EMC Compo 2011
Dubrovnik

PhD Seminar

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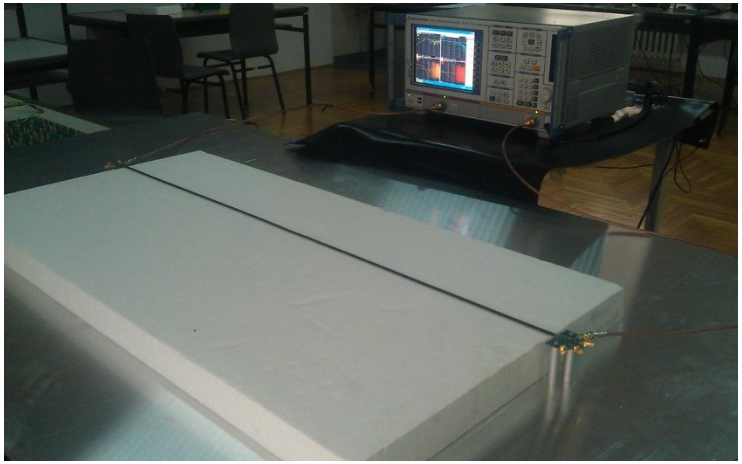
PhD Title	**High frequency cable modeling**
Project	“Golden gates”
Partner	ON Semiconductor

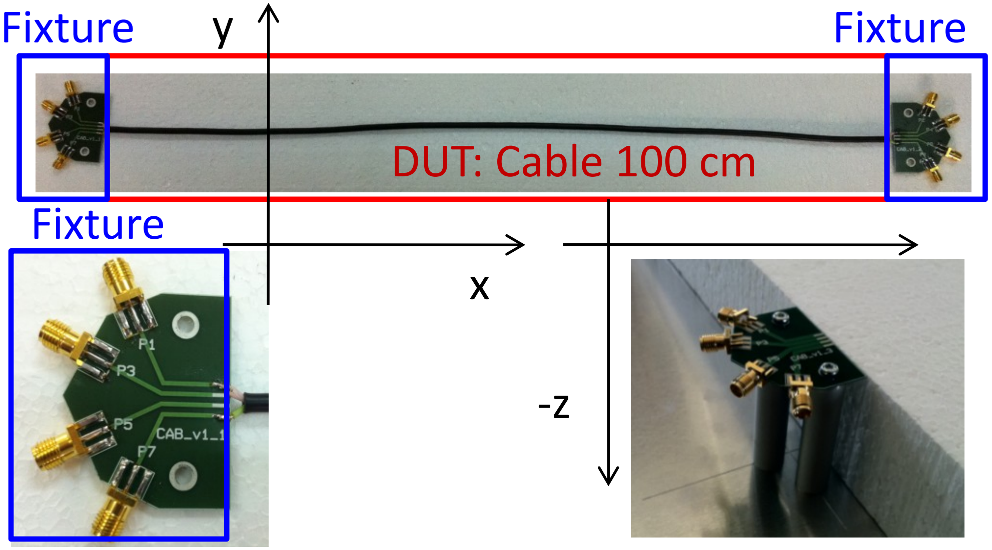
Motivation & Objectives

- Motivation:
  - Automotive industry:
    - The FlexRay comunication protocol
      - » Future replacement for CAN
      - » Developed from the year 2000 to the year 2010
      - » Baud rate: 10 Mbit/s
  - Sensitivity to EMI
- Objectives:
  - Cable models valid up to 3 GHz within 3 dB mismatch
    - Single-ended S parameters and mixed-mode S parameters
    - Valid for tools such as: Spectre, Hspice or Agilent ADS
  - The models should be simple and stable:
    - Simple: static RCLG matrices if possible
    - Stable: static RLCG matrices are frequency independent - stability
  - So far:
    - Only twisted pairs
    - The models are not based on geometry

Measurements & Modeling

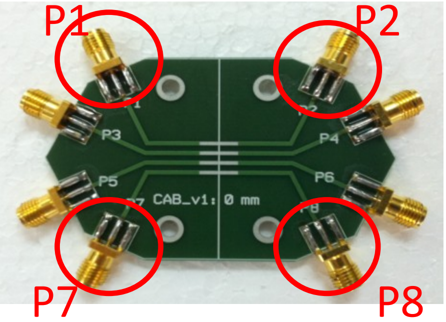
- Measurements:
  - Frequency domain: single-ended S parameters
  - Cables 5 cm above ground plane
  - Range: 300 kHz – 3 GHz
  - Cables:
    - Length 1m
    - 1 or 2 twisted pair
  - Extracted single-ended S parameters
    - Test fixture must be de-embedded – the fixtures must be modeled

