Signals and the Physical Layer

A **signal** is an electrical representation of data

Analog Signal

- Has continuous levels.
- Continuous over time.

The local loop of your telephone system, which goes from your house to the main office, is analog. It was originally intended for the transmission of voice signals, which are analog.

Digital Signal

Discrete levels. Ex: 0V, 5V.
Discrete time

Transmission of telephone data outside of the local loop is data.

A/D Conversion

Quantization – conversion of continuous levels to discrete levels.
Sampling – conversion from continuous time to discrete time.

Nyquist Sampling Theorem

In order to sample and faithfully reproduce a signal, it must be sampled at a rate that is twice the highest frequency component.

Aliasing can occur if a signal isn't sampled frequently enough.

Signal Impairments

- **Attenuation** – lose power, or the amplitude of the signal.
- **Attenuation distortion** – the attenuation could vary with the frequency. Not all frequencies necessarily get attenuated at the same rate.
- **Delay distortion** – not all the frequency components of a signal have the same amount of delay as they pass through the medium. This can be especially problematic in transmission of video data.
- **Intersymbol Interference –** some of the frequency components from the previous bit show up during the time frame of the next bit being sampled.

With an analog signal, to help get around attenuation, often the signal will be amplified at various points along the line. One problem with this, though, is that any noise will also get boosted. This could result in a worse signal.

Digital systems use **repeaters** instead. They restrengthen the signal. It does not repeat the noise, just the signal being transmitted.

Types of Noise

- **White (thermal) noise** – always present, but affects all frequencies the same. Cannot eliminate it. The amount of white noise that a signal contains can be calculated.
- **Impulse noise –** Has a larger affect when trying to transmit at a faster data rate. Comes in a burst.

  Possible causes include:
  - Lightning strike.
  - Machinery turning on and off in a factory environment
- **Cross Talk** – When wires run close to one another and affect the signal on adjacent wires.
  - This can be eliminated if a strict set of design rules is followed when laying out the PCB.

Nyquist Theorem

Can be used to help predict the maximum possible data rate to transmit. However, this assumes that a noiseless environment is present.

Given a medium with a bandwidth of B, the highest signal rate is 2B.

Example: Bandwidth of 3000 Hz. The signaling rate would be 6000 Hz

If the signal has multiple levels: $R = 2B\log_2 m$, where m is the number of signal levels.