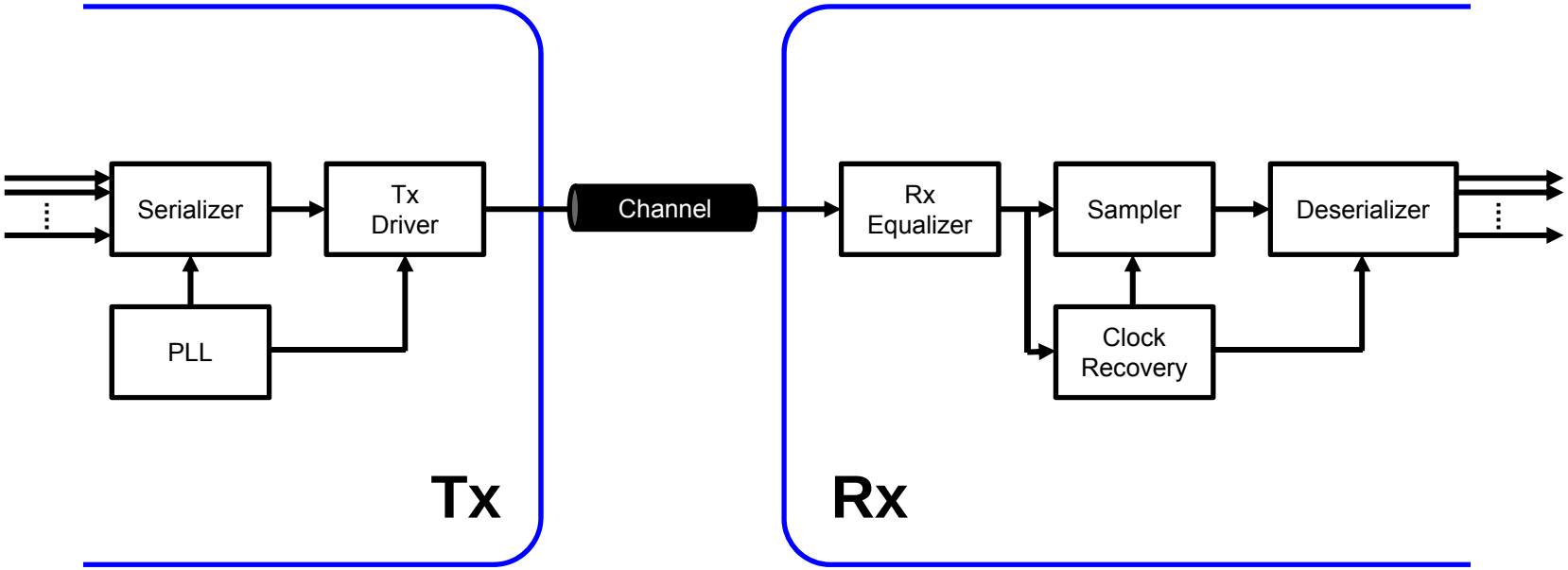
High-speed Serial Interface

Lect. 2 – Channel Characteristic

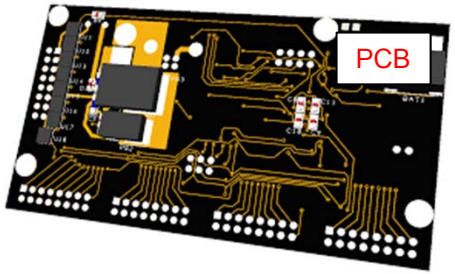
Block diagram

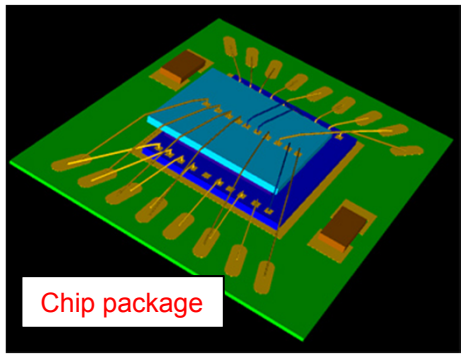
- Where are we today?