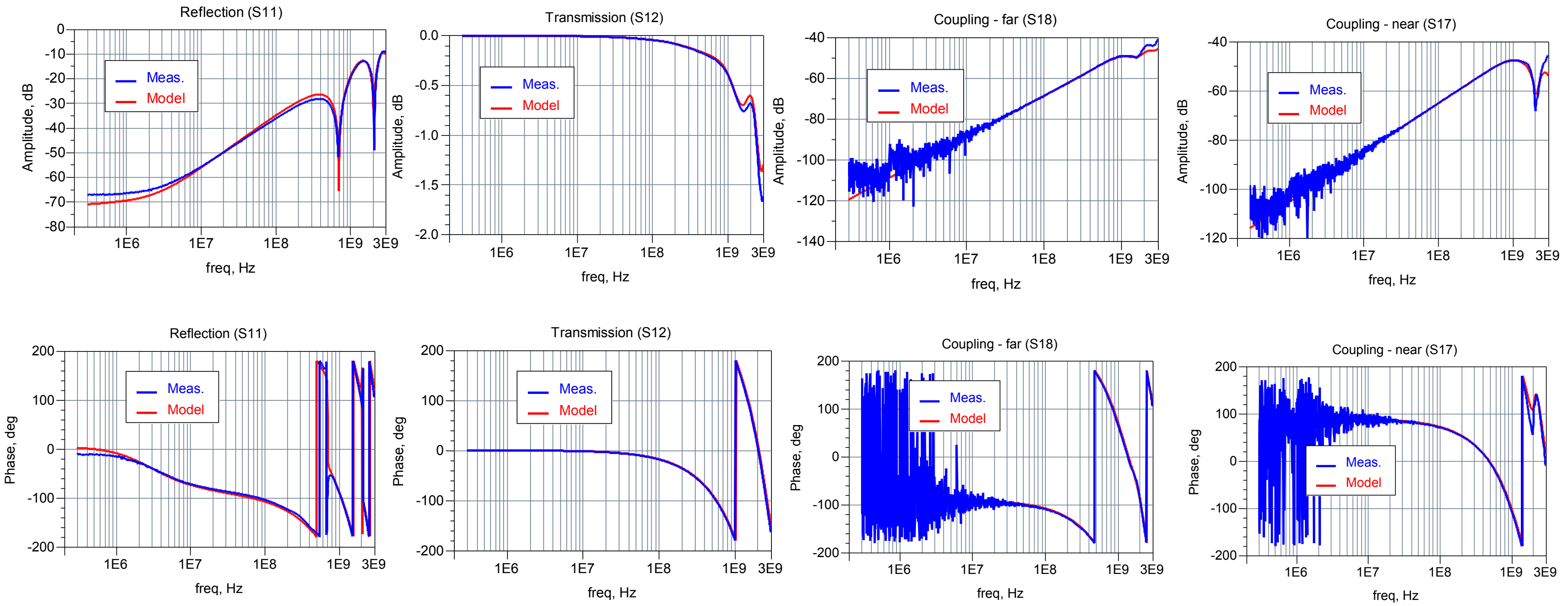




Test fixture

- Modeled in Agilent Momentum
- Comparison: measurement vs. model:





Measurements & Modeling

- Modeling - Challenges:
  - Stability of the model: in time domain
  - Simplicity:
    - Frequency dependent RLCG matrices are not option
    - Transmission lines are promising
  - 4 port network (1 twisted pair):
    - Described with transmission line in range: 300 kHz – 3 GHz
    - 2 conductors:
      - matrices are defined as lower triangular -> 3 (or 2) independent variables
    - E.g. *L* matrix

$$L = \begin{bmatrix} L_{11} & L_{12} \\ L_{21} & L_{22} \end{bmatrix}$$

L_{11}, L_{22} – self inductance

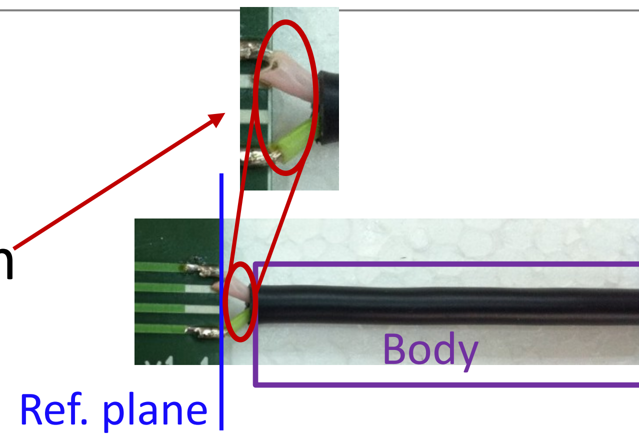
L_{12} =L_{21} – mutual inductance

  - Mixed-mode parameters (MM): calculated from single-ended parameters (SE) -> model must be very accurate

