Mod 4 – Cable Testing

CCNA 1 version 3.0

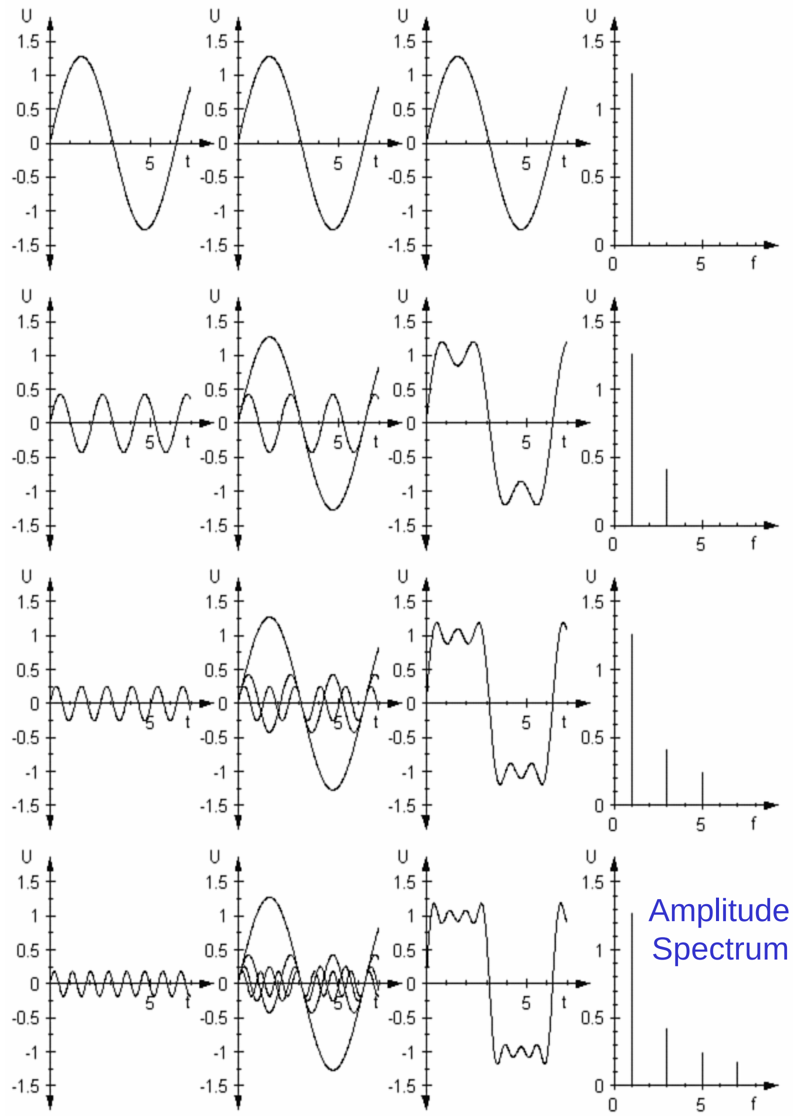
Overview

Students completing this module should be able to:

- Differentiate between sine waves and square waves.
- Define and calculate exponents and logarithms.
- Define and calculate decibels.
- Define basic terminology related to time, frequency, and noise.
- Differentiate between digital bandwidth and analog bandwidth.
- Compare and contrast noise levels on various types of cabling.
- Define and describe the affects of attenuation and impedance mismatch.
- Define crosstalk, near-end crosstalk, far-end crosstalk, and power sum near-end crosstalk.
- Describe how crosstalk and twisted pairs help reduce noise.
- Describe the ten copper cable tests defined in TIA/EIA-568-B.
- Describe the difference between Category 5 and Category 6 cable.

Signals as a combination of sine waves (Spectrum)

- Arbitrary signals can be represented as a sum of periodic sine waves.
- Mathematicians have developed a lot of tools (e.g. Fourier Series, Fourier Integral, ...) to compute the amplitude, phase and frequency of all sine waves contributing to a specific signal.
- The example to the right shows a periodic square wave (Period T=1s, base frequency f_1 = 1/T = 1 Hz) synthesized by sine waves. The contributing sine waves have the frequencies f_1, $3f_1$, $5f_1$, $7f_1$, ...
- The frequency content of arbitrary periodic signals can be an analyzed with the help of a Fourier Series.
- It can be shown that periodic signals with base frequency $f_1=1/T$ always consists of sine waves with the frequencies $f_n = n \cdot f_1$
- Signals can be equivalently represented by their time function or their frequeny function (also called spectrum)
- The time function shows how the signals varies over time.
- The spectrum shows frequency, amplitude ans phase of all sine waves contributing to the signal.



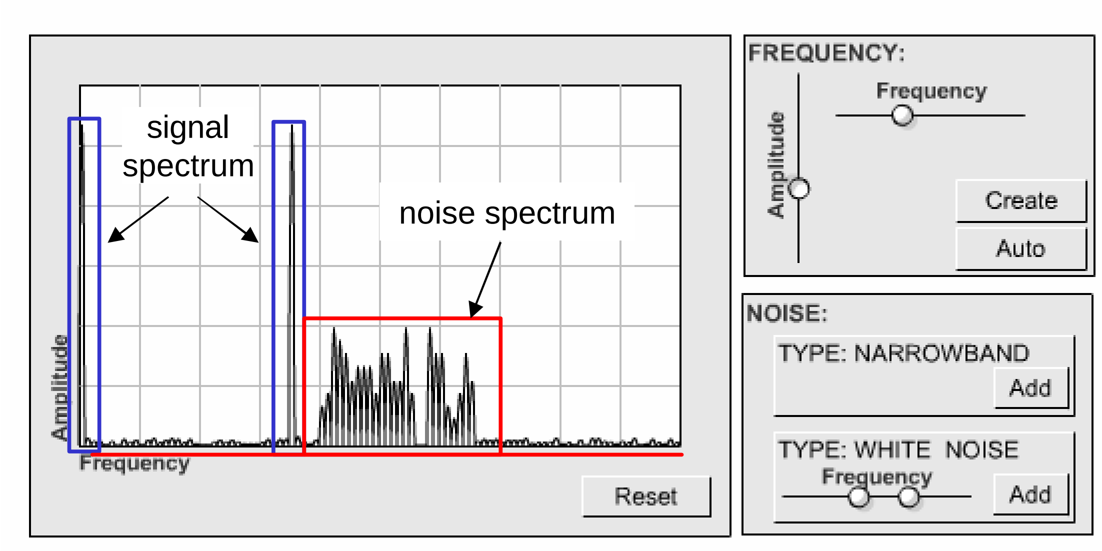
Look here for a demo: http://www.vs-c.de/ma/1/mc/ma_12/ma_12_01/ma_12_01_04

