Principles of Balanced Cabling Transmission

(tutorial with text in slides)

Transmission Parameters

Brand-Rex

electrical transmission:

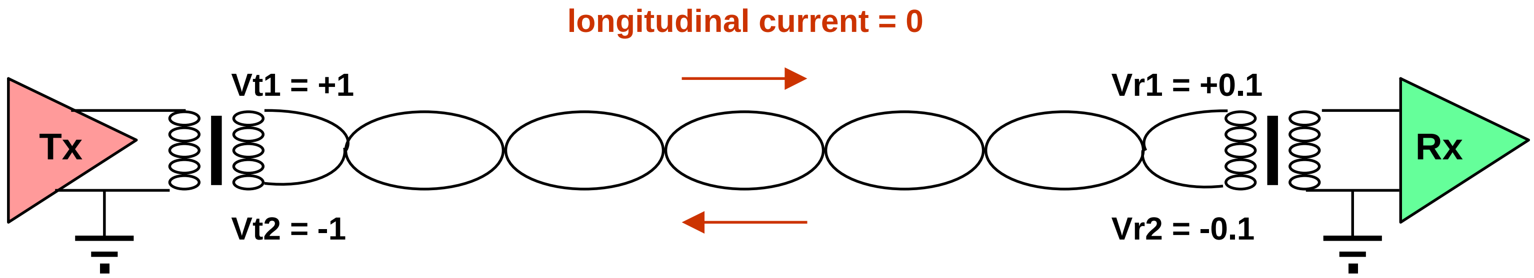
- **attenuation/insertion loss**
- ***attenuation unbalance (near-end)***
- ***attenuation unbalance (far-end)***
- **NEXT (pr-pr, powersum, alien)**
- **ACR (pr-pr, powersum, alien)**
- **FEXT (pr-pr, powersum, alien)**
- **ELFEXT (pr-pr, powersum, alien)**
- **return loss**
- **insertion loss deviation**
- **propagation delay & skew**
- ***surface transfer impedance***
- ***coupling attenuation***
- **dc resistance & current capacity**
- **resistance unbalance**

optical transmission:

- **attenuation/insertion loss**
- **return loss**
- **modal bandwidth**
- **modal dispersion**
- **propagation delay**
- **polarisation mode delay**

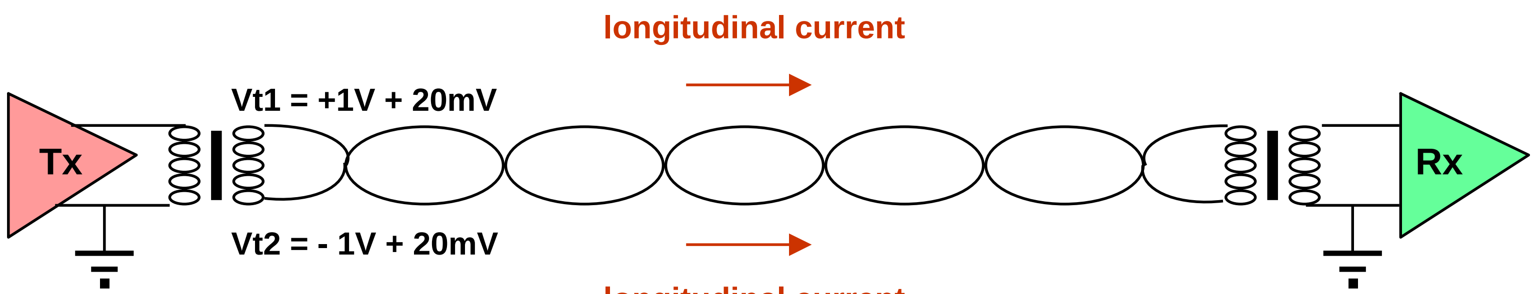
Electromagnetic parameters

Balanced Cable Attenuation



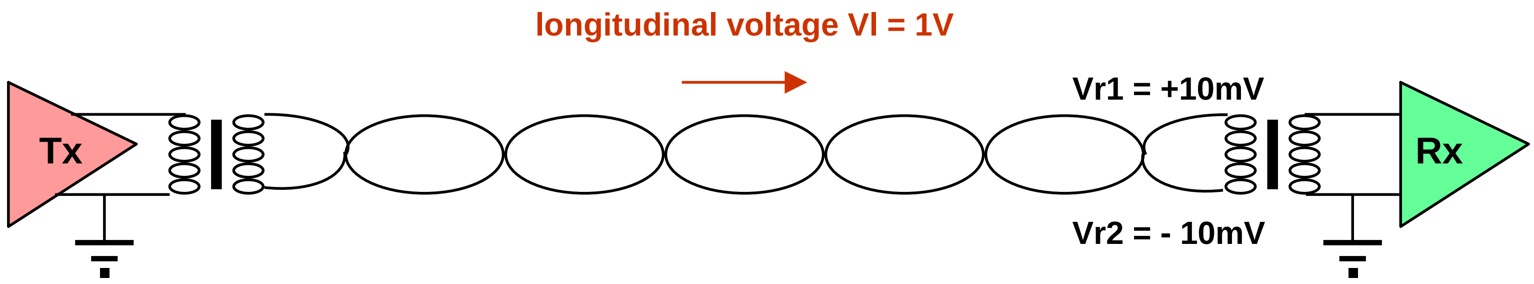
$$\text{Attenuation} = 20 \log \left[\frac{Vr1 - Vr2}{Vt1 - Vt2} \right] = 20 \text{ dB}$$