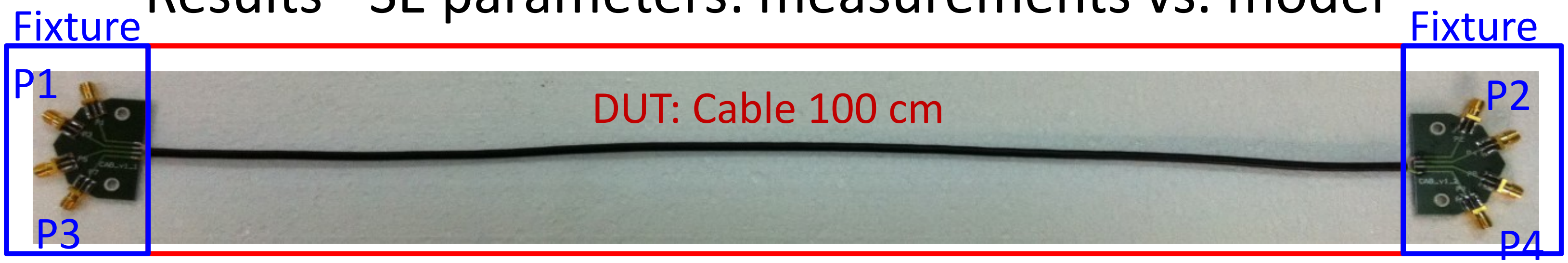
Measurements & Modeling

- Model:
  - The model includes:
    - Connection to fixure: l≈0.3 cm
    - Cable body: l≈100 cm
  - Agilent ADS
  - Transmission line model: *W element*
    - Telegraph equations, frequency dependent lossy transmission line
    - Static RLGC matrices: the frequency dependence is analytically predefined. Frequency dependent resistance is modeled as:

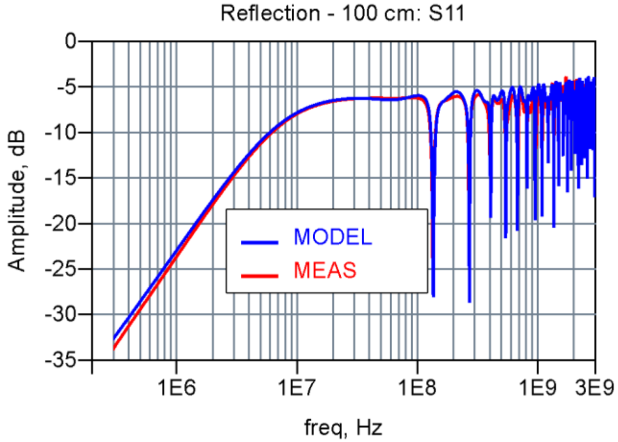
      $R = Ro + Rs(1+j)\sqrt{f}$ Ro – DC resistance, Rs - freq. dependent parameter
  - Assumption: electrical properties of both wires are the same
  - The models are based on measured single-ended S parameters

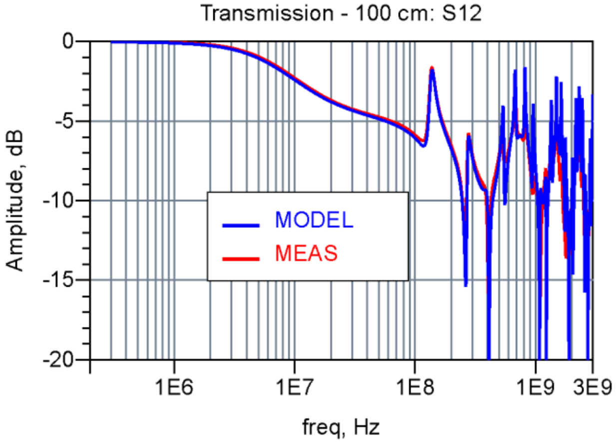


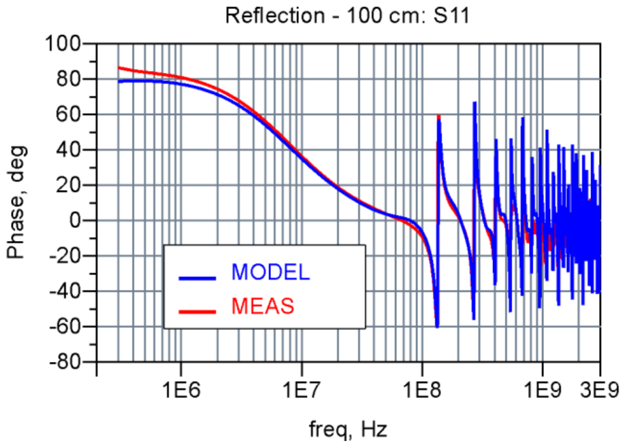
Results - SE parameters: measurements vs. model

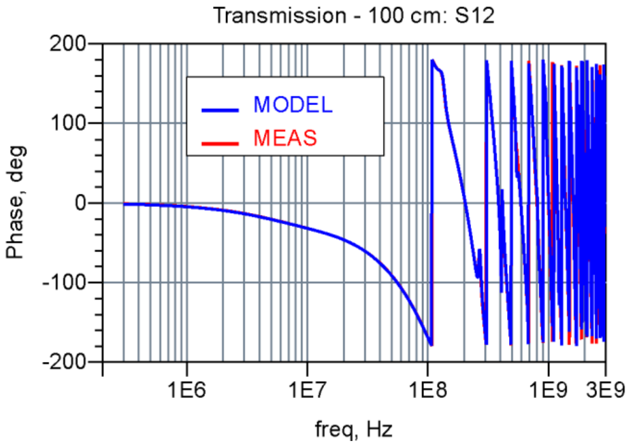


- Example - UTP FlexRay cable :



