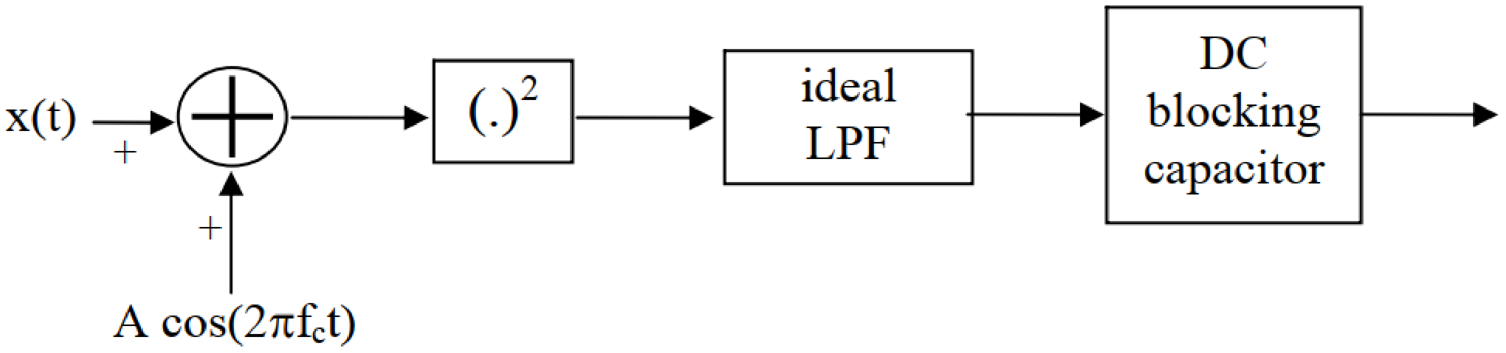
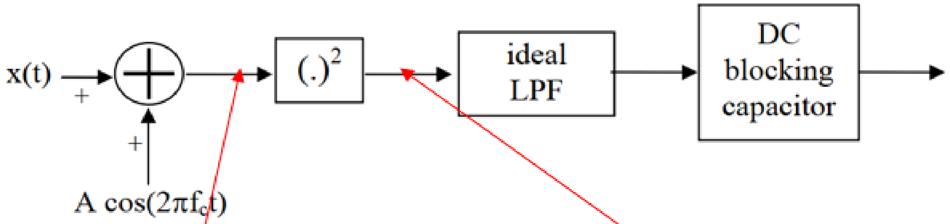
1. A DSBSC-AM signal $x(t) = \text{sinc}(1000t)\cos(2\pi f_c t)$ is demodulated using the system shown below. The box marked $(.)^2$ is a square-law device that produces an output equal to the square of its input. The DC blocking capacitor removes all DC components at its input.

(a) Show that the demodulated output contains distortion.

(b) How should the lowpass filter (LPF) be designed to minimize this distortion?

(c) What is the minimum carrier frequency f_c permitted for this demodulator?





$x(t) + Acos(2\pi f_c t)$

$(x(t) + Acos(2\pi f_c t))^{2}$

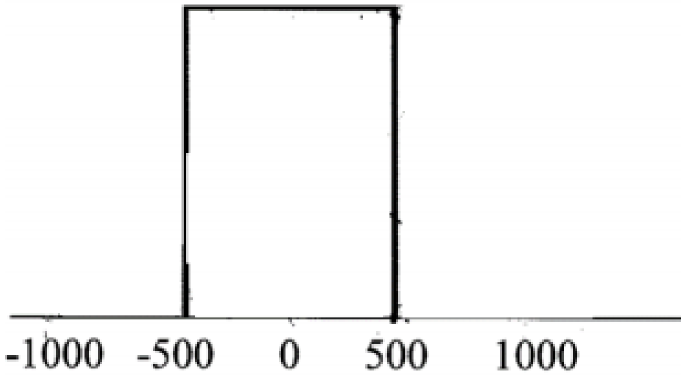
a) $[x(t) + Acos(2\pi f_c t)]^{2} = [sinc(1000t)cos(2\pi f_c t) + Acos(2\pi f_c t)]^{2}$

