## 6.1. Introduction

In electrical terms, noise may be defined as an unwanted form of energy which tend to interfere with the proper reception and reproduction of transmitted signals. For example, in receivers, several electrical disturbances produce noise and thus modifying the required signal in an unwanted form. In case of radio receivers, noise may produce hiss type sound in the output of loudspeaker. Similarly, in T.V. receivers, noise may produce 'snow' which becomes superimposed on the picture output. In addition to this, in pulse communications, noise may produce unwanted pulses or cancel the required pulses. In other words, we can say that noise may limit the performance of a communication system.

## 6.2. Classification of Noise

Although there are several ways of classifying the noise, but conveniently noise may be classified in two broad groups as under:

(i) External Noise

(ii) Internal Noise

ये ऐसी noise है जो कि comm^n system के externally generate होती हैं।

## 6.3. External Noise

*(U.P. Tech., Semester Exam., 2003-04)*

External noise may be defined as that type of noise which is generated external to a communication system *i.e.* whose sources are external to the communication system.

External noise can not be analysed quantitatively. In addition to this, for a given geographical point or location, external noise cannot be controlled. Thus, to reduce the effect of external noise, the only way is to shift the communication system to other place or location which has comparatively smaller external noise. Thus due to this reason, the satellite earth stations are generally located in noise-free valleys.

External noise may be classified as under:

(i) Atmospheric Noise

(ii) Extraterrestrial Noise

(iii) Industrial Noise

natural electrical disturbances जो कि atmosphere में पायी जाती हैं इसके कारण spurious produce होते हैं। ये atmospheric noise कहलाती हैं। signals

## 6.4. Atmospheric Noise

Atmospheric noise, which is also called static, is produced by lightning discharges in thunderstorms and other natural electrical disturbances which occur in the atmosphere. These electric impulses are random in nature. Thus this energy is spread over the complete frequency spectrum used for radio communication. Atmospheric noise contains spurious radio signals which are distributed over a wide frequency range. In fact, these spurious radio waves constituting the noise, propagate over the earth in the manner as the required radio waves of same frequency. Thus, due to this reason, at any given receiving point, the receiving antenna picks up not only the required signal but also the static from all the thunderstorms.

It has been observed that the field strength of atmospheric noise varies approximately inversely with the frequency. This concludes that large atmospheric noise is produced in low and medium frequency bands where as very small noise is produced in the VHF and *UHF* bands.

Thus Atmospheric noise becomes less severe at frequencies above about 30 MHz.

## 6.5. Extraterrestrial Noise

There are several types of extraterrestrial noise or space noise depending upon their sources. Extraterrestrial noise may be divided into following two sub-groups as under:

(i) Solar Noise

(ii) Cosmic Noise

### 6.5.1. Solar Noise

Solar noise is the electrical noise eminating from the Sun.

Under steady conditions, there is a regular radiation of noise from the Sun. This radiation of noise from the sun is due to the fact that sun is a big body at an extremely high temperature and it radiates electric energy in the form of noise over a very wide frequency spectrum including also the frequency spectrum which is occupied by radio communication. However, the condition of the Sun varies and follows an eleven years cycle. Hence at the peak of this eleven years cycle, the electrical disturbances are caused. This form of noise from electrical disturbance is in addition to the quiet noise from the Sun. Although this additional noise is produced from a small portion of the Sun's surface, it can still be larger than the quiet solar noise. The solar cycle repeats this type of electrical disturbances nearly every eleven years.

### 6.5.2. Cosmic Noise

Distant stars can also be considered Suns. These distant stars have high temperatures and therefore radiate noise in the same manner as the Sun. The noise received from these distant stars is thermal noise and is distributed almost uniformly over the entire sky. The noise is also received from the centre of our own galaxy, for other distant galaxies and from other virtual point sources such as quasers and pulsers. This type of galactic noise is quite intense but since it comes from very distant sources, the angle subtended by the earth is quite small. Therefore, the strength of galactic noise received on the earth gets diminished.

As a conclusion, we can say that the space noise is quite, significant at frequencies in the 1.43 GHz. Also, in the frequency range of 20 to 12 MHz, the space noise becomes the strongest noise component next only to the industrial noise. But, below 20 MHz, the space noise does not penetrates much through the ionosphere to reach the earth.

## 6.6. Industrial Noise

The industrial noise or man-made noise is that type of noise which is produced by such sources as automobiles and aircraft ignition, electrical motors, switch gears and leakage from high voltage transmission lines and several other heavy electrical equipments. Such type of noise is produced by the arc discharge taking place during operation of all these machines or equipments. Industrial or man-made noise is quite intensive in industrial areas, dense populated urban areas. Industrial noise in such areas much stronger than all other sources of noise in the frequency range extending from about 1 MHz to 600 MHz .

