UNIT 4 –NOISE CHARACTERISATION

NOISE

Noise is random, undesirable electrical energy that enters the communications system via the communicating medium and interferes with the transmitted message. However, some noise is also produced in the receiver.

With reference to an electrical system, noise may be defined as any unwanted form of energy which tends to interfere with proper reception and reproduction of wanted signal. Noise may be put into following two categories.

External noises, i.e. noise whose sources are external. External noise may be classified into the following three types:

Atmospheric noises

Extra-terrestrial noises

Man-made noises or industrial noises.

Internal noise in communication:

Noises which get, generated within the receiver or communication system.
Internal noise may be put into the following four categories.

- Thermal noise or white noise or Johnson noise
- Shot noise.
- Transit time noise
- Miscellaneous internal noise.

External noise cannot be reduced except by changing the location of the receiver or the entire system. Internal noise on the other hand can be easily evaluated mathematically and can be reduced to a great extent by proper design.

Explanation of External Noise

Atmospheric Noise: Atmospheric noise or static is caused by lighting discharges in thunderstorms and other natural electrical disturbances occurring in the atmosphere. These electrical impulses are random in nature. Hence the energy is spread over the complete frequency spectrum used for radio communication. Atmospheric noise accordingly consists of spurious radio signals with components spread over a wide frequency range. These spurious radio waves constituting the noise get propagated over the earth in the same fashion as the desired radio waves of the same frequency. Accordingly at a given receiving point, the receiving antenna picks up not only the signal but also the static from all the thunderstorms, local or remote.

Extra-terrestrial noise:

- Solar noise
- Cosmic noise

Solar noise:

This is the electrical noise emanating from the sun. Under quite conditions, there is a steady radiation of noise from the sun. This results because sun is a large body at a very high temperature (exceeding 6000°c on the surface), and radiates electrical energy in the form of noise over a very wide frequency spectrum including the spectrum used for radio communication. The intensity produced by the sun varies with time. In fact, the sun has a repeating 11-year noise cycle. During the peak of the cycle, the sun produces some amount of noise that causes tremendous radio signal interference, making many frequencies unusable for communications. During other years. The noise is at a minimum level.

Cosmic noise:

Distant stars are also suns and have high temperatures. These stars, therefore, radiate noise in the same way as our sun. The noise received from these distant stars is thermal noise (or black body noise) and is distributing almost uniformly over the entire sky. Noise is received from the centre of our own galaxy (The Milky Way) from other distant galaxies and from other virtual point sources such as quasars and pulsars.

Man-Made Noise (Industrial Noise):

By man-made noise or industrial- noise is meant the electrical noise produced by such sources as automobiles and aircraft ignition, electrical motors and switch gears, leakage from high voltage lines, fluorescent lights, and numerous other heavy electrical machines. Such noises are produced by the arc discharge taking place during operation of these machines. Such man-made noise is most intensive in industrial and densely populated areas. Man-made noise in such areas far exceeds all other sources of noise in the frequency range extending from about 1 MHz to 600 MHz

Explanation of Internal Noise in communication:

Thermal Noise: Conductors contain a large number of 'free" electrons and "ions" strongly bound by molecular forces. The ions vibrate randomly about their normal (average) positions, however, this vibration being a function of the temperature. Continuous collisions between the electrons and the vibrating ions take place. Thus there is a continuous transfer of energy between the ions and electrons. This is the source of resistance in a conductor. The movement of free electrons constitutes a current which is purely random in nature and over a long time averages zero.

There is a random motion of the electrons which give rise to noise voltage called thermal noise. Thus noise generated in any resistance due to random motion of electrons is called thermal noise or white or Johnson noise. The analysis of thermal noise is based on the Kinetic theory. It shows that the temperature of particles is a way of expressing its internal kinetic energy. Thus "Temperature" of a body can be said to be equivalent to the statistical rms value of the velocity of motion of the particles in the body. At -273°C (or zero degree Kelvin) the kinetic energy of the particles of a body becomes zero .Thus we can relate the noise power generated by a resistor to be proportional to its absolute temperature. Noise power is also proportional to the bandwidth over which it is measured. From the above discussion we can write down.

$$P_n \propto TB$$

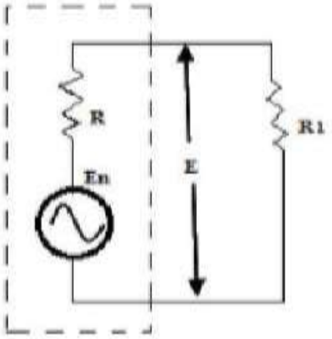
$$P_n = KTB \text{------ (1)}$$

Where Pn = Maximum noise power output of a resistor.