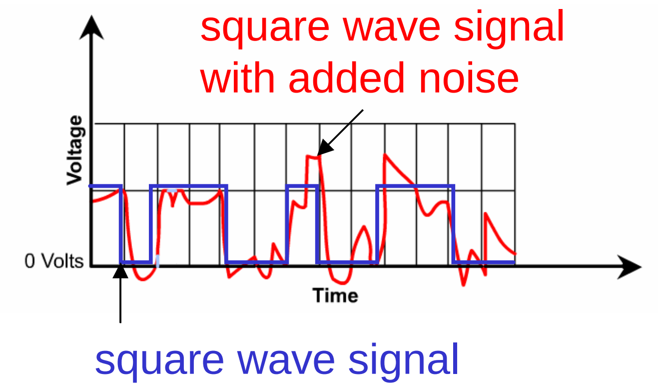
Measuring signals in time and frequency

- An oscilloscope is an important electronic device used to view the time function of electrical signals.
- The x-axis on the display represents time, and the y-axis represents voltage or current.
- There are usually up to **two y-axis inputs**, so two waves can be observed and measured at the same time.
- Analyzing signals using an oscilloscope is called **time-domain analysis**, because the x-axis or domain of the mathematical function represents time.

- A Spectrum Analyzer is an important electronic device used to measure the spectrum of electrical signals.
- Measurement of a signals frequeny content is also called **frequency-domain analysis**.
- In frequency-domain analysis, the x-axis represents frequency.
- An electronic device called a spectrum analyzer creates graphs for frequency-domain analysis.

Noise in time and frequency

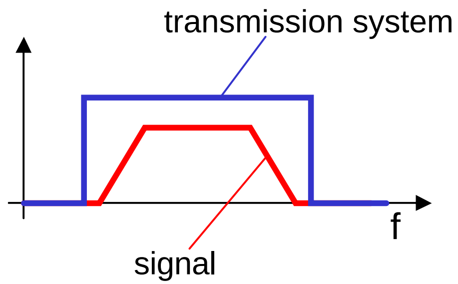


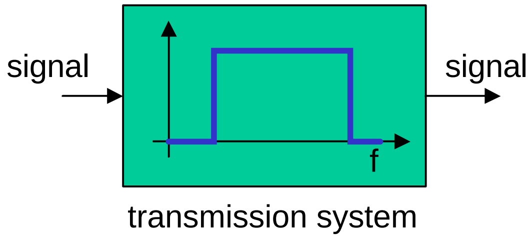


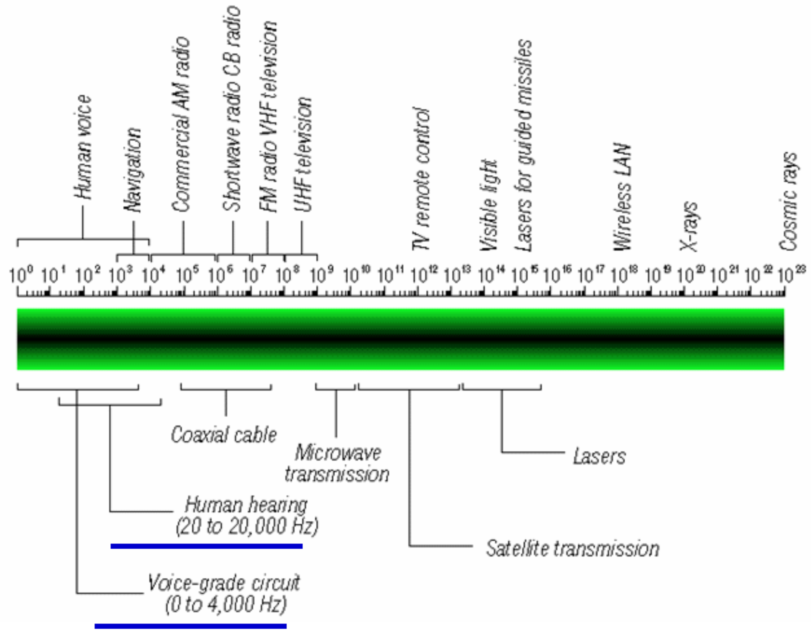
- There are many possible sources of noise:
  - Nearby cables which carry data signals
  - Radio frequency interference (RFI), which is noise from other signals being transmitted nearby
  - Electromagnetic interference (EMI), which is noise from nearby sources such as motors and lights
  - Laser noise at the transmitter or or shot noise (ge: Schrotrauschen) at the receiver front-end (electro-optical converter) for an optical signal

Interdependence of signal bandwidth and transmission bandwidth

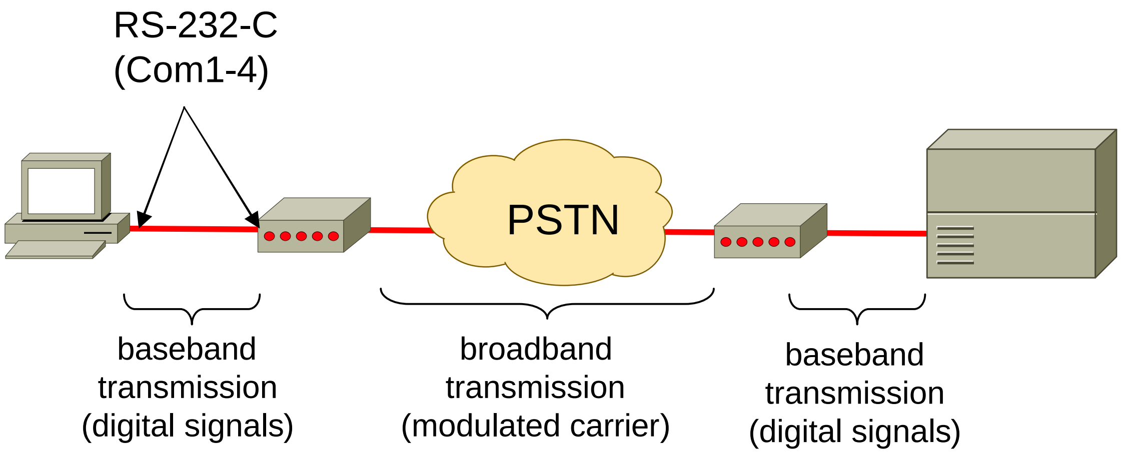
- The bandwidth of a signal is constituted by the difference between the highest and the lowest frequency of the sine waves which contribute to the signal.
- In order to transmit a signal over distance the transmission system must carry all sine waves contributing to this signals.
- The bandwidth of a transmission system is fixed by the difference of the highest and lowest sine wave frequency it can transmit.
- In order to transmit a signal without distortion, a transmission system (e.g. an amplifier or a cable) must have at least the same bandwidth as the signal.
- Because noise is present in all electrical systems, it's not a good idea to have transmission systems a larger bandwidth as the signals to be carried.
- Notice: Signals with hops theoretically are of infinite bandwidth.







