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UPKAR'S

A HANDBOOK ON COMMUNICATION TECHNOLOGY

[For Railway & Other Engineering (Diploma) Competitive Exams.]

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By

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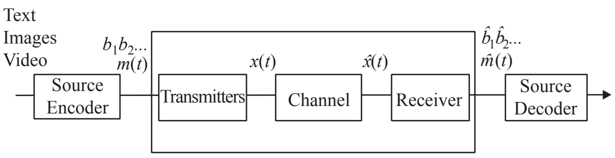
Contents

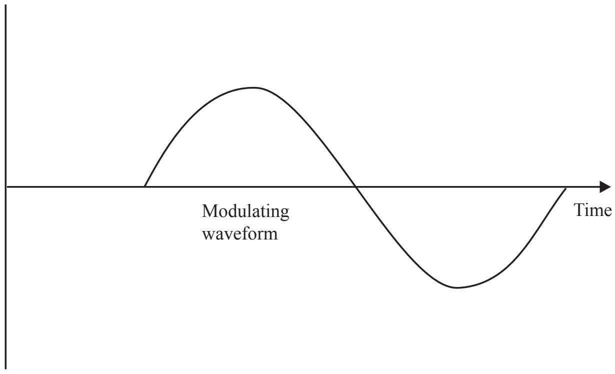
A Handbook on COMMUNICATION TECHNOLOGY

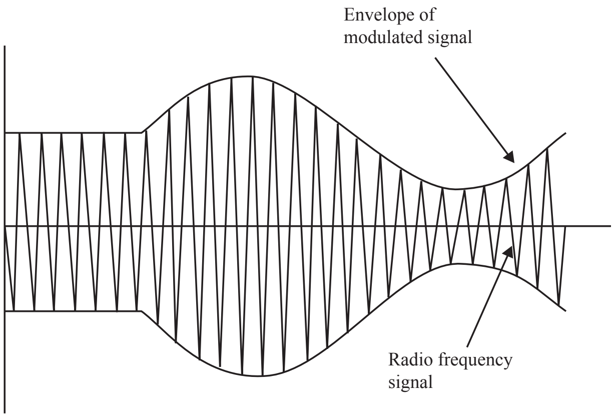
1. Analog Communications

- Analog Communication is a data transmitting technique in a format that utilizes continuous signals to transmit data including voice, image, video, electrons etc. An analog signal is a variable signal continuous in both time and amplitude which is generally carried by use of modulation.
- Analog circuits do not involve quantisation of information unlike the digital circuits and consequently have a primary disadvantage of random variation and signal degradation, particularly resulting in adding noise to the audio or video quality over a distance.
- Analog transmission is inexpensive and enables information to be transmitted from point-to-point or from one point to many.
- The Block diagram of a communication system is given below:



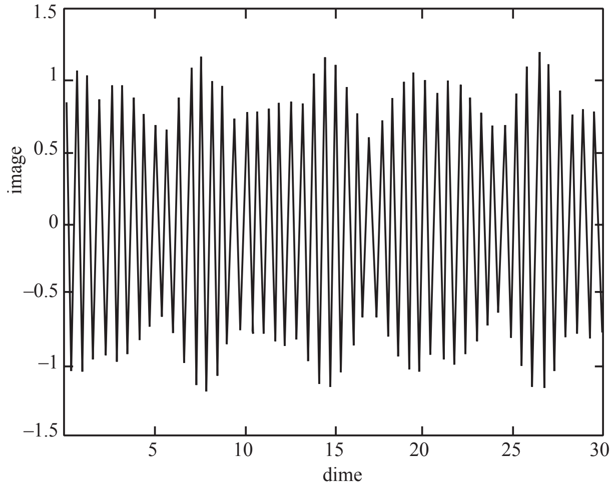
- The Source encoder converts message into message signal or bits. The Transmitter converts message signal or bits into format appropriate for channel transmission (analog/digital signal). The Channel introduces distortion, noise, and interference. Receiver decodes received signal back to message signal. Source decoder decodes message signal back into original message.
- **Amplitude Modulation :** Amplitude modulation (AM) is a technique used in electronic communication, most commonly for transmitting information via a radio carrier wave. AM works by varying the strength of the transmitted signal in relation to the information being sent. For example, changes in the signal strength can be used to specify the sounds to be reproduced by a loudspeaker, or the light intensity of television pixels. (Contrast this with frequency modulation, also commonly used for sound transmissions, in which the frequency is varied; and phase modulation, often used in remote controls, in which the phase is varied).
- In order that a radio signal can carry audio or other information for broadcasting or for two way radio communication, it must be modulated or changed in some way. Although there are a number of ways in which a radio signal may be modulated, one of the easiest, and one of the first methods to be used was to change its amplitude in line with variations of the sound.
- The basic concept surrounding what is amplitude modulation, AM, is quite straightforward. The amplitude of the signal is changed in line with the instantaneous intensity of the sound. In view of the way the basic signal 'carries' the sound or modulation, the radio frequency signal is often termed the "carrier".





