Combining the FDTD Algorithm with Signal Processing Techniques for Performance Enhancement

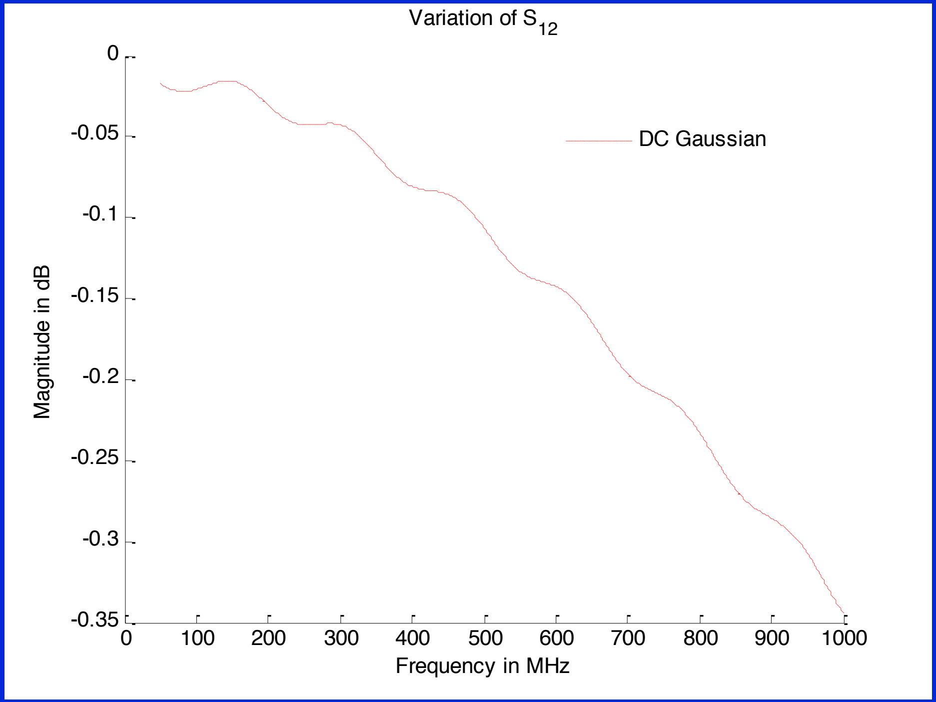
Kapil Sharma, K. Panayappan, Ravi K. Arya and R. Mittra

EMC Lab, The Pennsylvania State University
rajmittra@ieee.org

Conventional FDTD algorithm

- Time domain numerical convergence (e.g., below 30 dB levell is used as the termination criterion for
 conventional FDTD algorithm.

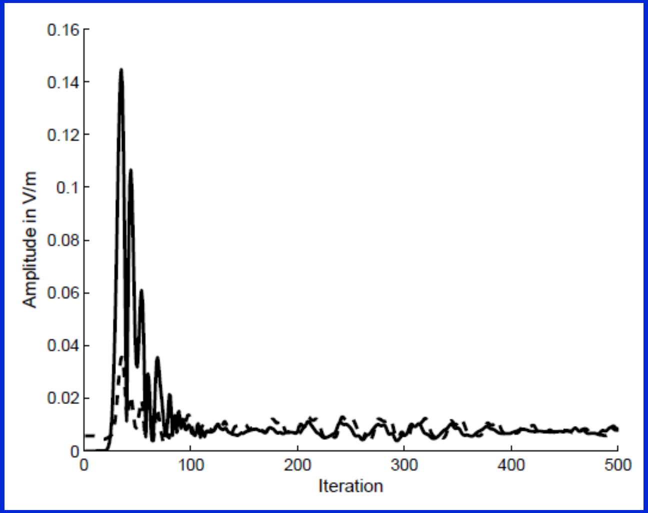
- The termination criterion used in conventional FDTD results in high computational cost
 when a given problem is solved for low frequencies, or when high-Q structures and
 dispersive dielectric medium are involved.



