

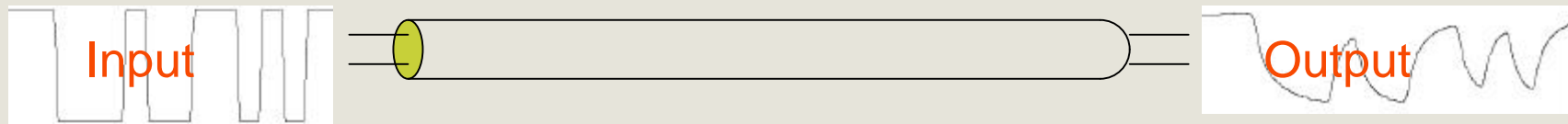
# SI and EMI issues on cable assemblies for multi-Gbit/s applications

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# SI issues for serial copper links for multi-Gbit/s data communication

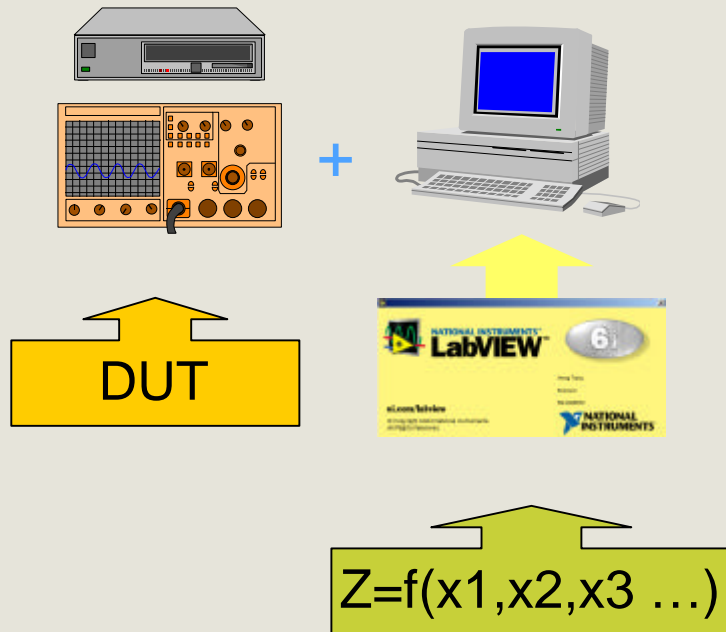
Interconnections are one of the bottlenecks

Length less than 20 meters are still cost effective solution



- Attenuation due to skin effect
- Dielectric losses
- Cross talk between pairs, especially single connectors
- Impedance mismatch
- Unbalance for a differential pair cable
- Skew of the pair cable
- EMI
- Flexibility

# Measurement and implementation of mathematical model



- Mixed mode S-parameter
- Characteristics impedance
- TDR waveform without “ghost”
- De-embedding
- Filtering effect
- .....

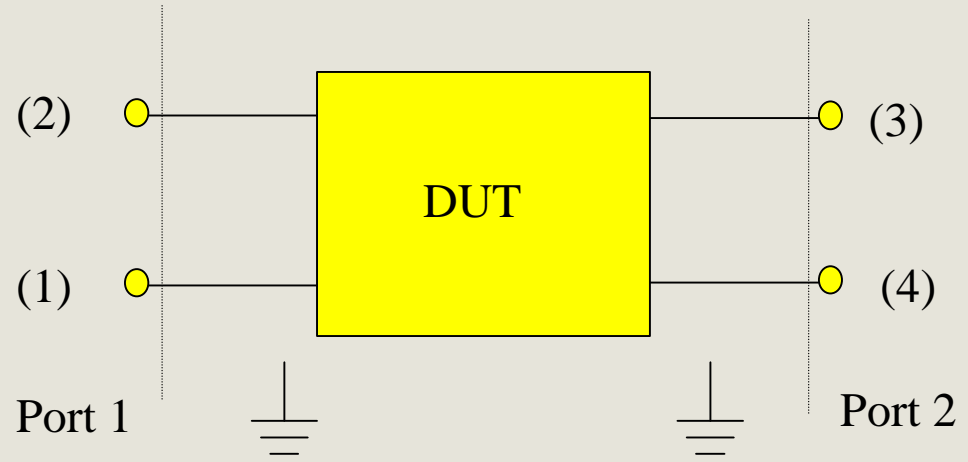
# Conversion from single ended S-parameters to mixed mode S-parameters

