***ATTENUATION***

Attenuation is a general term that refers to any reduction in the strength of a signal. Attenuation occurs with any type of signal, whether digital or analog. Sometimes called loss, attenuation is a natural consequence of signal transmission over long distances. The extent of attenuation is usually expressed in units called decibels (dBs).

If Ps is the signal power at the transmitting end (source) of a communications circuit and Pd is the signal power at the receiving end (destination), then Ps > Pd. The power attenuation Ap in decibels is given by the formula:

Ap = 10 log10(Ps/Pd)

Attenuation can also be expressed in terms of voltage. If Av is the voltage attenuation in decibels, Vs is the source signal voltage, and Vd is the destination signal voltage, then:

Av = 20 log10(Vs/Vd)

In conventional and fiber optic cables, attenuation is specified in terms of the number of decibels per foot, 1,000 feet, kilometer, or mile. The less the attenuation per unit distance, the more efficient the cable. When it is necessary to transmit signals over long distances via cable, one or more repeaters can be inserted along the length of the cable. The repeaters boost the signal strength to overcome attenuation. This greatly increases the maximum attainable range of communication.

# *BANDWIDTH*

1) In computer networks, bandwidth is often used as a synonym for data transfer rate - the amount of data that can be carried from one point to another in a given time period (usually a second). This kind of bandwidth is usually expressed in bits (of data) per second (bps). Occasionally, it's expressed as bytes per second (Bps). A modem that works at 57,600 bps hastwice the bandwidth of a modem that works at 28,800 bps. In general, a link with a high bandwidth is one that may be able to carry enough information to sustain the succession of images in a video presentation.

It should be remembered that a real communications path usually consists of a succession of links, each with its own bandwidth. If one of these is much slower than the rest, it is said to be a bandwidth bottleneck.

2) In electronic communication, bandwidth is the width of the range (or band) of frequencies that an electronic signal uses on a given transmission medium. In this usage, bandwidth is expressed in terms of the difference between the highest-frequency signal component and the lowest-frequency signal component. Since the frequency of a signal is measured in hertz (the number of cycles of change per second), a given bandwidth is the difference in hertz between the highest frequency the signal uses and the lowest frequency it uses. A typical voice signal has a bandwidth of approximately three kilohertz (3 kHz); an analog television (TV) broadcast video signal has a bandwidth of six megahertz (6 MHz) -- some 2,000 times as wide as the voice signal.

# *SIGNAL-TO-NOISE RATIO (S/N OR SNR)*

In analog and digital communications, signal-to-noise ratio, often written S/N or SNR, is a measure of signal strength relative to background noise. The ratio is usually measured in decibels (dB).

If the incoming signal strength in microvolts is Vs, and the noise level, also in microvolts, is Vn, then the signal-to-noise ratio, S/N, in decibels is given by the formula

S/N = 20 log10(Vs/Vn)

If Vs = Vn, then S/N = 0. In this situation, the signal borders on unreadable, because the noise level severely competes with it. In digital communications, this will probably cause a reduction in data speed because of frequent errors that require the source (transmitting) computer or terminal to resend some packets of data.

Ideally, Vs is greater than Vn, so S/N is positive. As an example, suppose that Vs = 10.0 microvolts and Vn = 1.00 microvolt. Then

S/N = 20 log10(10.0) = 20.0 dB

which results in the signal being clearly readable. If the signal is much weaker but still above the noise -- say 1.30 microvolts -- then

S/N = 20 log10(1.30) = 2.28 dB

which is a marginal situation. There might be some reduction in data speed under these conditions.

If Vs is less than Vn, then S/N is negative. In this type of situation, reliable communication is generally not possible unless steps are taken to increase the signal level and/or decrease the noise level at the destination (receiving) computer or terminal.

Communications engineers always strive to maximize the S/N ratio. Traditionally, this has been done by using the narrowest possible receiving-system bandwidth consistent with the data speed desired. However, there are other methods. In some cases, spread spectrum techniques can improve system performance. The S/N ratio can be increased by providing the source with a higher level of signal output power if necessary. In some high-level systems such as radio telescopes, internal noise is minimized by lowering the temperature of the receiving circuitry to near absolute zero (-273 degrees Celsius or -459 degrees Fahrenheit). In wireless systems, it is always important to optimize the performance of the transmitting and receiving antennas.

# *SIGNAL PROPAGATION DELAY*

1) Propagation delay, symbolized tpd, is the time required for a digital signal to travel from the input(s) of a logic gate to the output. It is measured in microseconds (µs), nanoseconds (ns), or picoseconds (ps), where 1 µs = 10-6 s, 1 ns = 10-9 s, and 1 ps = 10-12 s.

The propagation delay for an integrated circuit (IC) logic gate may differ for each of the inputs. If all other factors are held constant, the average propagation delay in a logic gate IC increases as the complexity of the internal circuitry increases. Some IC technologies have interently longer tpd values than others, and are considered "slower." Propagation delay is important because it has a direct effect on the speed at which a digital device, such as a computer, can operate. This is true of memory chips as well as microprocessors.

2) In a communications system, propagation delay refers to the time lag between the departure of a signal from the source and the arrival of the signal at the destination. This can range from a few nanoseconds or microseconds in local area networks (LANs) up to about 0.25 s in geostationary-satellite communications systems. Additional propagation delays can occur as a result of the time required for packets to make their way through land-based cables and nodes of the Internet.