$= [sinc(1000t) + A]^{2} cos^2(2\pi f_c t)$

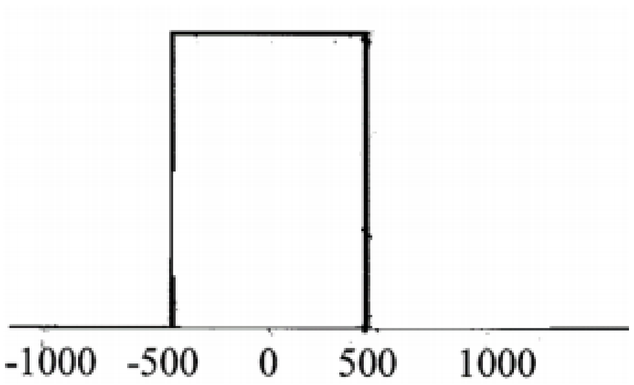
$= \frac{1}{2}[\boxed{sinc^2(1000t)+2Asinc(1000t)+ A^2}] + \frac{1}{2} cos(4\pi f_c t)[\boxed{sinc^2(100t)+2Asinc(1000t)+ A^2}]$

m(t)

$sinc(1000t)$ $\longrightarrow$



$sinc^2(1000t) \longrightarrow$



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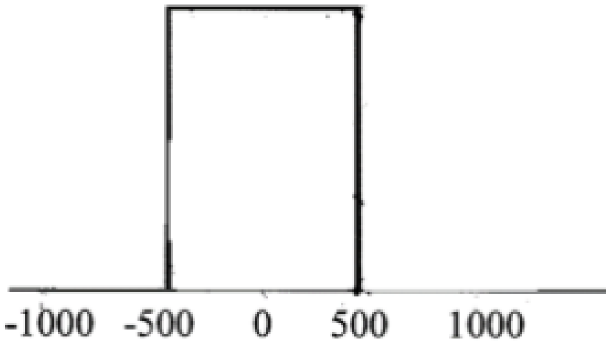
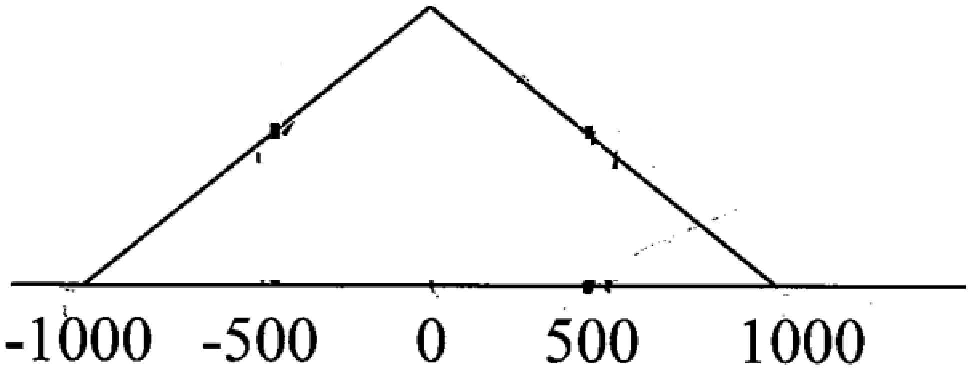
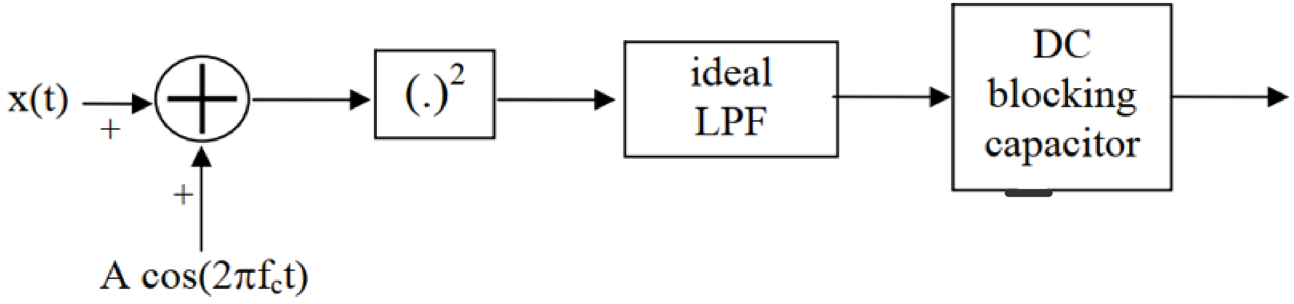
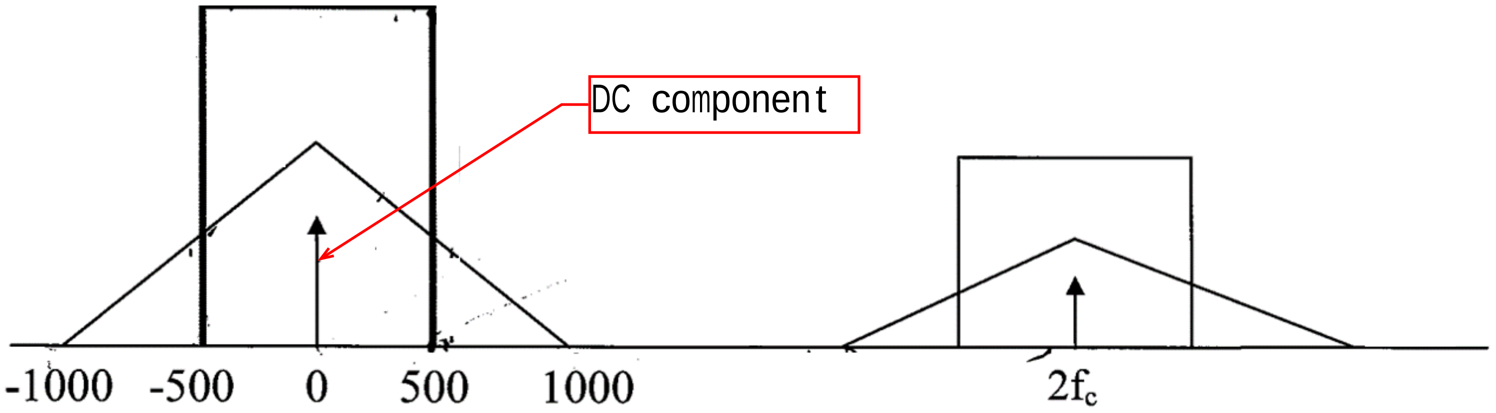