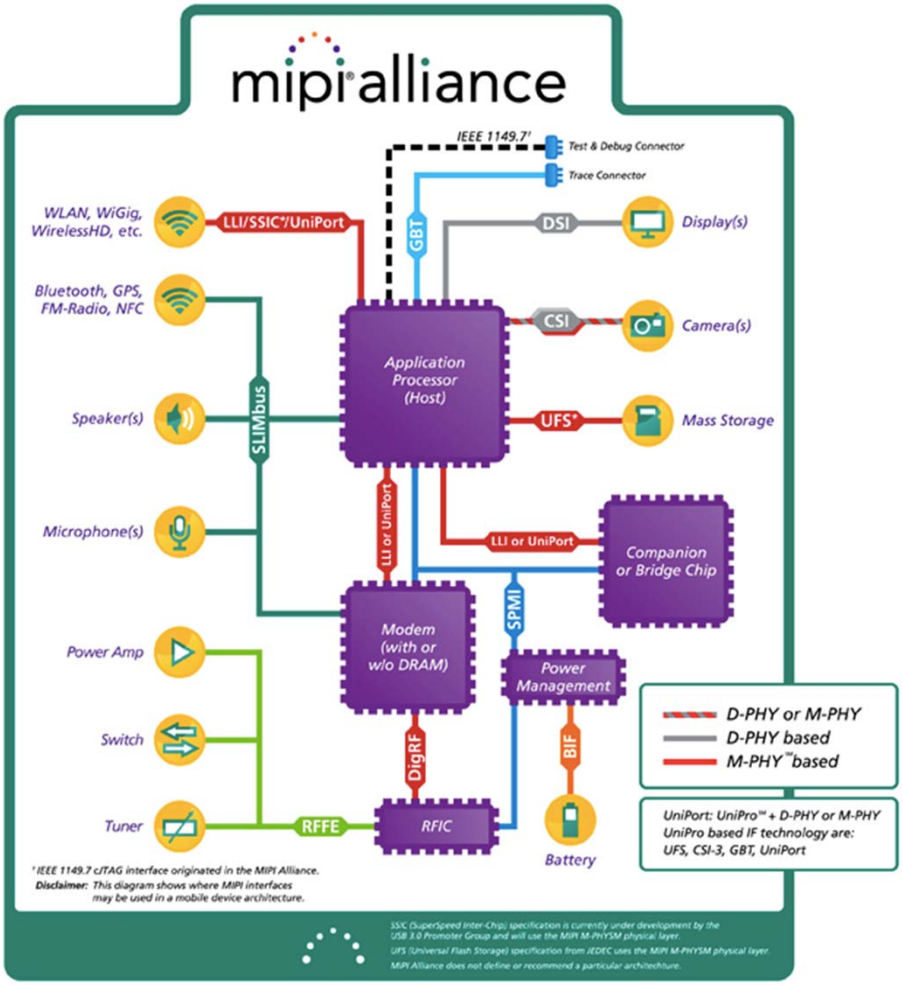


Interface Channels

- Chip-to-chip
  - PCB
  - Chip packages

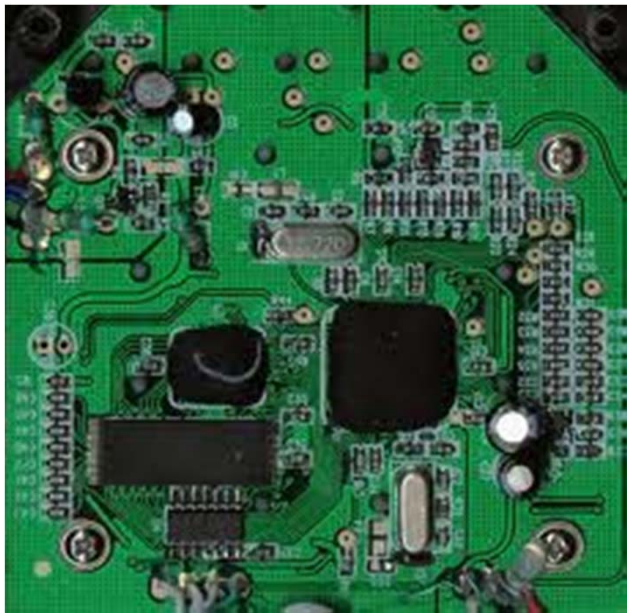


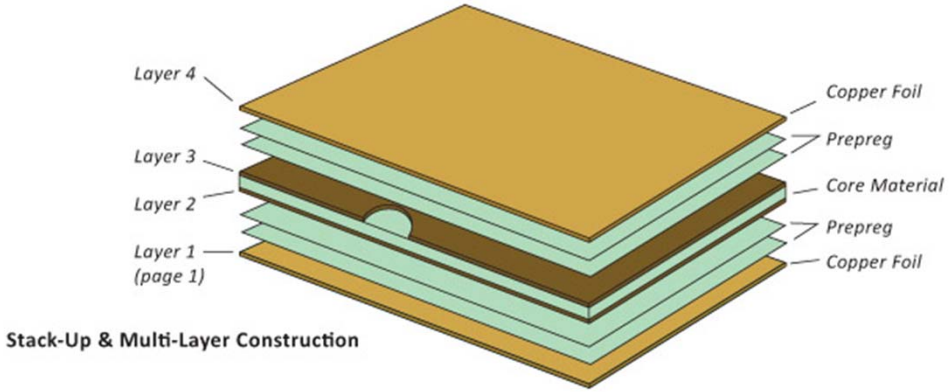




Interface Channels

- PCB





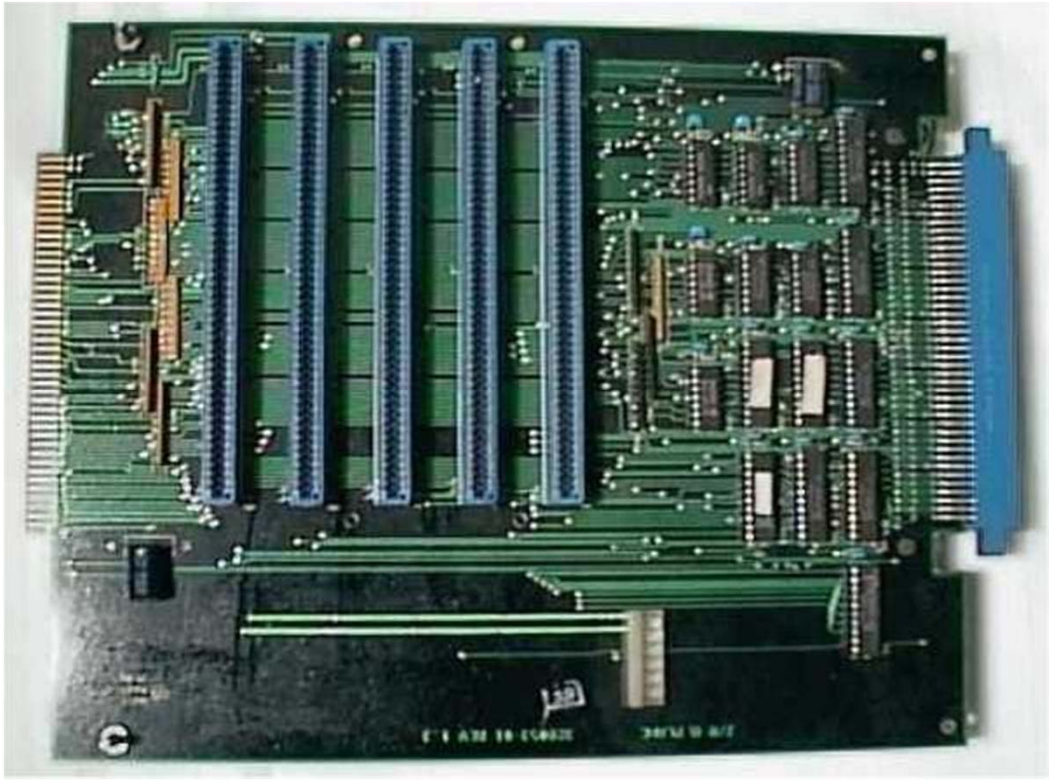
- PCB Stack-Up
Core (Copper traces with FR4)
+ Prepreg + Copper Foil

- Various stack-up schemes
(Signal, Power, Ground planes)

