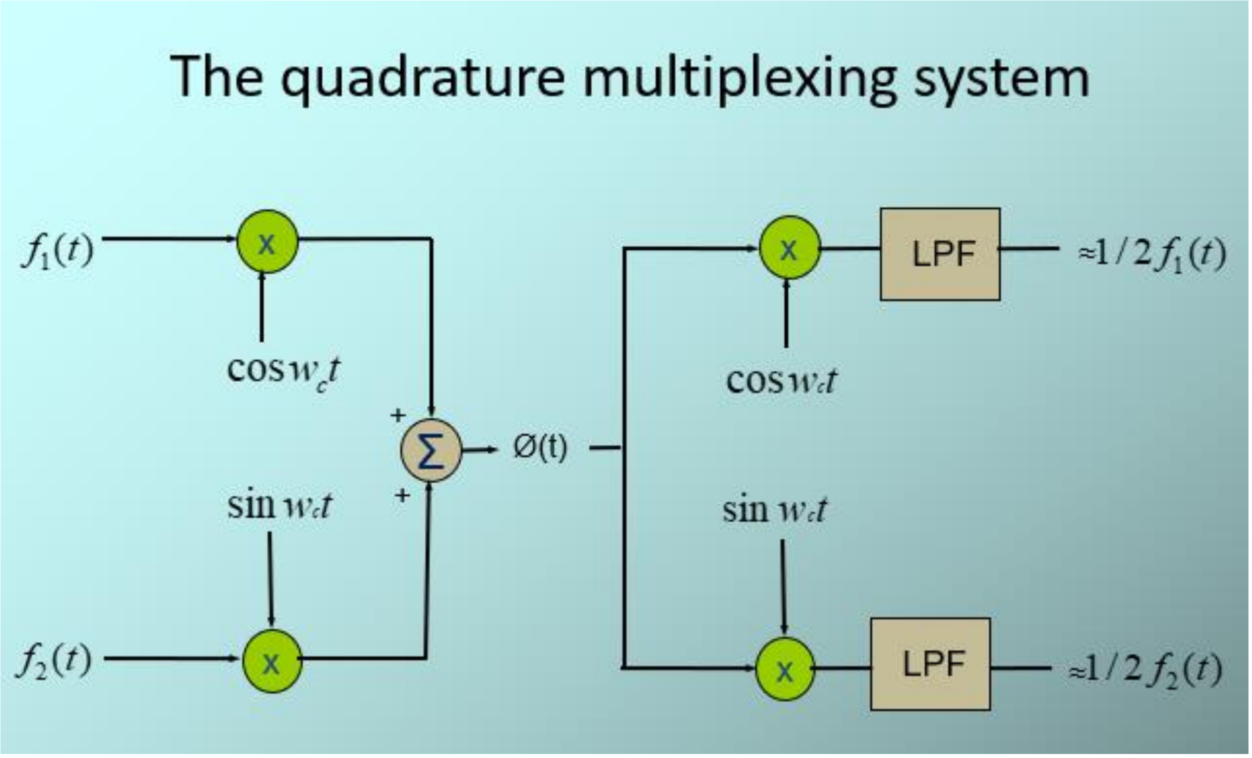
The quadrature multiplexing system



The diagram shows a quadrature multiplexing system, which allows two different baseband signals to be transmitted over the same carrier frequency without interfering with each other

ransmitter Side (Left Part of the Diagram)

We have two input signals:

f1(t) → first message signal

$f2(t)$ → second message signal

Both are multiplied by carrier waves.

Step 1: Modulation with Orthogonal Carriers

f1(t) is multiplied by:

cos(ωct)

f2(t) is multiplied by:

sin(ωct)

These two carriers are:

Same frequency ωc

90° out of phase (cosine and sine are orthogonal)

$$\int_0^T \cos(\omega_c t)\sin(\omega_c t)\,dt = 0$$

This is very important because:

That means they do not interfere with each other.

The two modulated signals are added:

$$\phi(t) = f_1(t)\cos(\omega_c t) + f_2(t)\sin(\omega_c t)$$

This single signal $\phi(t)$ now carries **both messages.**

This is called **Quadrature Modulation.**

Receiver Side (Right Part of the Diagram)

Now we must recover $f1(t)$And f2(t).

