Sir Jagadish Chandra Bose

Bose pioneered the investigation of radio and microwave optics, made significant contributions to plant science, and was a major force behind the expansion of experimental science on the Indian subcontinent.
IEEE named him one of the fathers of radio science.

Communication systems

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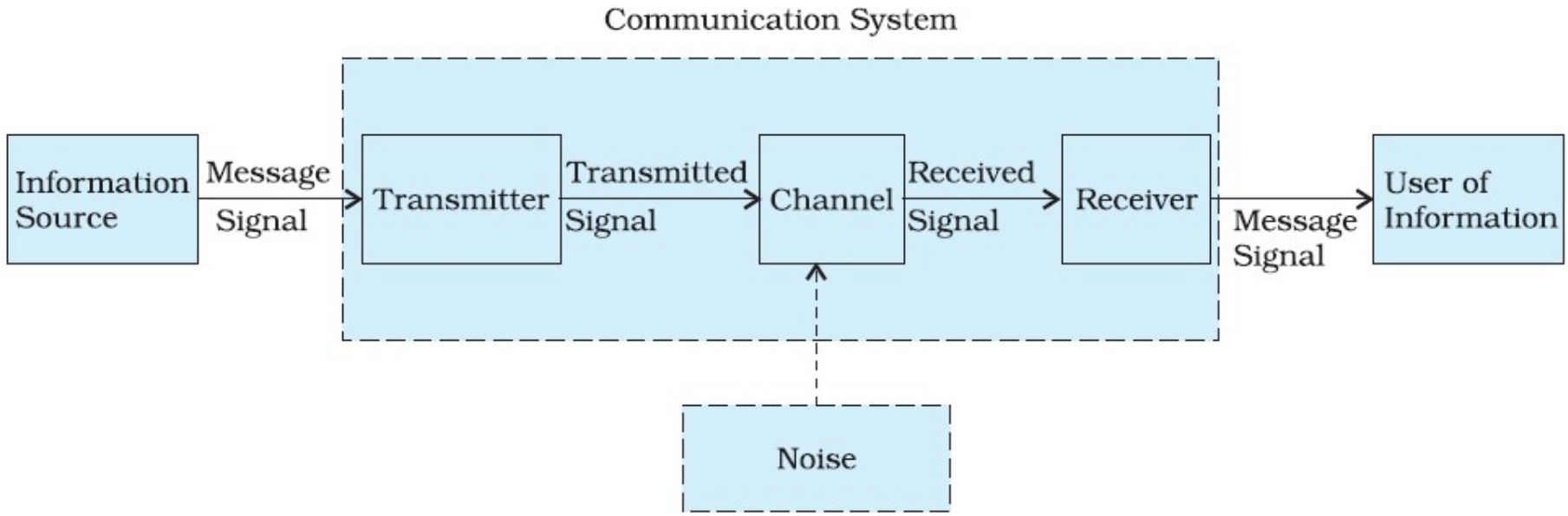
Block diagram of communication system



A communication system is a setup used for transferring information from one place to another. It consists of an information source, transmitter, channel, receiver, and user of information. The transmitter converts the message into a signal for transmission, the channel carries the signal. The receiver recovers the message from the received signal, delivering it to the user. Noise may interfere with the signal at various stages of this system. Communication systems can be analog or digital.

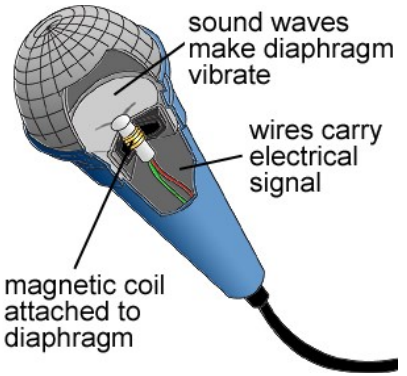
Two types of communication

Point to point communication :
Communication between a single transmitter and a single receiver.
Eg: telephonic communication

Broadcast :
Communication between a single transmitter and a large number of receivers.
Eg: Radio and television

Communication modes like conference calls, internet-based meetings, and group chats generally fall under neither strict “point to point” nor traditional “broadcast” categories. Instead, they fit into the point-to-multipoint category, where communication occurs between one sender and multiple specific receivers in an interactive, often bidirectional format.