- Voice grade telephone lines and equipment are designed to transmit tones between 300 and 3,400 Hertz
- *bandwidth* = 3,100 Hz or 3.1 KHz
- "most" of our human voice falls into this range
- Economics dictated the size of this bandwidth
- (Keyboard example)
- The "maximum" number of cycles (highest frequency) of an analog signal over voice grade telephone lines is 3,400 Hz (cycles per second)



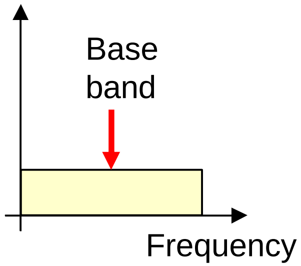
Modem

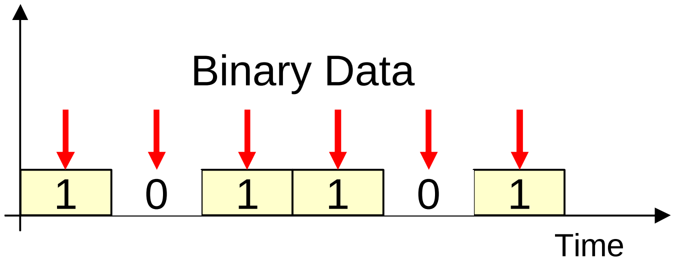
- MOdulator/DEModulator
- Computers use transmission interface standards such as RS-232-C using positive and negative voltages which form square waves, whereas the PSTN (Public Switched Telephone Network) is designed to carry analog signals (sine waves)
- converts analog (broadband) signals to digital (baseband) signals and vice versa
- One important application is broadband transmission of *digital* baseband signals information between computers over voice-grade telephone lines

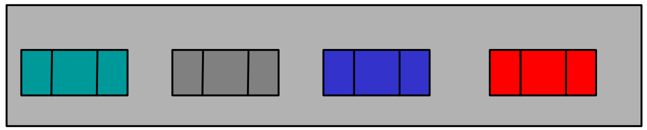
Transmission Terminology

Baseband transmission

- Describing a telecommunication system in which information is carried in digital form on a single unmultiplexed signal channel on the transmission medium. The frequency content of the information carrying signals range from zero or nearby zero up to a maximum frequency. This is the way digital signals are tranported over a baseband network such as Ethernet and Token Ring local area networks.



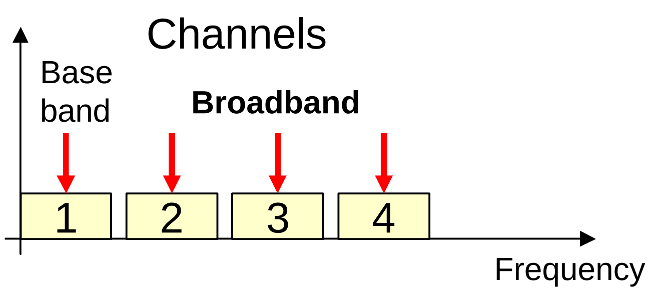




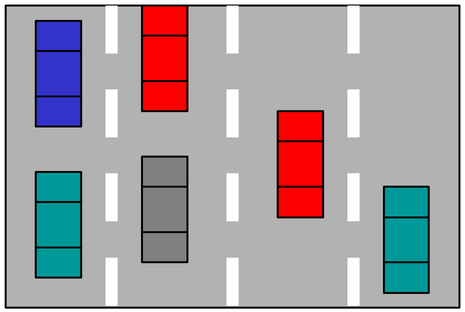
Analogy: single-track Highway

Broadband transmission

- In general, broadband refers to telecommunication with information carrying signals ranging in frequency from some high frequency up to some more high frequency with the intent to make them radiatable from antennas or matching the transmission characteristic of the media.
- If a wide band of frequencies is available, information can be multiplexed and sent on many different channels within the band concurrently (Frequency Division Multiplexing). This allows for more independent data transmissions in a given amount of time (much as more lanes on a highway allow more cars to travel on it in parallel).



Frequency Division Multiplexing (FDM)



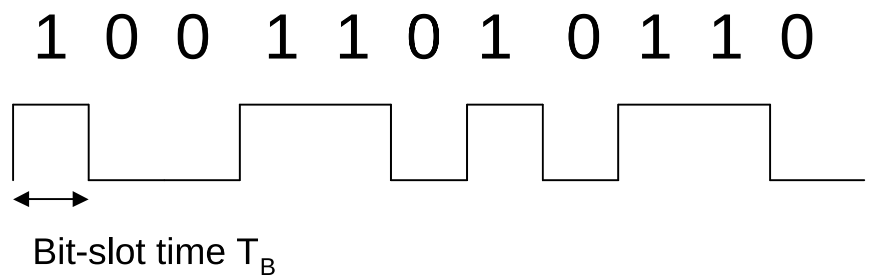
Analogy: multi-track Highway

Baseband Transmission Examples

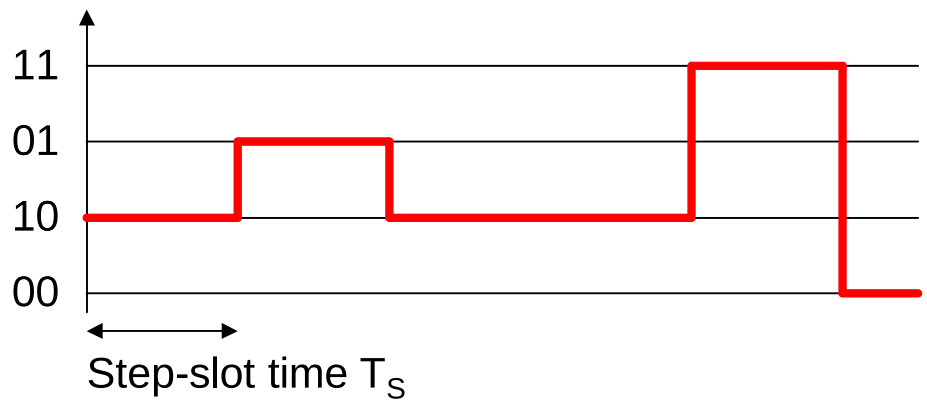
- Digital bitstreams are (usually) coded in analog signals with rectangle shapes.
- The time available for transmission of one is the bit-slot time T_B
- The amount of bits transmitted in one second is the bit rate r_B

$$r_B = \text{bits in one second} = \frac{1}{T_B}$$

- If the receiver is able to distinguish more than two signal amplitudes, other baseband signals can be constructed by using other types of line codes (e.g. the quaternary line code)
- The minimum time between the signal changes (T_S) is a measure of the needed transmission bandwidth
- Because T_S of the quaternary coding is twice as large as that of a binary coding this type of line coding needs only half as much bandwidth as binary coding.