Attenuation Unbalance, Near-end



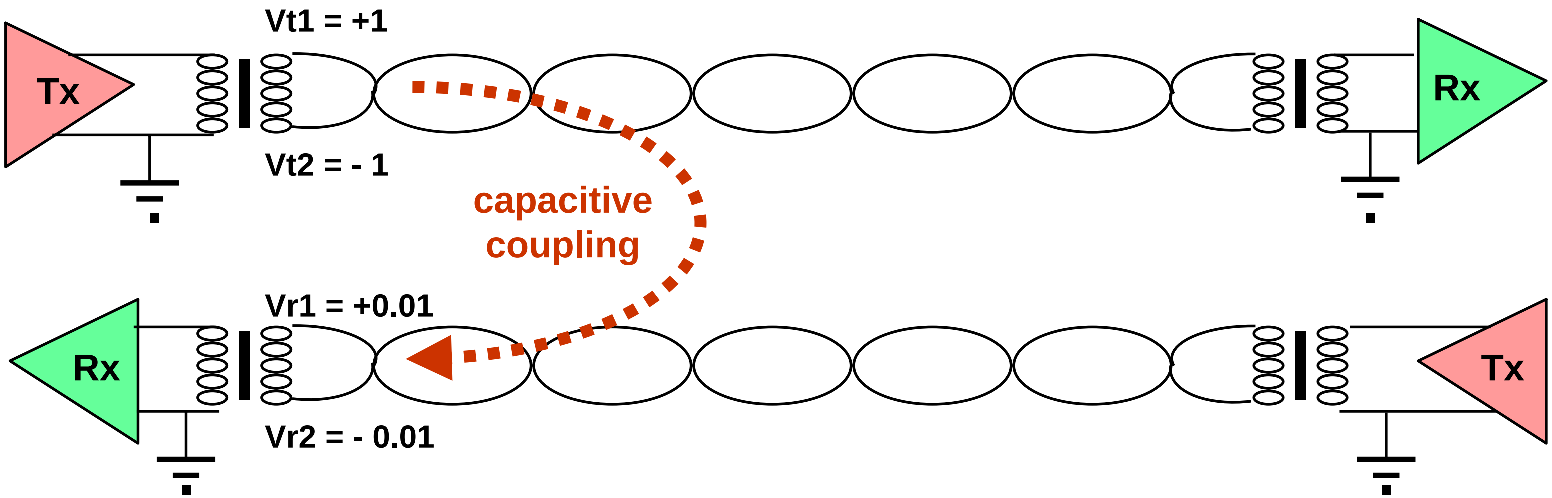
$$\text{Attenuation Unbalance, Near-end (LCL)} = -20 \log \left[\frac{\frac{Vt1 + Vt2}{2}}{Vt1 - Vt2} \right] = 40 \text{ dB}$$

Attenuation Unbalance, Far-end



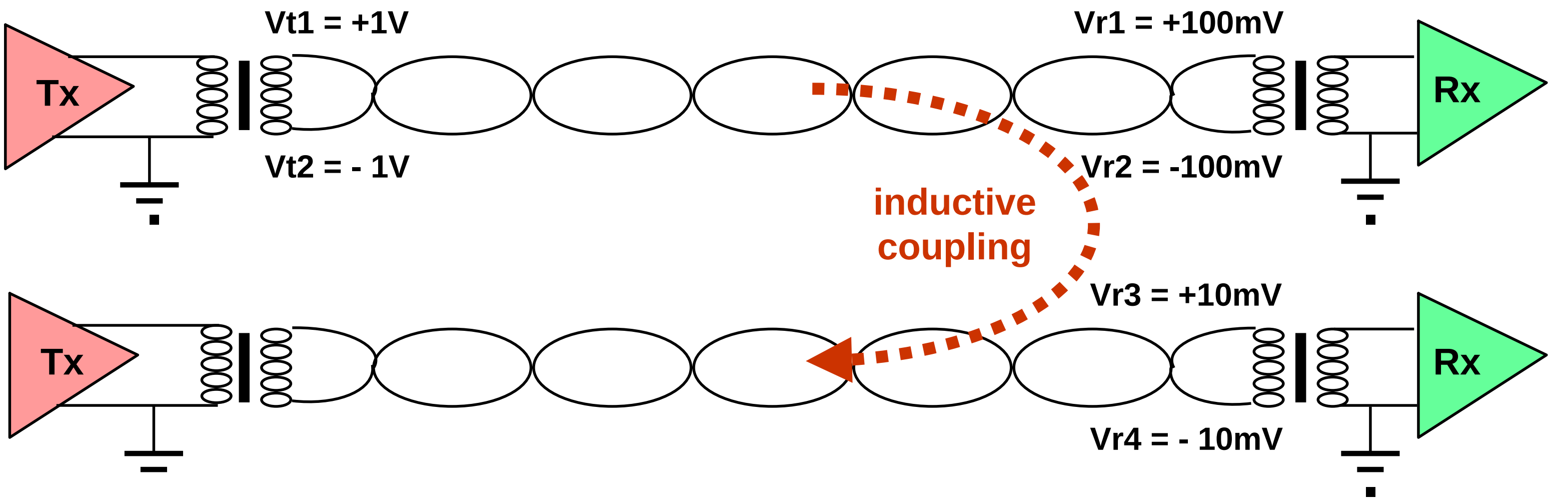
$$\text{Attenuation Unbalance, Far-end (LCTL)} = -20 \log \left[\frac{Vr1 - Vr2}{Vl} \right] = 34 \text{ dB}$$