Frequency	10 MHz	1 MHz	1 Hz
Time Steps	6.9582e+005	6.9582e+006	6.9582e+012

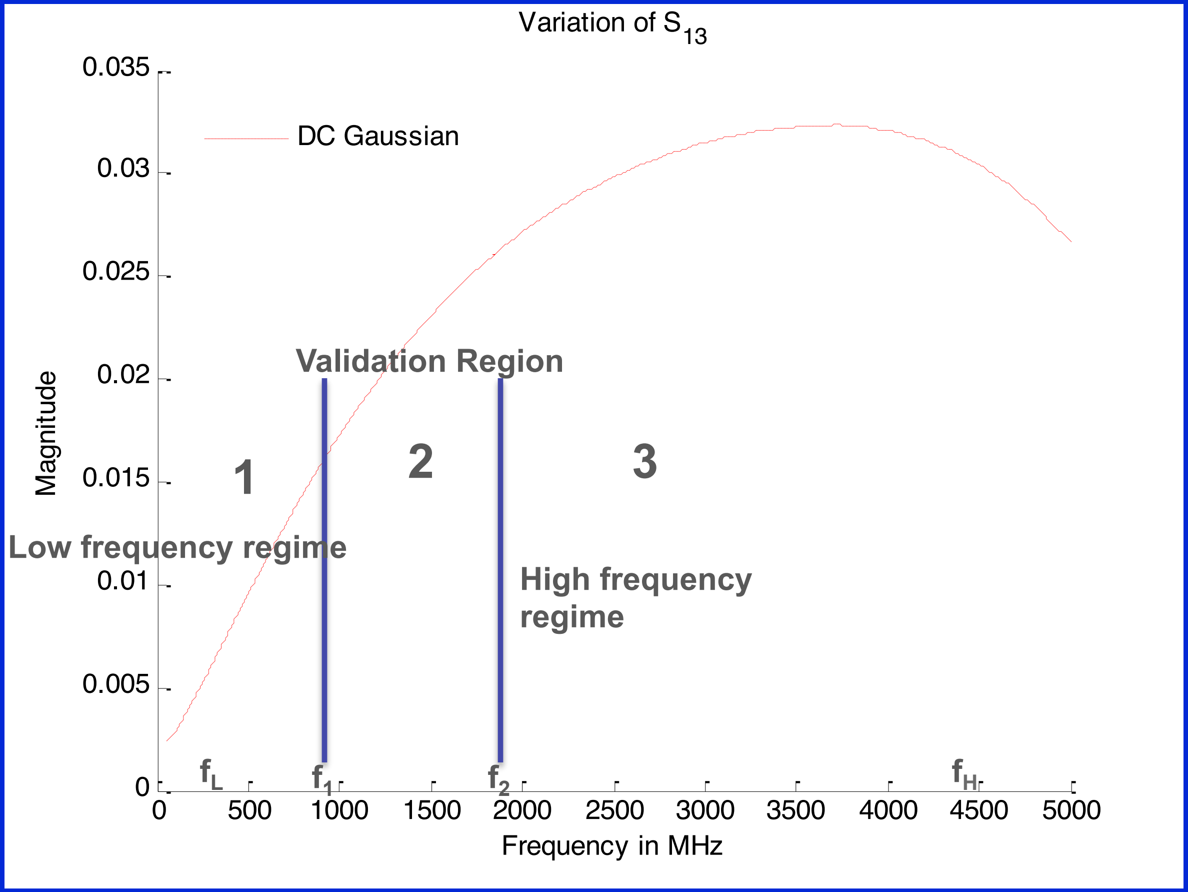
Proposed Solution - Efficient FDTD algorithm

- The proposed efficient FDTD algorithm utilizes signal processing techniques to check convergence in the frequency domain (as opposed to time domain), and thus differs from the conventional FDTD algorithm.
- First, we wait until the first overshoot of the time signature has occurred
- Then we compute the DFT of these samples at the lowest frequency of interest at the end of every 100 time steps.
- The FDTD algorithm is terminated when the difference between the successive DFT values becomes negligible.