K = Boltzmann's constant = 1.38 x10-23 joules I Kelvin.

T = Absolute temperature.

B = Bandwidth over which noise is measured.



$$P_n = \frac{E^2}{R_1} = \frac{E^2}{R} = \frac{(\frac{E_n}{2})^2}{R} = \frac{E_n^2}{4R}$$

$$[\therefore from\ Fig\ if\ R = R_2, E_n = \frac{E}{2}]$$

$$E_{n2} = 4RP_n$$

$$E_{n2} = 4R\ KTB$$

$$E_n = \sqrt{4KTRB} ---------- 2$$

Transit Time Noise:

Another kind of noise that occurs in transistors is called transit time noise. Transit time is the duration of time that it takes for a current carrier such as a hole or current to move from the input to the output. The devices themselves are very tiny, so the distances involved are minimal. Yet the time it takes for the current carriers to move even a short distance is finite. At low frequencies this time is negligible. But when the frequency of operation is high and the signal being processed is the magnitude as the transit time, then problem can occur. The transit time shows up as a kind of random noise within the device, and this is directly proportional to the frequency of operation.

Miscellaneous Internal Noises Flicker Noise:

Flicker noise or modulation noise is the one appearing in transistors operating at low audio frequencies. Flicker noise is proportional to the emitter current and junction temperature. However, this noise is inversely proportional to the frequency. Hence it may be neglected at frequencies above about 500 Hz and it, Therefore, possess no serious problem.

Transistor Thermal Noise:

Within the transistor, thermal noise is caused by the emitter, base and collector internal resistances. Out of these three regions, the base region contributes maximum thermal noise.

Partition Noise:

Partition noise occurs whenever current has to divide between two or more paths, and results from the random fluctuations in the division. It would be expected, therefore, that a diode would be less noisy than a transistor (all other factors being equal) If the third electrode draws current (i.e.., the base current). It is for this reason that the inputs of microwave receivers are often taken directly to diode mixers.

Shot Noise:

The most common type of noise is referred to as shot noise which is produced by the random arrival of 'electrons or holes at the output element, at the plate in a tube, or at the collector or drain in a transistor. Shot noise is also produced by the random movement of electrons or holes across a PN junction. Even through current flow is established by external bias voltages, there will still be some random movement of electrons or holes due to discontinuities in the device. An example of such a discontinuity is the contact between the copper lead and the semiconductor materials. The interface between the two creates a discontinuity that causes random movement of the current carriers.

2. Capture effect, threshold effect Pre-emphasis and de-emphasis

Capture effect:

In the frequency modulation, the signal can be affected by another frequency modulated signal whose frequency content is close to the carrier frequency of the desired FM wave. The receiver may lock such an interference signal and suppress the desired FM wave when interference signal is stronger than the desired signal. When the strength of the desired signal and interference signal are nearly equal, the receiver fluctuates back and forth between them, i.e., receiver locks interference signal for some times and desired signal for some time and this goes on randomly. This phenomenon is known as the capture effect.

FM Threshold Effect:

The output signal to noise ratio of FM receiver is valid only if the carrier to noise ratio is measured at the discriminator input is high compared to unity. It is observed that as the input noise is increased so that the carrier to noise ratio decreased, the FM receiver breaks. At first individual clicks are heard in the receiver output and as the carrier to noise ratio decreases still further, the clicks rapidly merge in to a crackling or sputtering sound.

FM threshold reduction:

This can be achieved by using an FM demodulator with negative feedback (FMFB) or by using a phase locked loop demodulator.

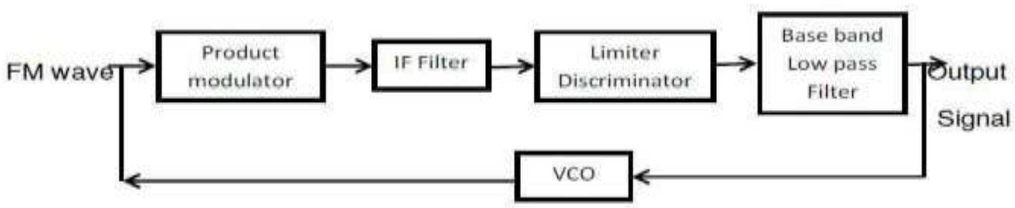


Fig.1 FM Threshold reduction

The conventional local oscillator is replaced by VCO. To understand the operation of this receiver, suppose that VCO is removed from the circuit and the feedback path is left open.