- Vias connect different layers

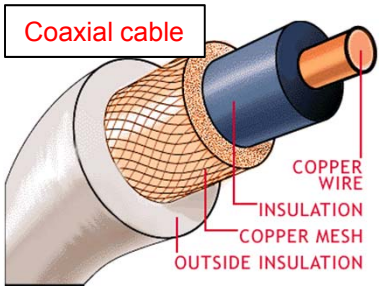
Interface Channels

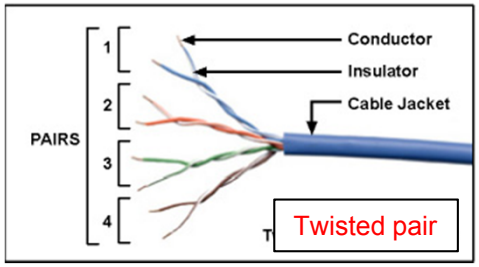
- Backplane and Linecard

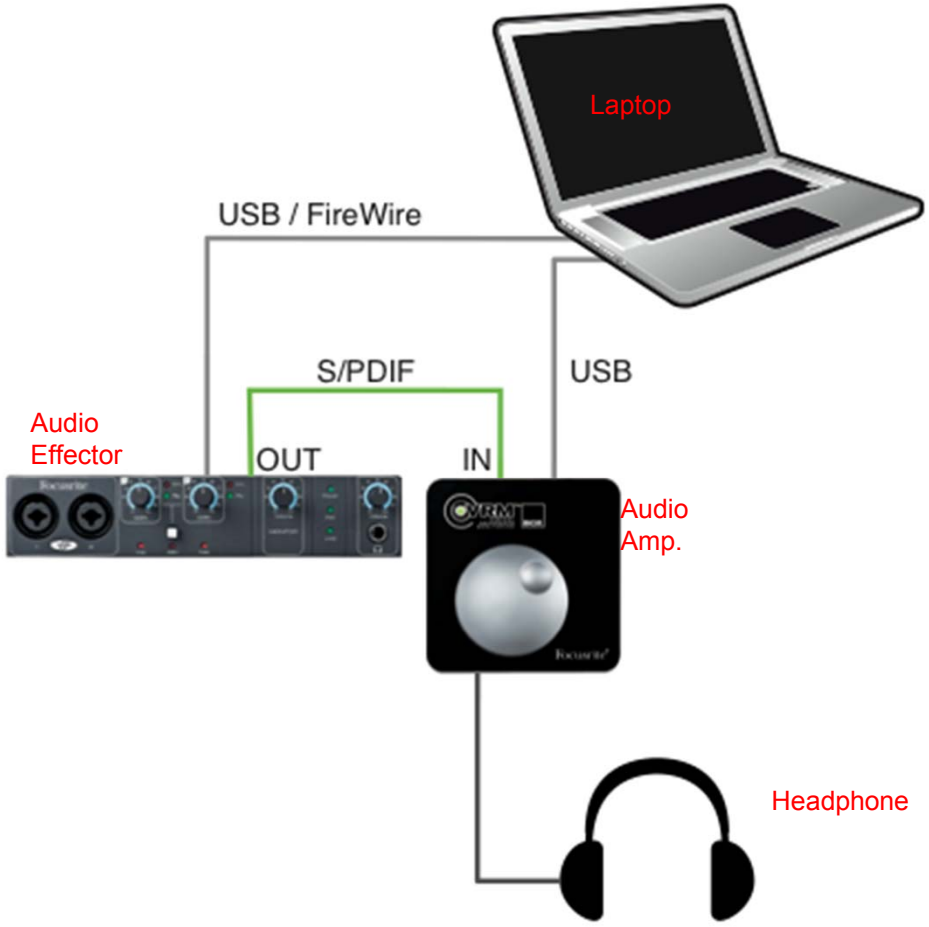


Interface Channels

- Box-to-box
  - Cables



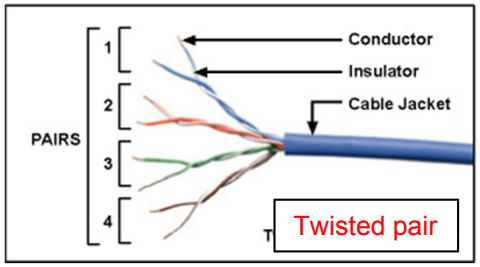


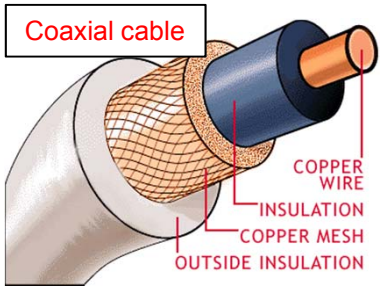


Interface Channels

- Box-to-box
  - Cables

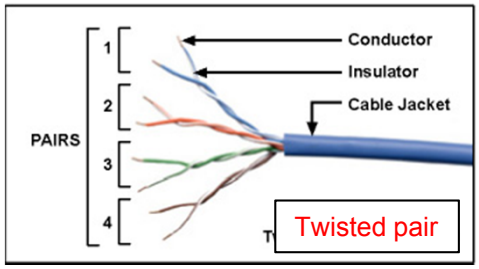
- Coaxial cable
- Mineral-insulated copper-clad cable
- Twinax cable
- Flexible cables
- Non-metallic sheathed cable
- Metallic sheathed cable
- Multicore cable
- Shielded cable
- Single cable
- Twisted pair
- Twisting cable





Interface Channels

- Twisted Pair

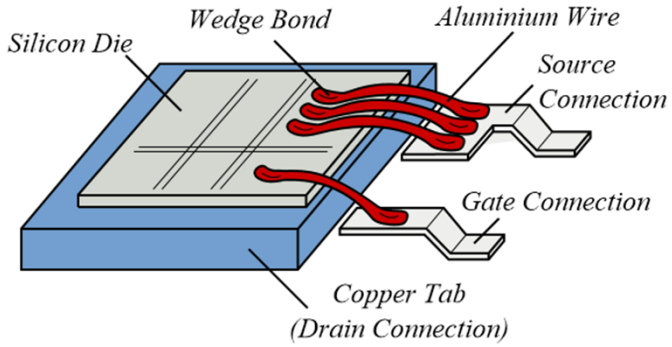


Name	Type	Bandwidth	Applications
Level 1		0.4 MHz	Telephone and modem lines
Level 2		4 MHz	Older terminal systems, e.g. IBM 3270
Cat3	UTP[7]	16 MHz[7]	10BASE-T and 100BASE-T4 Ethernet[7]
Cat4	UTP[7]	20 MHz[7]	16 Mbit/s[7] Token Ring
Cat5	UTP[7]	100 MHz[7]	100BASE-TX & 1000BASE-T Ethernet[7]
Cat5e	UTP[7]	100 MHz[7]	100BASE-TX & 1000BASE-T Ethernet[7]
Cat6	UTP[7]	250 MHz[7]	10GBASE-T Ethernet
Cat6a		500 MHz	10GBASE-T Ethernet
Class F	S/FTP [7]	600 MHz[7]	Telephone, CCTV, 1000BASE-TX in the same cable. 10GBASE-T Ethernet.
Class Fa		1000 MHz	Telephone, CATV, 1000BASE-TX in the same cable. 10GBASE-T Ethernet.

Chip package

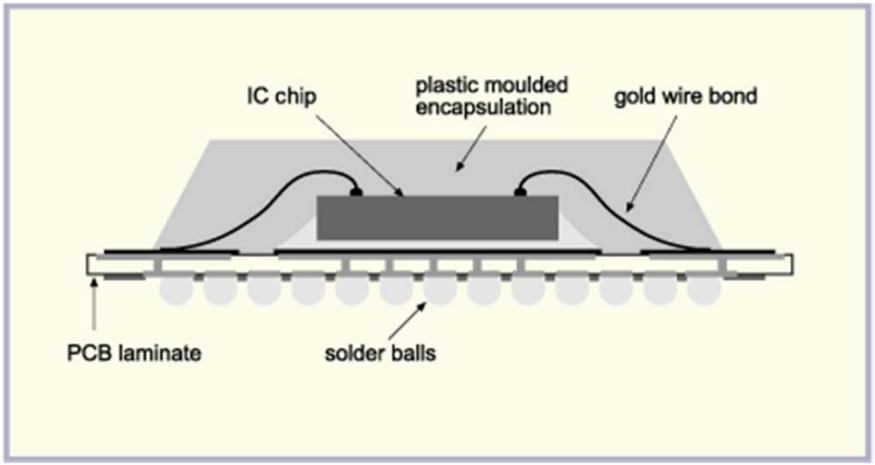
- Wire bonding
  - Bonding wires connect pads and package lead frames