Recovering f1(t)

The received signal is:

$$\phi(t) = f_1(t)\cos(\omega_c t) + f_2(t)\sin(\omega_c t)$$

Multiply it again by $\cos(\omega_c t)$:

$$\phi(t)\cos(\omega_c t)$$

Substitute:

$$= f_1(t)\cos^2(\omega_c t) + f_2(t)\sin(\omega_c t)\cos(\omega_c t)$$

Using trigonometric identities:

$$\cos^2(\omega_c t) = \frac{1}{2}(1 + \cos(2\omega_c t))$$

$$\sin(\omega_c t)\cos(\omega_c t) = \frac{1}{2}\sin(2\omega_c t)$$

So we get:

$$= \frac{1}{2}f_1(t) + \text{high-frequency terms}$$

Step 3 Low Pass Filter (LPF)

The LPF removes the high-frequency components at 2ωc

Remaining signal:

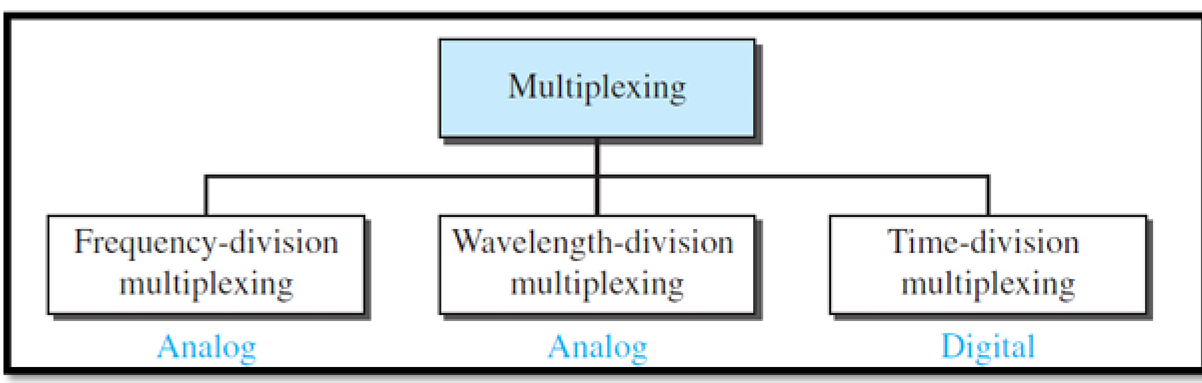
$$\approx 1/2 f1(t)$$

Multiplexing

is the set of techniques that allow the simultaneous transmission of multiple signals across a single data link. As data and telecommunications use increases, so does traffic. We can accommodate this increase by continuing to add individual links each time a new channel is needed; or we can install higher-bandwidth links and use each to carry multiple signals.

Types of Multiplexing

There are three basic multiplexing techniques: frequency-division multiplexing, wavelengthdivision multiplexing, and time-division multiplexing. The first two are techniques designed for analog signals, the third, for digital signals see Figure



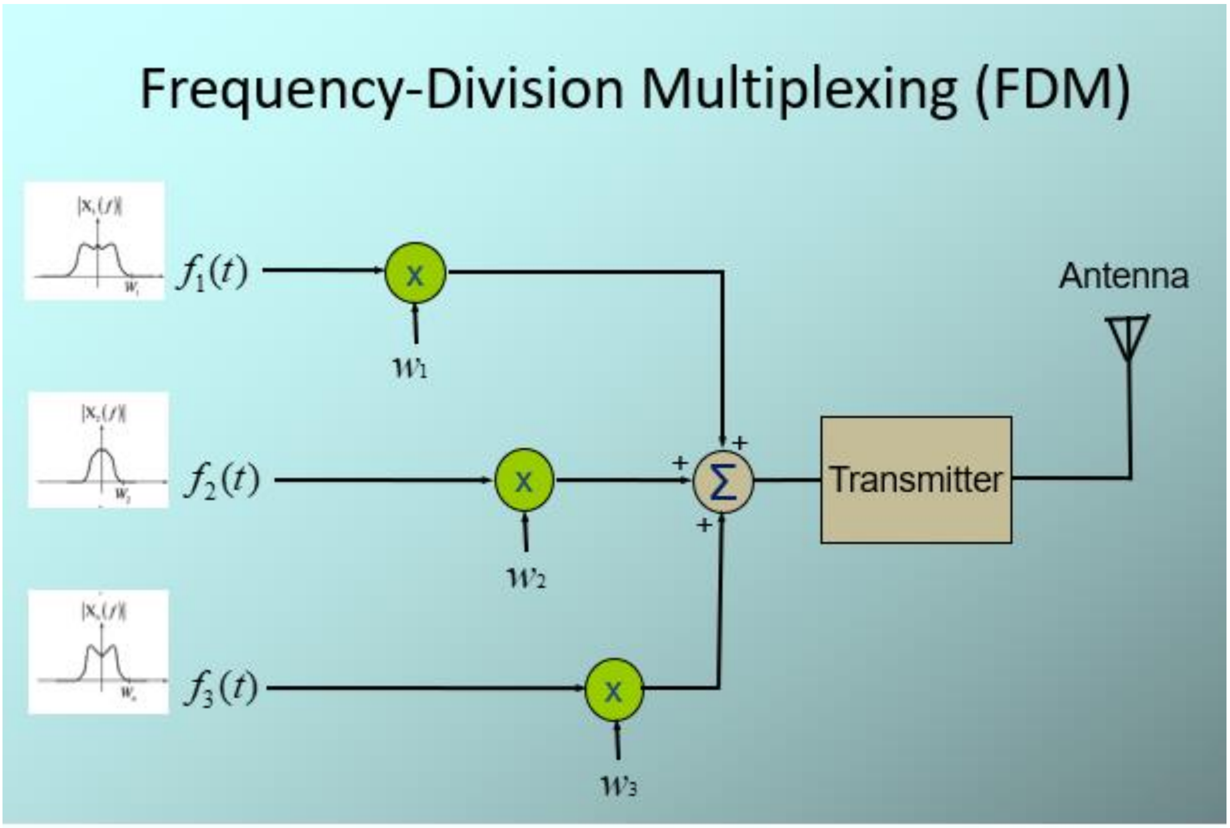
Frequency-Division Multiplexing (FDM)