Binary basebandsignal

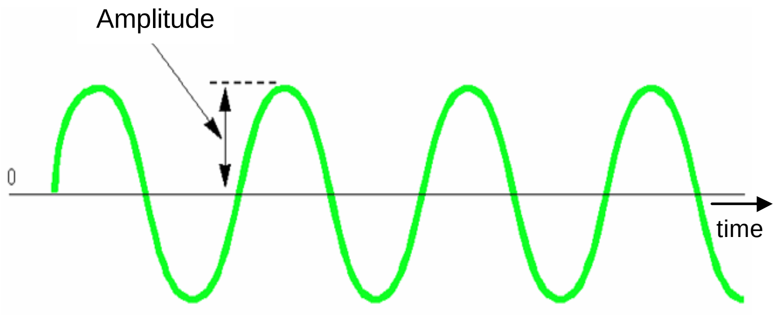


Quaternary Basebandsignal

$$\text{minimum transmission bandwidth needed} = \frac{1}{2T_S}$$

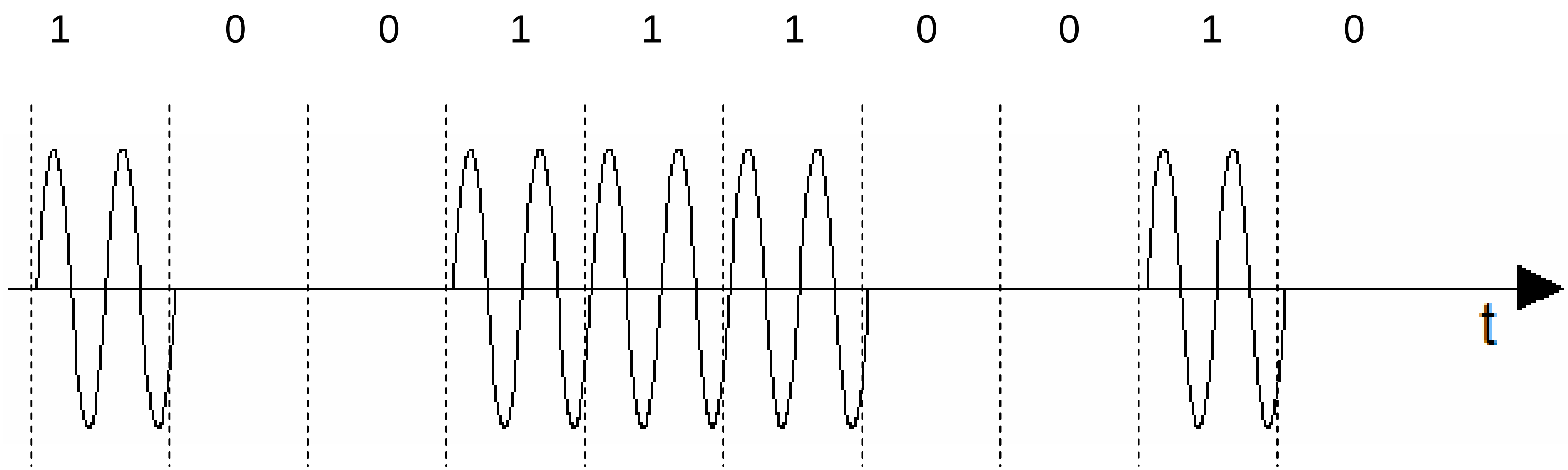
Broadband Transmission

- Broadband transmission requires a carrier signal to be modulated by the information carrying signals
- Usually steady state periodically signals with sinus shape and frequencies in the mid of the transmission band associated with the channel are used as carrier signals.
- Sine shaped carrier signals are characterized by
  - Amplitude
  - Frequency
  - Phase
- Each of these parameters can be varied synchronous with the information carrying signal. This process is called modulation
- Three types of modulation are in common use. According to the varied parameters they are called
  1. **amplitude** modulation
  2. **frequency** modulation
  3. **phase** modulation



Amplitude Modulation (AM)

- a modulation technique to vary the height the electrical signal (the sine wave or carrier wave with modems) to transmit ones and zeroes, while the frequency and phase of the carrier remains constant
- different amplitudes for 0's and 1's
- a.k.a. amplitude shift keying (ASK) or on-off keying (OOK)

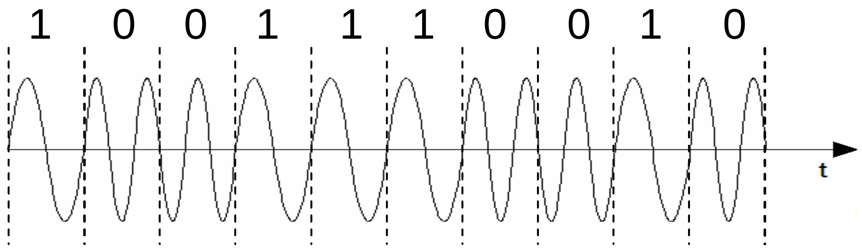


Frequency Modulation (FM)

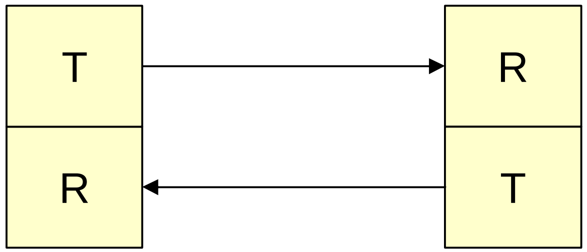
- a modulation technique to vary the frequency of the sine wave (or carrier wave) to transmit ones and zeroes, while the amplitude remains constant
- a.k.a. frequency shift keying (FSK)
- two separate frequencies for ones and zeroes

Full Duplex

- requires a minimum of four frequencies, two frequencies for each direction
- i.e. CCITT V.21 for 300 bps modems:



send	Bit	receive
1270 Hz	1	1270 Hz
1070 Hz	0	1070 Hz

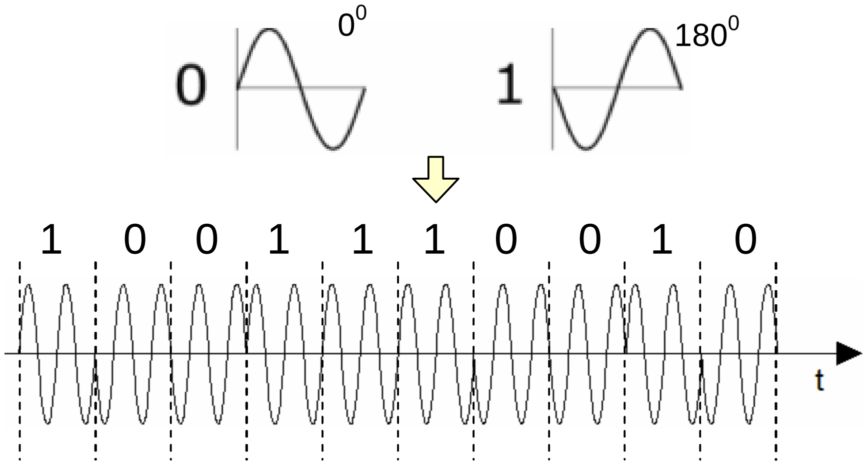


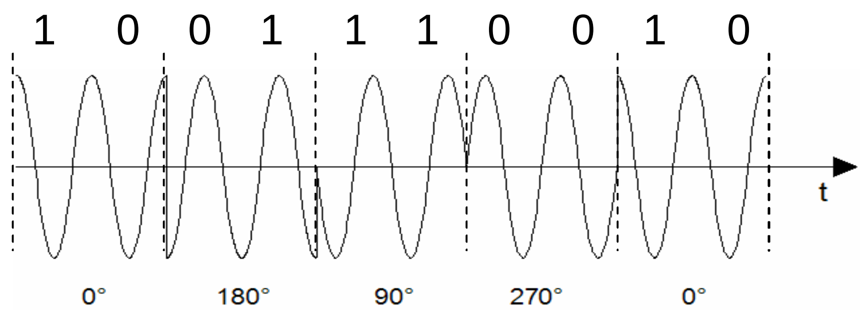
receive	Bit	send
2225 Hz	1	2225 Hz
2025 Hz	0	2025 Hz

300 bps modems

Phase Modulation (PM)

- a modulation technique to <u>vary the phase</u> of the sine wave (or carrier wave) to transmit ones and zeroes, while the <u>amplitude</u> and the <u>frequency</u> remains <u>constant</u>
- The example to the right uses 2 signal phases separated by a phase shift of 180 degrees. This example is a.k.a. <u>2-phase-shift-keying</u> (2-PSK)
- A different phase shift can be used to transmit more than one bit
- To be more concrete: Shifting in steps of $360/2^n$ degrees, n=2,3,... allows to transmit ***n bits at a time***





<u>4-PSK example</u>
(2 bits per phase change)

bits	phase
00	270^0
01	180^0
10	0^0
11	90^0

Full Duplex

- requires a minimum of two frequencies, one frequency for each direction

Bits per second vs. Baud and High-speed modems

- The number of amplitude, frequency or phase changes per second is called transmission rate (ge: Schrittrate) and is measured in baud.

Baseband transmission

- The transmission rate $1/T_S$ is limited by the channel bandwidth B:

$$B \geq \frac{1}{2T_S} \Rightarrow \text{transmission rate} = 1/T_S \leq 2 \cdot B$$

- With binary transmission each change transmits only one bit (e.g. 2-PSK), and transmission rate in baud and bit rate in bps are equal:
- bit rate with binary line code = transmission rate ⇒ bit rate ≤ 2 · B
- High speed modems transmit more than one bit per change (e.g. 4-PSK transmits 2 bits per change). Therefore

bit rate with quaternary line code = 2 · transmission rate ⇒ bit rate ≤ 4 · B

- More general: Coding of 2^n bits into one change asserts

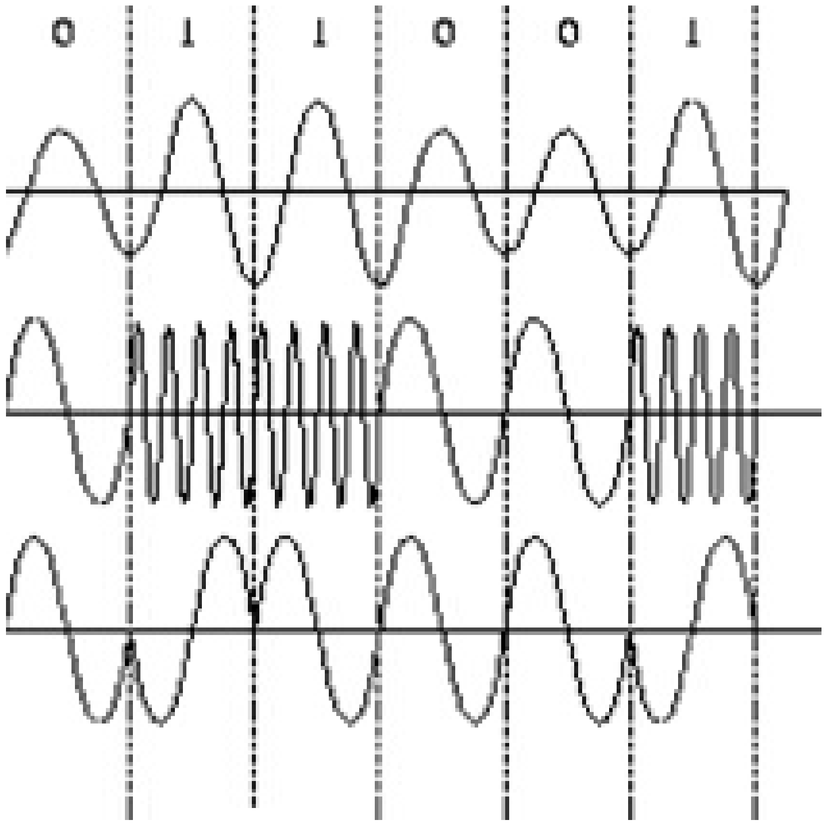
bit rate ≤ n · 2 · B

Broadband transmission

- Maximum transmission rate is only half of baseband transmission rate e.g. with voice grade telephone channels (bandwidth = 3100 Hz) the following transmission capacities are given:

Modulation	transmission rate	bit rate
2-PSK	3100 baud	3100 bps
4-PSK	3100 baud	6200 bps
8-PSK	3100 baud	9300 bps

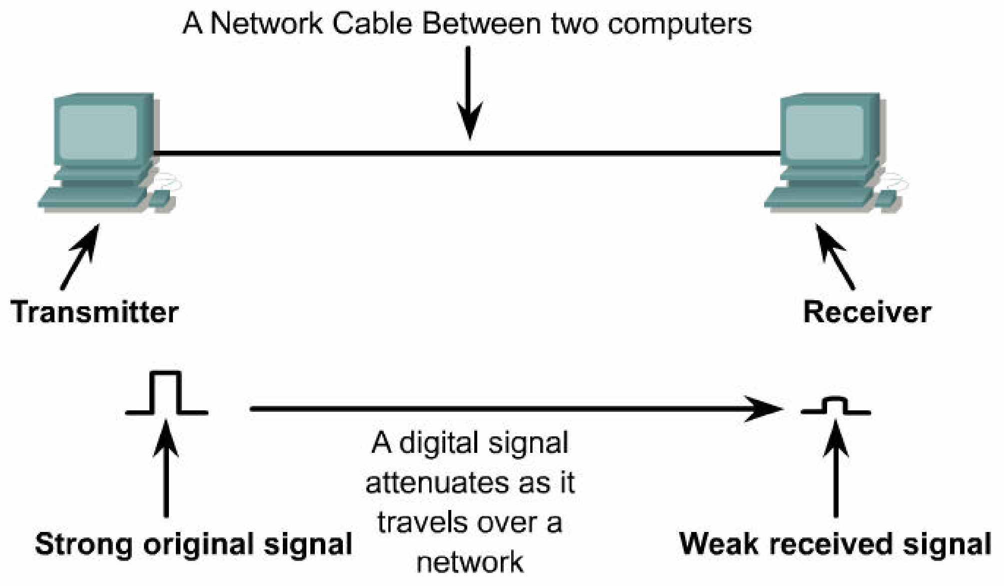
- Amplitude Modulation (AM)
- Frequency Modulation (FM)
- Phase Shift Keying (PSK)



Objectives

- Define and describe the affects of attenuation and impedance mismatch.
- Define crosstalk, near-end crosstalk, far-end crosstalk, and power sum near-end crosstalk.
- Describe how crosstalk and twisted pairs help reduce noise.
- Describe the ten copper cable tests defined in TIA/EIA-568-B.
- Describe the difference between Category 5 and Category 6 cable.