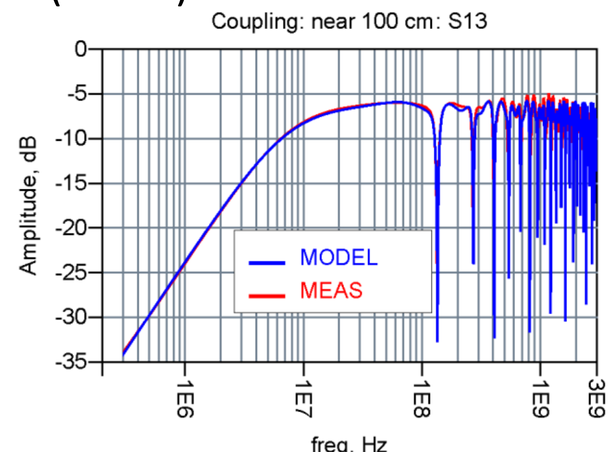


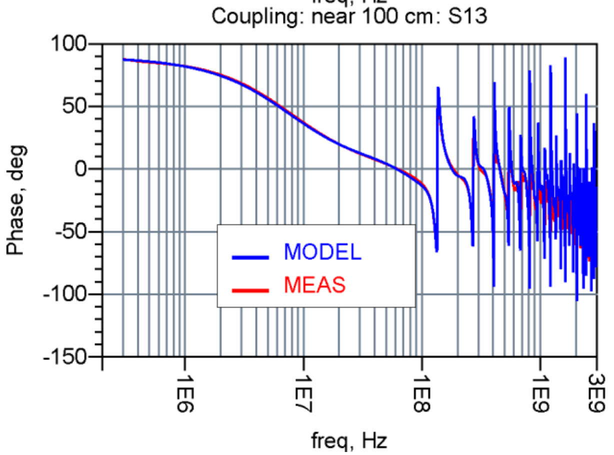




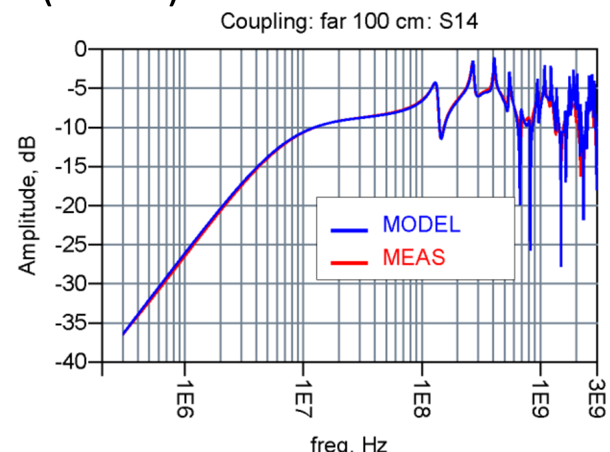
Results - SE parameters: measurements vs. model

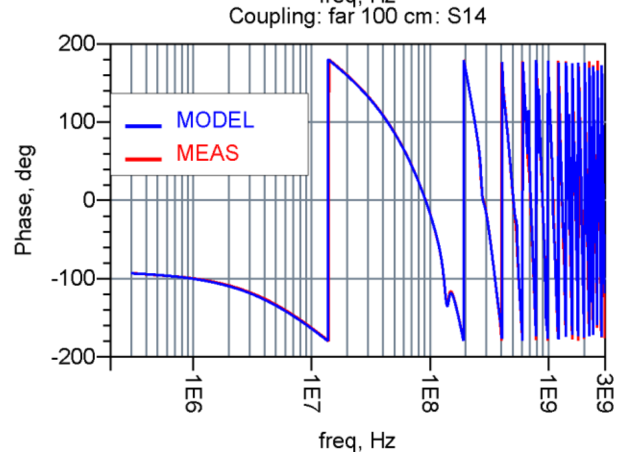
- Coupling
- Near (P1-P3)





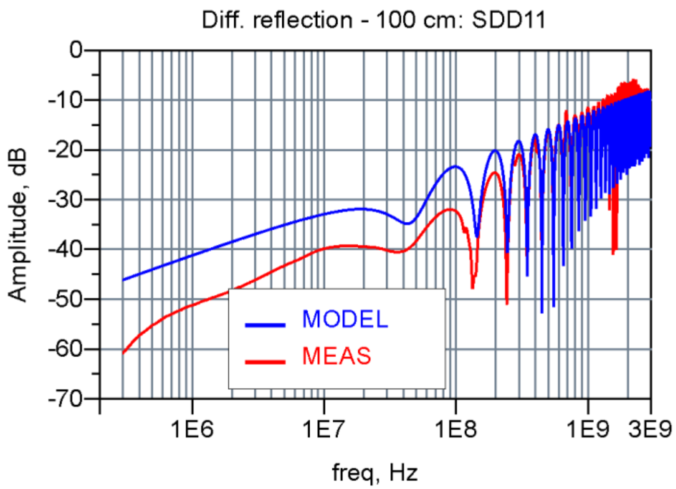
Far (P1-P4)