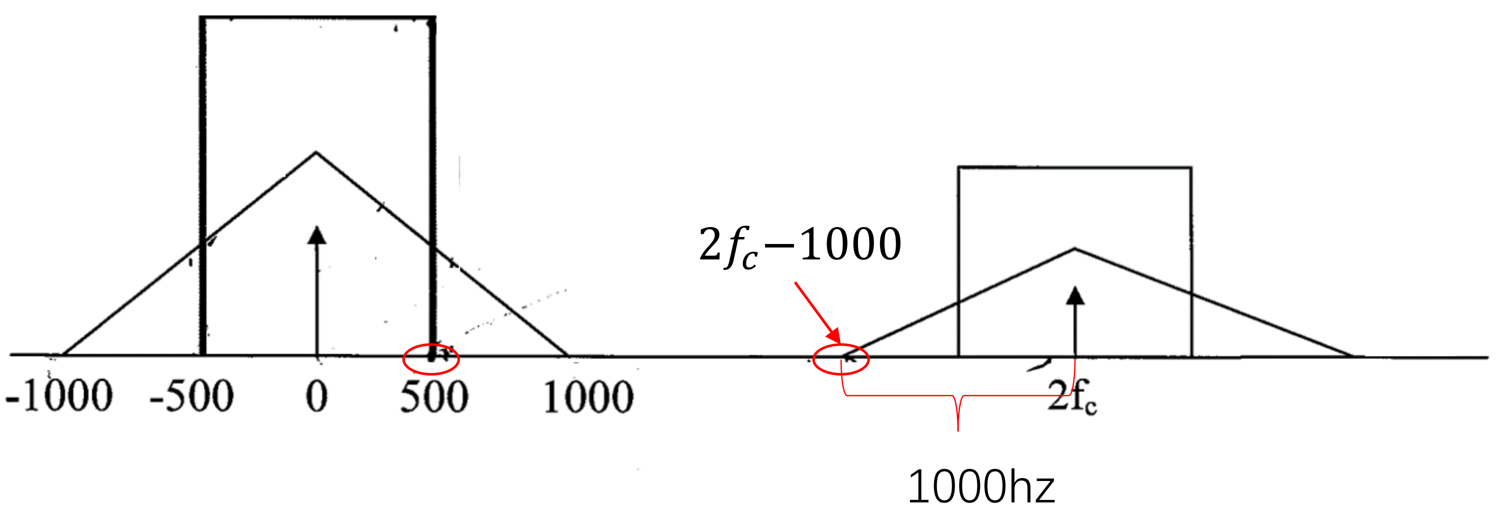
Amplitude spectrum:





Output = A$sinc(1000t)$+distortion

b) BW = 500hz



c) $2f_c-1000 > 500$

$f_c > 750Hz$

2. A QAM signal with a carrier frequency of 4KHz is formed by modulating a message signal $s_1(t)$ = 1 volt onto the in-phase carrier and another message signal $s_2(t)$ = -1 volt onto the quadrature-phase carrier.

   (a) Determine the time-domain expression of the QAM signal. Write your answer as a single cosine term.

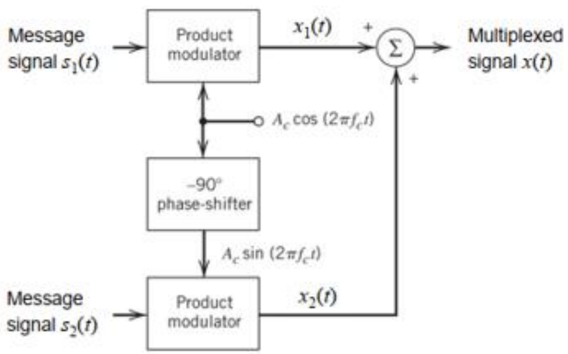
   (b) Demodulate the QAM signal obtained in Part (a) using a coherent detector.

a) QAM signal $= s_1(\mathrm{t})\cos(2\pi f_c t) + s_2(\mathrm{t})\sin(2\pi f_c t)$

$$= \cos(8000\pi t) - \sin(8000\pi t)$$

$$= \sqrt{2}\cos\left(8000\pi t + \frac{\pi}{4}\right)$$

QAM Generation:



b) 1. In- phase demodulator output:

$$= [\sqrt{2}\ \cos\left(8000\pi t + \frac{\pi}{4}\right) * \cos(8000\pi t)]_{LPF}$$

$$= \frac{\sqrt{2}}{2}[\cos\left(\frac{\pi}{4}\right) + \cos(16000\pi t + \frac{\pi}{4})]_{LPF}$$

