NOISE AND ITS TYPES

Introduction

Undesired sound that is intrinsically objectionable or that interferes with other sounds being listened to. In electronics and information theory, noise refers to those random, unpredictable, and undesirable signals, or changes in signals, that mask the desired information content. In radio, this noise is called static; in television, it is called snow. White noise is a complex signal or sound covering the entire range of component frequencies, or tones, all of which possess equal intensity.

In other words we can say that, noise is a random fluctuation in an electrical signal, a characteristic of all electroniccircuits.Noise generated by electronic devices varies greatly, as it can be produced by several different effects. Thermalnoise is unavoidable at non-zero temperature, while other types depend mostly on device type (such as shotnoise, which needs steep potential barrier) or manufacturing quality and semiconductor defects, such as conductance fluctuations, including noise.

In communicationsystems, noise is an error or undesired random disturbance of a useful information signal in a communicationchannel. The noise is a summation of unwanted or disturbing energy from natural and sometimes man-made sources. Noise is, however, typically distinguished from interference, (e.g. cross-talk, deliberate jamming or other unwanted electromagnetic interference from specific transmitters), for example in the signal-to-noise ratio (SNR), signal-to-interference ratio (SIR) and signal-to-noise plus interference ratio (SNIR) measures. Noise is also typically distinguished from distortion, which is an unwanted systematic alteration of the signal waveform by the communication equipment, for example in the signal-to-noise and distortion ratio (SINAD). In a carrier-modulated passband analog communication system, a certain carrier-to-noise ratio (CNR) at the radio receiver input would result in a certain signal-to-noise ratio in the detected message signal. In a digital communications system, a certain E_b/N_0 (normalized signal-to-noise ratio) would result in a certain bit error rate (BER).

Classification of Noise

Noise may be put into following two categories: External noises, i.e. noise whose sources are external and Internal noise, i.e. whose noise sources are generated internally by the circuit or the communication system.

External noise may be classified into the following three types:

   1. Atmospheric noises
   2. Extraterrestrial noises
   3. Man-made noises or industrial noises.

2. Internal noise in communication, i.e. noises which get, generated within the receiver or communication system.

   Internal noise may be put into the following four categories.

   1. Thermal noise or white noise or Johnson noise
   2. Shot noise.
   3. Transit time noise
   4. 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. As already said, because of the fact that internal noise can be reduced to a great extent, study of noise characteristics is a very important part of the communication engineering.

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.

The field strength of atmospheric noise varies approximately inversely with the frequency. Thus large atmospheric noise is generated in low and medium frequency (broadcast) bands while very little noise is generated in the VHF and UHF bands. Further VHF and UHF components of noise are limited to the line-of-sight (less than about 80 Km) propagation. For these two-reasons, the atmospheric noise becomes less severe at Frequencies exceeding about 30 MHz.

Extraterrestrial Noise

There are numerous types of extraterrestrial noise or space noises depending on their sources. However, these may be put into following two subgroups.

1. ***Solar noise***
2. ***Cosmic noise***

Solar Noise

Thisis 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. We also receive noise from the center 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

1. **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.

2. **Shot noise**

   Intermediation noise is produced when there is some non linearity in the transmitter,receiver, or intervening transmission system. Normally, these components behave aslinear systems; that is, the output is equal to the input, times a constant. In a nonlinear system, the output is a more complex function of the input. Such non linearity can be caused by component malfunction or the use of excessive signal strength. It is under these circumstances that the sum and difference terms occur.

3. Flicker noise

Flicker noise is a type of electronic noise with a 1/*f*, or pinkpower density spectrum. It is therefore often referred to as 1/*f* noise or pink noise, though these terms have wider definitions. It occurs in almost all electronic devices, and can show up with a variety of other effects, such as impurities in a conductive channel, generation and recombination noise in a transistor due to base current, and so on. 1/*f* noise in current or voltage is always related to a direct current because it is a resistance fluctuation, which is transformed to voltage or current fluctuations via Ohm's law.

In mechanics, it was found in the earth’s rate of rotation, undersea currents and the hourglass flow of sand fluctuationsIn electronic devices, it shows up as a low-frequency phenomenon, as the higher frequencies are overshadowed by white noise from other sources. In oscillators, however, the low-frequency noise can be mixed up to frequencies close to the carrier which results in oscillator phase noise.Flicker noise is found in carbon composition resistors, where it is referred to as *excess noise*, since it increases the overall noise level above the thermal noise level, which is present in all resistors.