➔ Inductance due to wires



Limited pin number

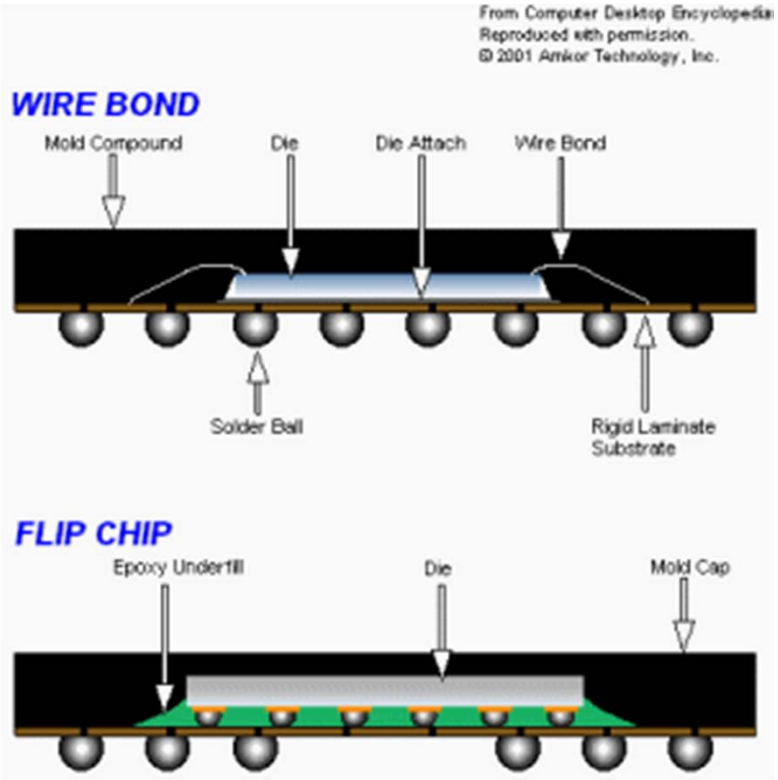
Ball Grid Array



Note: Reproduced from the only available original

Chip package

- Flip Chip



- Package type often decides the maximum data rate!

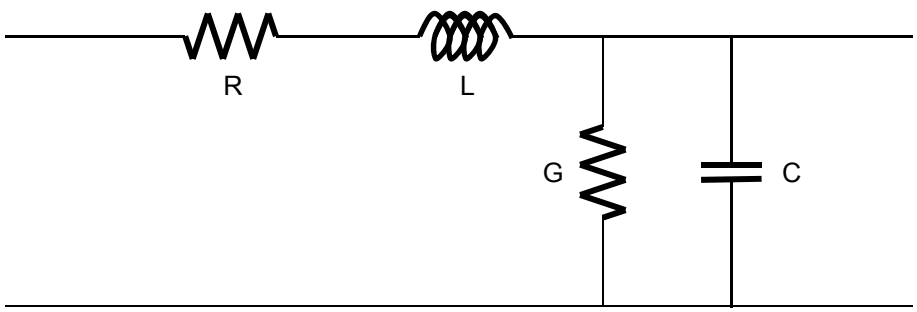
Interface Channels

- Relatively-large SNR and Bandwidth
  - Compared with wireless application
  - ➔ Simple modulation such as ASK, NRZ is often sufficient
- Frequency-Dependent Loss
  - Dielectric loss
  - Skin effect
- Reflection
  - Broadband impedance matching

Channel loss

- Two main loss components
  - Dielectric loss
  - Skin effect

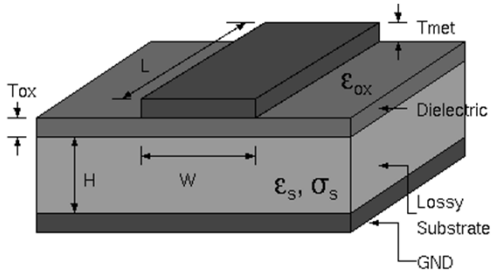
- In the view of transmission line,
  - Dielectric loss → G↑
  - Skin effect → R↑

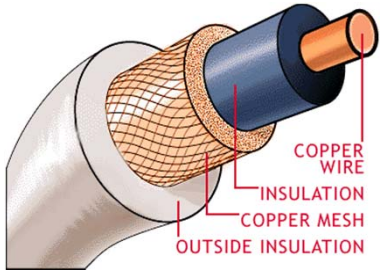


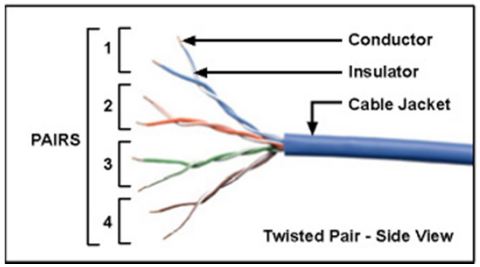
Channel loss

- Dielectric loss
  - Loss between 2 metal separated by insulation material
  - Occurs in any kind of channels including insulation
  - Loss increases as f ↑