Near-End Crosstalk (NEXT)



$$\text{NEXT} = -20 \log \left[\frac{Vr1 - Vr2}{Vt1 - Vt2} \right] = 40 \text{ dB}$$

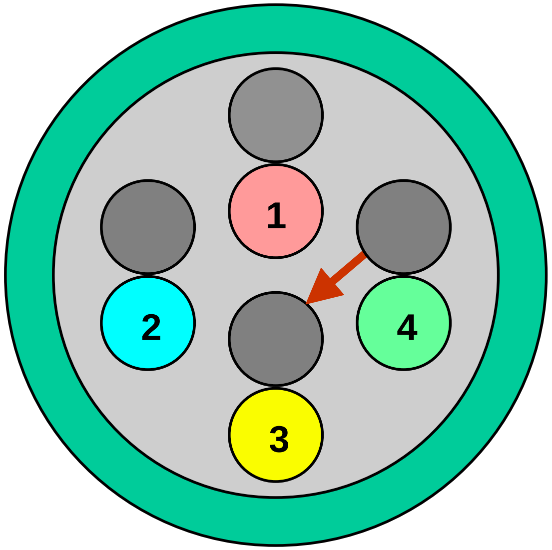
Far-End Crosstalk (FEXT)



$$\text{FEXT} = -20 \log \left[\frac{Vr3 - Vr4}{Vt1 - Vt2} \right] = 20\ \text{dB}$$

$$\text{ELFEXT} = -20 \log \left[\frac{Vr3 - Vr4}{Vr1 - Vr2} \right] = 40\ \text{dB}\ \ (\text{FEXT - Attenuation})$$

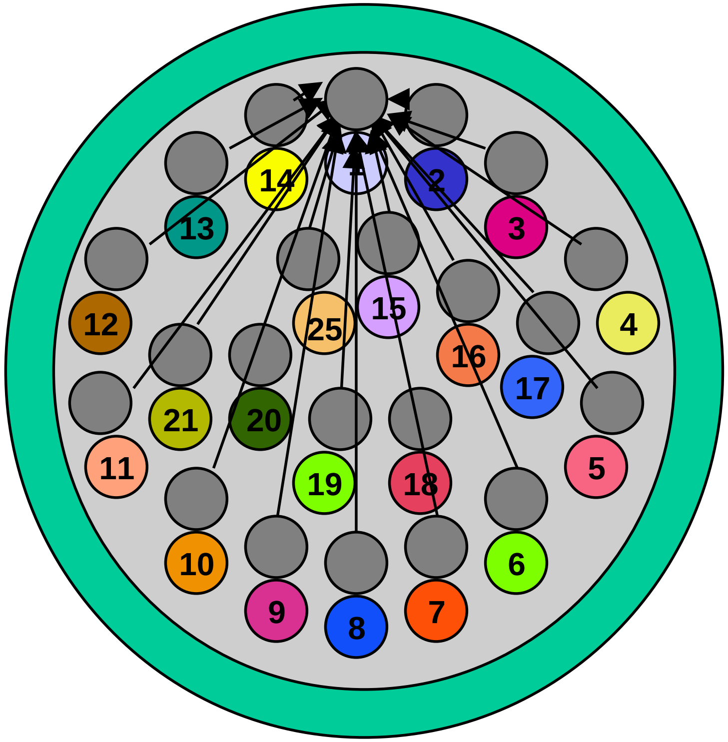
Pair- to- Pair Crosstalk



- **applies NEXT and ELFEXT**
- **measured from both ends**
- **pair-to-pair crosstalk worst of:**

pair 1 to pair 2	***pair 2 to pair 3***
pair 1 to pair 3	***pair 2 to pair 4***
pair 1 to pair 4	***pair 3 to pair 4***