In contrast, wire-wound resistors have the least amount of flicker noise. Since flicker noise is related to the level of DC, if the current is kept low, thermal noise will be the predominant effect in the resistor, and the type of resistor used may not affect noise levels, depending the frequency window

4. Intermodulation noise

Intermodulation or intermodulation distortion (IMD) is the amplitude modulation of signals containing two or more different frequencies in a system with nonlinearities. The intermodulation between each frequency component will form additional signals at frequencies that are not just at harmonic frequencies (integermultiples) of either, but also at the sum and difference frequencies of the original frequencies and at multiples of those sum and difference frequencies.

Intermodulation is caused by non-linearbehaviour of the signal processing being used. The theoretical outcome of these non-linearities can be calculated by generating a Volterra series of the characteristic, while the usual approximation of those non-linearities is obtained by generating a Taylor series.

Intermodulation is rarely desirable in radio or audio processing, as it creates unwanted spurious emissions, often in the form of sidebands. For radio transmissions this increases the occupied bandwidth, leading to adjacent channel interference, which can reduce audio clarity or increase spectrum usage. It should not be confused with harmonic distortion (which has common musical applications), nor with intentional modulation (such as a frequency mixer in superheterodyne receivers) where signals to be modulated are presented to an intentional nonlinear element (multiplied) (see non-linearmixers such as mixer diodes and even single-transistor oscillator-mixer circuits). In audio, the intermodulation products are nonharmonically related to the input frequencies and therefore "off-key" with respect to the common Western musical scale

5. Crosstalk

Crosstalk has been experienced by anyone who, while using the telephone, has been able to hear another conversation; it is an unwanted coupling between signal paths. It can occur by electrical coupling between nearby twisted pair or, rarely, coax cable lines carrying multiple signals. Crosstalk can also occur when unwanted signals are picked up by microwave antennas; although highly directional, microwave energy does spread during propagation. Typically, crosstalk is of the same order of magnitude (or less) as thermal noise.

6. Impulse noise

Impulse noise is generally only a minor annoyance for analog data. For example, voice transmission may be corrupted by short clicks and crackles with no loss of intelligibility. However, impulse noise is the primary source of error in digital data communication. For example, a sharp spike of energy of 0.01-second duration would not destroy any voice data, but would wash out about 50 bits of data being transmitted at 4800 bps.

7. Interference

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8. Burst noise

Burst noise is a type of electronic noise that occurs in semiconductors. It is also called popcorn noise, impulse noise, bi-stable noise, or random telegraph signal (RTS) noise.

It consists of sudden step-like transitions between two or more discrete voltage or current levels, as high as several hundred microvolts, at random and unpredictable times. Each shift in offset voltage or current often lasts from several milliseconds to seconds, and sounds like popcorn popping if hooked up to an audio speaker.[1]

Popcorn noise was first observed in early point contact diodes, then re-discovered during the commercialization of one of the first semiconductorop-amps; the 709.[2] No single source of popcorn noise is theorized to explain all occurrences, however the most commonly invoked cause is the random trapping and release of charge carriers at thin film interfaces or at defect sites in bulk semiconductor crystal. In cases where these charges have a significant impact on transistor performance (such as under an MOS gate or in a bipolar base region), the output signal can be substantial. These defects can be caused by manufacturing processes, such as heavy ion implantation, or by unintentional side-effects such as surface contamination

9. Transit time noise

Transit time is (he 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.

10. Avalanche noise

Avalanche noise is the noise produced when a junction diode is operated at the onset of avalanche breakdown, a semiconductor junction phenomenon in which carriers in a high voltage gradient develop sufficient energy to dislodge additional carriers through physical impact, creating ragged current flows.

Noise reduction techniques

In many cases noise found on a signal in a circuit is unwanted. When creating a circuit, one usually wants a true output of what the circuit has accomplished. There are many different noise reduction techniques that can change a noisy altered output signal to a more theoretical output signal.