- The process of modulating a carrier is exactly the same as mixing two signals together, and as a result both sum and difference frequencies are produced. Therefore when a tone of 1 kHz is mixed with a carrier of 1 MHz, a 'sum' frequency is produced at 1 MHz + 1 kHz, and a difference frequency is produced at 1 MHz – 1 kHz, *i.e.* 1 kHz above and below the carrier.
- In Amplitude Modulation or AM, the carrier signal is given by $A\cos(\omega * t)$.
- It has an amplitude of 'A' modulated in proportion to the message bearing (lower frequency) signal $m(t)$ to give $A(1 + m(t))\cos(\omega_c t)$
- The magnitude of $m(t)$ is chosen to be less than or equal to 1, from reasons having to do with demodulation, i.e. recovery of the signal from the received signal. The modulation index is then defined to be $\beta = \max m(t)$

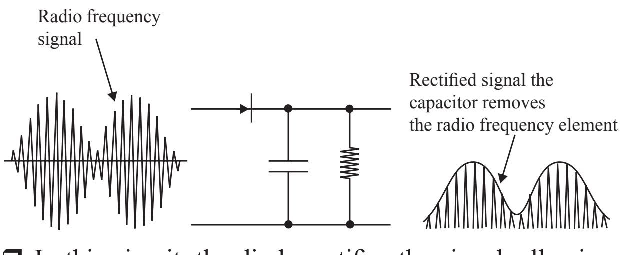
- ❒ The frequency of the modulating signal is chosen to be much smaller than that of the carrier signal.



- ❒ AM signal is of the form

$$A(1+\beta\sin\omega_m t)\cos(\omega_c t) = A\cos\omega_c t + \frac{A\beta}{2}(\cos((\omega_c+\omega_m)t)+\cos((\omega_c-\omega_m)t))$$

- ❒ This has frequency components at frequencies ω_c, $\omega_c + \omega_m$, $\omega_c - \omega_m$.
- ❒ The version of AM that we described is called Double Side Band AM or DSBAM since we send signals at both $\omega_c - \omega_m$ and at $\omega_c + \omega_m$.
- ❒ It is more efficient to transmit only one of the side bands (so-called Single Side Band AM or USBAM, LSBAM for upper and lower side bands respectively), or if the filtering requirements for this are too arduous to send a part of one of the side band. This is what is done in commercial analog NTSC television, which is known as Vestigial Side Band AM.
- ❒ **Amplitude Demodulation :** Amplitude modulation, AM, is one of the most straightforward ways of modulating a radio signal or carrier. The process of demodulation, where the audio signal is removed from the radio carrier in the receiver is also quite simple as well. The easiest method of achieving amplitude demodulation is to use a simple diode detector. This consists of just a handful of components : a diode, resistor and a capacitor.