$$|H(f)| = e^{-\frac{l\pi tan\delta\sqrt{\varepsilon_r}}{c}\cdot 2fe}$$

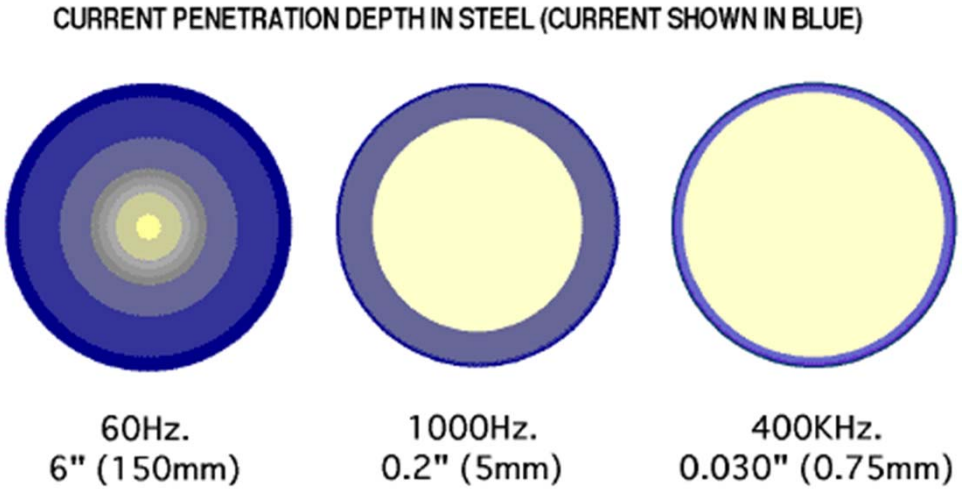






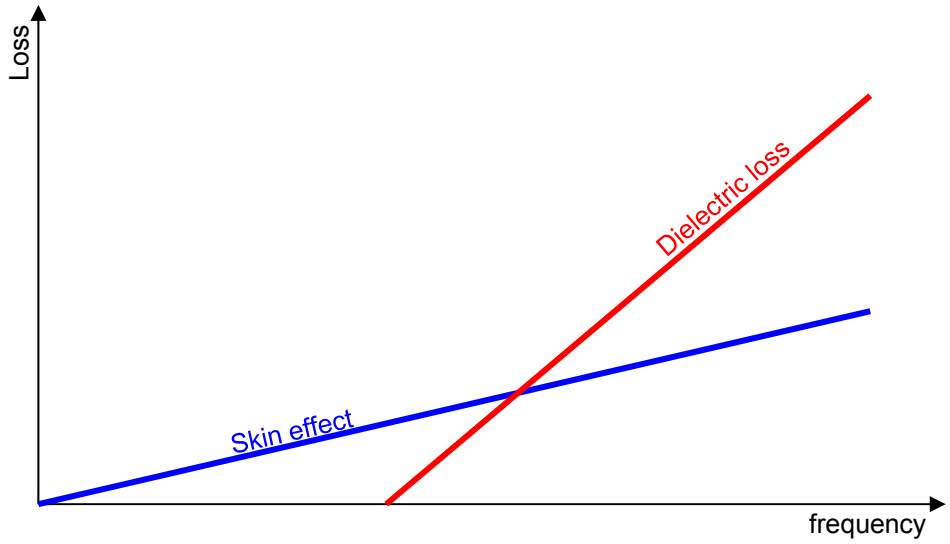
Channel loss

- Skin effect
  - As frequency increases, less current flows at the center of conductor.
  - Loss increases as $\sqrt{f} \uparrow$



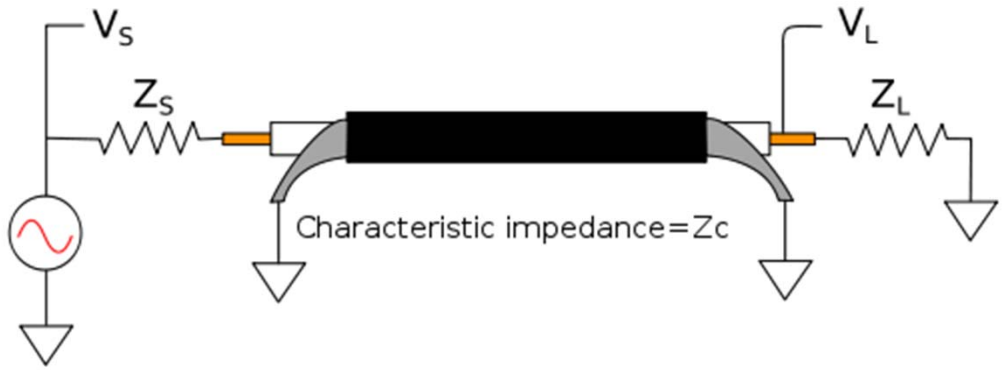
Channel loss

- Total loss
  - In low frequency, skin effect > dielectric loss
  - In high frequency, skin effect < dielectric loss



- Bandwidth limitation due to f-dependent loss!

