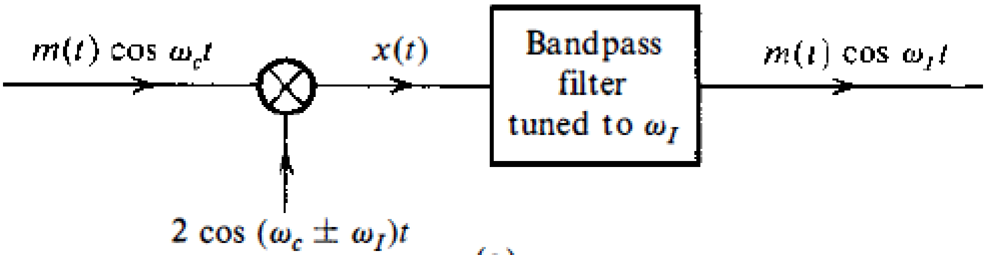
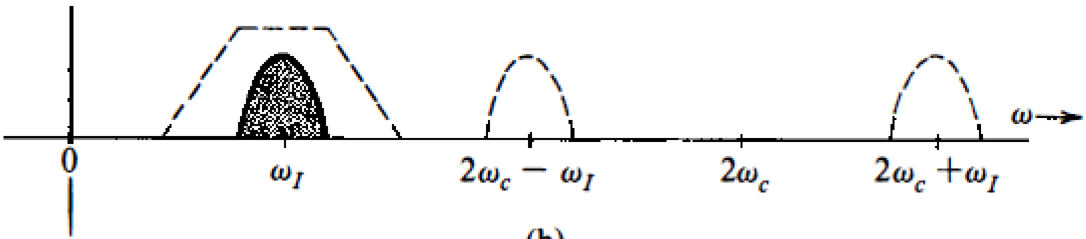
Frequency Mixer or Converter

We shall analyze a frequency mixer, or frequency converter, used to change the carrier frequency (**Heterodyning**) of a modulated signal $\boldsymbol{m(t)\cos(w_c\, t)}$ from $\boldsymbol{w_c}$ to another frequency w_I . This can be done by multiplying $\boldsymbol{m(t)\cos(w_c\, t)}$ by $\boldsymbol{2\cos(w_{mix}\, t)}$, where $\boldsymbol{w_{mix} = w_c + w_I}$ or $\boldsymbol{w_{mix} = w_c - w_I}$, and then bandpass-filtering the product, as shown in Figure bellow



(a)



(b)

$x(t) = m(t)\cos(w_c\, t)\, 2\cos(w_{mix}\, t)$

$x(t) = m(t)[\cos(w_c - w_{mix})\, t + \cos(w_c + w_{mix})\, t]$

If we select $\boldsymbol{w_{mix} = w_c - w_I}$ then

$x(t) = m(t)[\cos(w_c - w_c + w_I)\, t + \cos(w_c + w_c - w_I)\, t]$

$x(t) = m(t)[\cos(w_I)\, t + \cos(2w_c - w_I)\, t]$

If we select $\boldsymbol{w_{mix} = w_c + w_I}$ then

$x(t) = m(t)[\cos(w_c - w_c - w_I)\, t + \cos(w_c + w_c + w_I)\, t]$

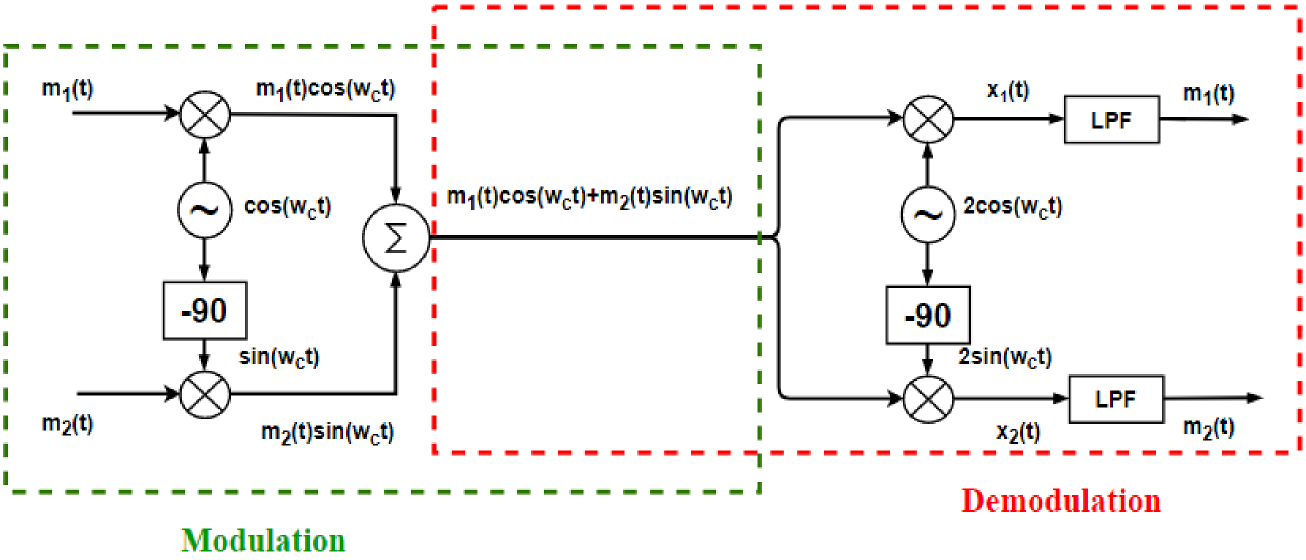
$x(t) = m(t)[\cos(w_I)\, t + \cos(2w_c + w_I)\, t]$