Power- Sum Crosstalk



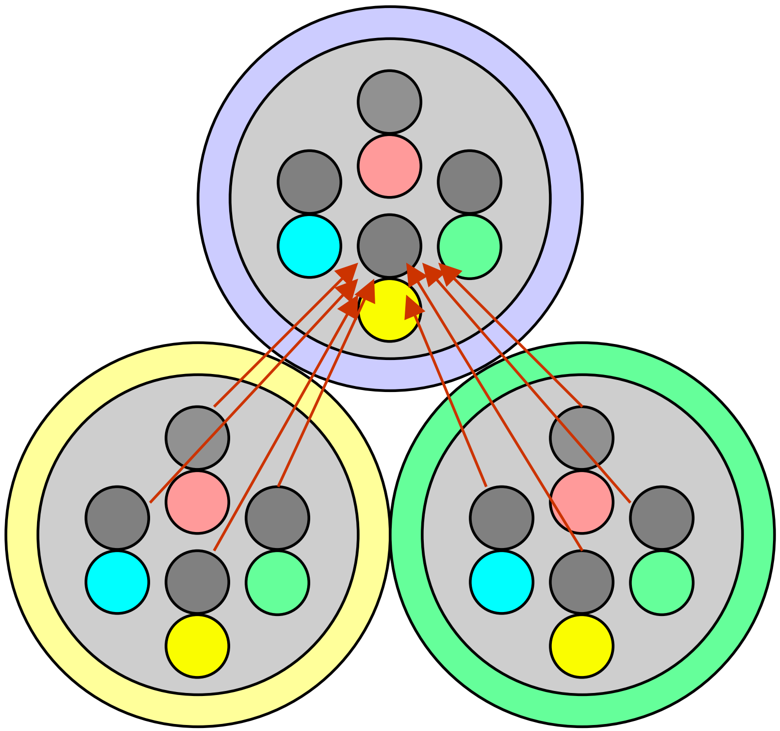
- effect of multiple disturbers
- applies to NEXT & ELFEXT
- total crosstalk power is:

$$\sqrt{(P_{2\text{-}1})^2 + (P_{3\text{-}1})^2 + (P_{4\text{-}1})^2 \text{ etc}}$$

- 3dB worse than pair-to-pair when using 4-pair cables
- calculated from pair-to-pair NEXT for larger bundles