Assume that the wide band FM is applied to the receiver input, and a second FM from the same source but with a modulation index a fraction smaller is applied to the VCO terminal of the product modulator. The output of the product modulator consists of sum and difference frequency components. The IF filter is designed to pass only difference frequency component. The frequency deviation of the IF filter output would be small, although the frequency deviation of both input FM wave is large, since the difference between their instantaneous deviations is small.
Hence, the modulation indices would subtract, and the resulting FM wave at the IF filter output have a smaller modulation index than the input FM waves. This means that the IF filters bandwidth in fig above need only be a fraction of that required for either wideband FM wave. It is now apparent that Second wide band FM waves replaced by VCO feed by o/p of low pass filter.

Pre-Emphasis and De-Emphasis in an FM system

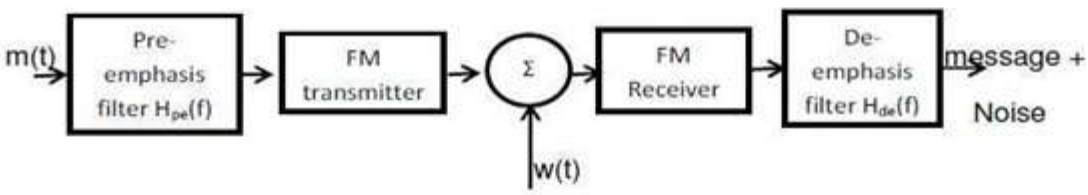


Fig. 2 Pre-emphasis and De-emphasis in FM

In this method, we artificially emphasize the high frequency components of the message signal prior modulation in the transmitter before the noise is introduced in the receiver. The low frequency and high frequency portions of the PSD of the message are equalized in such a way that the message fully occupies the frequency band allotted to it. Then, at the discriminator output in the receiver perform the inverse operation by de-emphasizing the high frequency components to restore the message. In this process, the high frequency noise is reduced thereby effectively increasing the output SNR of the system.

1. Two resistors of 20KΩ and 50KΩ at room temperature 17°C for a Bandwidth of 100 KHZ. calculate the thermal noise.

Thermal noise voltage $V_{TN}^2 = 4KT\Delta f\ R$ volts.

$T = 273° + 17° = 290°K;$

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

BW $\Delta f = 100$ KHZ.

$R_1 = 20K\Omega$

$R_2 = 50K\Omega$

i] Resistors are in series

$R_{eq} = R_1 + R_2$

$= (20+50) \times 10^3 = 70K\Omega$

$V_{TN}^2 = 4KT\ R_{eq}\ \Delta f$

$= 4 \times 1.38 \times 10^{-23} \times 70 \times 10^3 \times 100 \times 10^3 \times 290$

$= 0.112 \times 10^{-9}$

$V_{TN} = 10.585 \times 10^{-6}$ V.

ii] Resistors are in parallel.

$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}\ \Omega$

$= \frac{20 \times 50 \times 10^6}{70 \times 10^3} = 14.287 \times 10^3$

$V_{TN}^2 = 4 \times 1.38 \times 10^{-23} \times 100 \times 10^3 \times 290 \times 14.287 \times 10^3$

$= 4.78\ \mu V$,

2. Calculate the thermal noise power available from any resistor at room temp. 290K for BW of 1MHz. Calculate the corresponding noise voltage given R = 50Ω

Thermal noise power $P_n = KT\Delta f$

$= 1.38 \times 10^{-23} \times 290 \times 1 \times 10^{6}$

$P_n = 4.002 \times 10^{-15}$ Watts.

Noise voltage $V_n = \sqrt{4KT\Delta f R}$

$= \sqrt{4 \times 1.38 \times 10^{-23} \times 1 \times 10^{6} \times 290 \times 50}$

$= 8.94 \times 10^{-7}$ Volts.

3. Determine the rms value of shot noise current in the case of PN Junction carrying 10mA of avg. current. If operating temperature is 290°K and BW = 10KHZ

$I_{rms} = \sqrt{2qI_0 B \Delta f}$

$q = 1.67 \times 10^{-19}$ coloumbs.

$= \sqrt{2 \times 1.67 \times 10^{-19} \times 10 \times 10^{-3} \times 10 \times 10^{3} \times 290}$

$= 3.112 \times 10^{-6}$ Amps.

4. The ct through diode is 10mA. Determine the rms value of the shot current in 20KH BW.

$I_{rms} = \sqrt{2qI_0 B}$

$= \sqrt{2 \times 1.67 \times 10^{-19} \times 10 \times 10^{-3} \times 20 \times 10^{3}}$

$= 8.173$ n amp.