Since industrial or man-made noise is highly variable and hence can be analyzed only statistically.

## 6.7. Internal Noise

*(U.P. Tech., Semester, Exam., 2004-05)*

Internal noise is that type of noise which is generated internally or within the communication system or receiver. Internal noise may be treated quantitatively and can also be reduced or minimized by proper system design. Since internal noise is randomly distributed over the entire frequency spectrum, the noise present in a given bandwidth $B$ is the same at any frequency in the frequency spectrum. Hence, this random noise power is proportional to the bandwidth over which it is measured. Internal noise may be classified as under:

(*i*) Shot noise
(*ii*) Partition noise
(*iii*) Low frequency or Flicker noise
(*iv*) High-frequency or transit-time noise
(*v*) Thermal noise

## 6.8. Shot Noise

Shot noise arises in active devices due to random behaviour of charge carries. In electron tubes, shot noise is generated due to the random emission of electrons from cathodes, whereas in semiconductor devices shot noise is generated due to the random diffusion of minority carries or simply random generation and recombination of electron-hole pairs.

In fact, the current in electron devices (*i.e.* tubes or solid state device) flows in the form of discrete pulses, every time a charge carrier moves from one point to the other (*i.e.* cathode to plate). Hence, although the current appears to be continuous, it is still a discrete phenomena. Figure 6.1 shows this nature of current variation with time.

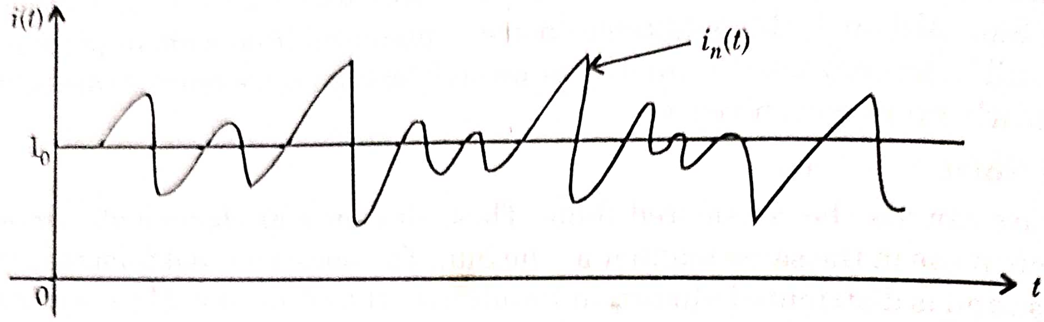


**Fig. 6.1.** *Current variation with time*

The current fluctuates about a mean value $I_0$. The current $i_n(t)$ wiggles around the mean value. This current is called as shot-noise current. The wiggling nature of this current is not visualized by normal instruments and normally it is assumed that the current is a constant equal to $I_0$. This wiggling nature of the current may be observed in a fast sweep oscilloscope.

Therefore, the total current $i(t)$ can be expressed as

$$i(t) = I_0 + i_n(t) \quad ...(6.1)$$

Here $I_0$ is the mean (constant) and $i_n(t)$ is the fluctuating (shot-noise) current.

**6.8.1. Power Density Spectrum of Shot Noise in Diodes**

We know that shot noise current is given by the expression

$$i(t) = I_0 + i_n(t) \quad ...(6.2)$$

The time-varying component $i_n(t)$ of the current $i(t)$ is always random in nature and hence it cannot be expressed as a function of time. This means that it is an indeterministic function. However, this indeterministic random function $i_n(t)$ may be specified by its power density spectrum.

In fact, the number of electrons, which contribute to the random current $i_n(t)$ is large. Assuming that the electrons do not interact with each other during their movement or emission, this process (event) can be treated as statistically independent. Now, according to central limit theorem, such a process has a Gaussian distribution. Therefore, the shot-noise is Gaussian distributed with a zero mean value.

We can treat the total diode current as the sum of the current pulses and each pulse is formed by the transit of an electron from the cathode, to the anode. For all practical purposes, it may be observed that the power density spectrum of the statistically independent non-interacting random noise current $i_n(t)$ is expressed as

$$S_i(w) = qI_0 \quad ..(6.3)$$

Here $q$ is the electronic charge and $I_0$ is the mean value of the current in amperes.