Alien Crosstalk

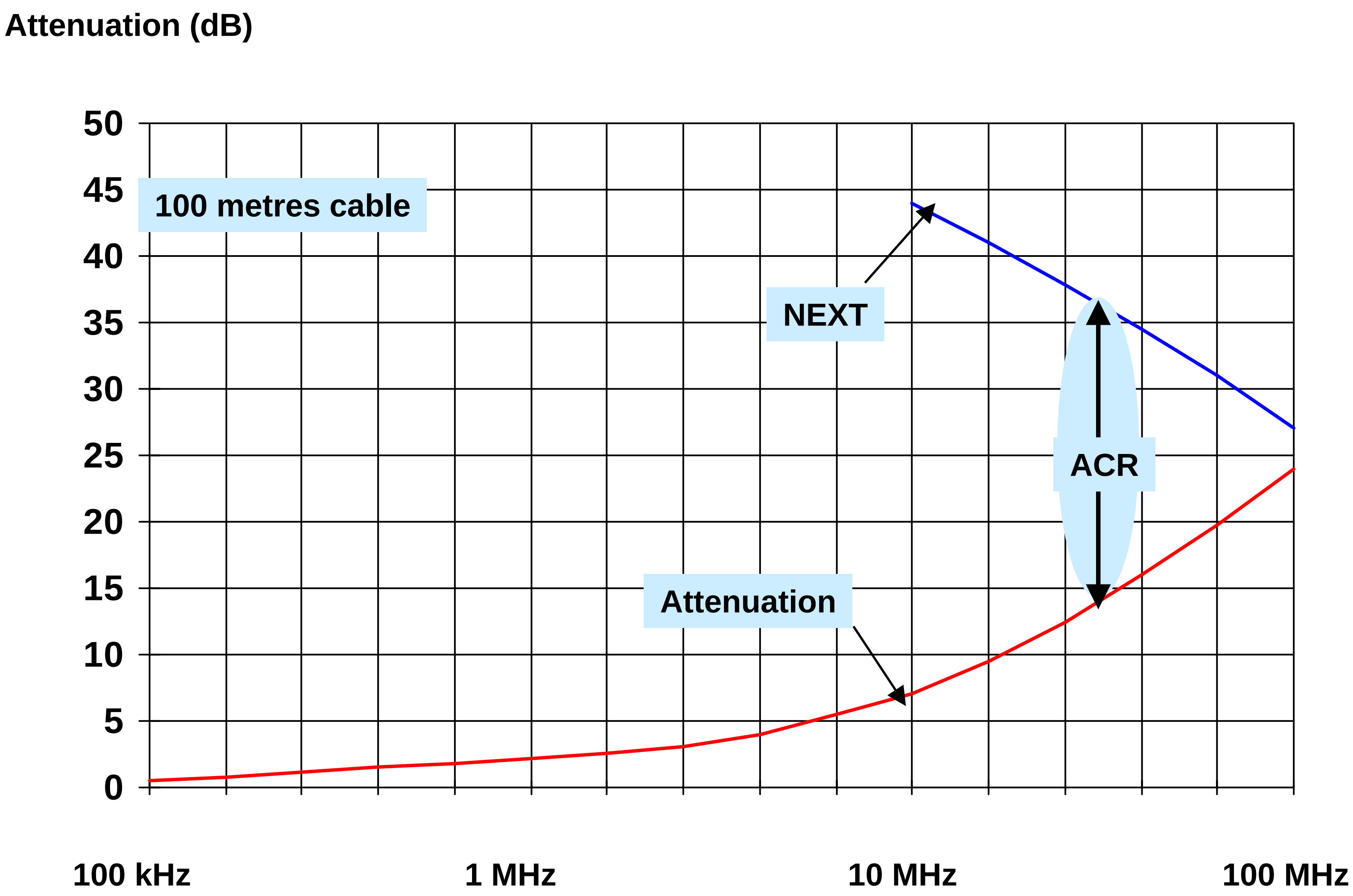
Brand-Rex



- crosstalk from adjacent <u>cables</u>
- multiple disturber phenomenon
- calculated from worst pair-to-pair NEXT value of individual cable
- specified for twisted pair Ethernet
- noise is uncorrelated, <u>unlike</u> own NEXT and ELFEXT noise

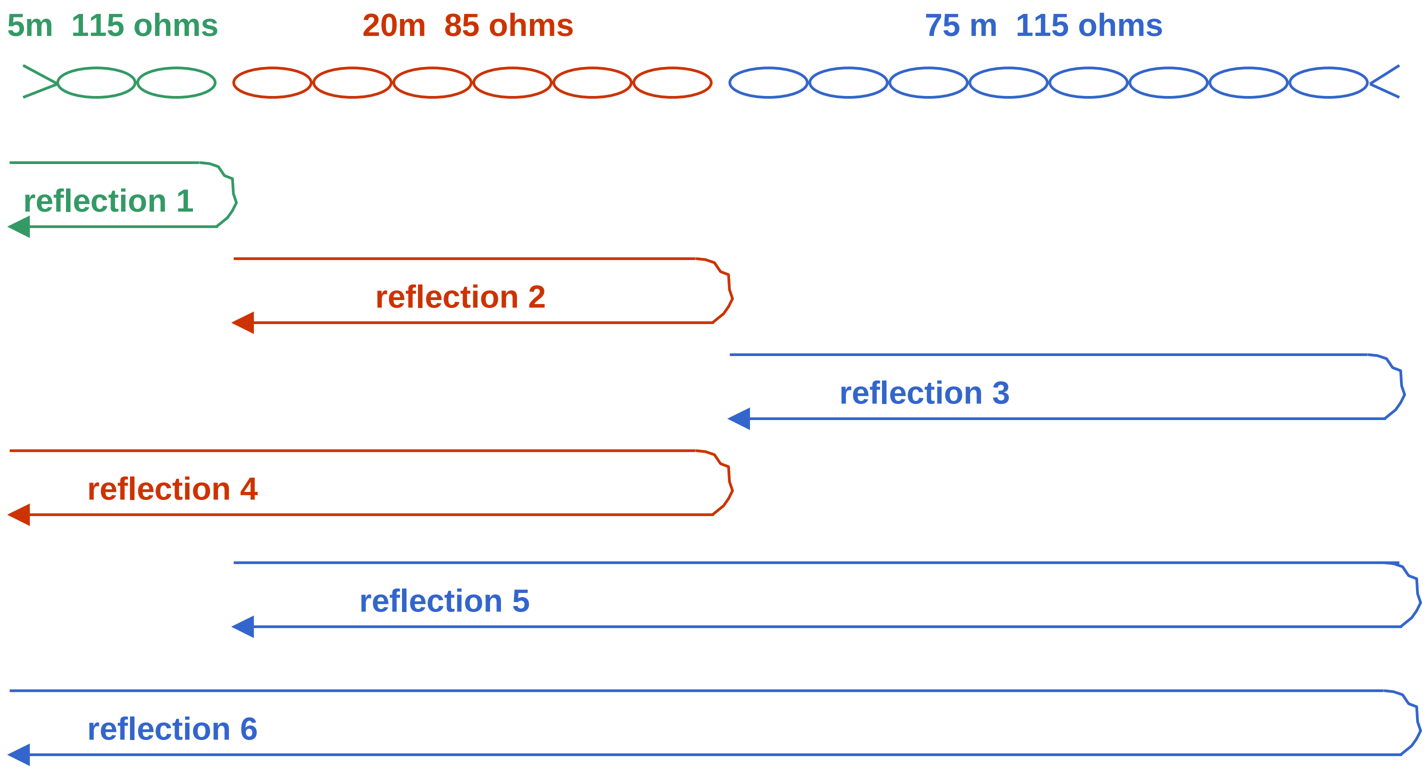
Attenuation:Crosstalk Ratio (ACR)

