

# MIMO Model for Copper Cable: Quantitative Analysis of Matching to Measured Data

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# Review and Motivation

- $K \times K$  channel matrix  $H(f)$  represents  $K$  twisted pairs
- Matrix element  $H_{mn}(f)$  is the channel transfer function from line  $n$  to line  $m$
- FEXT in EFM is a dominant noise source.
- FEXT mitigation schemes will gain importance.
- Appropriate MIMO model is needed to evaluate the performance and complexity of the various schemes.

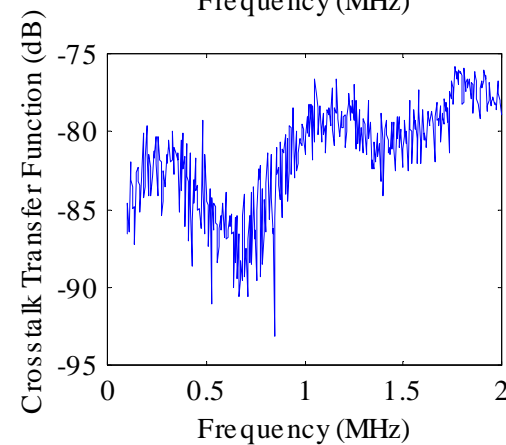
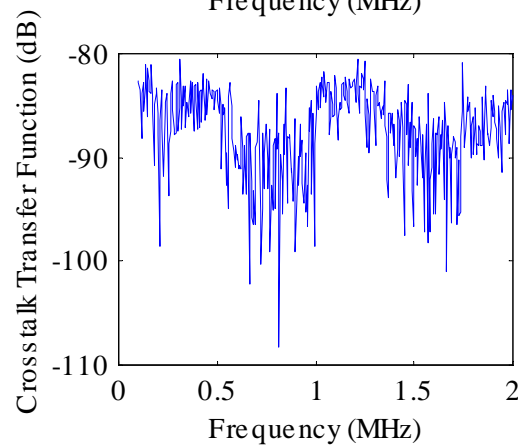
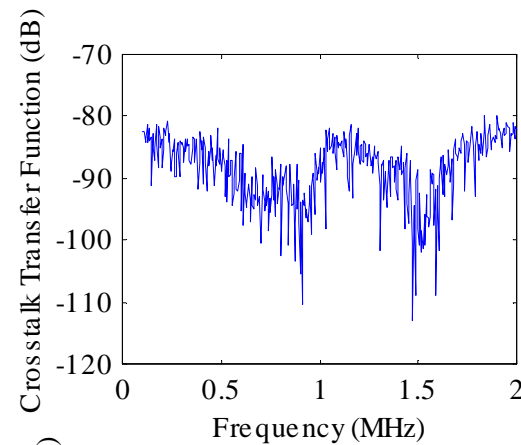
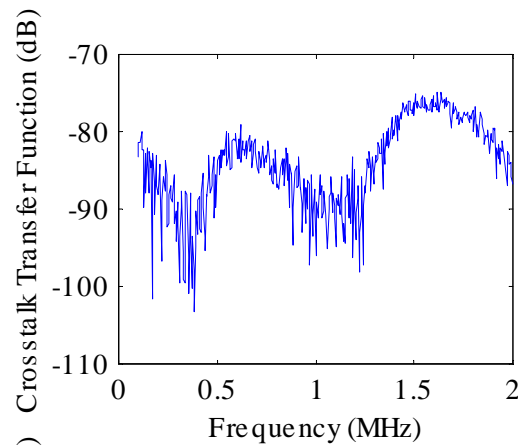


# Measured Data

- Model is evaluated based upon data which has been provided by Telcordia.
- Measured data shows that a majority of cases exhibit a wide-scale frequency variation in the crosstalk channel function.
- Focused on the downstream crosstalk channels since the upstream channels are the same by reciprocity