Frequency-division multiplexing (FDM) is an analog technique that can be applied when the bandwidth of a link (in hertz) is greater than the combined bandwidths of the signals to be transmitted. In FDM, signals generated by each sending device modulate different carrier frequencies. These modulated signals are then combined into a single composite signal that can be transported by the link. Carrier frequencies are separated by sufficient bandwidth to accommodate the modulated signal. These bandwidth ranges are the channels through which the various signals travel. Channels can be separated by strips of unused bandwidth—guard bands—to prevent signals from overlapping. In addition, carrier frequencies must not interfere with the original data frequencies

What is FDM?

Frequency-Division Multiplexing (FDM) is a technique used to transmit multiple signals simultaneously over the same communication channel by assigning each signal a different carrier frequency.

Each message occupies a separate frequency band



Step 1: Modulation

Each signal is multiplied by a different carrier frequency

$\cos(\omega_1 t) \times f_1(t)$

$\cos(\omega_2 t) \times f_2(t)$

$\cos(\omega_3 t) \times f_3(t)$

Carriers are separated in frequency

This shifts each signal to a different frequency band

Step 2: Summation

All modulated signals are added together

$$f_3(t)\cos(\omega_3 t) + f_2(t)\cos(\omega_2 t) + f_1(t)\cos(\omega_1 t) = s(t)$$

Now all signals share the same transmission channel

Step-3

The combined signal goes into:

Transmitter → Antenna → Channel

Receiver Side (Concept):