Terminology in communication systems



Transducer :
Converts one form of energy to another (other forms of energy to electrical or vice-versa). Eg: speaker, mic

Signal:
Information converted in electrical form and suitable for transmission. Signals may be digital or analog.

Noise:
Unwanted signals present in the message signals in a communication.

Transmitter :
Converts the message signal produced by the source of information into a form suitable for transmission.

Receiver :
Extracts desired message signals received from the transmitter.

Repeater :
A combination of transmitter and receiver to increase the range of communication.

Terminology in communication systems

Channel :
It is the physical medium connecting the transmitter and the receiver. It may be a combination of cables and wires or wireless.

Attenuation :
Loss of strength of a signal as it propagates through the channel of communication.

Amplification :
Increasing the amplitude of the signal. Necessary power for amplification is provided by a d.c. source.

Range :
Largest distance between the source and destination up to which the signal can be received.

Bandwidth :
Frequency range of electromagnetic spectrum over which an equipment operates or the frequency range occupied by a signal.

Terminology in communication systems

Modulation :
Superimposition of the message signal on another signal of high frequency.
The high frequency signal is called carrier signal.

Demodulation :
Retrieval of signal from the modulated signal received by the receiver.

Modem
Modem is a device which acts as a modulator for outgoing signal and a demodulator for incoming signals

Bandwidth :

Frequency range of electromagnetic spectrum over which an equipment operates or the frequency range occupied by a signal.

Bandwidth based on signal of communication

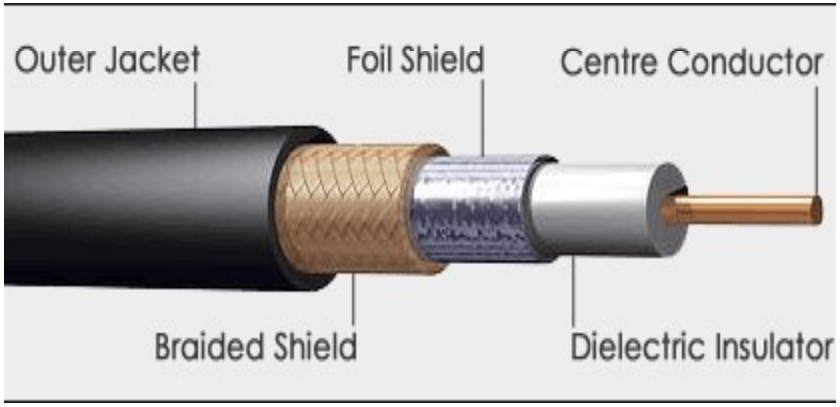
Each kind of signal requires a different set of range of frequencies.

Speech	: 300 Hz to 3100 Hz	$\Rightarrow$	2800 Hz
Music	: 20 Hz to 20 kHz	$\Rightarrow$	20 kHz
Video	: 4.2 MHz		
TV signals	: 6 MHz		