Proposed Solution – Low Frequency Processing

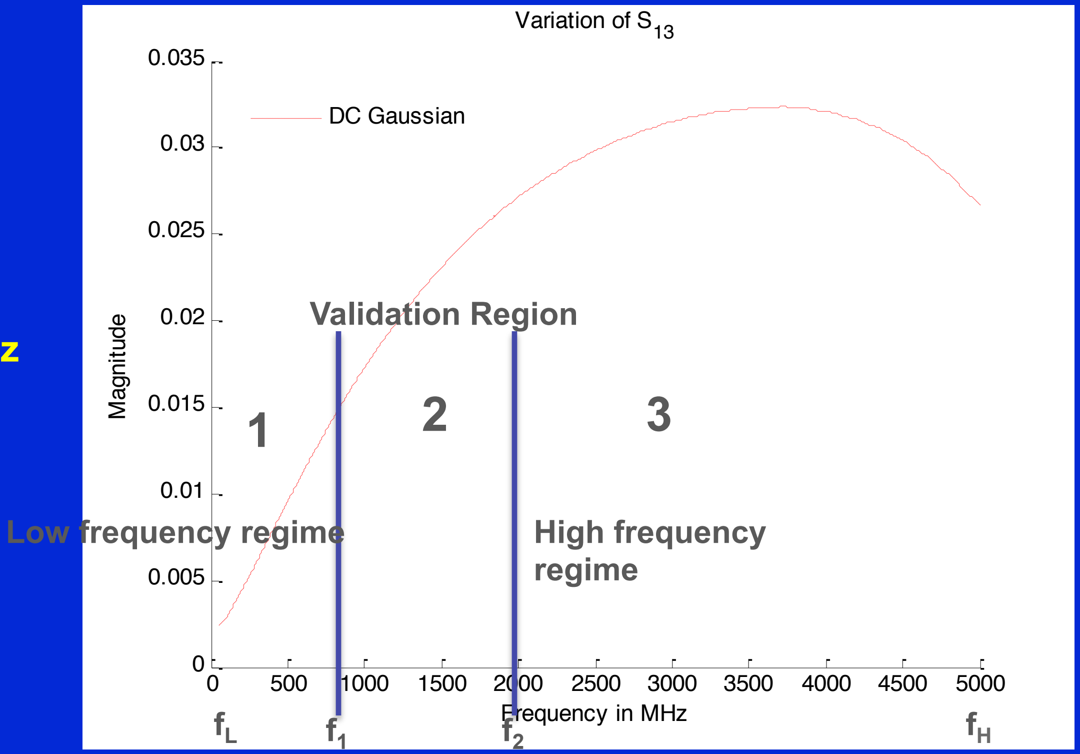
Frequency Definitions:
f_L - User Input
f_1 - 500 – 1000 MHz
f_2 - 2 f_1 /3 f_1
f_H - User Input



- Region 3: High frequency regime - Use DC Gaussian pulse results.
- Region 1: Low frequency regime - Use the proposed method.
- Region 2: Validation region – Use the Single Frequency results in this region to validate the smoothed DC Gaussian results.

Proposed Solution – Low Frequency Processing (Contd.)

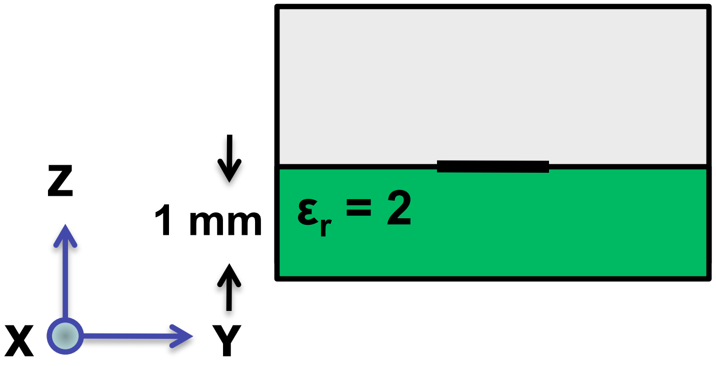
Frequency Definitions:
f_L - User Input
f_1 - 500 – 1000 MHz
f_2 - 2 f_1 /3 f_1
f_H - User Input