It may be noted that the power density spectrum in equation (6.3) is frequency independent. This type of frequency independence is only up to a frequency range determined by the transit time of an electron to reach from the anode to the cathode. Beyond this frequency range, the power density varies with frequency as shown in figure 6.2.

The transit time of an electron in a diode depends upon anode voltage $V$ and may be expressed as

$$\tau = 3.36 \times \frac{d}{\sqrt{V}} \ \mu \text{ sec.} \quad ...(6.4)$$

Here $d$ is the spacing between anode and the cathode.

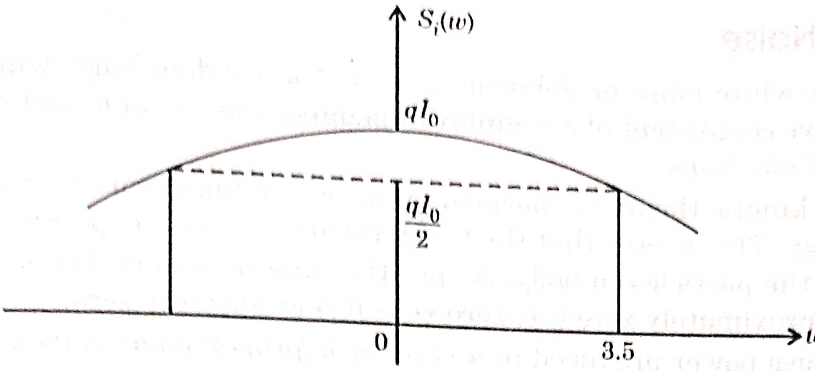


**Fig. 6.2.**

## 6.9. Partition Noise

Partition noise is generated in a circuit when a current has to divide between two or more paths. This means that the partition noise results from the random fluctuations in the division. Hence, it is expected that a diode must be less noisy than a transistor, all else being equal. Due to this reason, the inputs of microwave receivers are generally taken directly to the diode mixers. For partition noise, the spectrum is a flat spectrum. Also, the active three terminal components in which the control terminal draws less current are less noisy. In recent time, Metal-Semiconductor Field Effect Transistors have been developed which draws almost zero gate bias current. Due to this reason, these devices have low partition noise and therefore finds applications in low noise microwave amplification.

## 6.10. Flicker Noise, or Low-Frequency Noise

At low frequencies (below few kHz), a particular type of noise appears. The power spectral density of this noise increases as the frequency decreases. This noise is called as flicker noise or ($1/f$) noise. In case of vacuum tubes, the main causes of flicker noise are slow changes which take place in the oxide structure of oxide coated cathodes and migration of impurity ions.

In semiconductor devices, flicker noise is generated from the fluctuations in the carrier density and creates more problems in semiconductor amplifying device than in vacuum tubes at low frequencies.

Actually, the fluctuations in the carrier density generates fluctuations in the conductivity of the material. This produces a fluctuating voltage drop when a direct current flows. This fluctuating voltage drop is called as the flicker-noise voltage. The power density spectrum of the flicker noise is inversely proportional to frequency. Mathematically,

$$S(w) \propto \frac{1}{f} \quad \text{...(6.5)}$$

Therefore, the flicker noise becomes significant at very low frequencies, generally below a few kHz.

## 6.11. Transit-Time Noise or High Frequency Noise

It is generally observed in semiconductor devices, when the transit-time of charge-carries crossing a junction is comparable with the time-period of the signal, some charge-carries diffuse back to the source or emitters. This process gives rise to an input admittance in which the conductance component increases with frequency. This conductance has a noise current source which is associated with it in parallel. Because this conductance increases with frequency, the power spectral density will also increase.

## 6.12. Thermal Noise

The thermal noise or white noise or Johnson noise is the random noise which is generated in a resistor or the resistive component of a complex impedance due to rapid and random motion of the molecules, atoms and electrons.

According to the kinetic theory of thermodynamics, the temperature of a particle denotes its internal kinetic energy. This means that the temperature of a body expresses the rms value of the velocity of motion of the particles in body. As per this kinetic theory, the kinetic energy of these particles becomes approximately zero (*i.e.* zero velocity) at absolute zero.

Therefore, the noise power produced in a resistor is proportional to its absolute temperature. Also the noise power is proportional to the bandwidth over which the noise is measured.

Therefore the expression for maximum noise power output of a resistor may be given as

$$P_n \propto T.B$$

or

$$P_n = k.T.B \quad \text{...(6.6)}$$

where $k$ = Boltzmann's constant

$= 1.38 \times 10^{-23}$ Joule/deg. K

$T$ = absolute temperature

$B$ = Bandwidth of interest in Hz.