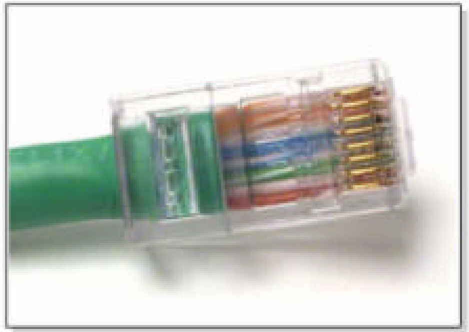
Attenuation and insertion loss on copper media

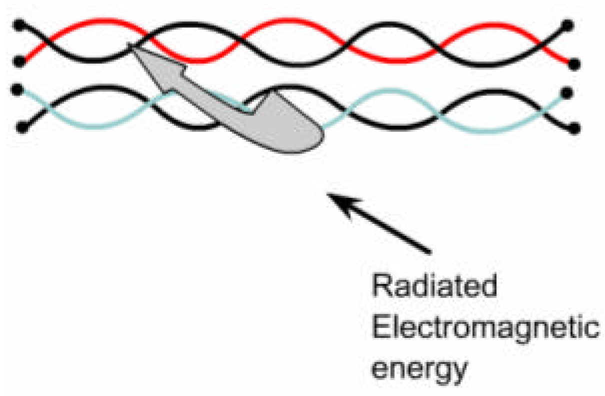


- Attenuation is the decrease in signal amplitude over the length of a link.
- Long cable lengths and high signal frequencies contribute to greater signal attenuation.

Crosstalk as one source of noise on copper media

- **Crosstalk** involves the ***transmission of signals from one circuit to a nearby circuit.***
- When voltages change on a wire, electromagnetic energy is generated.
- This energy radiates outward from the transmitting wire like a radio signal from an transmitting antenna.
- Adjacent wires in the cable act like receiving antennas, receiving the transmitted energy, which interferes with data on those wires.
- The overspilling energy is also called ***crosstalk*** energy
- Twisted-pair cable is designed to minimize crosstalk:
  - In twisted-pair cable, a pair of wires is used to transmit one signal.
  - The wire pair is twisted so that each twist experiences similar crosstalk but with opposite polarity so that cross talk in successive twists cancels out.
  - Untwisting a pair destroys this cancellation mechanism.



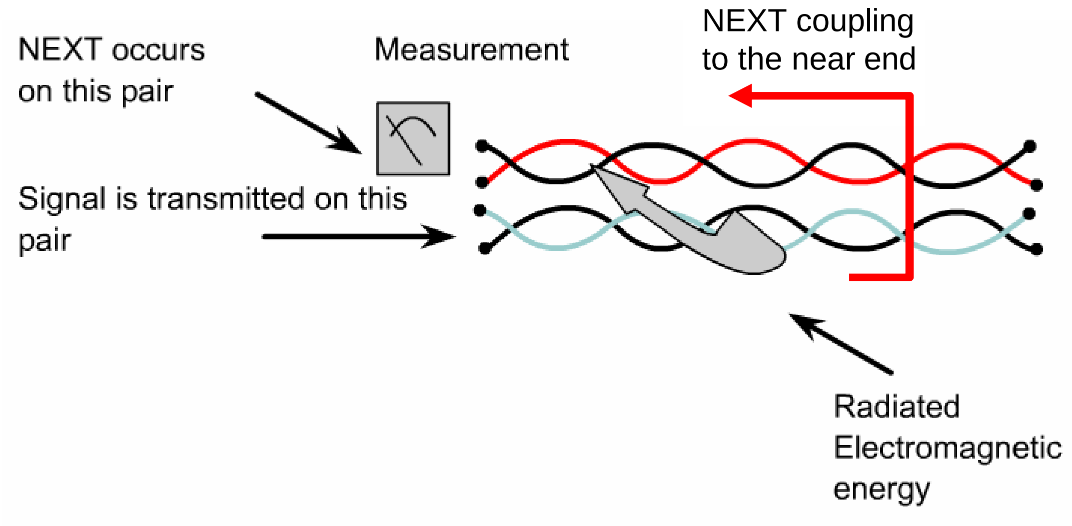


Types of crosstalk

There are three distinct types of crosstalk:

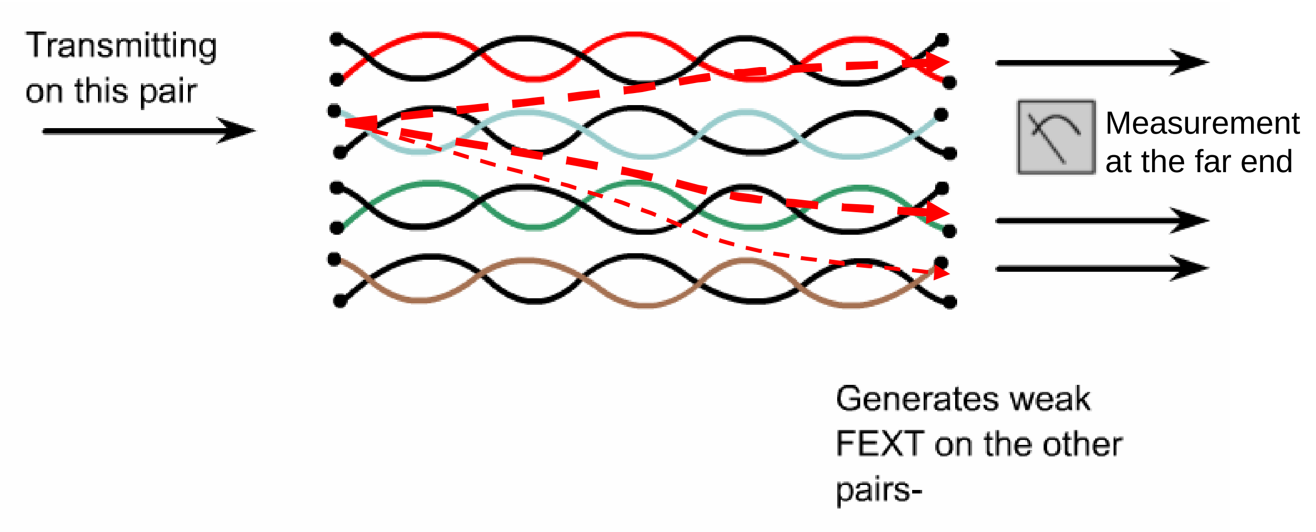
- Near-end Crosstalk (NEXT)
- Far-end Crosstalk (FEXT)
- Power Sum Near-end Crosstalk (PSNEXT)