a bandpass filter at the output, tuned to $\boldsymbol{w_I}$, will pass the term $\boldsymbol{m(t)\cos(w_I\, t)}$ and suppress the other term

$\boldsymbol{output = m(t)\cos(w_I\, t)}$

Quadrature Amplitude Modulation (QAM)

QAM operates by transmitting two DSB signals using carriers of the same frequency but in phase quadrature, as shown in Figure below. This scheme is known as **quadrature amplitude modulation (QAM) or quadrature multiplexing.** As shown Figure, the boxes labeled $-\pi/2$ are phase shifters that delay the phase of an input sinusoid by $-\pi/2$rad. If the two baseband message signals for transmission are $\boldsymbol{m_1(t)}$ and $\boldsymbol{m_2(t)}$, the corresponding QAM signal $\varphi_{QAM}(t)$.



Thus, two baseband signals, each of bandwidth B Hz, can be transmitted simultaneously over a bandwidth $2f_m$ by using DSB transmission and quadrature multiplexing. The upper channel is also known as the **in-phase**(I) channel and the lower channel is the **quadrature**(Q) channel. Both signals $\boldsymbol{m_1(t)}$ and $\boldsymbol{m_2(t)}$ can be separately demodulated.

Modulation in-phase(I) channel and quadrature(Q) channel

$$x_1(t) = m_1(t)\cos(w_c\, t)$$

$$x_2(t) = m_2(t)\sin(w_c\mathrm{t})$$

$$\boldsymbol{\varphi_{QAM}(t) = m_1(t)\cos(w_c\, t) + m_2(t)\sin(w_c \mathrm{t})}$$

Demodulation

1- In-phase (I) channel

$x_1(t) = \varphi_{QAM}(t)\, 2\cos(w_c\, t)$

$x_1(t) = [m_1(t)\cos(w_c\, t) + m_2(t)\sin(w_c t)]2\cos(w_c\, t)$

$x_1(t) = 2m_1(t)\cos^2(w_c\, t) + 2m_2(t)\sin(w_c \mathrm{t})\cos(w_c\, t)$

$x_1(t) = m_1(t)(1 + \cos(2w_c\, t)) + 2m_2(t)\sin(w_c \mathrm{t})\cos(w_c\, t)$

$x_1(t) = m_1(t) + m_1(t)\cos(2w_c\, t) + m_2(t)\sin(2w_c \mathrm{t})$

After lowpass filter (LPF)

$\boldsymbol{output_1 = m_1(t)}$

2- Quadrature(Q) channel

$x_2(t) = \varphi_{QAM}(t)\, 2\sin(w_c \mathrm{t})$

$x_2(t) = [m_1(t)\cos(w_c\, t) + m_2(t)\sin(w_c t)]\, 2\sin(w_c \mathrm{t})$

$x_2(t) = 2m_1(t)\cos(w_c\, t)\sin(w_c \mathrm{t}) + 2m_2(t)\sin^2(w_c t)$

$x_2(t) = 2m_1(t)\sin(w_c \mathrm{t})\cos(w_c\, t) + m_2(t)(1 - \cos(2w_c\, t))$

$x_2(t) = m_1(t)\sin(2w_c \mathrm{t}) + m_2(t) - m_2(t)\cos(2w_c\, t)$

After lowpass filter (LPF)

$\boldsymbol{output_2 = m_2(t)}$

Multiplexing

Multiplexing is a technique in which several message signals are combined into a composite signal for transmission over a common channel.
These signals to be transmitted over the common channel must be kept apart so that they do not interfere with each other, and hence they can be separated easily at the receiver end.