$$a_{dm1} = \frac{1}{\sqrt{2}}(a_1 - a_2)|_{x=0}$$

$$b_{dm1} = \frac{1}{\sqrt{2}}(b_1 - b_2)|_{x=0}$$

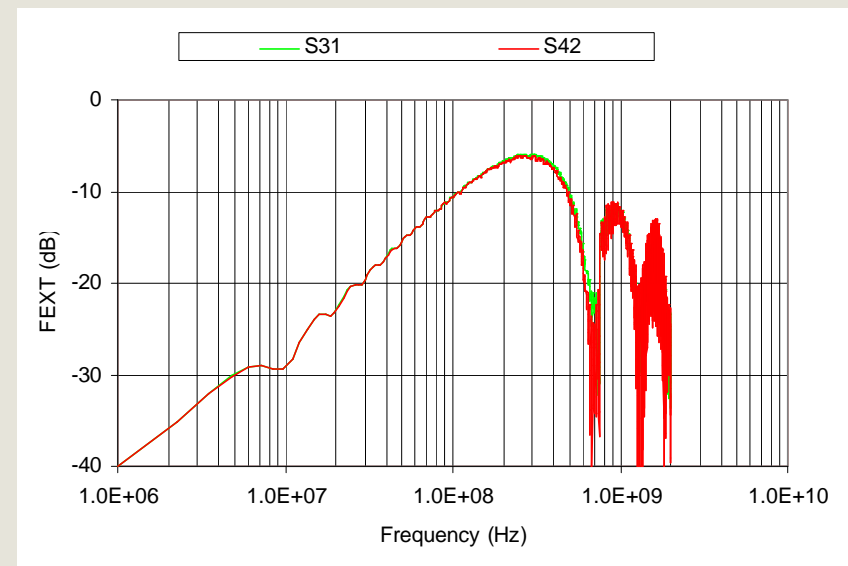
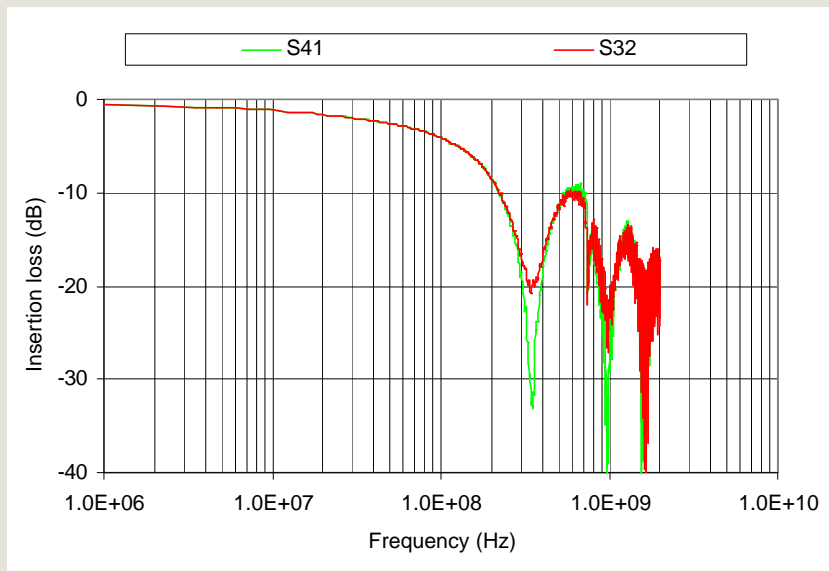
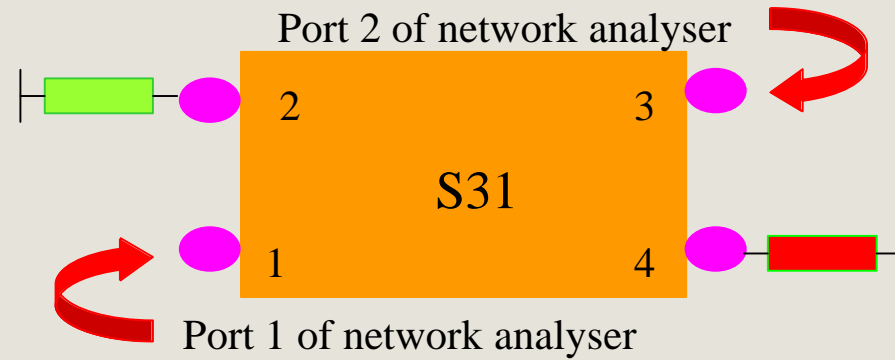
$$a_{cm1} = \frac{1}{\sqrt{2}}(a_1 + a_2)|_{x=0}$$