Near-end Crosstalk (NEXT)



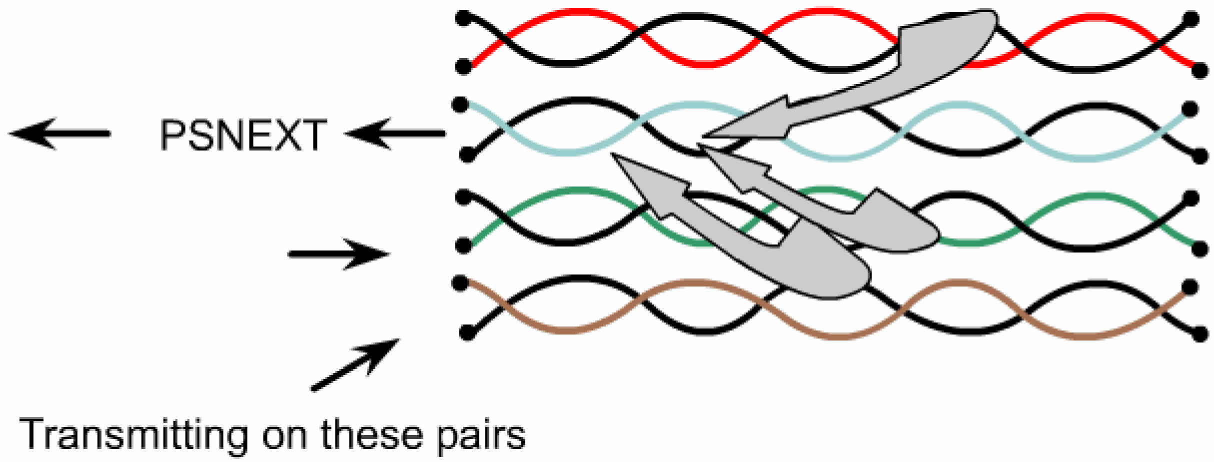
- The mechanism of coupling signals to neighbor circuits and propagating to the near end is called **near-end crosstalk, or NEXT**.
- **Near-end crosstalk (NEXT)** is computed as the ratio of voltage amplitude between the transmitted test signal and the crosstalk signal when measured from the same end of the link.

Far-end Crosstalk (FEXT)



- The mechanism of coupling signals to neighbor circuits and propagating to the far end are called **far-end crosstalk, or FEXT**.
- **Far-end crosstalk (FEXT)** is computed as the ratio of voltage amplitude between the transmitted test signal and the crosstalk signal when measured from the opposite end of the link.
- Due to attenuation, far-end crosstalk occurring further away from the transmitter creates less noise on a cable than NEXT.
- Thus, FEXT is not as significant a problem as NEXT.

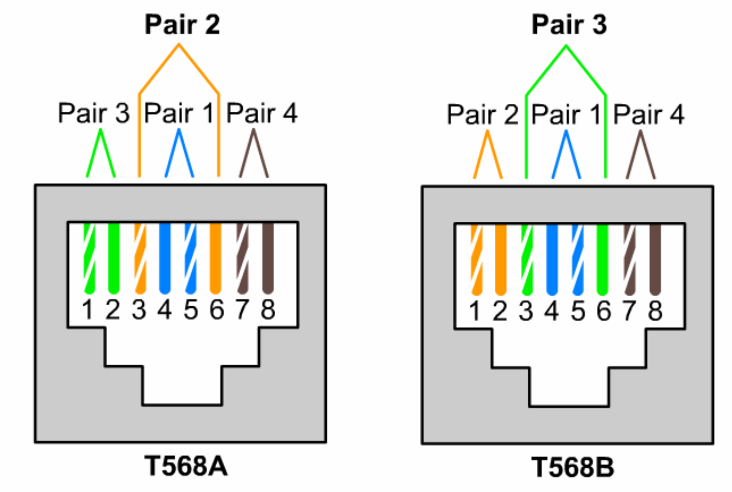
Power Sum Near-end Crosstalk (PSNEXT)



- **Power Sum NEXT (PSNEXT)** measures the cumulative effect of NEXT from all wire pairs in the cable.
- PSNEXT is computed for each wire pair based on the NEXT effects of the other three pairs.
- The combined effect of crosstalk from multiple simultaneous transmission sources can be very harmful to the signal.

Cable testing standards

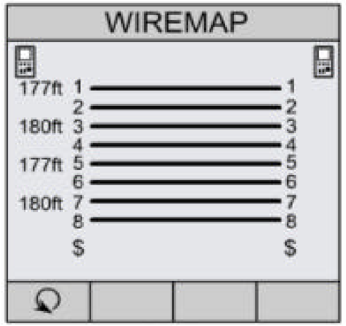
- The Ethernet standard specifies that each of the pins on an RJ-45 connector have a particular purpose.
- A NIC **transmits** signals on **pins 1 and 2**, and it **receives** signals on **pins 3 and 6**.
- The wires in UTP cable must be connected to the proper pins at each end of a cable.



now obsolete!

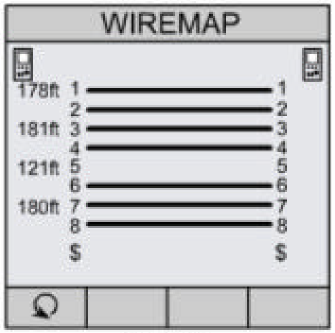
Cable testing standards

- The **wire map** test insures that no open or short circuits exist on the cable.



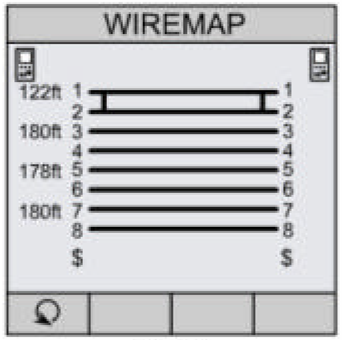
Good Wiremap

- An **open circuit** occurs if the wire does not attach properly at the connector.