Brand-Rex



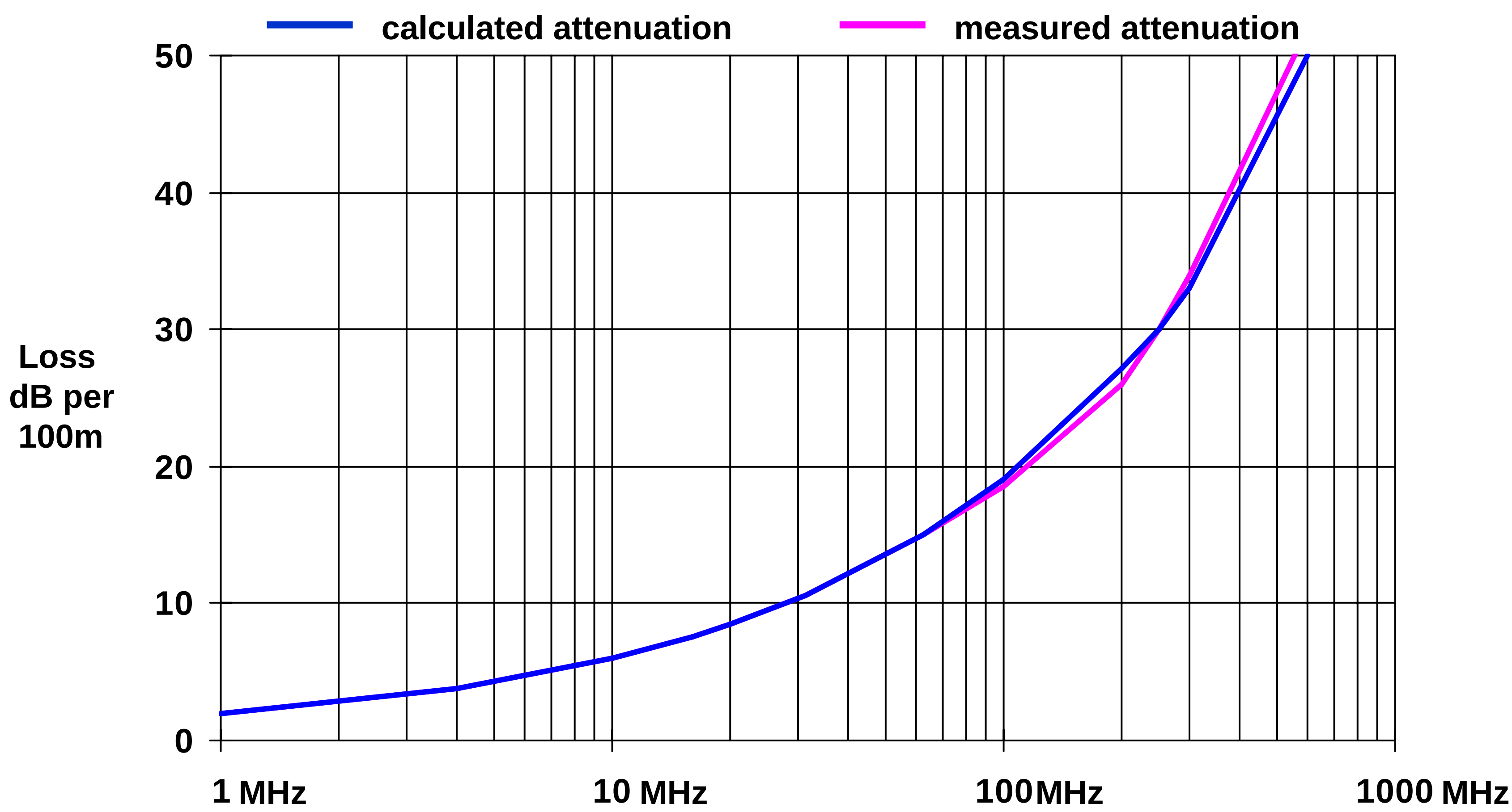
Return Loss

Brand-Rex



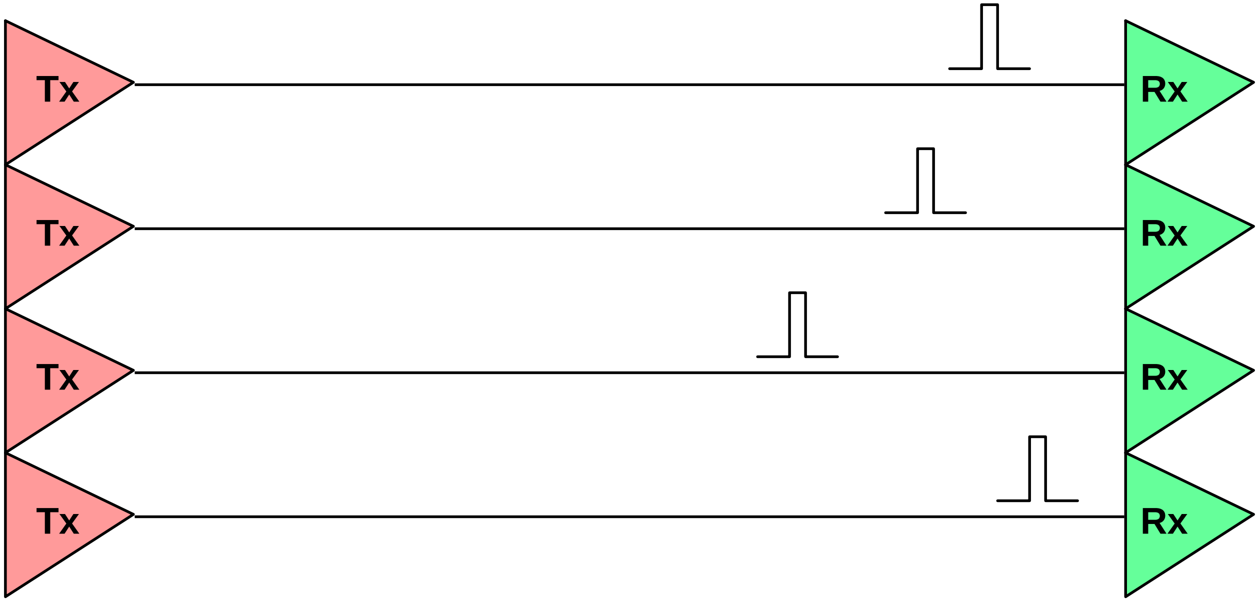
$$\text{Return Loss} = 20 \log \left[\frac{Zin + Zout}{Zin - Zout} \right] = 20 \log \left[\frac{115 + 85}{115 - 85} \right] = 16.5 \text{ dB}$$

Insertion Loss Deviation