$$b_{cm1} = \frac{1}{\sqrt{2}}(b_1 + b_2)|_{x=0}$$

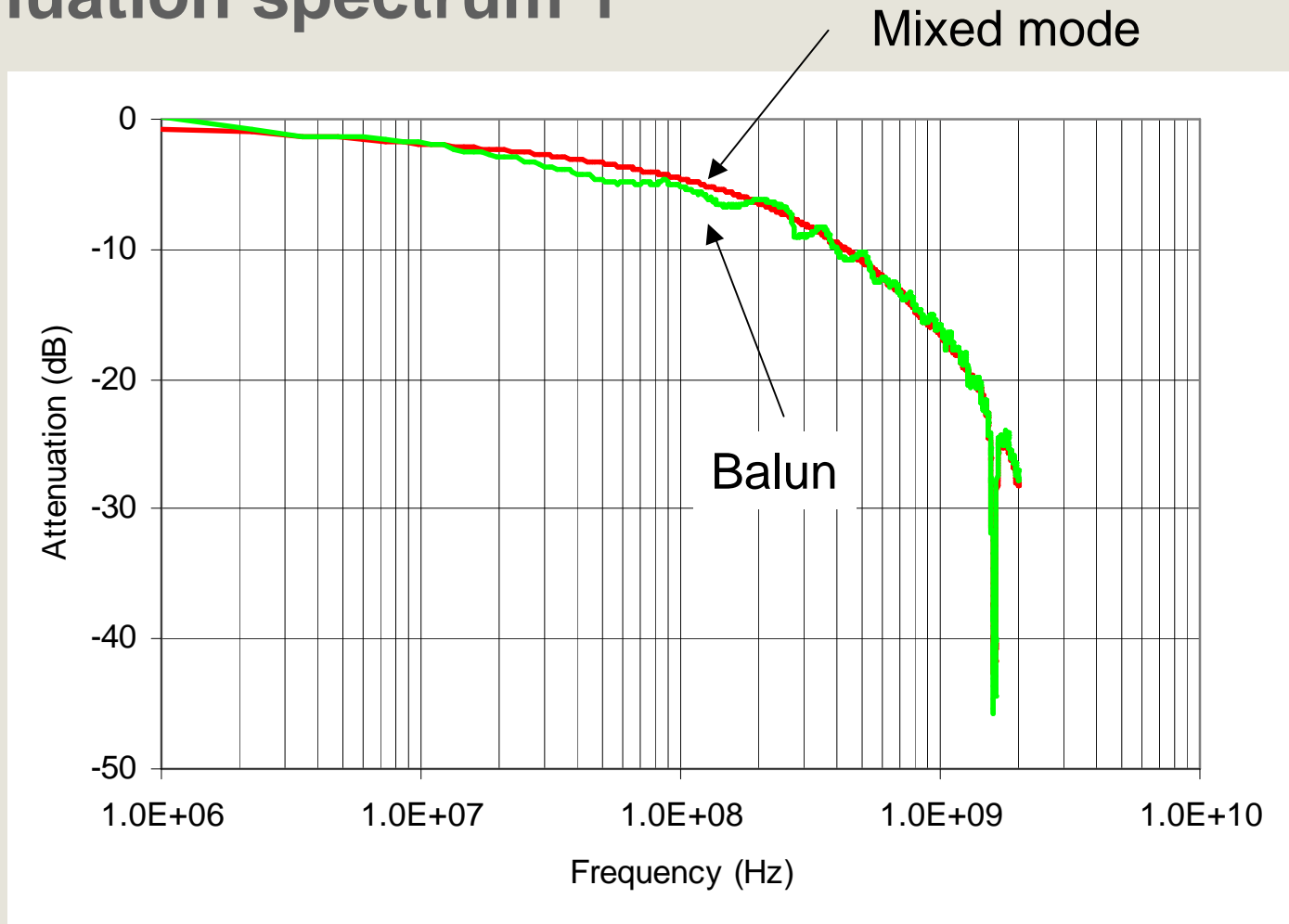


$$\begin{bmatrix} S_{dd11} & S_{dd12} & S_{dc11} & S_{dc12} \\ S_{dd21} & S_{dd22} & S_{dc21} & S_{dc22} \\ S_{cd11} & S_{cd12} & S_{cc11} & S_{cc12} \\ S_{cd21} & S_{cd22} & S_{cc21} & S_{cc22} \end{bmatrix} = M \begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{23} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{34} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{bmatrix} M^{-1}$$

