ECE 528 – Understanding Power Quality

http://www.ece.uidaho.edu/ee/power/ECE528/

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Lecture 41

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Today…

- Wiring for communications
  - Decibels
  - Coupling
  - Avoiding power system/communication system interactions
    - UTP – Unshielded Twisted Pair
  - Differential communications

References: (*I strongly recommend both if you are interested in high frequency and electromagnetic compatibility*)

- *Electromagnetic Compatibility Engineering*, by Henry W. Ott
- *Technical Tidbits* posts from February 2002, March, 2002, and April 2005 on Douglas Smith's High Frequency Measurements Web Page (www.emcesd.com)

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Some communications terminology

- The decibel - dB
  - Used to compare power ratios

$$dB = 10\log\frac{P_2}{P_1}$$

  - Try it!
    - Express a 100:1 (P_2:P_1) power ratio in dB
    - Express a 0.5:1 (P_2:P_1) power ratio in dB

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The decibel in communication circuits

- Used to measure loss of signal strength
- Used to measure interference from neighboring communication circuits
- Used to compare different circuit configurations
  - If voltage or current are measured:

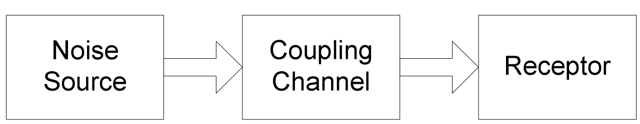
$$P = \frac{V^2}{R} \qquad \log A^n = n\log A \qquad dB = 20\log\frac{V_2}{V_1}$$

- Try it: V_1=5V, V_2=1V, what is the ratio in dB?

Communication circuit problems

- Coupling (again) – interference from neighboring power or communication circuits
  - Conductive
  - Capacitive (electric field)
  - Inductive (magnetic field)
  - Far field – combined electromagnetic field
- Signal attenuation – loss of signal strength between the sending and receiving ends

The noise path



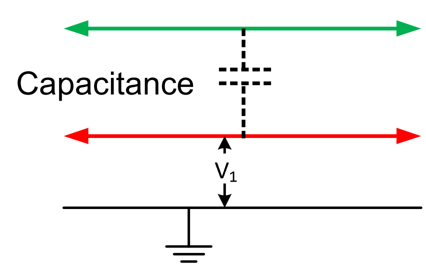
- All three components are necessary for a noise problem
- Three possible solutions:
  - Suppress the noise at the source
  - Make the receptor immune to the noise
  - Remove or reduce the coupling

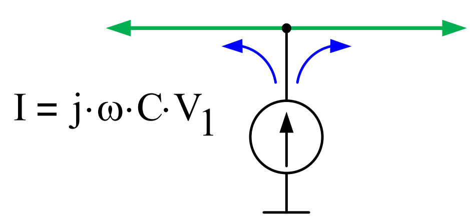
Conductive coupling

- Two or more devices sharing conductors so that current on the conductors due to one device results in voltage fluctuations at the other devices.
- This is why isolated grounds are sometimes used
  - They reduce the "sharing" of the grounding conductor

Capacitive coupling

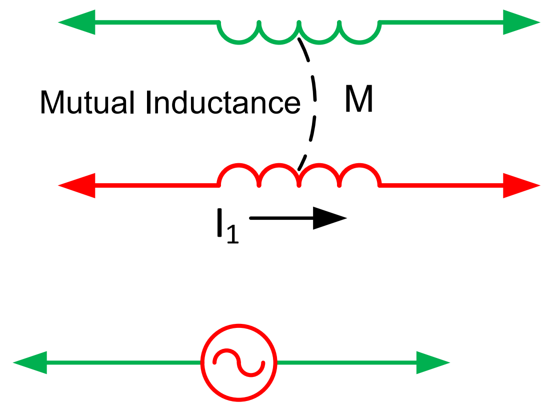
- Produced by the electric field between conductors (voltage)
- Acts as a current injection point
- Directly proportional to:
  - Frequency
  - Voltage
  - Conductor length
- Inversely proportional to:
  - Conductor separation





Inductive coupling

- Produced by the magnetic field between conductors (current in aggressor or source)
- Acts as a series voltage source
- Directly proportional to:
  - Frequency
  - Current
  - Conductor length
- Inversely proportional to:
  - Conductor separation



$$V = j \cdot \omega \cdot M \cdot I_1$$

UTP – Unshielded twisted pair

- UTP cable is widely used as the standard cable for computer networking and industrial control systems
- Category 5e cable is a networking cable used in Ethernet and other protocols and designed for frequencies up to 100MHz
- How does Category 5e cable (and the communication systems that use it) address capacitive and inductive coupling?