Hardware method:

Hardware noise reduction is accomplished by incorporating into the instrument design components such as filters, choppers, shields, modulators, and synchronous detectors. These devices remove or attenuate the noise without affecting the analytical signal significantly. Hardware devices and techniques are as follows:

1. **Faraday cage**

   A Faraday cage is a good way to reduce the overall noise in a complete circuit. The Faraday cage can be thought of as an enclosure that separates the complete circuit from outside power lines and any other signal that may alter the true signal. A Faraday cage will usually block out most electromagnetic and electrostatic noise.

2. **Capacitive coupling**

   A current through two resistors, or any other type of conductor, close to each other in a circuit can create unwanted capacitive coupling. If this happens an AC signal from one part of the circuit can be accidentally picked up in another part. The two resistors (conductors) act like a capacitor thus transferring AC signals. There may be other reasons for which capacitive coupling is wanted but then it would not be thought of as electronic noise.

3. **Ground loops**

   When grounding a circuit, it is important to avoid ground loops. Ground loops occur when there is a voltage drop between the two ground potentials. Since ground is thought of as 0V, the presence of a voltage is undesirable at any point of a ground bus. If this is the case, it would not be a true ground. A good way to fix this is to bring all the ground wires to the same potential in a ground bus.

4. **Shielding cables**

In general, using shielded cables to protect the wires from unwanted noise frequencies in a sensitive circuit is good practice. A shielded wire can be thought of as a small Faraday cage for a specific wire as it uses a plastic or rubber enclosing the true wire. Just outside of the rubber/plastic covering is a conductive metal that intercepts any noise signal. Because the conductive metal is grounded, the noise signal runs straight to ground before ever getting to the true wire. It is important to ground the shield at only one end to avoid a ground loop on the shield.

5. **Twisted pair wiring**

Twisting wires very tightly together in a circuit will dramatically reduce electromagnetic noise. Twisting the wires decreases the loop size in which a magnetic field can run through to produce a current between the wires. Even if the wires are twisted very tightly, there may still be small loops somewhere between them, but because they are twisted the magnetic field going through the smaller loops induces a current flowing in opposite ways in each wire and thus cancelling them out.

6. **Notch filters**

Notch filters or band-rejection filters are essential when eliminating a specific noise frequency. For example, in most cases the power lines within a building run at 60 Hz. Sometimes a sensitive circuit will pick up this 60 Hz noise through some unwanted antenna (could be as simple as a wire in the circuit). Running the output through a notch filter at 60 Hz will amplify the desired signal without amplifying the 60 Hz noise. So in a sense the noise will be lost at the output of the filter.

Software Method: Software methods are based upon various computer algorithms that permit extraction of signals from noisy data. Hardware convert the signal from analog to digital form which is then collected by computer equipped with a data acquisition module. Software programs are as follows:

1. **Ensemble Averaging:** In ensemble averaging, successive sets of data stored in memory as arrays are colleted and summed point by point. After the collection and summation are complete, the data are averaged by dividing the sum for each point by the number of scans performed. The signal-to-noise ratio is proportional to the square root of the number of data collected.
2. **Boxcar Averaging:** Boxcar averaging is a digital procedure for smoothing irregularities and enhancing the signal-to-noise ratio. It is assumed that the analog analytical signal varies only slowly with time and the average of a small number of adjacent points is a better measure of the signal than any of the individual points. In practice 2 to 50 points are averaged to generate a final point. This averaging is performed by a computer in real time, i.e., as the data is being collected. Its utility is limited for complex signals that change rapidly as a function of time.
3. **Digital filtering:** Digital filtering can be accomplished by number of different well-characterized numerical procedure such as (a) Fourier transformation and (b) Least squares polynomial smoothing.

   (a) Fourier transformation: In this transformation, a signal which is acquired in the time domain, is converted to a frequency domain signal in which the independent variable is frequency rather than time. This transformation is accomplished mathematically on a computer by a very fast and efficient algorithm. The frequency domain signal is then multiplied by the frequency response of a digital low pass filter which remove frequency components. The inverse Fourier transform then recovers the filtered time domain spectrum.

   (b) Least squares polynomial data smoothing: This is very similar to the boxcar averaging. In this process first 5 data points are averaged and plotted. Then moved one point to the right and averaged. This process is repeated until all of the points except the last two are averaged to produce a new set of data points. The new curve should be somewhat less noisy than the original data. The signal-to-noise ratio of the data may be enhanced by increasing the width of the smoothing function or by smoothing the data multiple times.