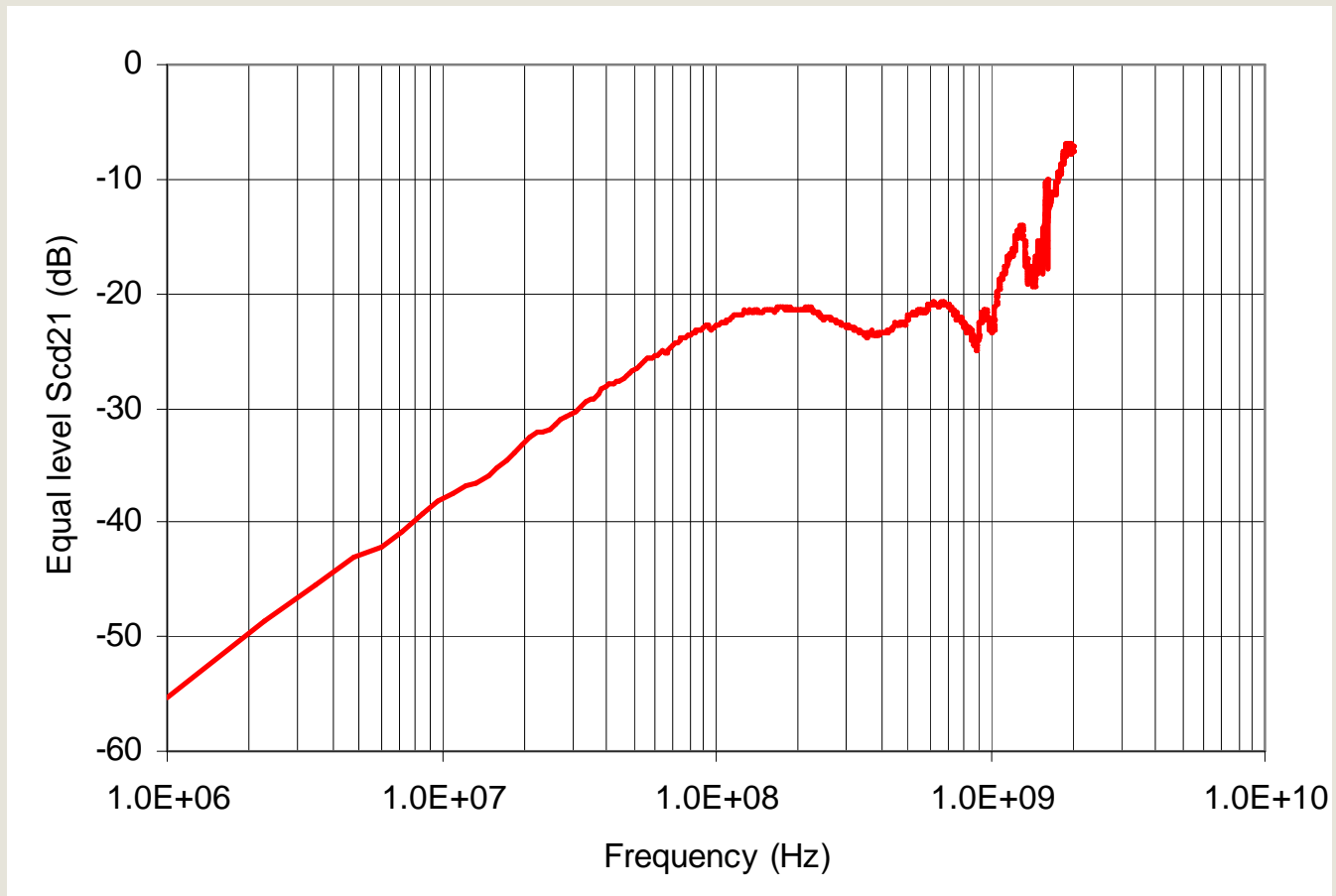
# Single ended to DM and CM