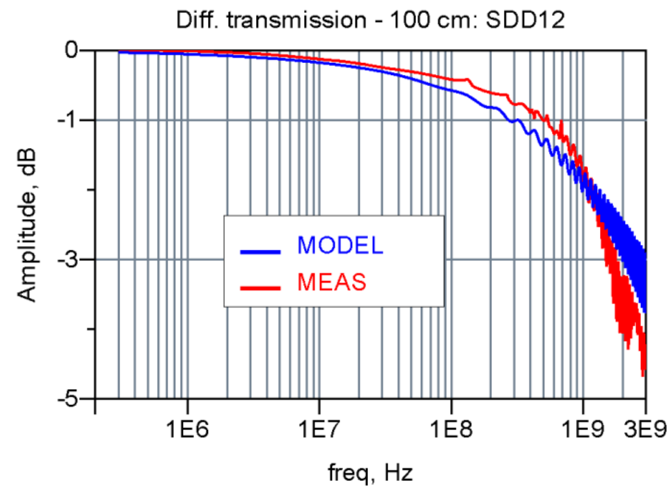


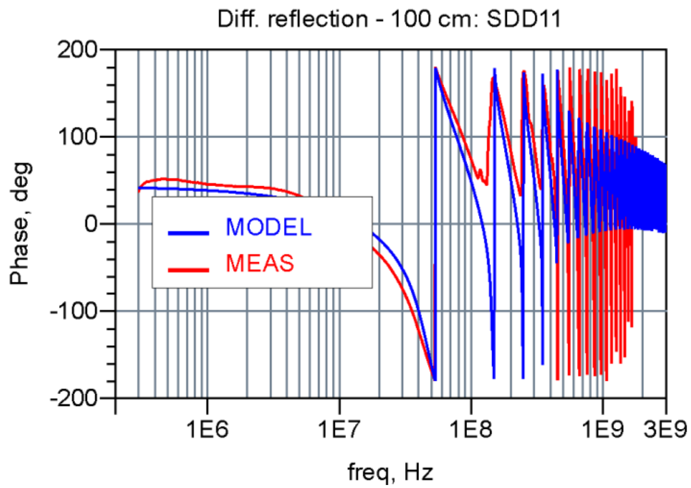


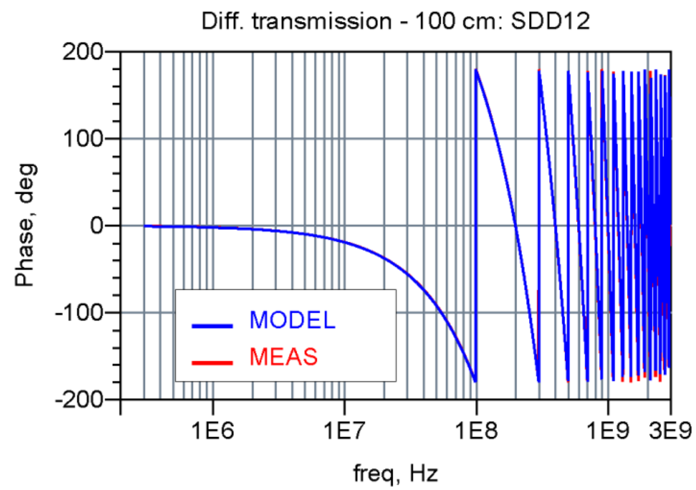
Results - MM parameters: measurements vs. model