# Measured Channels showing Wide-scale Frequency Variations



# Crosstalk Channel Model

- Without frequency variations

$$H_{mn}(f) = k_{cross} f |H(f)| e^{j(2\pi f\tau + \phi_{mn})}$$

$$k_{cross} = \sqrt{k_{FEXT} d (K - 1)^{-0.2}}$$

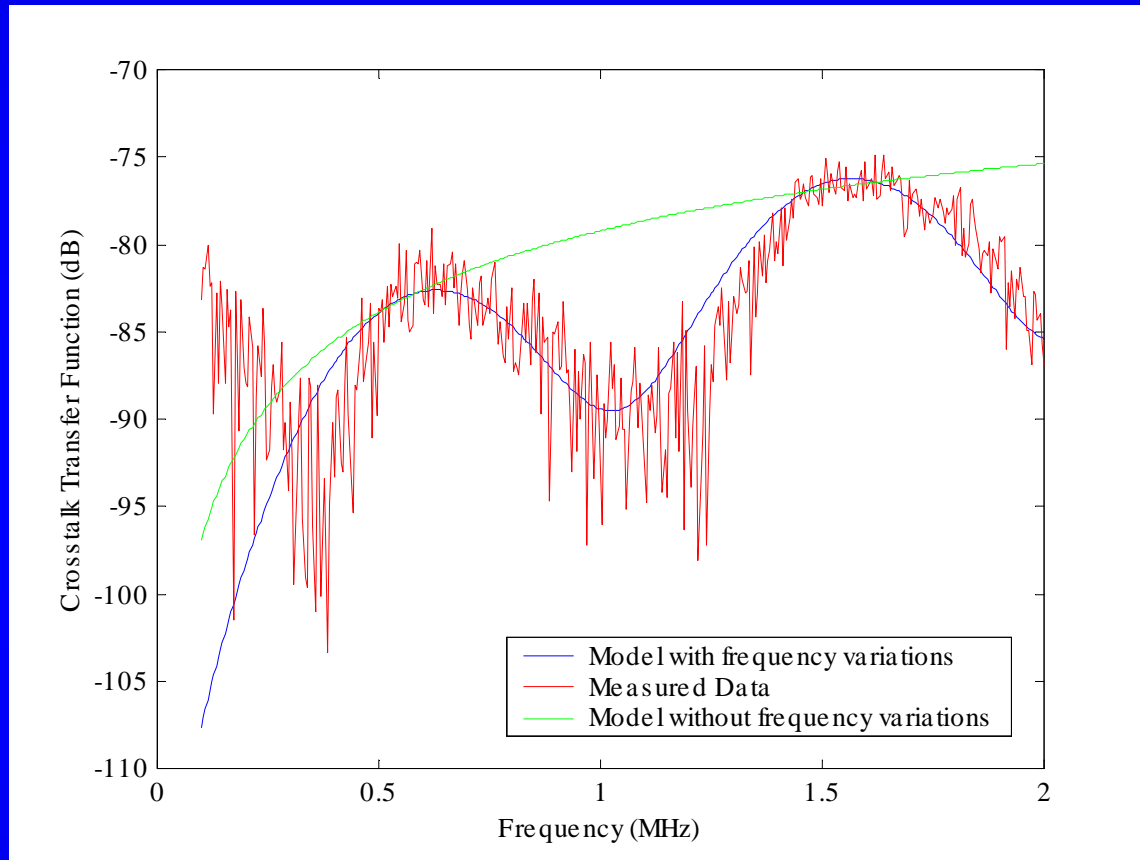
- With frequency variations

$$H_{mn}(f) = k_{cross} f |H(f)| e^{j(2\pi f\tau + \phi_{mn})} [1 + \alpha \cos(2\pi f\beta + \gamma)]$$

- $\alpha$ ,  $\beta$  and  $\gamma$  are random variables with statistics based on measured data where the mean values are close to the fixed values in the previously presented model
- Open to input regarding model parameters



# Both Models versus Measured Data



- Model MUST account for frequency variation.



# Metric

- Average of absolute error
  - Without frequency variations: 5.1343 dB
  - With frequency variations: 3.2739 dB



# Conclusions

- Need MIMO model for copper cable.
- Proposed crosstalk channel model accounts for the wide-scale variations in frequency enabling realistic evaluations of FEXT cancelling algorithms.

