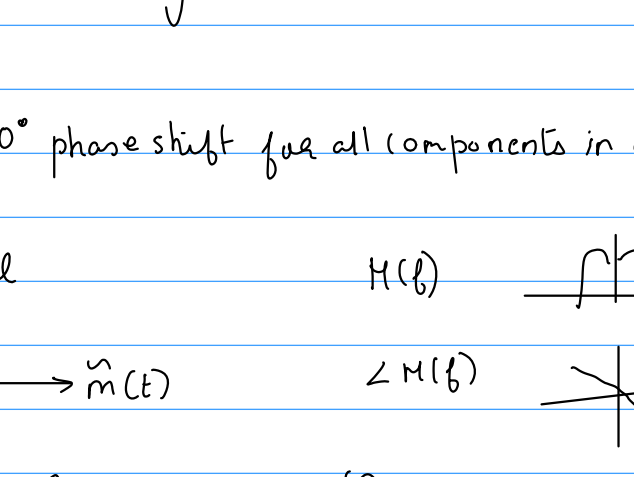


## SSB modulation/demodulation



How to look at SSB signals in time domain?

Hilbert Transform



H/W: UH

 $(\ast 1/\pi t)$  in time domain  
 how does this equivalence come about?

wideband 90° phase shifter.

$$\cos(2\pi f_c t) \rightarrow H(\cdot) \rightarrow$$

$$\frac{1}{2} \uparrow \quad \quad \uparrow \frac{1}{2} \quad = \quad \left( \frac{e^{j2\pi f_c t} + e^{-j2\pi f_c t}}{2} \right) \rightarrow (\cdot) \rightarrow \begin{matrix} -j e^{j2\pi f_c t} & + & j e^{-j2\pi f_c t} \\ \sin(2\pi f_c t) & \leftarrow & \frac{e^{j2\pi f_c t} - e^{-j2\pi f_c t}}{2j} \end{matrix}$$

what we obtain is a 90° phase shift for all components in a signal?

 $m(t)$  - baseband signal

$$H(f) \quad \text{plot of } H(f) = -j \operatorname{sgn}(f)$$

$$m(t) \rightarrow H(\cdot) \rightarrow \tilde{m}(t)$$

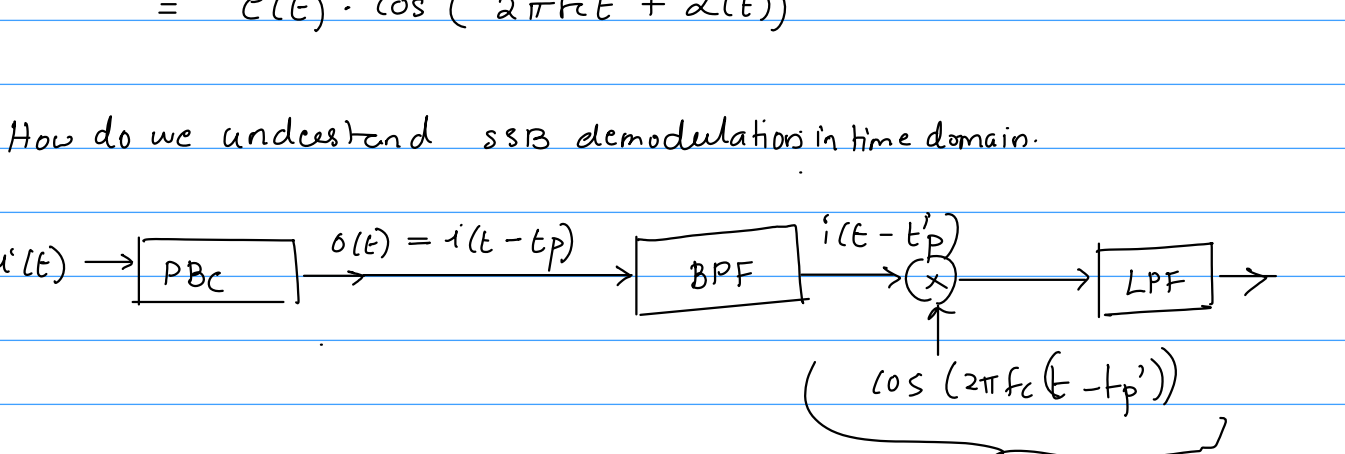
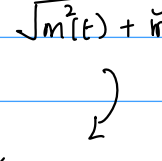
$$\angle H(f) \quad \text{plot of } \angle H(f) = -90^\circ$$