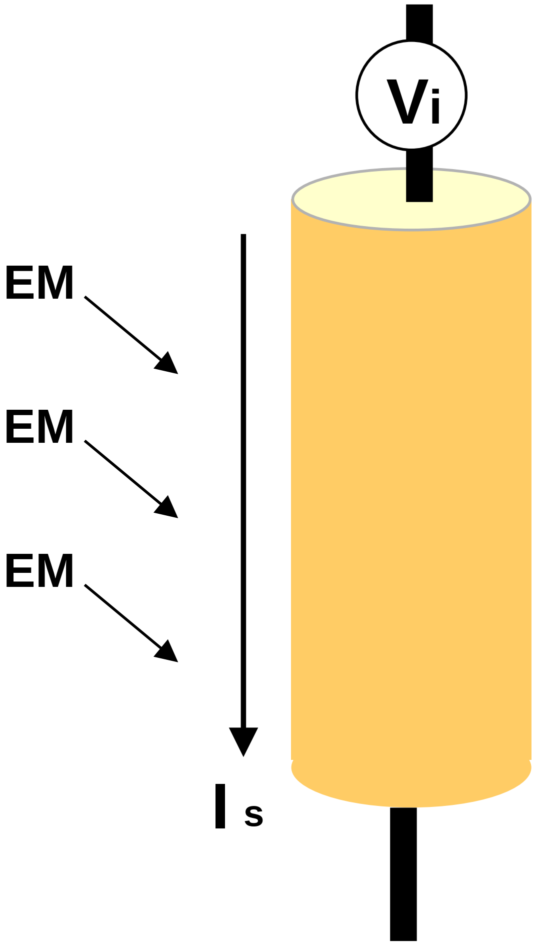


Delay & Skew

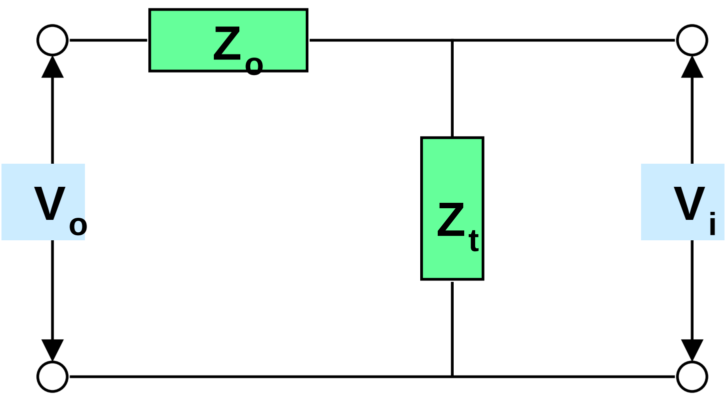
- velocity of propagation is 0.60c to 0.95c
- varies with dielectric & pair twist length
- some applications limit link delay to 1us
- multipair applications expect skew <50ns