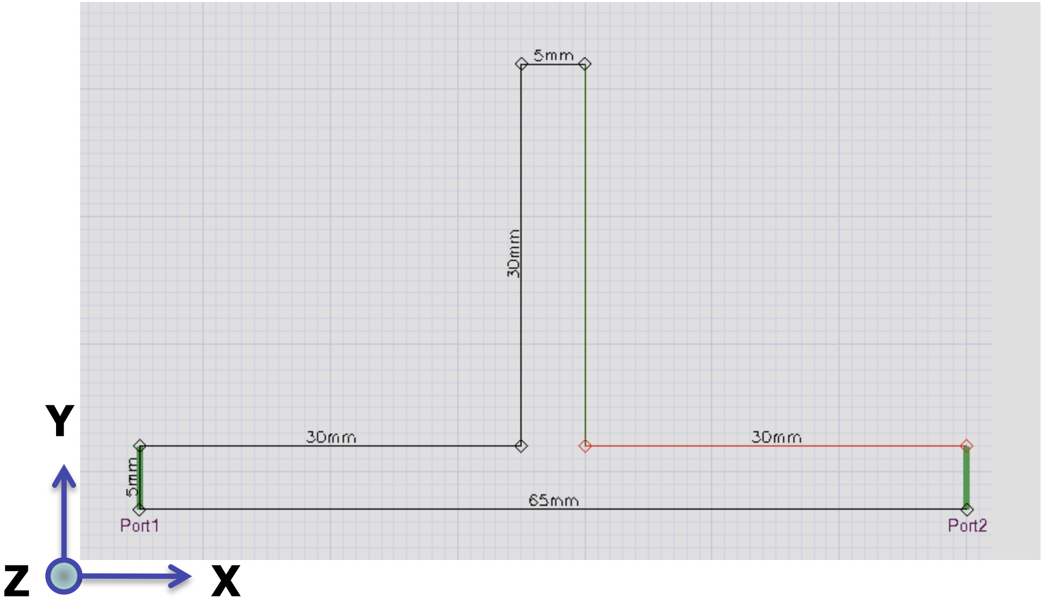


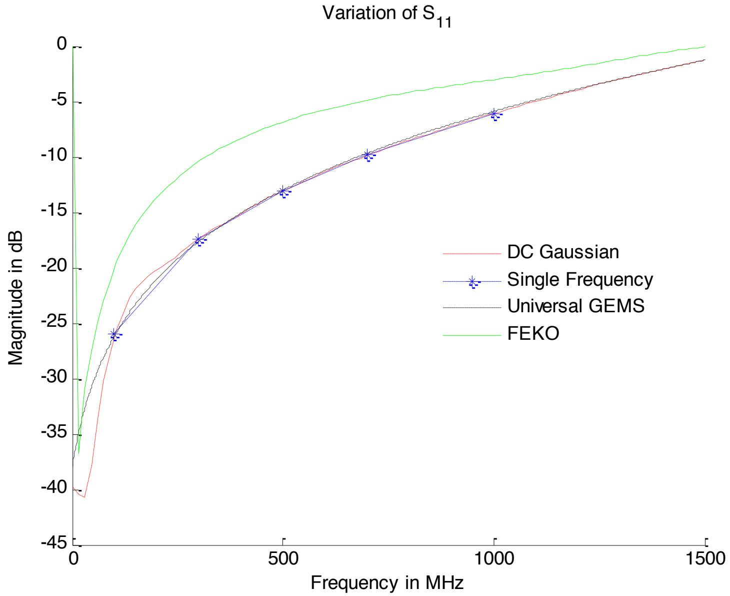
- Smooth the DC Gaussian Results.
- Fit the curve from f_L to f_1 with the DC values, using a quadratic curve. The choice of f1 can be fine tuned based on the quality of the resulting fit.
- Validate the smoothed "DC Gaussian" results in region 2 by comparing them with those generated by "Single Frequency" simulations at a few points (typically 2 or 3).