- Differential – differential: reflection and transmission



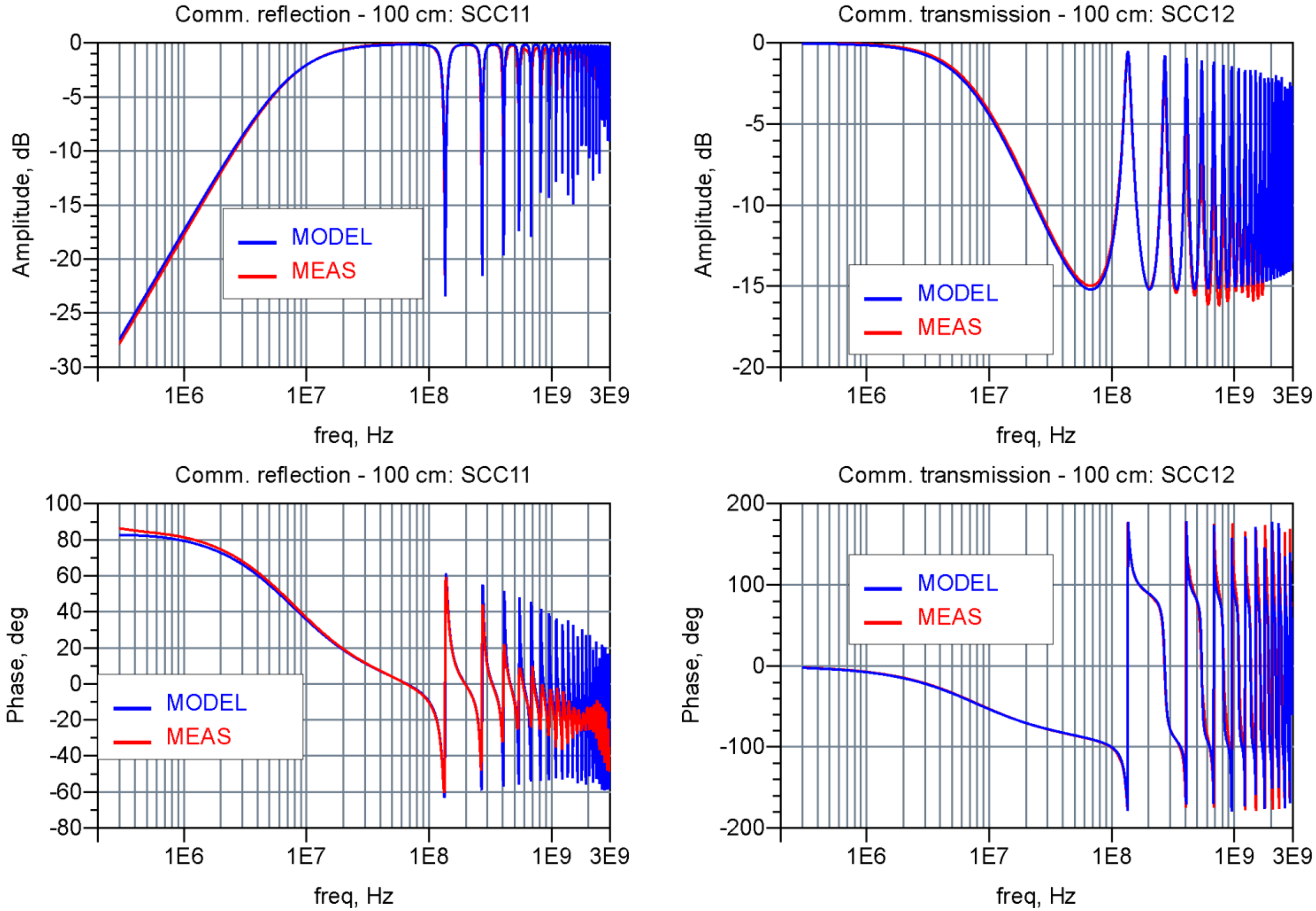






Results - MM parameters: measurements vs. model

- Common – common: reflection and transmission

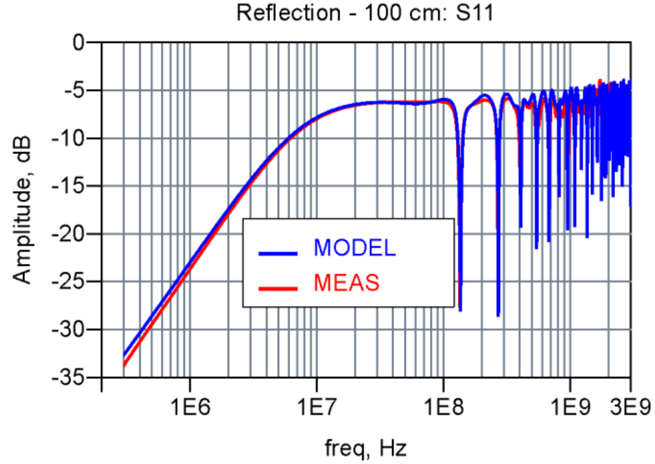


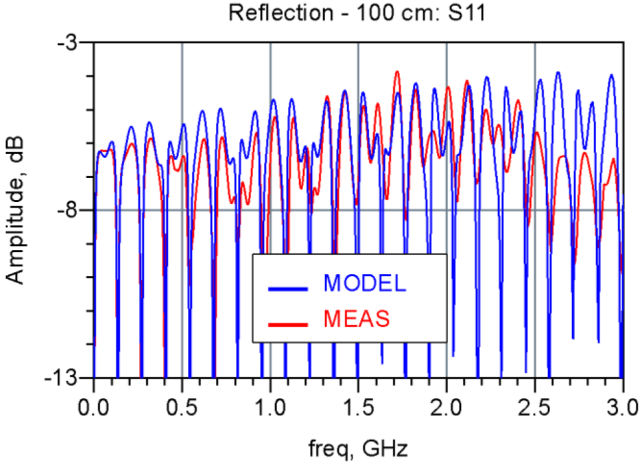
Perspectives

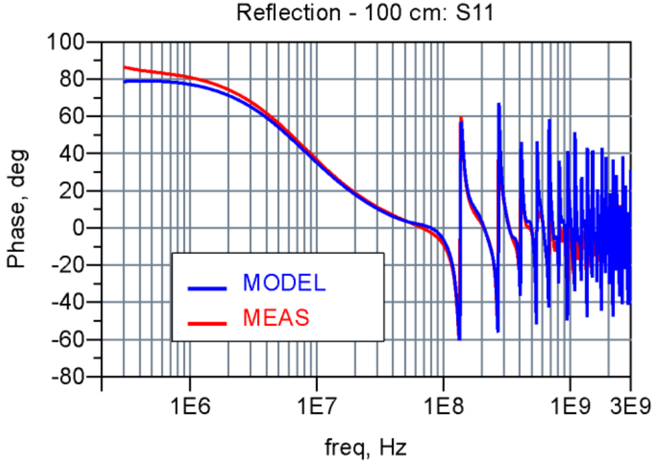
- Industrial application:
  - Project is supported by ON semiconductor
  - The FlexRay communication protocol is future replacement for CAN protocol
- Future modeling:
  - The models must be within 3 dB mismatch up to 3 GHz
  - Improvement in mixed-mode parameters