Bandwidth based on channel of communication

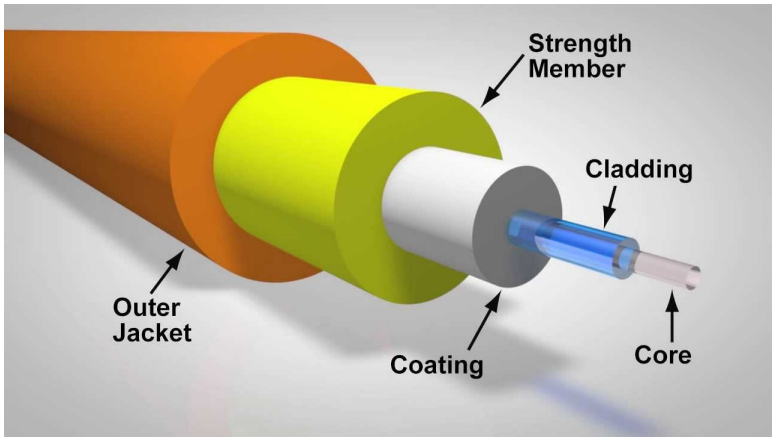
Each kind of channel can transmit signal of a set of range of frequencies. The operational range of different communication channels are

(a) Coaxial cable : 18 GHz
(bandwidth of 750 Mz)



(b) Free space : kHz to GHz

(c) OFC : 1 THz to 1000 THz
(bandwidth of 100 Gz)



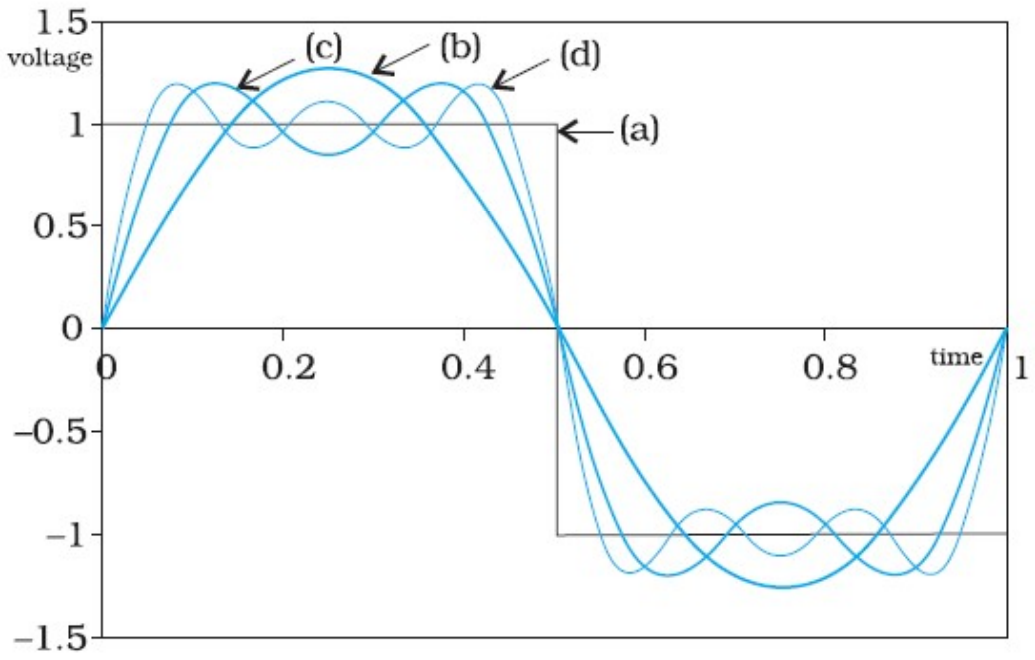
(d) TV signals : 6 MHz

Bandwidth and digital communication

Each rectangular wave of a digital signal can be assumed to be consisting of various harmonics of a fundamental frequency.

To reproduce the digital signal precisely infinite higher harmonics are required.

The number of higher harmonics used is based on the kind of information to be transmitted and the bandwidth is allotted accordingly.