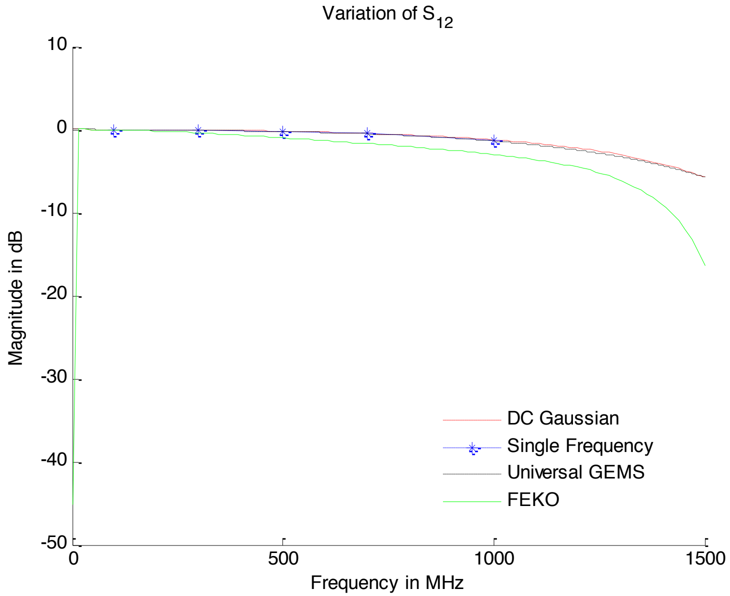
RF Filter

f @ 0 Hz to 1.5 GHz