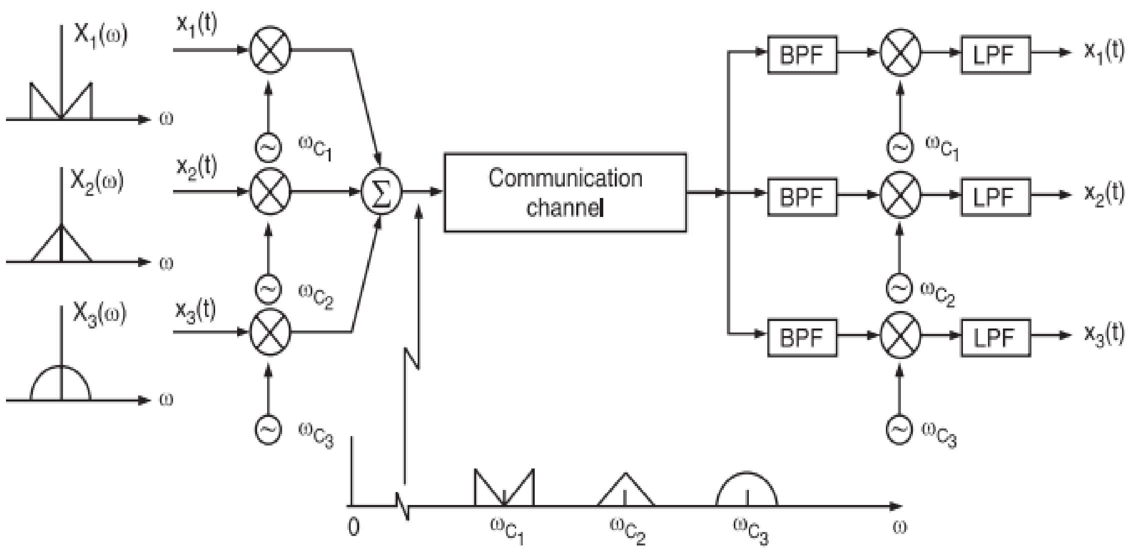
Basically, multiplexing is of two types such as :

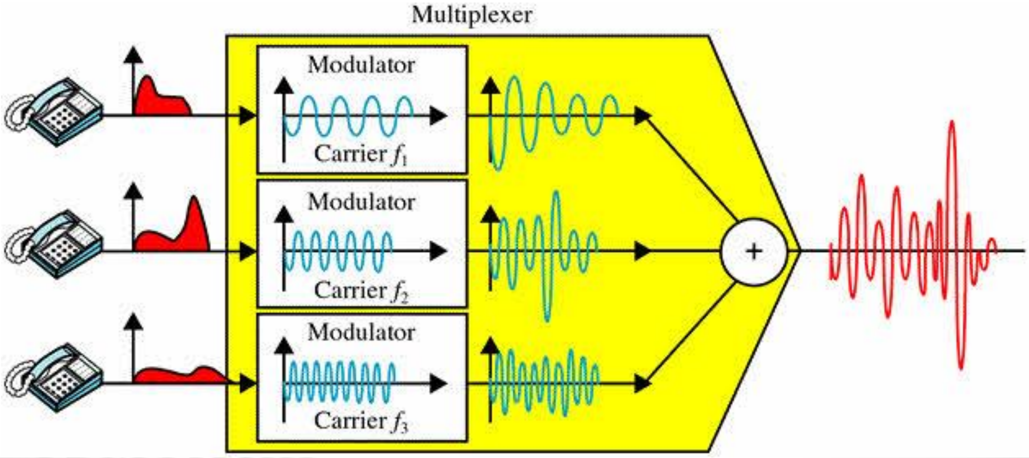
1- Frequency Division Multiplexing (FDM)
2- Time Division Multiplexing (TDM)

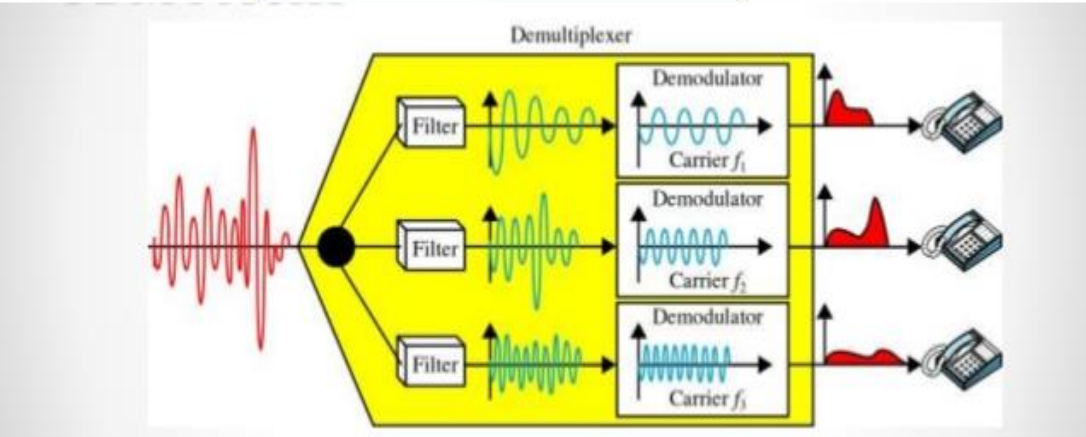
Frequency Division Multiplexing (FDM)

Frequency division multiplexing (**FDM**): is a technique by which the total bandwidth available in a communication medium is divided into a series of non-overlapping frequency bands, each of which is used to carry a separate signal. This allows a single transmission medium such as a cable or optical fiber to be shared by multiple independent signals. Another use is to carry separate serial bits or segments of a higher rate signal in parallel.

The most common example of frequency-division multiplexing is radio and television broadcasting, in which multiple radio signals at different frequencies pass through the air at the same time.







H.W: What is the disadvantage of Frequency Division Multiplexing (FDM)