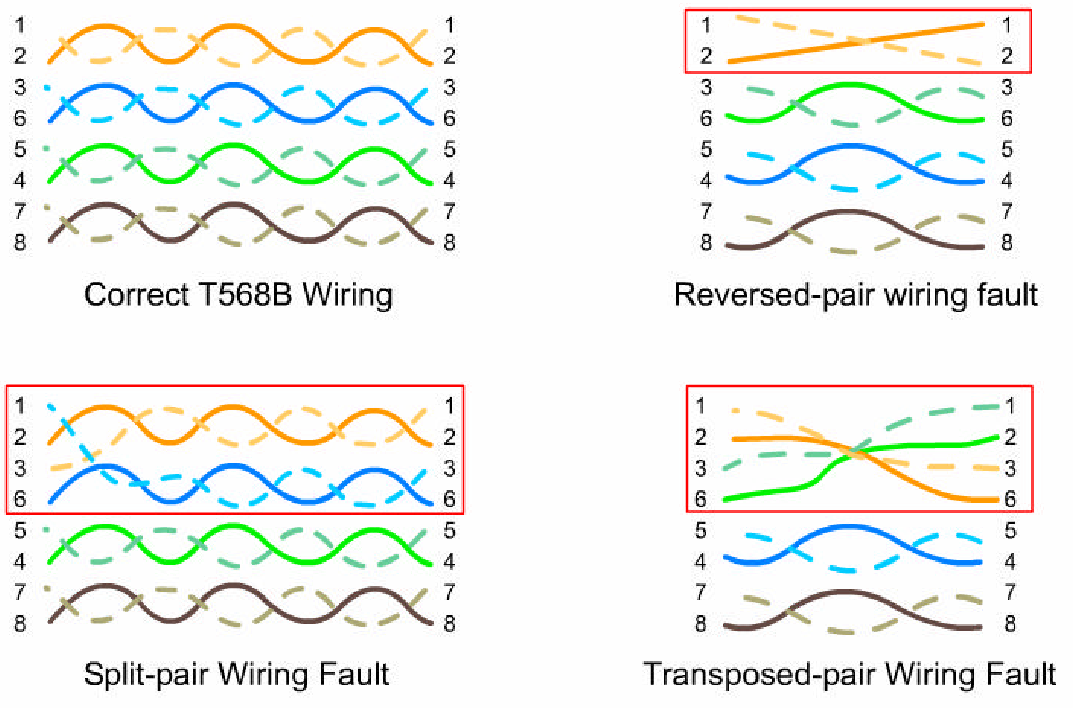
Open

- A **short circuit** occurs if two wires are connected to each other.



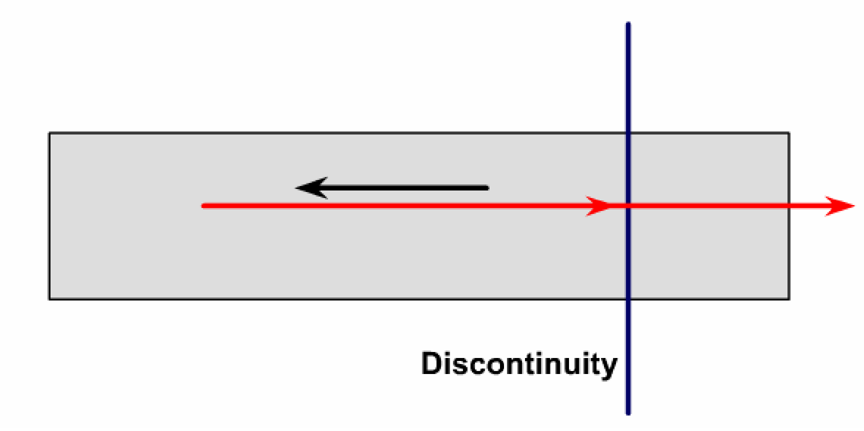
Short

Cable testing standards



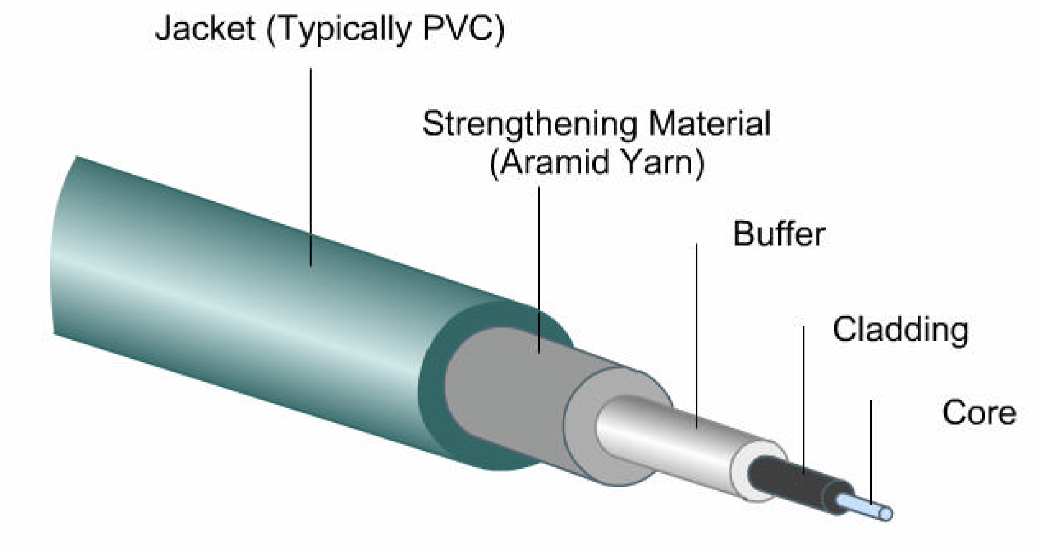
- The wire map test also verifies that all eight wires are connected to the correct pins on both ends of the cable.
- There are several different wiring faults that the wire map test can detect.
- Transposed-pair wiring faults occur when a wire pair is connected to completely different pins at both ends.

Testing optical fiber



- Fiber links are subject to the optical equivalent of UTP impedance discontinuities.
- When light encounters an optical discontinuity, some of the light signal is reflected back in the opposite direction with only a fraction of the original light signal continuing down the fiber towards the receiver.
- This results in a reduced amount of light energy arriving at the receiver, making signal recognition difficult.
- Just as with UTP cable, improperly installed connectors are the main cause of light reflection and signal strength loss in optical fiber.

Advantages of optical fiber transmission media



- Absence of electrical signals → No copper needed → Leightweight cables.
- Small fiber diameter → thin cables → easy to bend
- There are no crosstalk problems on fiber optic cable.
- External electromagnetic interference has no affect on fiber cabling.
- Attenuation does occur on fiber links, but to a lesser extent than on copper cabling.

A new standard

- On June 20, 2002, the Category 6 (or Cat 6) addition to the TIA-568 standard was published.
- The official title of the standard is ANSI/TIA/EIA-568-B.2-1.
- Although the Cat 6 tests are essentially the same as those specified by the Cat 5 standard, Cat 6 cable must pass the tests with higher scores to be certified.
- Cat6 cable must be capable of carrying frequencies up to 250 MHz and must have lower levels of crosstalk and return loss.