$$= \frac{\sqrt{2}}{2}\cos\left(\frac{\pi}{4}\right) = \frac{1}{2}$$

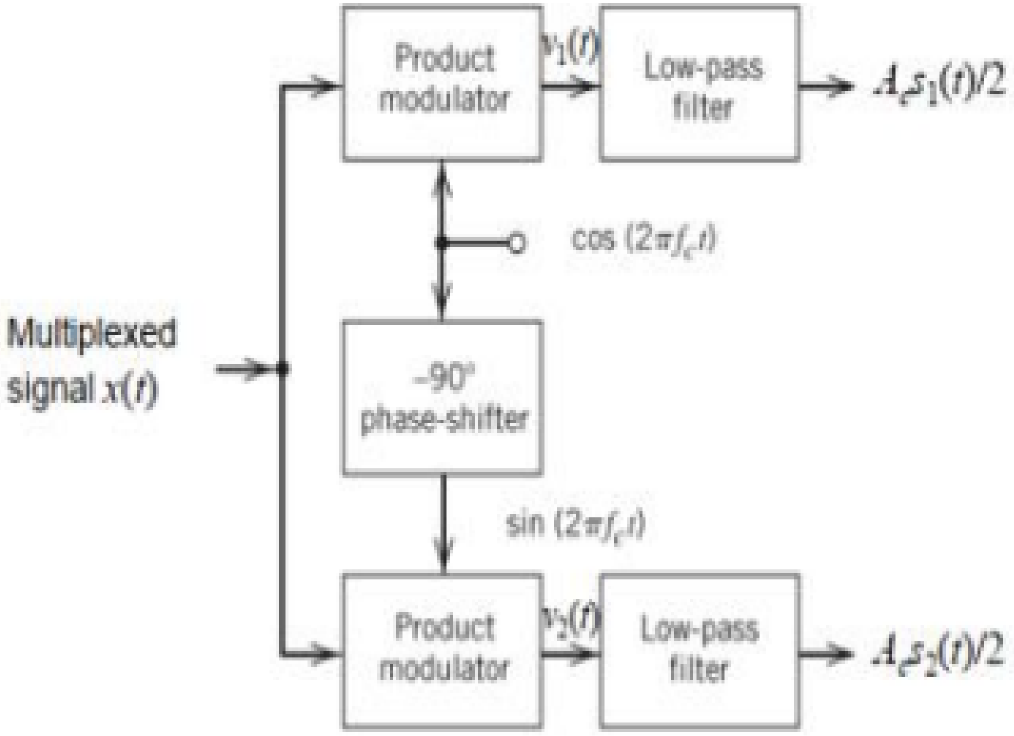
2. Q- phase demodulator output:

$$= [\sqrt{2}\ \cos\left(8000\pi t + \frac{\pi}{4}\right) * \sin(8000\pi t)]_{LPF}$$

$$= \frac{\sqrt{2}}{2}[-\sin\left(\frac{\pi}{4}\right) + \sin(16000\pi t + \frac{\pi}{4})]_{LPF}$$

$$= -\frac{\sqrt{2}}{2}\sin\left(\frac{\pi}{4}\right) = -\frac{1}{2}$$

QAM Detection:

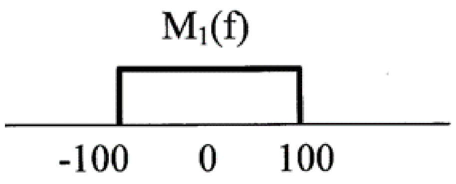


3. Given two message signals $m_1(t) = \mathrm{sinc}(200t)$ and $m_2(t) = 2\cos(2\pi f_0 t)$ where f_0 can range from 0Hz to 120Hz. Compare the minimum amount of bandwidth required to transmit them using

(a) DSBSC-AM and frequency division multiplexing (FDM)