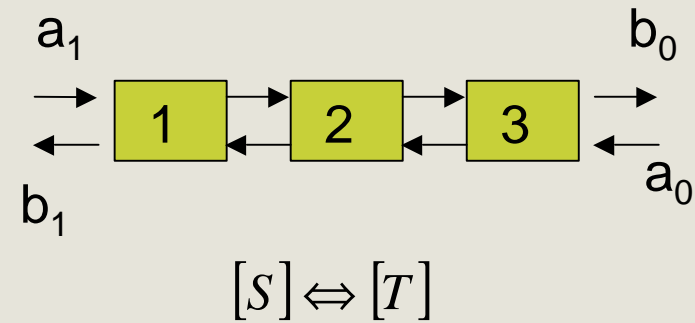
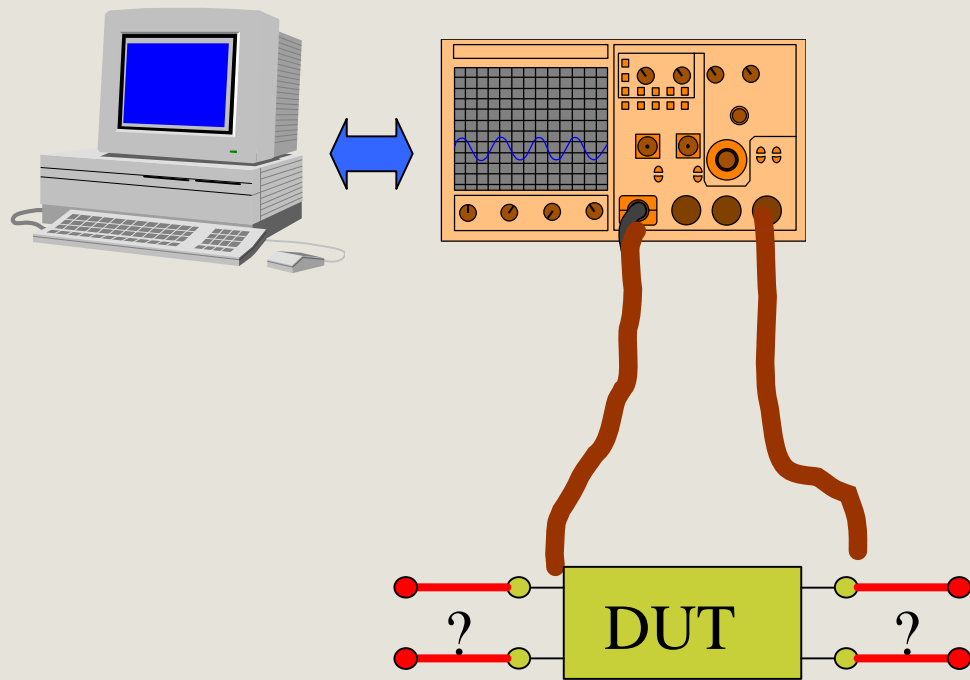
# Attenuation spectrum 1