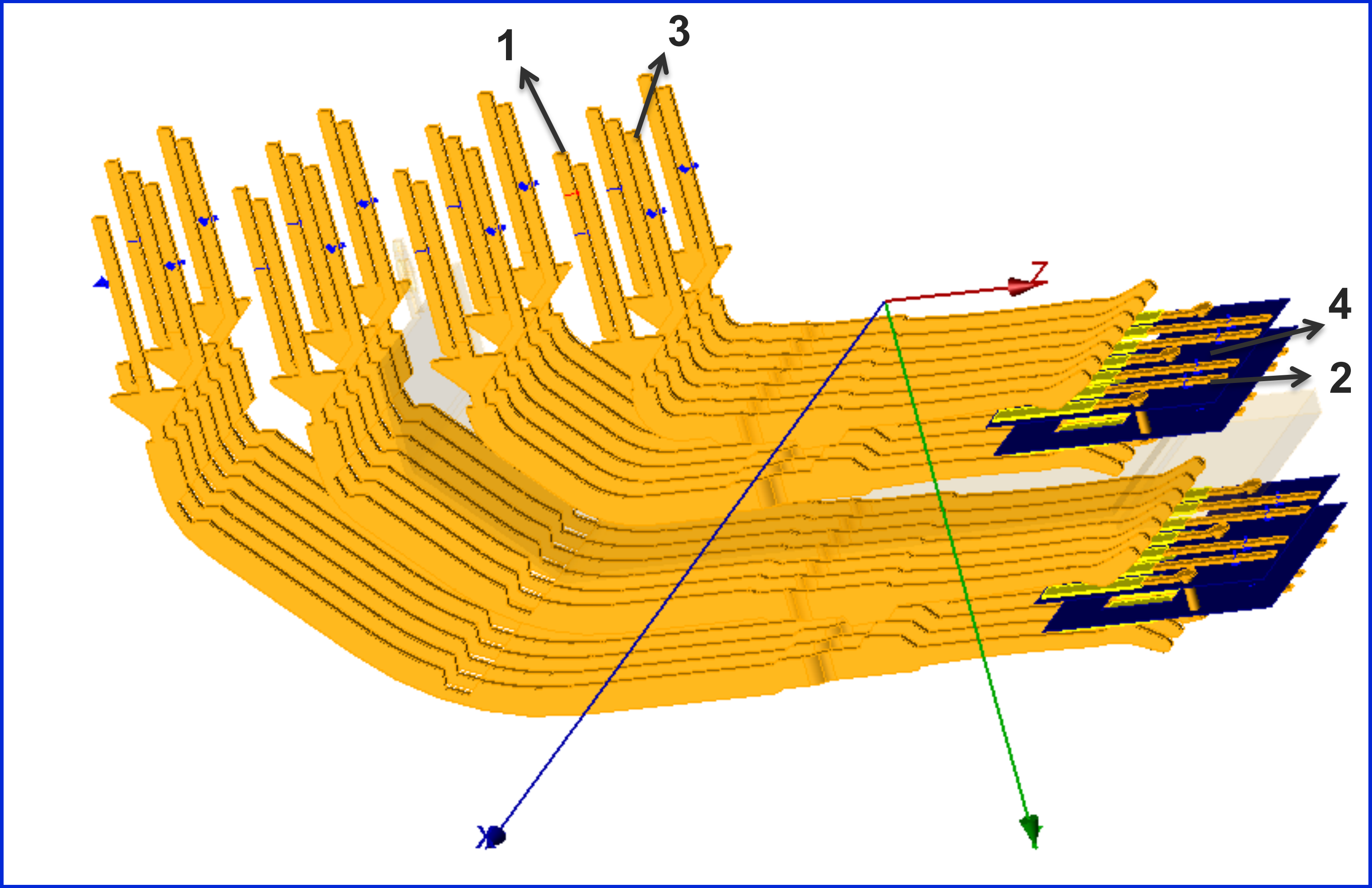




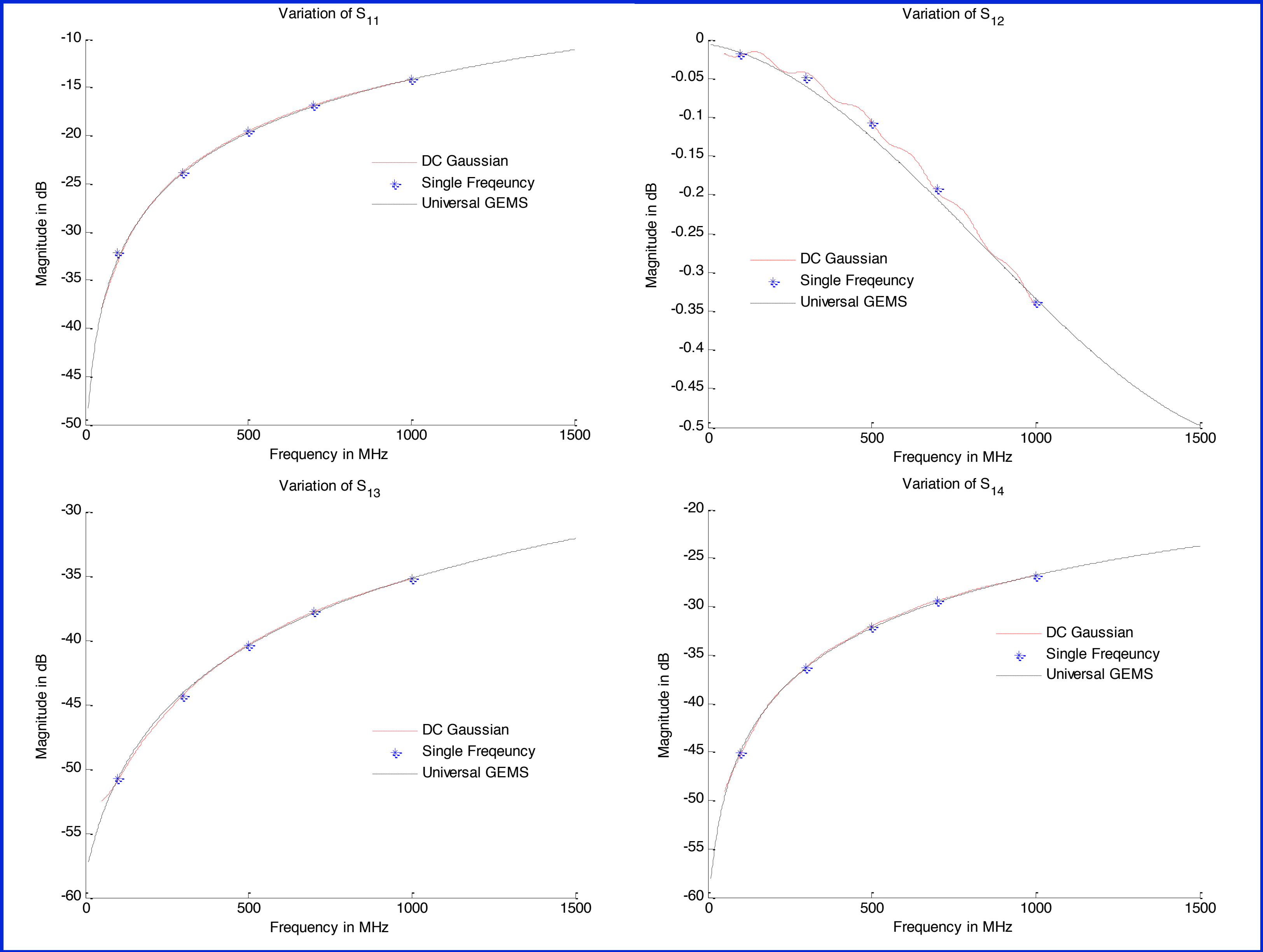


Connector