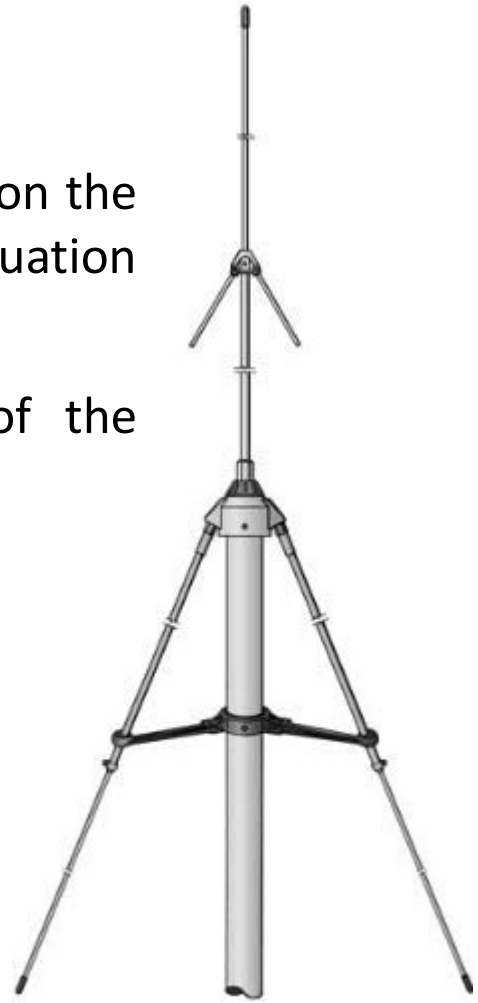


Communication systems

Service	Frequency bands	Comments
Standard AM broadcast	540-1600 kHz	
FM broadcast	88-108 MHz	
Television	54-72 MHz	VHF (very high frequencies)
	76-88 MHz	TV
	174-216 MHz	UHF (ultra high frequencies)
	420-890 MHz	TV
Cellular Mobile Radio	896-901 MHz	Mobile to base station
	840-935 MHz	Base station to mobile
Satellite Communication	5.925-6.425 GHz	Uplink
	3.7-4.2 GHz	Downlink

Ground wave communication

- Transmitting and receiving antennas are located close to the ground
- Size of the antenna for communication is equal to $\lambda/4$
- Standard AM transmission uses ground wave communication.
- A large amount of attenuation takes place, due to induction on the ground during propagation of the wave. Extent of attenuation increases with frequency of the signal.
- Range depends on transmission power and frequency of the transmitted signal (less than a few MHz)