At the receiver

Bandpass filter tuned to $\omega 1$

→ extracts signal 1

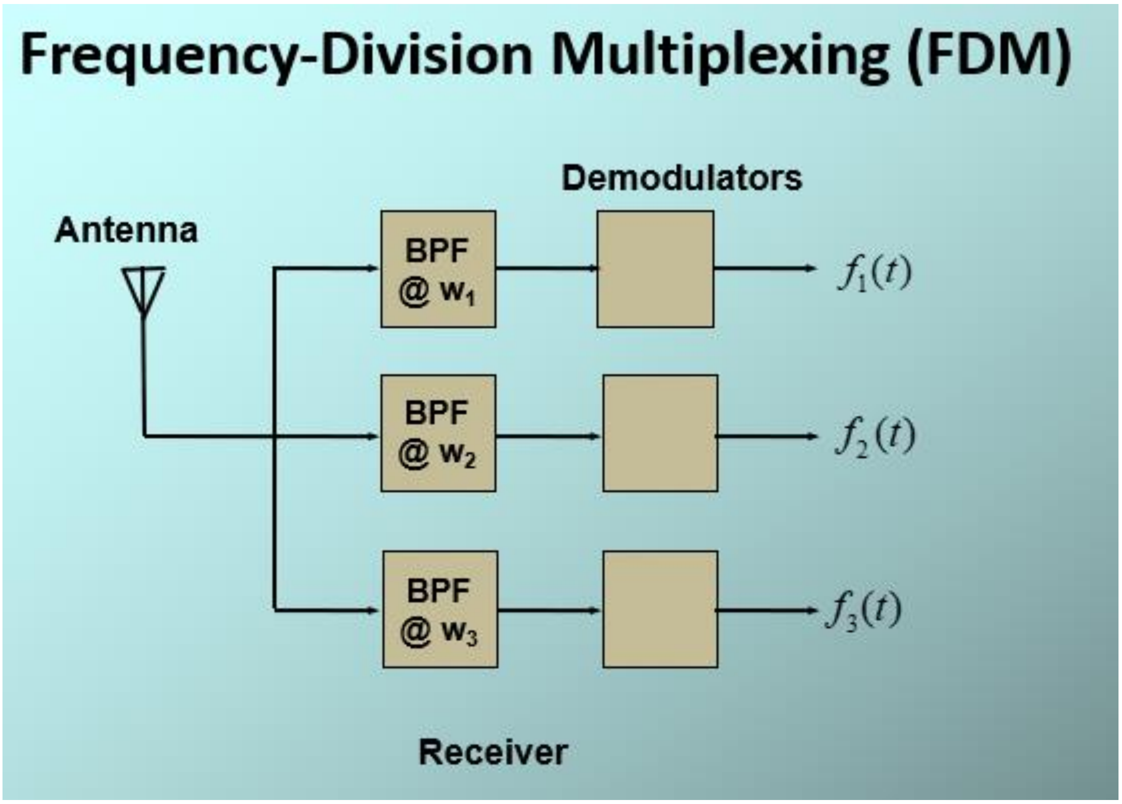
Bandpass filter tuned to $\omega 2$

→ extracts signal 2

Bandpass filter tuned to $\omega 3$

→ extracts signal 3

Each signal is then demodulated to recover the original baseband signal



Quadrature Multiplexing	FDM
Same carrier frequency	Different carrier frequencies
Uses phase separation (90°)	Uses frequency separation
More bandwidth efficient	Needs more bandwidth

Applications of FDM

FDM is used in:

Radio broadcasting

Television broadcasting

Cable TV

Satellite systems

Analog telephone systems

Applications of Amplitude Modulation:

1. Used to carry message signals in early telephone lines.
2. Used to transmit Morse code using radio and other communication systems.
3. Used in Navy and Aviation for communications as AM signals can travel longer distances.
4. Widely used in amateur radio.

An AM transmitter radiates 9 kW when the carrier is unmodulated and 10.125 kW when the carrier is sinusoidally modulated. Find the modulation index and percentage of modulation. Now, if another sine wave, corresponding to 40 percent modulation is transmitted simultaneously, then calculate the total radiated power

Solution: (i) for a single-tone sinusoidal amplitude modulation the total power is

$$P_t = P_c \left(1 + \frac{m^2}{2}\right)$$

P_t =modulated or total power
P_c =unmodulated or carrier power
m_a =modulation index
P_t =10.125 kW
P_c =9 kW

$$(i)\, 1 + \frac{m_a^2}{2} = \frac{P_t}{P_c}, \quad \frac{m_a^2}{2} = \frac{P_t}{P_c} - 1 = \frac{10.125}{9} - 1$$

$$\frac{m_a^2}{2} = 1.125 - 1 = 0.125, \quad m_a^2 = 0.25$$

$$m_a = 0.5$$

(ii) That in case of modulation by two sinusoidal waves, the total modulation index m_t is

$$m_t = \sqrt{m_1^2 + m_2^2}$$

$$m_1 = m_a = 0.5$$

$$Given \quad that \quad m_2 = 0.4$$

$$m_t = \sqrt{(0.5)^2 + (0.4)^2}, m_t = \sqrt{(0.25) + (0.16)}$$

$$m_t = 0.64$$

$$P_T = Pc \quad (1 + \frac{m^2}{2}) = 9(1 + \frac{(0.64)^2}{2})$$

$$P_T = 9(1 + 0.205) = 10.84 \quad kW$$

1. The highest modulation frequency typically used in AM broadcast is

(a) 5 kHz (b) 10 kHz (c) 15 kHz (d) 25 kHz

2. The household receiver are

(a) Synchronous detectors b) radio receivers (c) envelope detectors

3. The purpose of balance modulator is to eliminate

(a) the carrier (b) Upper sideband (c) lower sideband (d) base band signal