# Mode conversion spectrum



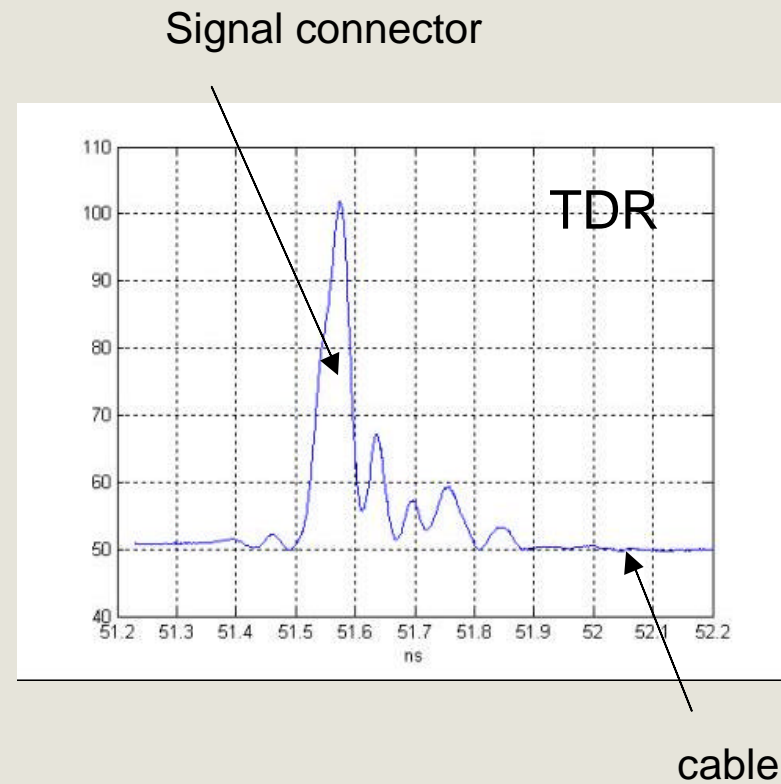
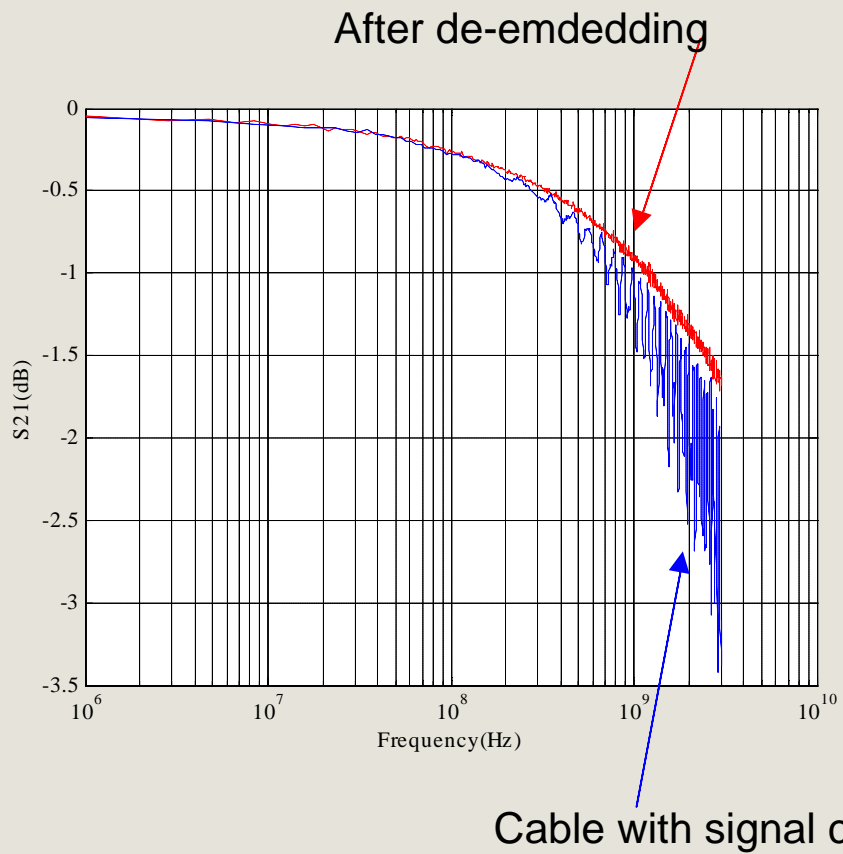
# De-embedding to eliminate connector and fixture and to find transmission line parameters



$$\begin{bmatrix} a_1 \\ b_1 \end{bmatrix} = [R_1] \cdot [R_2] \cdot [R_3] \cdot \begin{bmatrix} a_0 \\ b_0 \end{bmatrix}$$

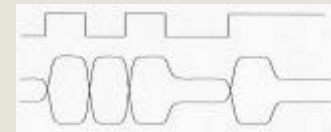
Signal connector: one of the weak point of the link