$$(m(t) + j\tilde{m}(t)) \xrightarrow{F} M(f) + j\tilde{M}(f)$$

$$\tilde{M}(f) = -j \operatorname{sgn}(f) M(f)$$

$$M(f) + j\tilde{M}(f) = M(f) - j^2 \operatorname{sgn}(f) M(f) = (m(t) + j\tilde{m}(t)) \xrightarrow{F} M(f) + \operatorname{sgn}(f) M(f) = M(f) + \operatorname{sgn}(f) M(f) =$$

$$m(t) - j\tilde{m}(t)?$$



$$i(t) = m(t) \cos(2\pi f_c t) + \tilde{m}(t) \sin(2\pi f_c t)$$

$$\frac{1}{2} \left[ M(f-f_c) + M(f+f_c) \right] + \frac{1}{2} \left[ \tilde{M}(f-f_c) - \tilde{M}(f+f_c) \right]$$

$$\tilde{M}(f) = -j \operatorname{sgn}(f) M(f)$$

$$\frac{1}{2} \left( -j \tilde{M}(f-f_c) \right) = \frac{1}{2} \left( -\operatorname{sgn}(f-f_c) M(f-f_c) \right)$$

$$= \frac{1}{2} \left( M(f-f_c) \right) \quad \text{(only lower sideband)}$$

$$M(f-f_c) \quad \text{(only lower sideband)}$$

Suppose we need to generate a USB signal?

$$\textcircled{1} m(t) \sin(2\pi f_c t) + \tilde{m}(t) \cos(2\pi f_c t) \rightarrow ?$$

$$\textcircled{2} m(t) \cos(2\pi f_c t) - \tilde{m}(t) \sin(2\pi f_c t) \rightarrow \text{USB signal}$$

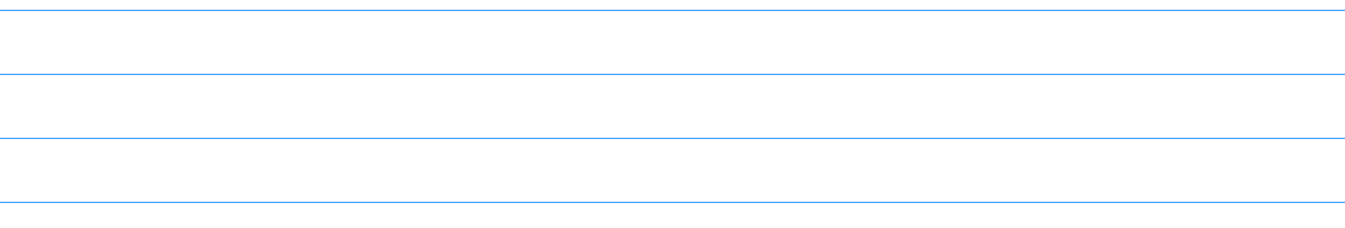
How is the carrier signal modulated in case of SSB?

$$\frac{m(t) \cos(2\pi f_c t) - \tilde{m}(t) \sin(2\pi f_c t)}{\sqrt{m(t)^2 + \tilde{m}(t)^2}} \left( \frac{m(t)}{\sqrt{m(t)^2 + \tilde{m}(t)^2}} \cos(2\pi f_c t) - \frac{\tilde{m}(t)}{\sqrt{m(t)^2 + \tilde{m}(t)^2}} \sin(2\pi f_c t) \right)$$

$$e(t) \left( \cos(\alpha(t)) \cos(2\pi f_c t) - \sin(\alpha(t)) \sin(2\pi f_c t) \right)$$

$$= e(t) \cdot \cos(2\pi f_c t + \alpha(t))$$

How do we understand SSB demodulation in time domain.



$$i(t - t_p) = m(t - t_p) \cos(2\pi f_c(t - t_p)) + \tilde{m}(t - t_p) \sin(2\pi f_c(t - t_p))$$

$$\times \cos(2\pi f_c(t - t_p)) \quad t = t - t_p$$

$$= \frac{m(t)}{2} \cos(2\pi f_c t) + \frac{m(t)}{2} \cos(2\pi f_c t) - \frac{\tilde{m}(t)}{2} \sin(2\pi f_c t) - \frac{\tilde{m}(t)}{2} \sin(2\pi f_c t)$$

$$= m(t) \cos(2\pi f_c t) - \tilde{m}(t) \sin(2\pi f_c t)$$

$$\text{cut-off by the LPF}$$

$$\text{Quadrature carrier multiplexing: } (m_1(t) \cos(2\pi f_c t) + m_2(t) \sin(2\pi f_c t)) \times \cos(2\pi f_c t)$$

$$\times \sin(2\pi f_c t)$$