Time-Domain Modeling of Group-Delay Characteristics of Ultra-Wideband Printed-Circuit Antennas

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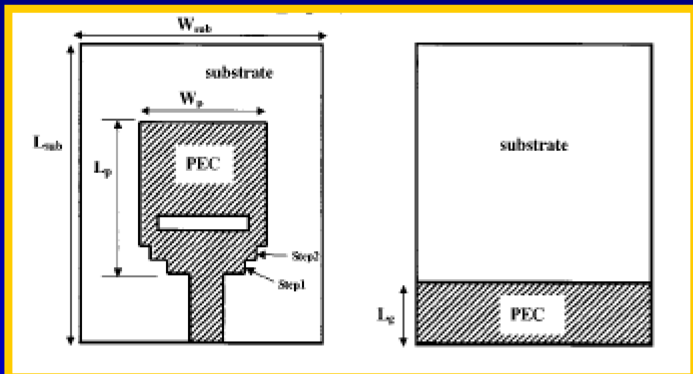
Outline

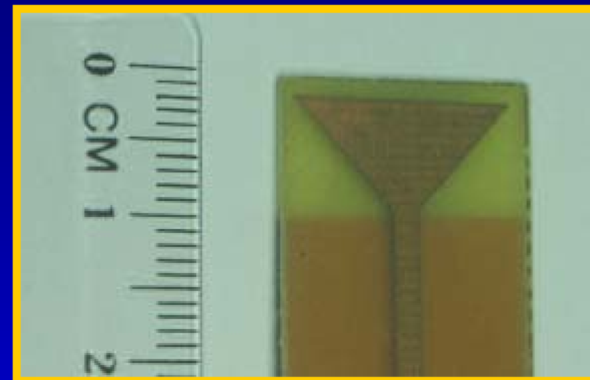
- Introduction/Motivation
- Ultra-Wideband Printed-Circuit Antennas
- Phase Center Calculations
- Group Delay Calculations
- Coplanar UWB Antenna
- Microstrip UWB Antenna
- Conclusions

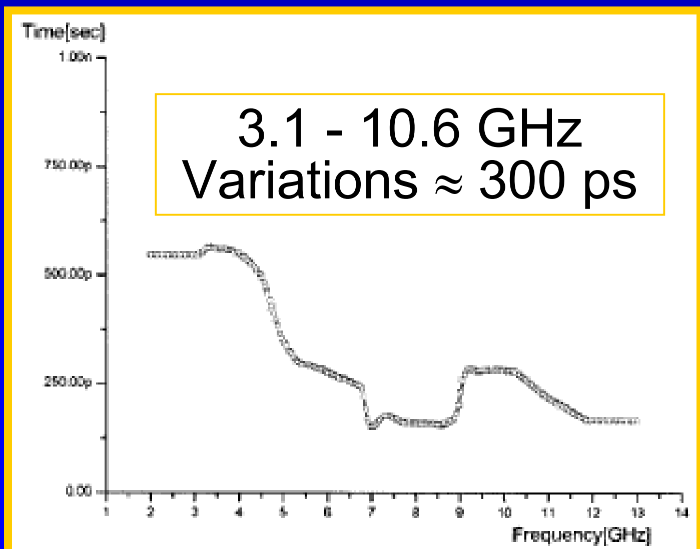
Introduction/Motivation

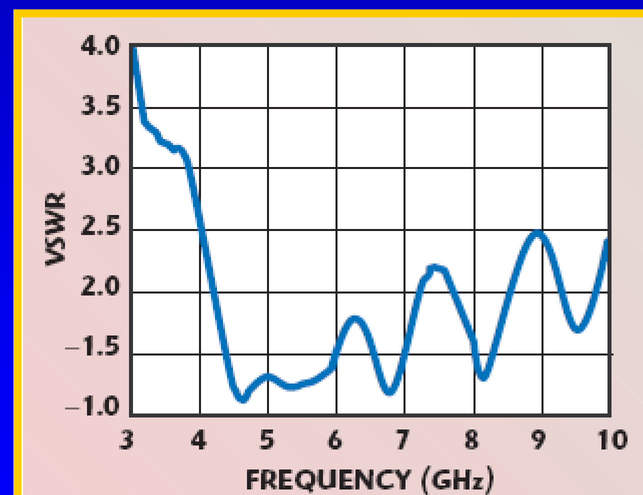
- Ultra Wide-Band (UWB) technology has received increased attention with the release of the 3.1-10.6 GHz band.
- UWB antennas in printed-circuit technologies within relatively small substrate areas is of primary importance in short-range and high bandwidth applications.
- UWB systems involve the transmission and reception of short pulses; the variations of radiated amplitudes and phases over frequency contribute to the distortion of the pulse.
- Phase distortions are represented by either a varying phase center over frequency or by the group delay.
- This presentation focuses on a time-domain approach (transient analysis) to determine the group delay of printed-circuit UWB antennas.
- The TLM method (MEFiSTo-3D) is used as a simulation tool.