- ❒ In this circuit, the diode rectifies the signal, allowing only half of the alternating waveform through. The capacitor is used to store the charge and provide a smoothed output from the detector, and also to remove any unwanted radio frequency components. The resistor is used to enable the capacitor to discharge. If it were not there and no other load was present, then the charge on the capacitor would not leak away, and the circuit would reach a peak and remain there.
- ❒ **Advantages of Amplitude Modulation (AM):** There are several advantages of Amplitude modulation, and some of these reasons have meant that it is still in widespread use today:
  (a) It is simple to implement.
  (b) It can be demodulated using a circuit consisting of very few components
  (c) AM receivers are very cheap as no specialised components are needed.
- ❒ **Disadvantages of Amplitude Modulation :** Amplitude modulation is a very basic form of modulation, and although its simplicity is one of its major advantages, other more sophisticated systems provide a number of advantages. Accordingly it is worth looking at some of the disadvantages of amplitude modulation.
  (a) It is not efficient in terms of its power usage
  (b) It is not efficient in terms of its use of bandwidth, requiring a bandwidth equal to twice that of the highest audio frequency
  (c) It is prone to high levels of noise because most noise is amplitude based and obviously AM detectors are sensitive to it.
- ❒ Thus, AM has advantages of simplicity, but it is not the most efficient mode to use, both in terms of the amount of space or spectrum it takes up, and the way in which it uses the power that is transmitted. This is the reason why it is not widely used these days both for broadcasting and for two way radio communication.
- ❒ **Single Side Band Modulation :** Single Side Band modulation is widely used in the HF portion, or short wave portion of the radio spectrum for two way radio communication. There are many users of Single Side Band modulation. Many users requiring two way radio Communication will use Single Side Band and they range from marine applications, generally HF point to point transmissions, military as well as radio amateurs or radio hams.
- ❒ Single Side Band, SSB modulation is basically a derivative of Amplitude Modulation, AM. By removing some of the components of the ordinary AM signal it is possible to significantly improve its efficiency.
- ❒ **SSB Receiver :** While signals that use Single Side Band modulation are more efficient for two way radio Communication and more effective than ordinary AM, they do require an increased level of complexity in the receiver. As SSB modulation has the carrier removed, this needs to be re-introduced in the receiver to be able to reconstitute the original audio. This is achieved using an internal oscillator called a Beat Frequency Oscillator (BFO) or Carrier Insertion Oscillator (CIO). This generates a carrier signal that can be mixed with the incoming SSB signal, thereby enabling the required

audio to be recovered in the detector. Typically the SSB detector itself uses a mixer circuit to combine the SSB modulation and the BFO signals. This circuit is often called a product detector because (like any RF mixer) the output is the product of the two inputs.

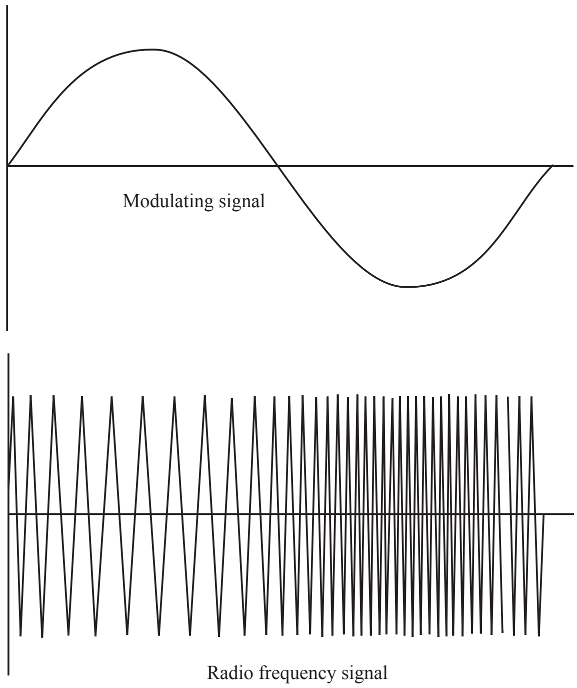
❒ In view of its popularity it is necessary to know how to tune an SSB signal and receive the SSB signal in the best way to ensure that the best copy is obtained. Although it is slightly more difficult to tune than an AM or FM signal, with a little practice, it is easy to become used to tuning them in. When receiving SSB it is necessary to have a basic understanding of how a receiver works. Most radio receivers that will be used to receive SSB modulation will be of the superheterodyne type. Here the incoming signals are converted down to a fixed intermediate frequency. It is at this stage where the BFO signal is mixed with the incoming SSB signals. It is necessary to set the BFO to the correct frequency to receive the form of SSB, either LSB or USB, that is expected. Many radio receivers will have a switch to select this, other receivers will have a BFO pitch control which effectively controls the frequency.