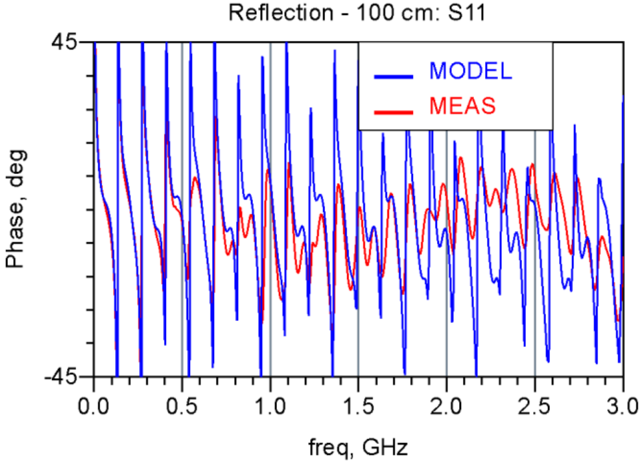
Appendix

- SE - reflection: lin



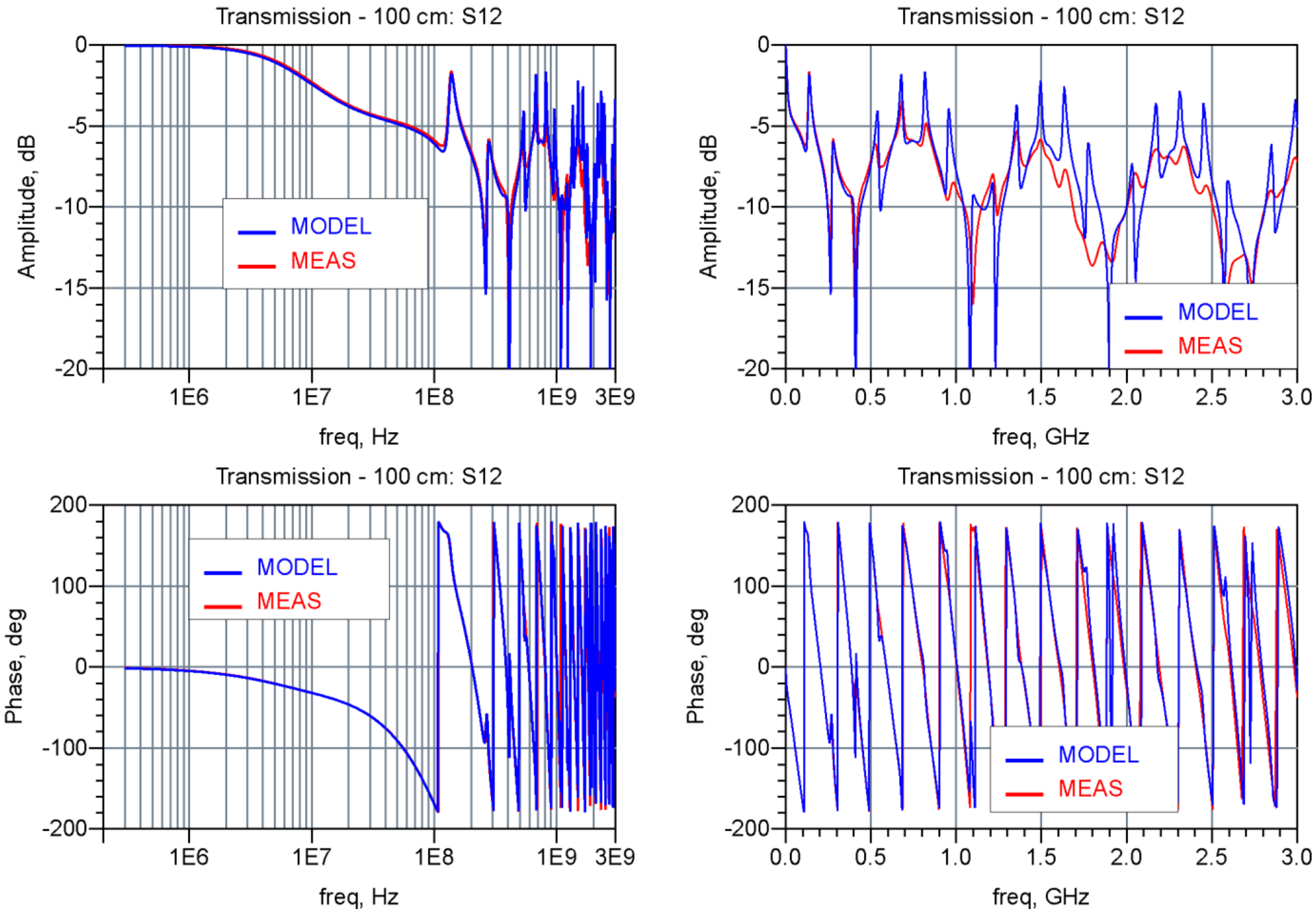






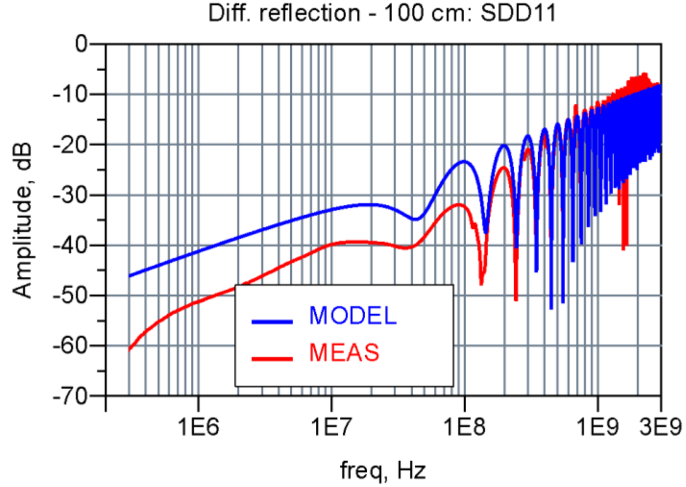
Appendix

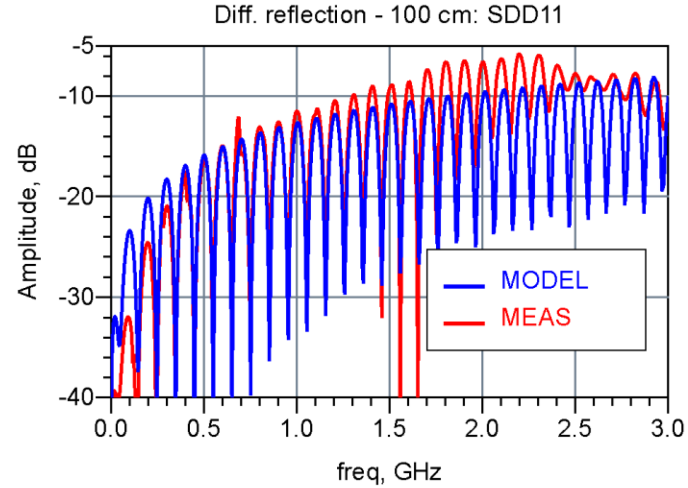