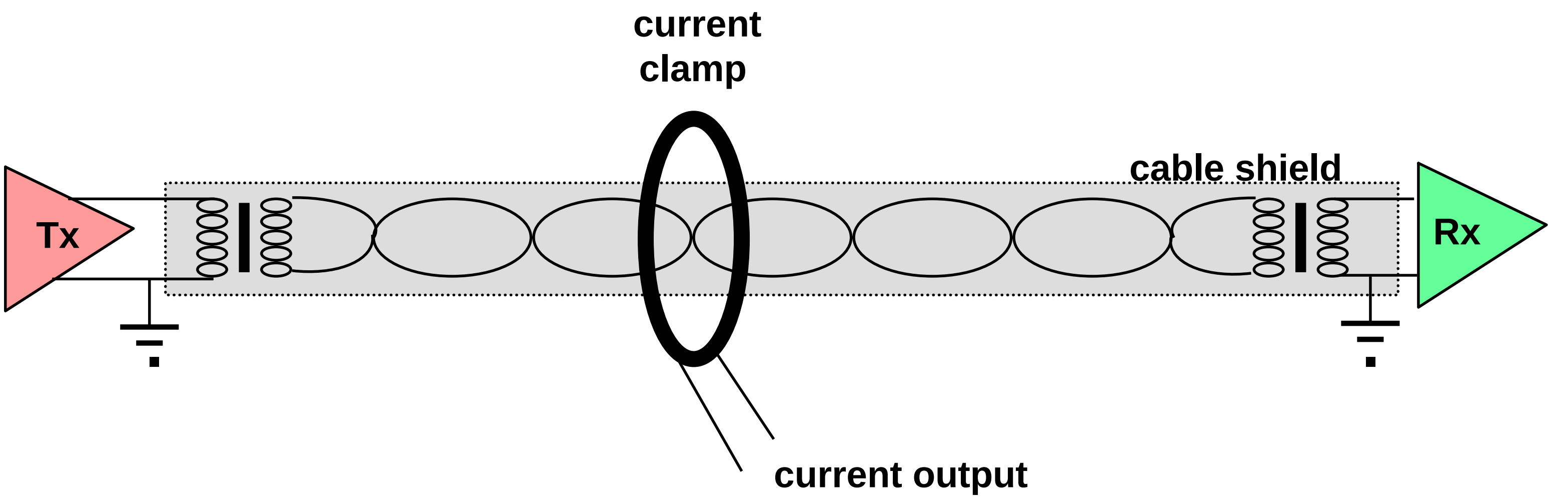
Surface Transfer Impedance



$$Z_t = \frac{V_i}{I_s}$$ ohms per metre



Coupling Attenuation



$$\text{Coupling Attenuation} = 20 \log \left[\frac{\text{common-mode signal power}}{\text{differential signal power}} \right]$$

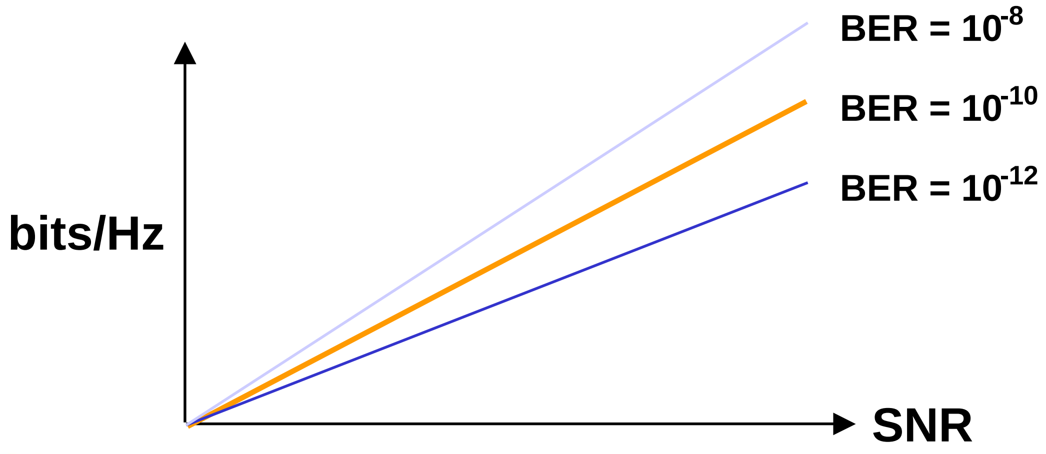
MHz vs Mbit/s

Brand-Rex

channel information capacity determined by:

1. available bandwidth in MHz
2. efficiency of line encoding
3. signal processing intelligence

Shannon Limit relates code efficiency to SNR:



Error Management

- errors from internal + external noise
  - » internal noise is more correlated (own-crosstalk, return loss)
  - » external noise is less correlated (alien crosstalk, electromagnetic noise)
- LANs designed to tolerate bit errors
  - » bit error detection in frame via CRC
  - » bit error correction in frame via FEC
  - » frame re-transmission via L4 protocol
- important to maintain a good SNR
  - » high attenuation/crosstalk/RL margins
  - » good electromagnetic performance