❒ **SSB Advantages :** Single side band modulation is often compared to AM, of which it is a derivative. It has several advantages for two way radio communication that more than outweigh the additional complexity required in the SSB receiver and SSB transmitter required for its reception and transmission.
(a) As the carrier is not transmitted, this enables a 50% reduction in transmitter power level for the same level of information carrying signal. [NB for an AM transmission using 100% modulation, half of the power is used in the carrier and a total of half the power in the two sideband - each sideband has a quarter of the power.]
(b) As only one side band is transmitted there is a further reduction in transmitter power.
(c) As only one side band is transmitted the receiver bandwidth can be reduced by half. This improves the signal to noise ratio by a factor of two, i.e. 3 dB, because the narrower bandwidth used will allow through less noise and interference.
(d) Single Side Band modulation, SSB is the main modulation format used for analogue voice transmission for two way radio communication on the HF portion of the radio spectrum. Its efficiency in terms of spectrum and power when compared to other modes means that for many years it has been the most effective option to use. Now some forms of digital voice transmission are being used, but it is unlikely that single side band will be ousted for many years as the main format used on these bands.

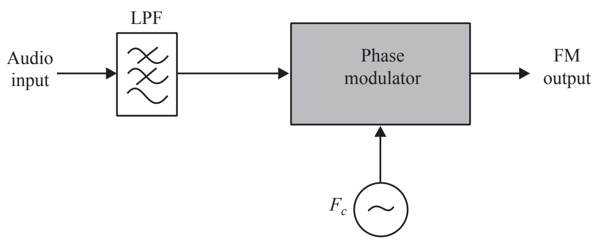
❒ **Frequency Modulation :** While changing the amplitude of a radio signal is the most obvious method to modulate it, it is by no means the only way. It is also possible to change the frequency of a signal to give frequency modulation or FM. Frequency modulation is widely used on frequencies above 30 MHz, and it is particularly well known for its use for VHF FM broadcasting.

❒ Although it may not be quite as straightforward as amplitude modulation, nevertheless frequency modulation, FM, offers some distinct advantages. It is able to provide near interference free reception, and it was for this reason that it was adopted for the VHF sound broadcasts. These transmissions could offer high fidelity audio, and for this reason, frequency modulation is far more popular than the older transmissions on the long, medium and short wave bands. In addition to its widespread use for high quality audio broadcasts.

❒ To generate a frequency modulated signal, the frequency of the radio carrier is changed in line with the amplitude of the incoming audio signal.



❒ When the audio signal is modulated onto the radio frequency carrier, the new radio frequency signal moves up and down in frequency. The amount by which the signal moves up and down is important. It is known as the deviation and is normally quoted as the number of kilohertz deviation. As an example the signal may have a deviation of ±3 kHz. In this case the carrier is made to move up and down by 3 kHz.



Frequency Modulation

- **Advantages of Frequency Modulation, FM :** FM is used for a number of reasons and there are several Advantages of Frequency Modulation. In view of this it is widely used in a number of area to which it is ideally suited. Some of the Advantages of Frequency Modulation are noted below:

  (a) Resilience to Noise : One particular Advantage of Frequency Modulation is its resilience to signal level variations. The modulation is carried only as variations in frequency. This means that any signal level variations will not affect the audio output, provided that the signal does not fall to a level where the receiver cannot cope. As a result this makes FM ideal for mobile radio communication applications including more general two-way radio communication or portable applications where signal levels are likely to vary considerably. The other advantage of FM is its resilience to noise and interference. It is for this reason that FM is used for high quality broadcast transmissions.