# Example for de-embedding

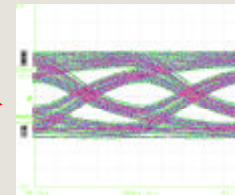


# Solutions for improvement of SI for the links

Using pre-emphasis technology

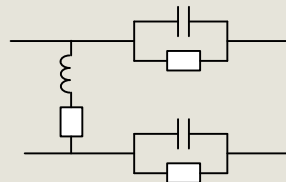


Using expansive high frequency cable



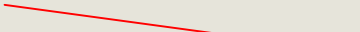
Gauge 22 cable self-equalization

Using passive RC type equalizer



RLRC circuit topology

Using combined methods

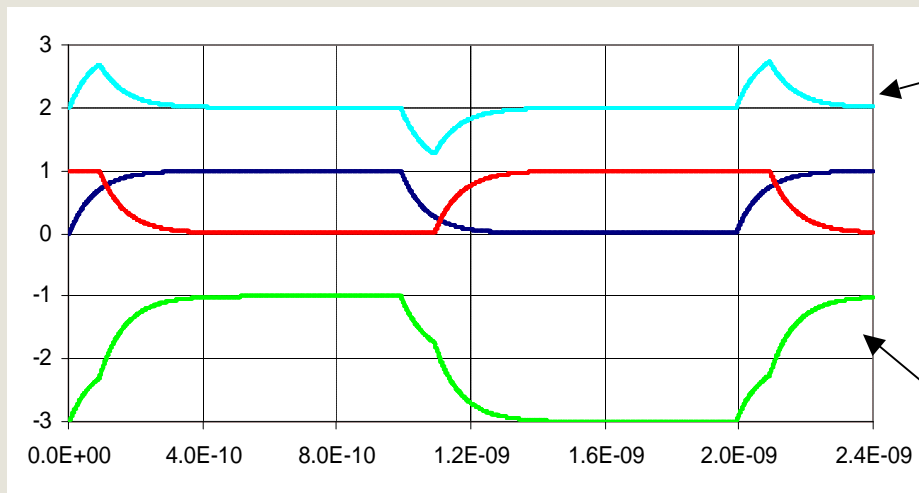


**Cost effective and application cost**



# EMI issues for serial copper links

The serial links are electrical long for multi-Gbit/s data communications



1Gbit/s, common mode and differential mode signals are shifted for viewing

Common mode signal

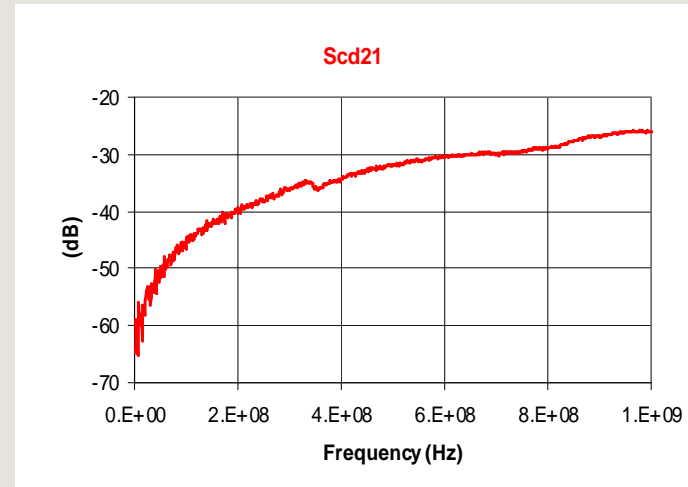
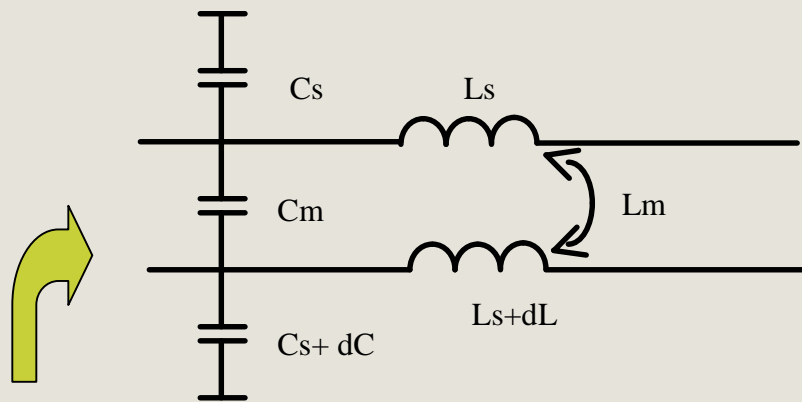


Skew of the cable  
Unbalanced signals  
Mode conversion

...

Differential mode signal

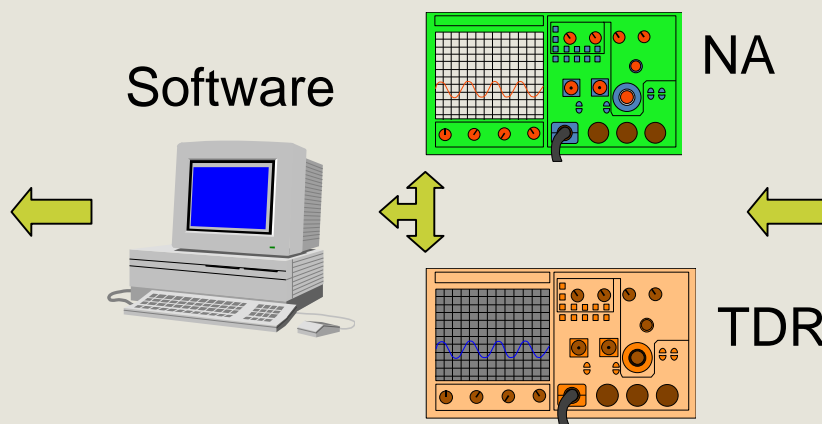
# Modelling balanced and unbalanced cable