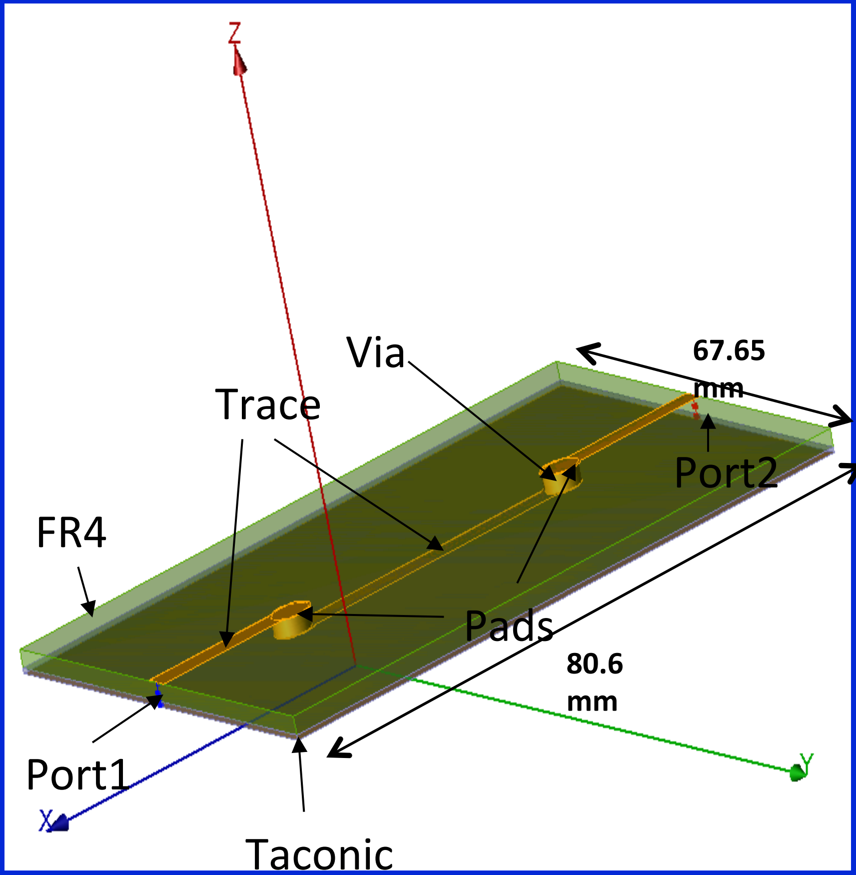
f @ 10 MHz to 1.5 GHz



Connector (Contd.)