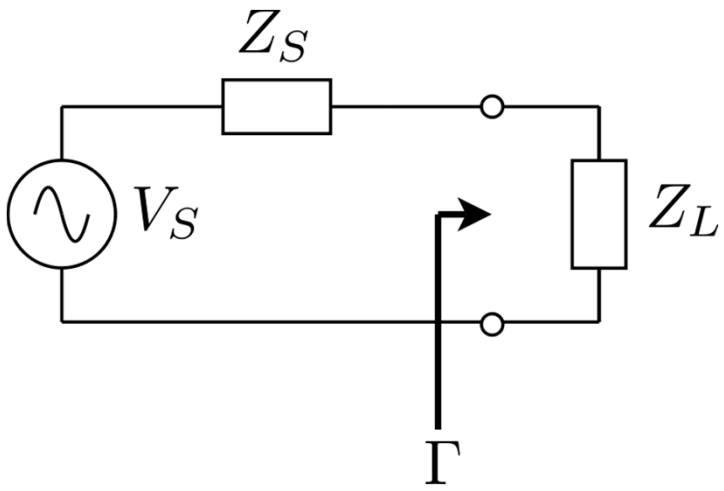
Impedance mismatch

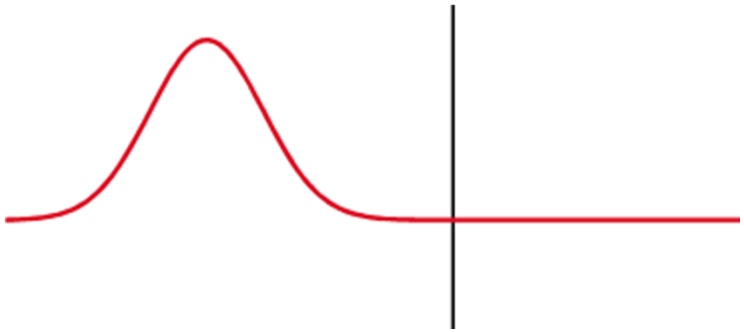


- Ideally $Z_s = Z_c = Z_L$
- Practically not possible to achieve this due to PVT variations for ICs, manufacturing uncertainties for PCB traces and vias, connectors