Mixed mode

+

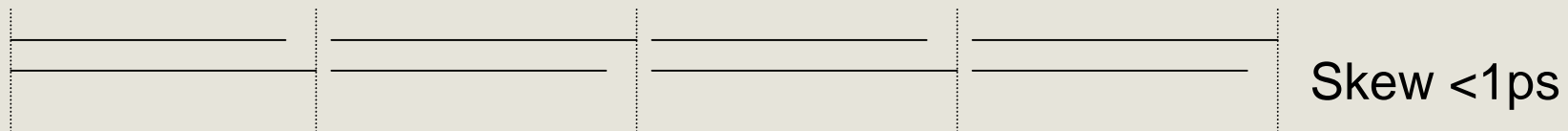
Impedance  $Z_d, Z_C$   
Time delay  $T_d, T_C$



## Practical problem for EMI simulation

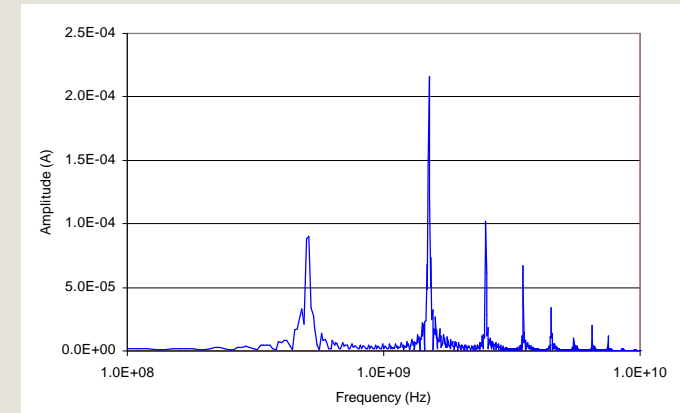
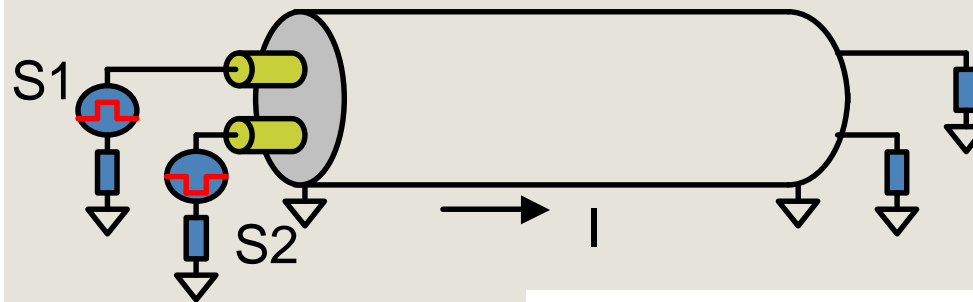
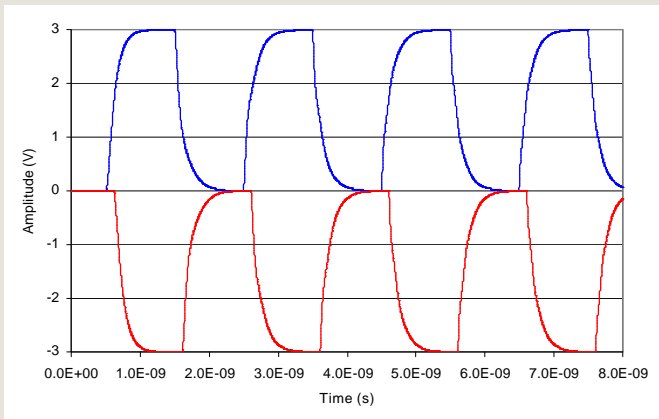
Distinguishing EMC discipline from SI is that the nonideal aspects and parasitic effects.

For SI simulation, nonideal and parasitic gives accuracy problem. For EMI, nonideal and parasitic are dominant effects. This makes modelling for EMC calculation much more difficult and imprecise.



# Example for simulation

simulate unbalanced signal travelling in a shielded unbalanced pair



## Summary

- Experimental verification of a cable assembly is straightforward, mixed mode, de-embedding, TDR, eye-diagram.
- Simulation of the cable assembly for SI is available in a certain extent.
- Reasonable assumptions have to be made for simulation of cable assembly for EMI study. Cautions must be taken for implementation of EMI simulation.
- Control SI and EMI characteristics for a cable assembly is essential for system functionalities.