Vias in a Printed Circuit Board Geometry



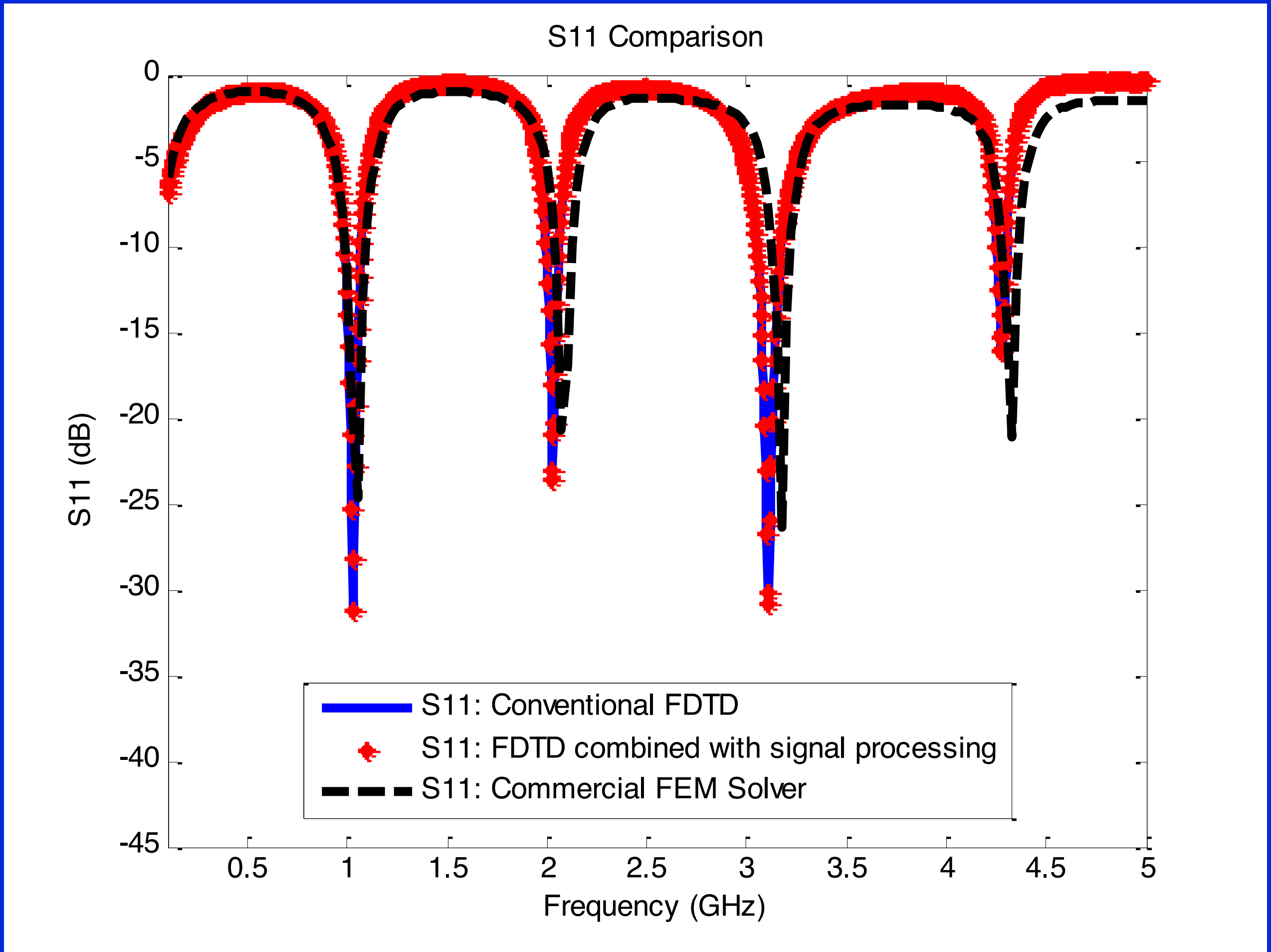
Trace: 17.7 micron thick, 3.557 mm wide

Dielectric Substrates:
FR4: εr = 4.47, tanδ = 0.016, height: 1.905 mm

Taconic: εr = 10, tanδ = 0.0035, height: 0.508 mm

Via diameter: 4.8 mm
Pad diameter: 5.2 mm

Comparison of simulated return loss (S_{11})



Same accuracy is obtained in return loss (S11) using conventional FDTD and efficient FDTD algorithms.

Results obtained using FDTD compare well against those obtained using commercial FEM solver.

Comparison of computational resources utilized

Parameter	Commercial FEM	Conventional FDTD	FDTD using signal processing
Time	36 min, 36 sec	33 min, 15 sec	29 min, 30 sec
Memory	207 MB	68 MB	68 MB

Use of signal processing along with conventional FDTD algorithm reduces the computation time as compared to conventional FDTD algorithm.

Also, computational resources utilized by both FDTD algorithms are less than those utilized by the commercial FEM solver.

Conclusions

- An efficient FDTD algorithm has been proposed in this work, which utilizes signal processing techniques to reduce the overall computational cost.
- Results for different test examples demonstrated show that the FDTD algorithm used along with signal processing reduces computational cost while maintaining the accuracy of the results. Cost savings vary depending on the nature of the problem and the frequency range of interest. The savings can range from a few percent to a large factor.

References

- [1] Kane S. Yee, "Numerical Solution of Initial Boundary Value Problems Involving Maxwell's Equations in Isotropic Media," IEEE Trans. On Antennas and Propagation, vol.14, no.3, pp. 302-307, May 1966.
- [2] Wenhua Yu, Xiaoling Yang, Yongjun Liu and Raj Mittra, Electromagnetic Simulation Techniques Based on the FDTD Method, John Wiley & Sons, Inc., 2009.
- [3] R. Mittra, Computer Techniques for Electromagnetics, New York: Hemisphere Publication Corporation, 1987.
- [4] Kadappan Panayappan, Novel Frequency Domain Techniques and Advances in Finite Difference Time Domain (FDTD) Method for Efficient Solution of Multiscale Electromagnetic Problems, PhD Dissertation, The Pennsylvania State University, 2013.

Thank You

Questions ?