  (b) Easy to Apply Modulation at a Low Power Stage of the Transmitter : Another Advantage of Frequency modulation is associated with the transmitters. It is possible to apply the modulation to a low power stage of the transmitter, and it is not necessary to use a linear form of amplification to increase the power level of the signal to its final value.

  (c) It is possible to use efficient RF amplifiers with frequency modulated signals: It is possible to use non-linear RF amplifiers to amplify FM signals in a transmitter and these are more efficient than the linear ones required for signals with any amplitude variations (e.g. AM and SSB). This means that for a given power output, less battery power is required and this makes the use of FM more viable for portable two-way radio applications.

- **Applications :**

  (a) Magnetic tape storage

  (b) Sound : FM is also used at audio frequencies to synthesize sound. This technique, known as FM synthesis, was popularized by early digital synthesizers and became a standard feature for several generations of personal computer sound cards.

  (c) Radio

  (d) As the name implies, wideband FM (WFM) requires a wider signal bandwidth than amplitude modulation by an equivalent modulating signal, but this also makes the signal more robust against noise and interference. Frequency modulation is also more robust against simple signal amplitude fading phenomena.

  (e) FM receivers employ a special detector for FM signals and exhibit a phenomenon called capture effect, where the tuner is able to clearly receive the stronger of two stations being broadcast on the same frequency.

  (f) An FM signal can also be used to carry a stereo signal.

PRACTICE EXERCISE

1. Communication is a process of:
   (A) transfer of information
   (B) transfer of energy
   (C) transfer of channel
   (D) none of these
2. An example of communication service:
   (A) printer (B) television
   (C) both (A) and (B) (D) none of these
3. For sea water with $\sigma = 5$ mho/m and $\varepsilon_r = 80$, what is the distance for which radio signal can be transmitted with 90° attenuation at 25 kHz?
   (A) 0.322 m (B) 3.22 m
   (C) 32.2 m (D) 322 m
4. Two metal rings 1 and 2 are placed in a uniform magnetic field which is decreasing with time with their planes perpendicular to the field. If the rings are identical except that ring 2 has a thin air gap in it, which one of the following statements is correct?
   (A) No. e.m.f. is induced in ring 1
   (B) An e.m.f. is induced in both the rings
   (C) Equal joule heating occurs in both the rings
   (D) Joule heating does not occur in either ring
5. The electric field of a wave propagating through a lossless medium (μ_0, 81 ε_0) is—
   $$\bar{E} = 10 \cos(6\pi \times 10^8 t - \beta x)\,\bar{a}_y$$
   What is the phase constant β of the wave?
   (A) 2 π rad/m (B) 9 π rad/m
   (C) 18 π rad/m (D) 81 π rad/m
6. Which one of the following gives the values of the attenuation factor α and phase shift factor β for a wave propagated in a good dielectric having $\sigma/(\omega\varepsilon) << 1$?
   (A) $\alpha = \dfrac{\left[\sigma\sqrt{\mu/\varepsilon}\right]}{2}$; $\beta = \omega\sqrt{\mu\varepsilon}$
   (B) $\alpha = \sqrt{\mu/\varepsilon}$; $\beta = \sqrt{\omega\mu/\varepsilon}$
   (C) $\alpha = \dfrac{\left[\sigma\sqrt{\mu/\varepsilon}\right]}{2}$; $\beta = \sqrt{\omega\mu\varepsilon}$
   (D) $\alpha = 0$; $\beta = \omega^2\mu\varepsilon$
7. If the phase velocity of a plane wave in a perfect dielectric is 0.4 times its value in free space, then what is the relative permittivity of the dielectric?
   (A) 6.25 (B) 4.25
   (C) 2.5 (D) 1.25

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