Ultra-Wideband Printed-Circuit Antennas – Examples: Microstrip





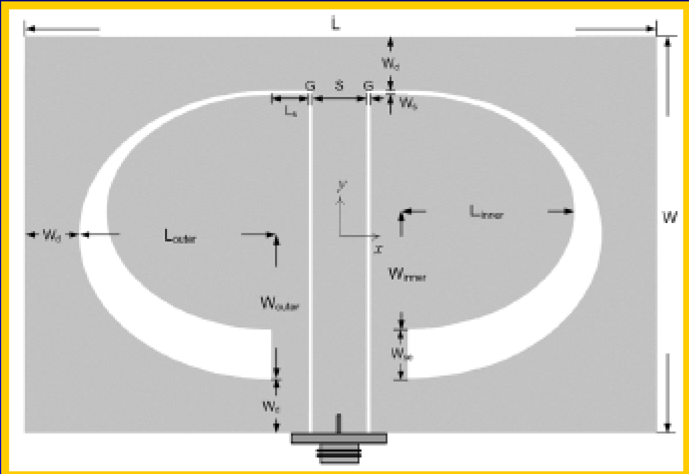


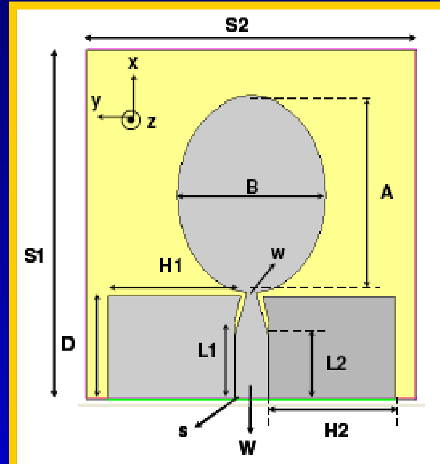


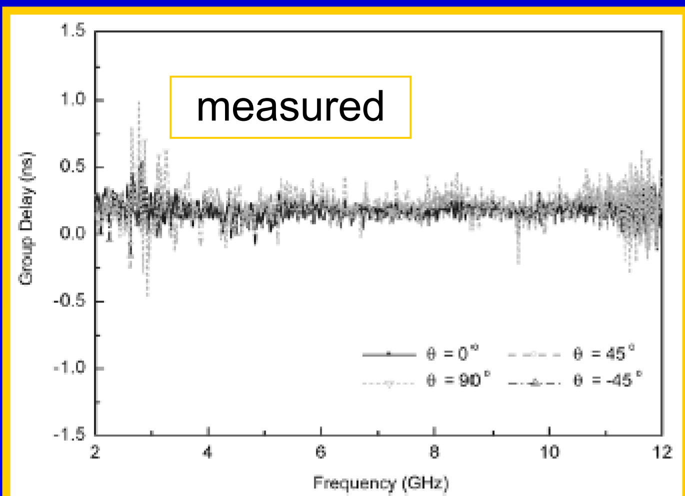
Choi, Park, Kim, Park, MOTL, No. 5, March 2004

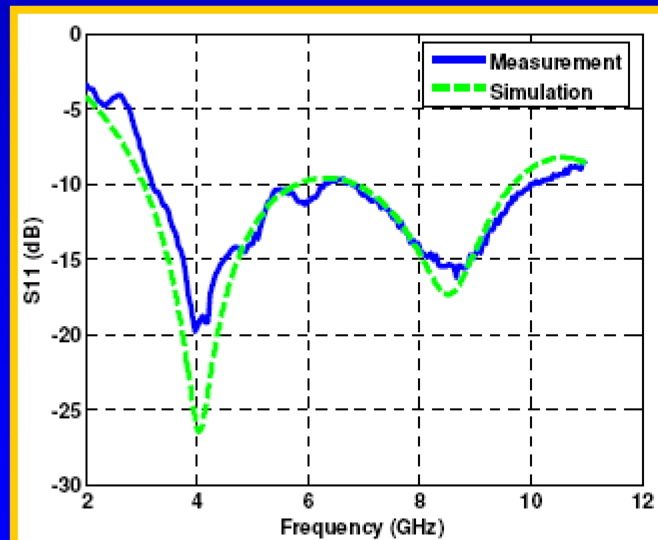
Chuang, Lin, Kan, Microw. J., Jan. 2006
and
Lin, Kan, Kuo, Chuang, MWCL, Oct. 2005