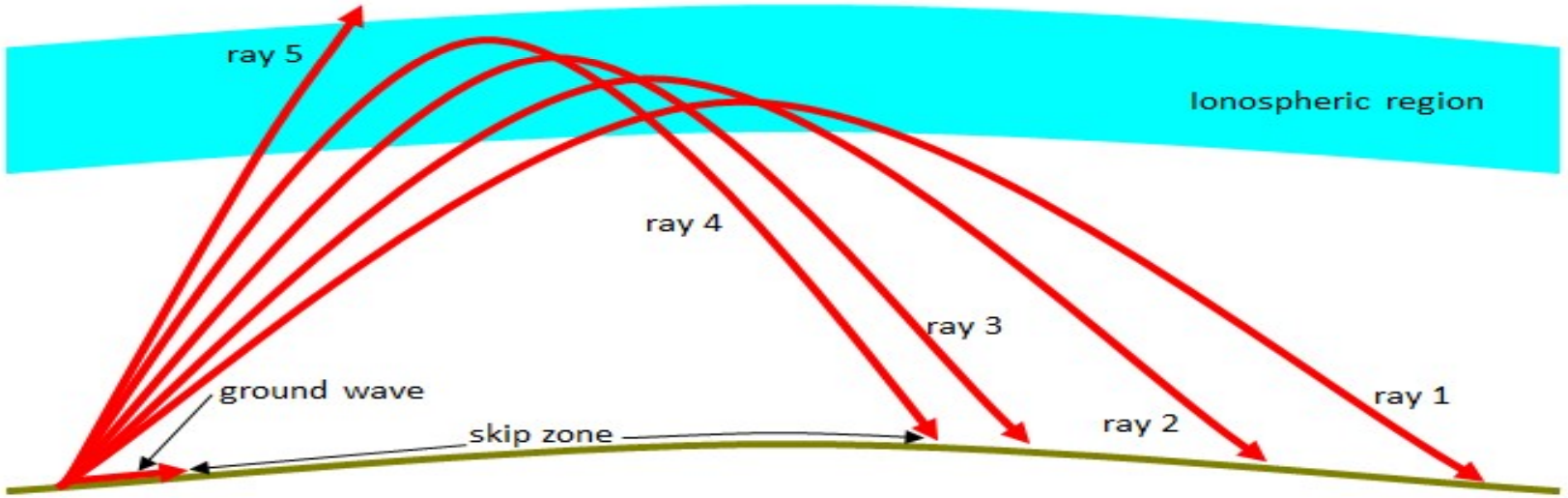


Sky wave communication

Long distance communication is possible due to reflection of radio waves at ionosphere.

Ionosphere is a layer of atmosphere having high density of ions . It is at an altitude of about 65 km to 400 km.

Waves in the range of 3 to 30 MHz are reflected by ionosphere. Waves of higher frequencies escape through ionosphere.



At lesser heights there is more density of air but lesser ionization due to radiation.
At greater heights there is more ionization but lesser density of air.

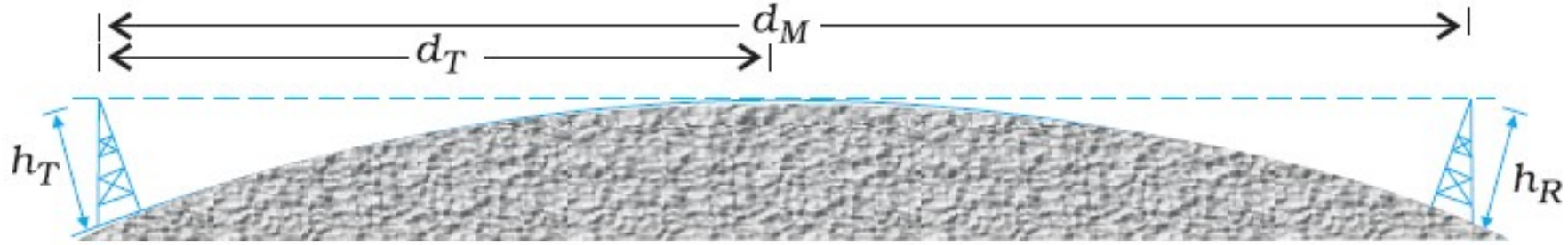
Space wave communication

This is used in **L**ine **O**f **S**ight (LOS) communication and satellite communication.

At about 40 MHz space wave communication is the only viable mode of communication.

Other modes of communication suffer from large attenuations and sky wave cannot be operated at more than 30 MHz.

Space wave communication



Use of **L**ine **O**f **S**ight (LOS) places a limitation on the range on the space wave communication from tower to tower located on ground.