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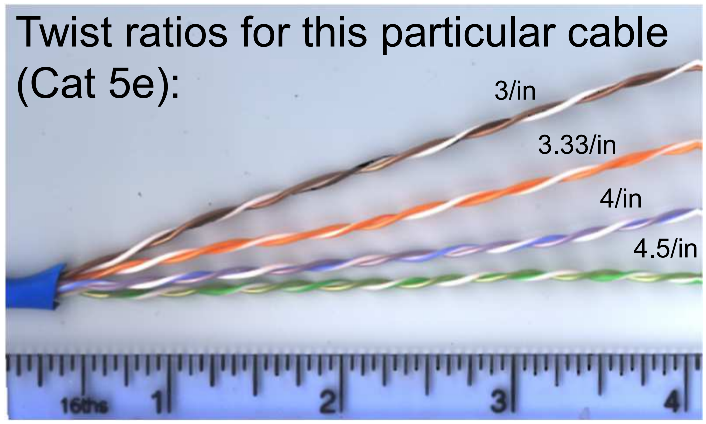
Overcoming coupling
UTP – Unshielded Twisted Pair

- Construction: Cat 5e
  - #24AWG solid copper conductors
  - 4 twisted pairs
  - Varying "lays" or twist rates
  - No shield



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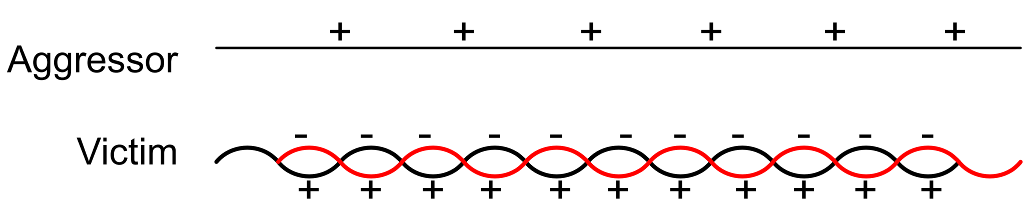
Benefits of twisting each pair

- Capacitive coupling
  - A nearby "aggressor" circuit is creating an electric field in the area of the twisted pair
  - Twists help prevent differential voltage from developing between conductors in the pair



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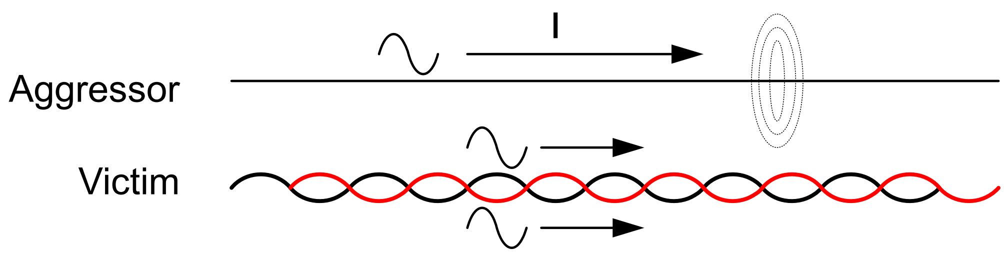
Benefits of twisting each pair

- Inductive coupling
  - A nearby "aggressor" circuit is creating a magnetic field in the area of the twisted pair
  - Twists force induced EMF to be "common mode"



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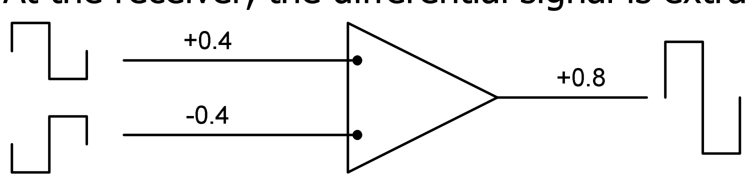
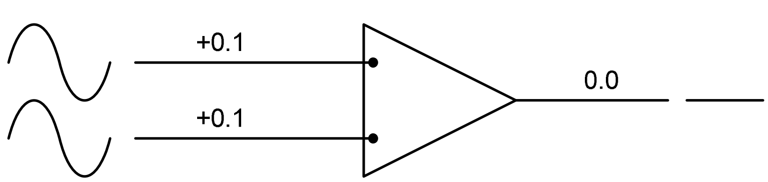
Differential communication signal and common mode noise