- SE - transmission: lin

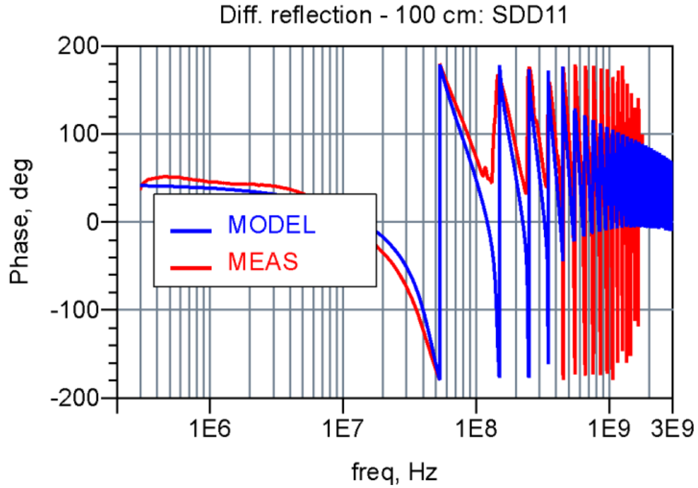


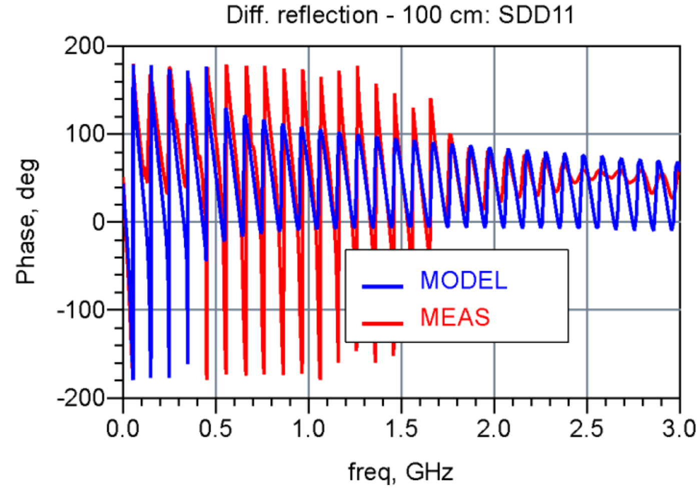
Appendix

- MM differential – differential reflection









Appendix

- MM common – common transmission