$$R^2 + d^2 = (R+h)^2$$

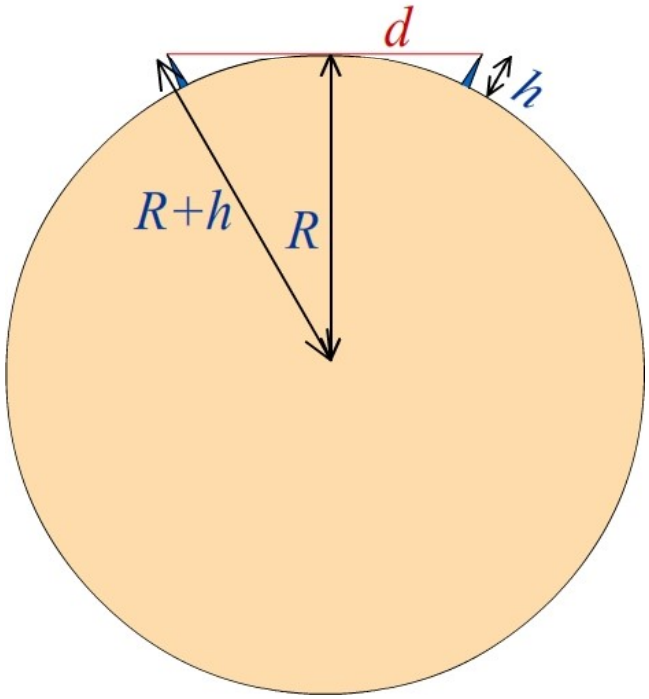
$$R^2 + d^2 = R^2 + h^2 + 2Rh$$

$$d^2 = h^2 + 2Rh$$

$h << R$ therefore

$$d = \sqrt{2Rh}$$

$$d_{\text{total}} = \sqrt{2Rh_T} + \sqrt{2Rh_R}$$



Limitation of direct transmission of signals :

- Size of antennas : Size of the antenna for communication is equal to $\lambda/4$

  For example, at a transmission frequency of 1000 Hz size of the antenna should be at least 3.75 km !

- Power : Power radiated by antennas is related to its length (l) and wavelength of the signal (λ) as

$$P \propto \left(\frac{l}{\lambda}\right)^2$$

  Therefore, greater power of transmission for greater range requires lower wavelengths

Modulation

It is the process of varying one or more properties (i.e. amplitude, frequency or phase) of a periodic waveform called the *carrier signal*, with anther signal called the *modulation signal* that contains information to be transmitted.

Amplitude modulation

Amplitude of carrier wave is modulated based on the amplitude of signal wave .

Carrier wave

$$c(t) = A_c \sin(\omega_c t)$$

Modulating wave

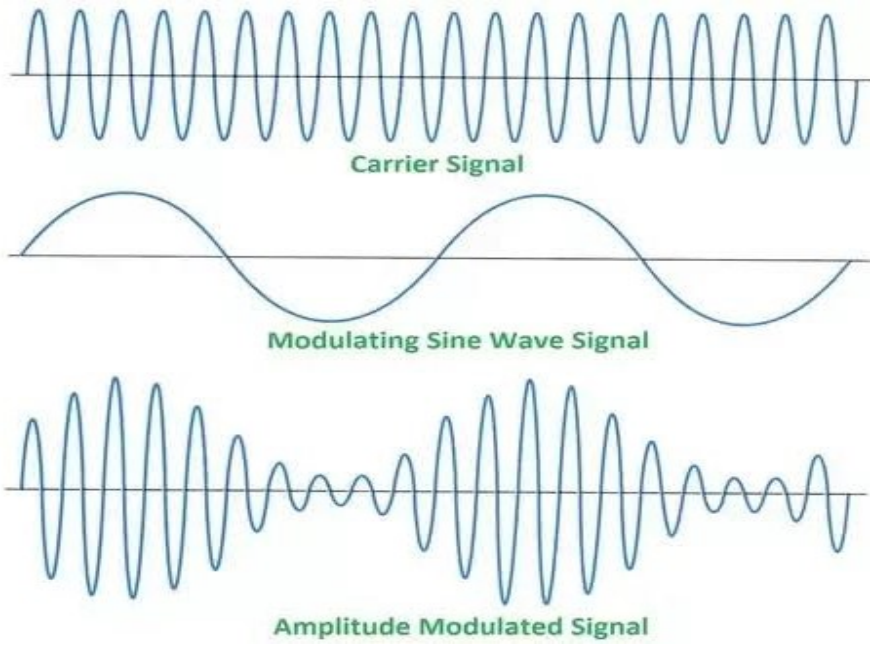
$$m(t) = A_m \sin(\omega_m t)$$

Modulated wave

$$c_m(t) = \left(A_c + A_m \sin(\omega_m t)\right) \sin(\omega_c t)$$

$$c_m(t) = A_c \left(1 + \frac{A_m}{A_c} \sin(\omega_m t)\right) \sin(\omega_c t)$$

$$c_m(t) = A_c \sin(\omega_c t) + \mu A_c \sin(\omega_m t) \sin(\omega_c t)$$



Modulation index

Ratio of amplitude of modulating signal to the amplitude of the carrier wave.