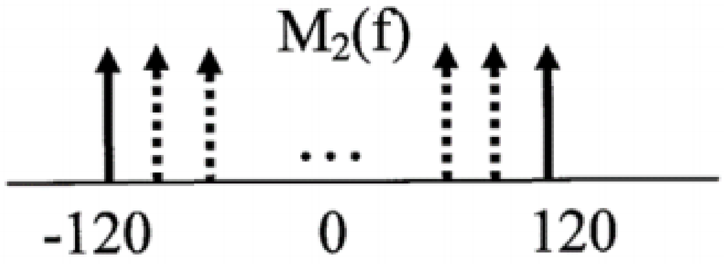
(b) QAM

$m_1(t) = \mathrm{sinc}(200t) \rightarrow M_1(f) = 1/200\ \mathrm{rect}(f/200)$



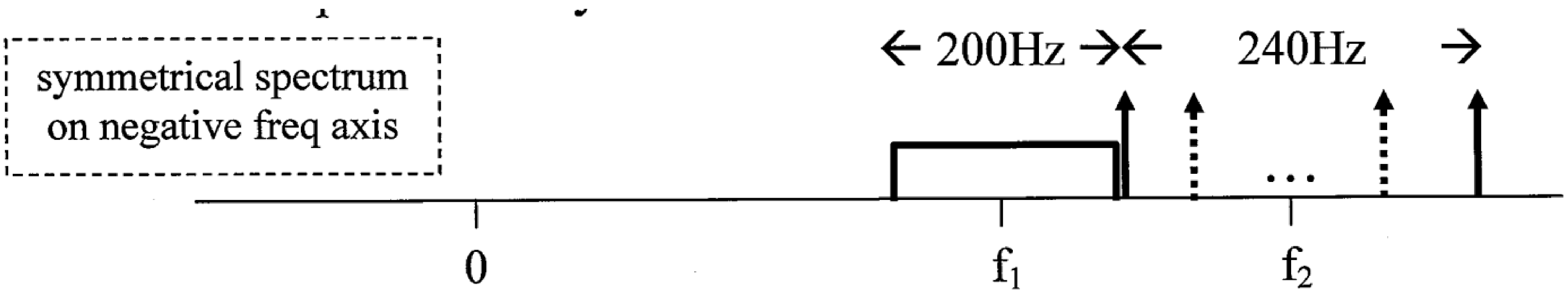
Bw = 100Hz

$m_2(t)$



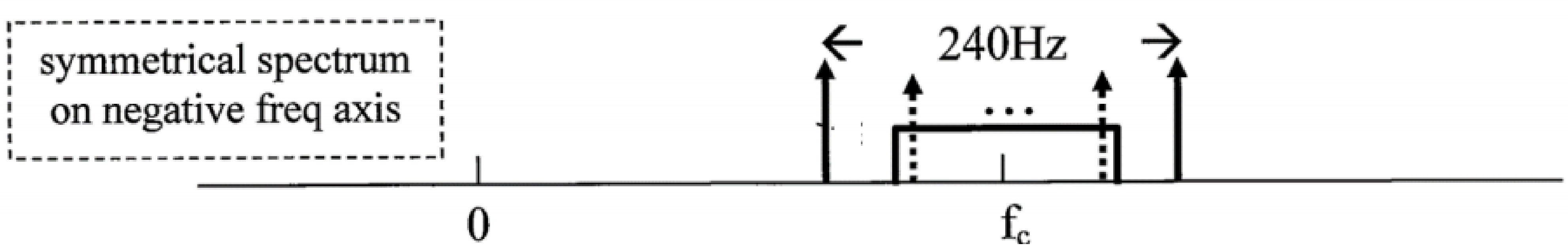
Bw = 120Hz

a) FDM signal = $m_1(t)\cos(2\pi f_1 t)+ m_2(t)\cos(2\pi f_2 t)$



BW = 200 + 240 ≥ 440 Hz

b) QAM signal = $m_1(t)\cos(2\pi f_c t) + m_2(t)\sin(2\pi f_c t))$



BW = 240 ≥ 240 Hz