- At the receiver, the differential signal is extracted



- The common mode noise is cancelled



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Other benefits of twisting the signal pairs

- Signal cables can be the aggressor too:
  - One signal pair could be the aggressor for other signal pairs in the same cable or other nearby signal cables
  - Twisting the pairs minimizes the capacitive coupling to other nearby circuits
- Different twist ratios
  - help minimize “crosstalk” - the coupling of signals from one twisted pair to another, either in the same cable or other nearby cables

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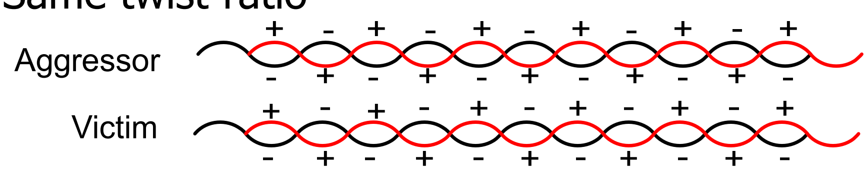
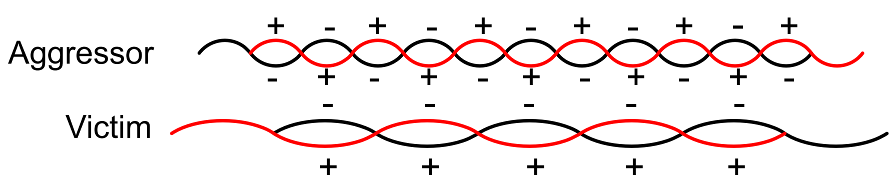
Benefits of twisting: Minimizing crosstalk

- Same twist ratio



Note capacitive coupling

- Different twist ratios



Capacitive coupling cancels

Installation issues

- Delay skew
  - Different twist ratios result in each pair being a slightly different length
  - Signals on one pair may take longer to travel from one end of the cable to the other than signals on another, less twisted pair
  - May be an issue with long cables and video signals

Installation issues

- Maintaining twist ratios
  - Cable bends and terminations can untwist the pairs
  - Some manufacturers fuse the insulation between pairs to keep conductor separation to a minimum
  - Bends need to be gradual, and twist ratios need to be maintained into connectors

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Installation issues

- Nearby power conductors
  - The NEC requires a minimum spacing of 2 inches between power and communication circuits
  - Generally, avoiding close, long parallel runs of power and signal cables is sufficient to avoid problems

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Some communication cabling terms (calculations are in dB, i.e. -20log(ratio) *Don't just use the ratio!*)

$$\frac{V_{out}}{V_{in}}$$

Attenuation: The loss in signal power between the sending and receiving end

$$Attenuation = -20 \cdot log\left(\frac{V_{out}}{V_{in}}\right)$$

$$\frac{V_{xtalk\_near\_end}}{V_{in}}$$

NEXT: (Near end crosstalk) the sending end signal power on one pair that appears at the sending end on any other pair in the cable

$$\frac{V_{xtalk\_far\_end}}{V_{in}}$$

FEXT: (Far end crosstalk) the sending end signal power on one pair that appears at the receiving end on any other pair in the cable

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Some communication cabling terms (calculations are in dB, i.e. 20log(ratio))

$$\frac{V_{xtalk\_far\_end}}{V_{out}}$$

ELFEXT: Equal Level FEXT – The receiving end signal power on one pair that appears on any other pair in the cable at the receiving end

$$\frac{V_{reflected}}{V_{in}}$$

Return Loss: The amount of sending end signal power that is reflected back on the same pair – due to manufacturing variations or flaws in the signal conductors

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Cat 5e performance standard at 100MHz

	Connectors	Channel
Attenuation	0.4 dB	24 dB
NEXT	40 dB	30.1 dB
FEXT	35 dB	-
ELFEXT*	-	17.4 dB
Return Loss	18 dB	10 dB

Channel - The link (cable and connectors) between the local and remote equipment
*ELFEXT (Equal Level FEXT) = FEXT – Attenuation
FEXT and Attenuation are measured, ELFEXT is calculated

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Next time…

- 42: PQ recorders / Stray voltage
  - Recorder location and impact on what we record
- 43: PQ equipment and tools / Wiring and grounding summary
- 44: Summary / closing remarks