$$\mu = \frac{A_m}{A_c}$$

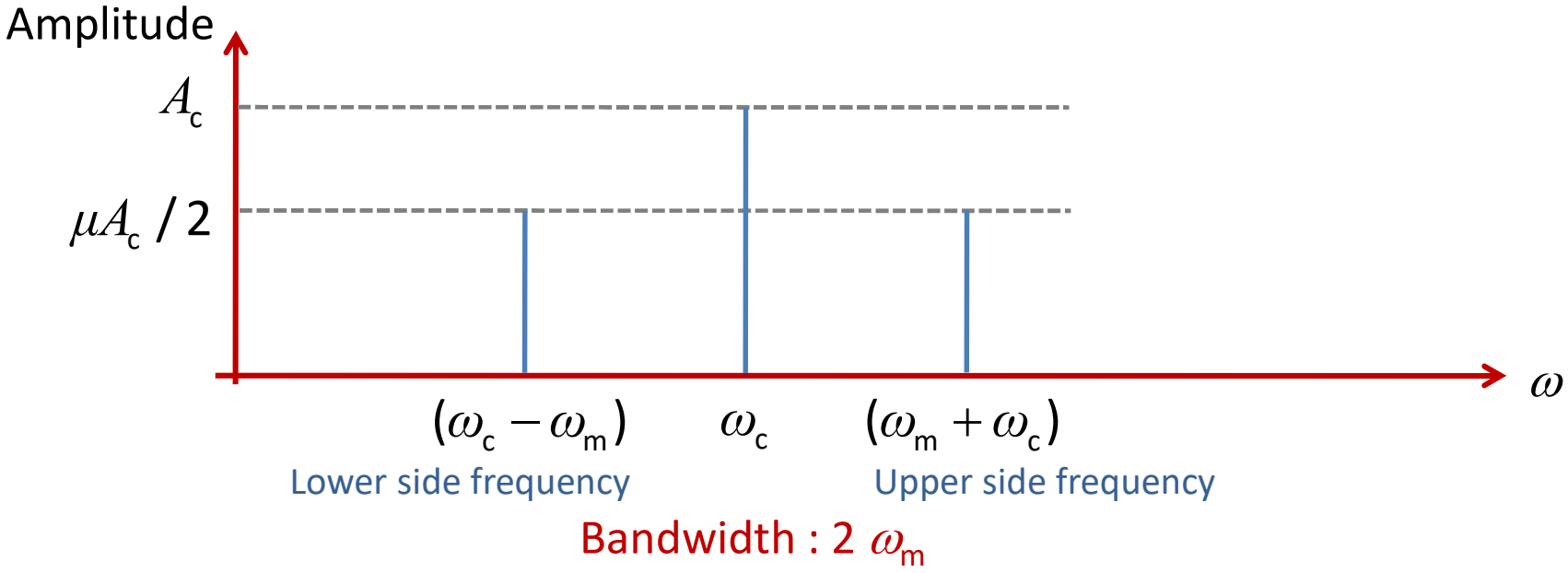
Modulating index is kept less than 1 to minimize distortion in the signal.

Lower side and upper side frequencies

$$c_m(t) = A_c \sin(\omega_c t) + \mu A_c \sin(\omega_c t) \sin(\omega_m t)$$

Using the relation $\sin A \sin B = \frac{1}{2}[\cos(A - B) - \cos(A + B)]$

$$c_m(t) = A_c \sin(\omega_c t) + \frac{\mu A_c}{2}\cos(\omega_c - \omega_m)t - \frac{\mu A_c}{2}\cos(\omega_m + \omega_c)t$$



Bandwidth : 2 ω_m

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