Impedance mismatch

- Reflection

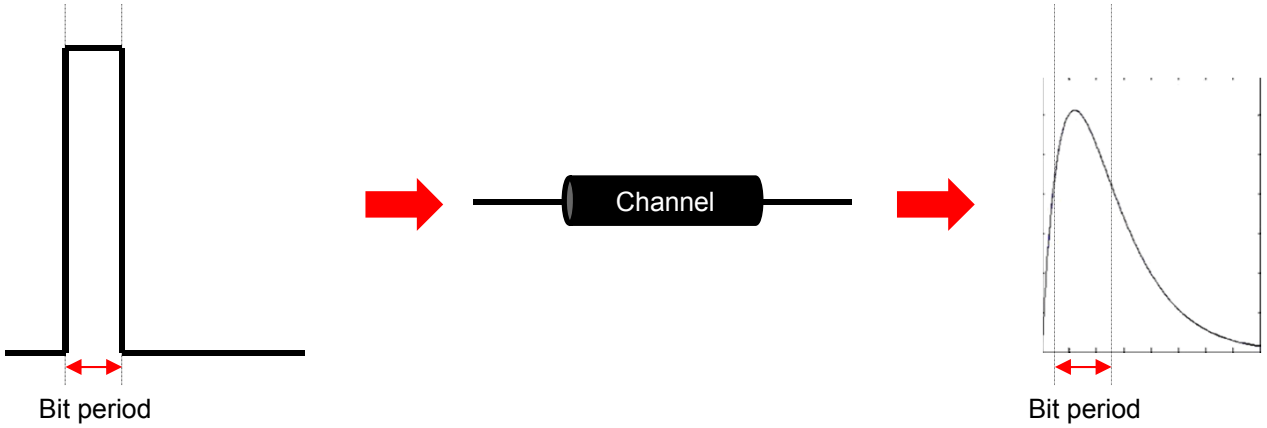




$$\Gamma = \frac{Z_L - Z_S}{Z_L + Z_S}$$

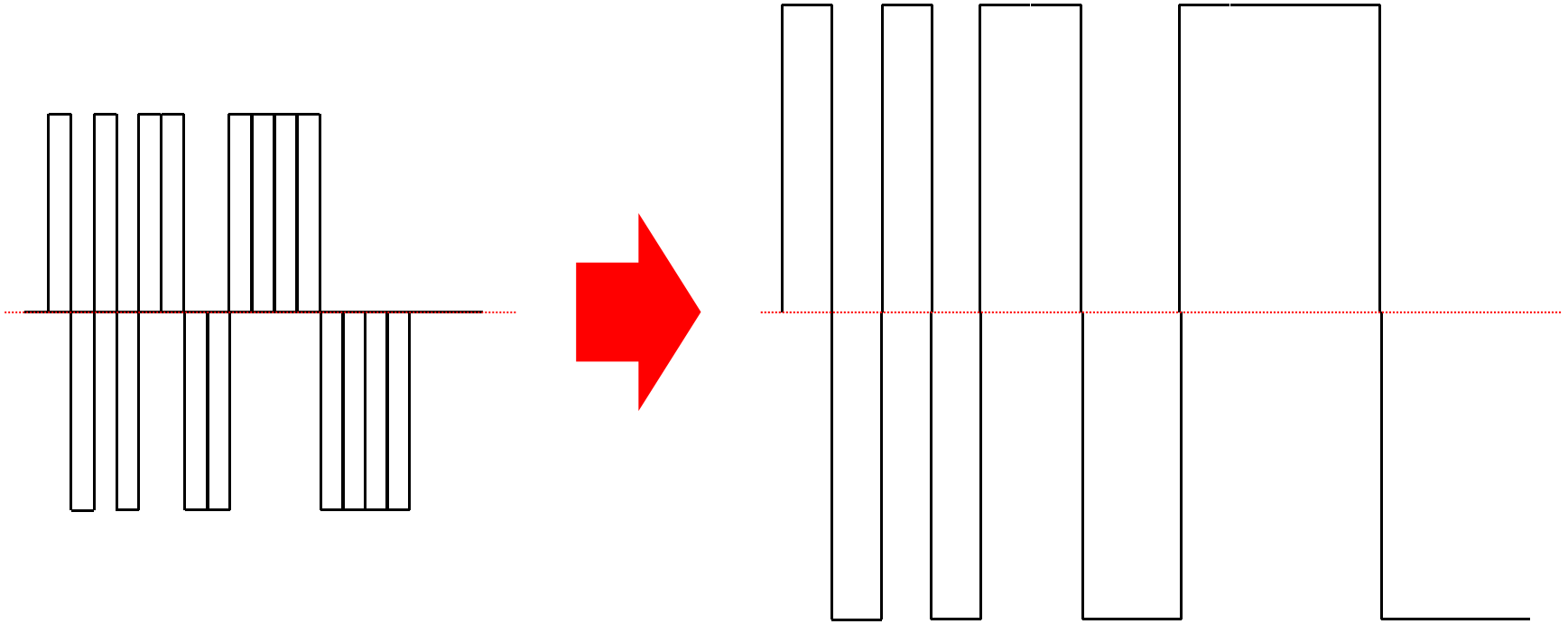
Inter-symbol interference

- Channel with f-dependent loss, reflection distorts pulse response
  - Pulse response outside bit period becomes non-zero.
  - Waveform of present bit is affected by former bits.



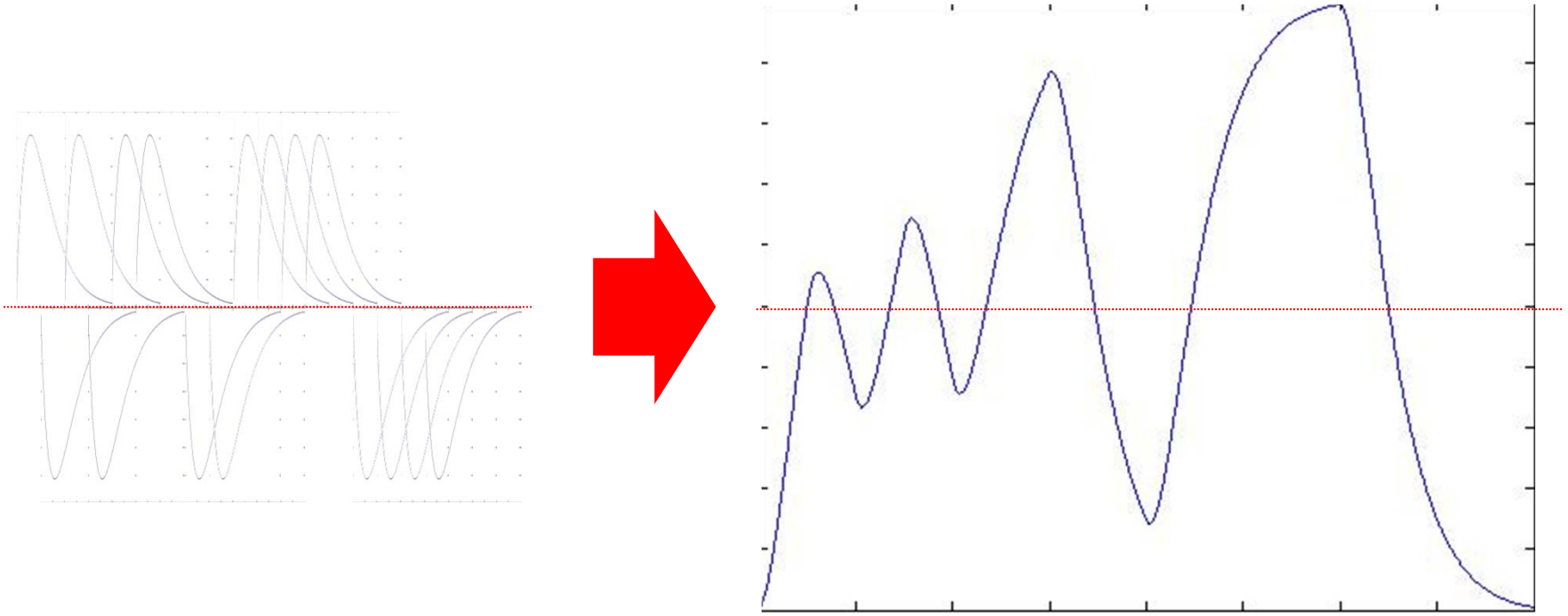
Inter-symbol interference

- Waveform example: ideal case
  - Given data pattern: 1010110011110000



Inter-symbol interference

- Waveform example: w/ ISI
  - Given data pattern: 1010110011110000



Inter-symbol interference

- How ISI affects performance?
  - Receiver has sampling circuits (ADC or D-FF).
  - Sampling circuits require setup/ hold time to meet required BER spec.

1. ISI distorts position of edge
2. Setup/ hold margin of sampling circuit ↓
3. Error sampling ↑
4. BER performance ↓