Ultra-Wideband Printed-Circuit Antennas – Examples: Coplanar









Ma,Tseng,Trans AP, Apr. 2006

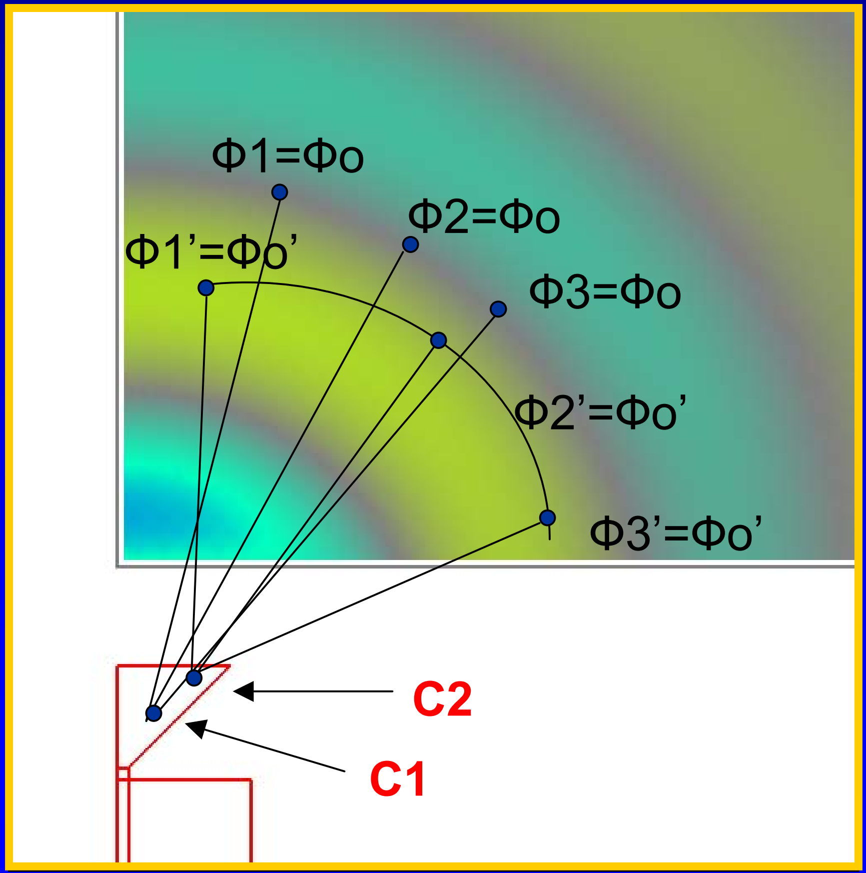
Nikolaou, Anagnostou, Ponchak, Tentzeris, Papapolymerou, ,APS Dig., 2006

Phase Center Calculations - Method I

Frequency domain Far field

- Calculate the spherical wave front in the far field.
- Compute the apparent phase center along the antenna surface or axis.

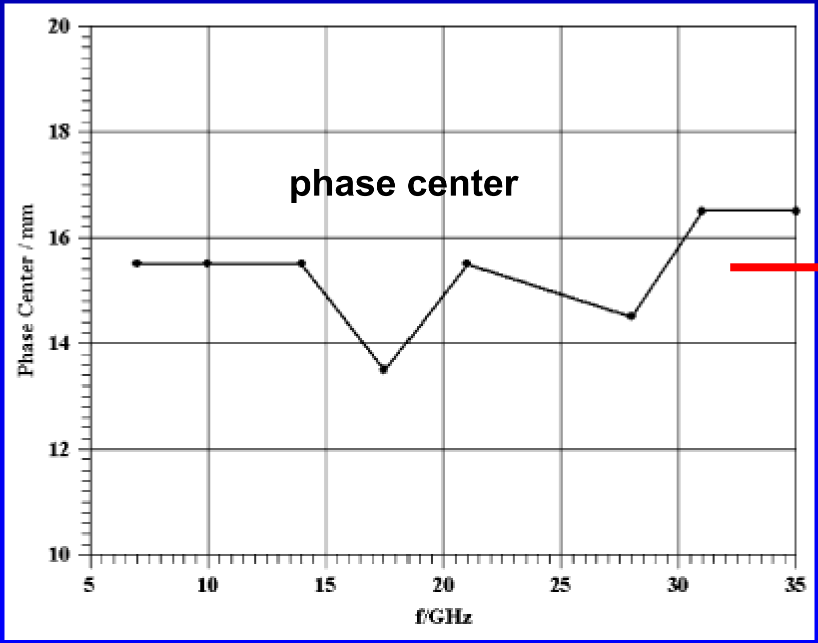
Time consuming !

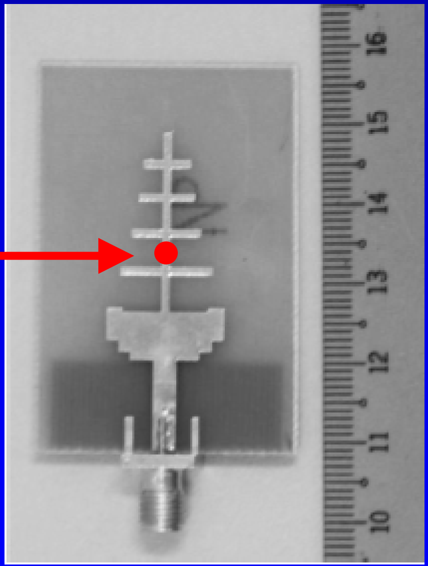


Phase Center Calculations - Method II

<u>Frequency domain</u> Near field

- From a reference point on the surface of the antenna, compute the phase variation in the near field over the main beam.
- A valid phase center location is detected if the phase variation over the main beam is within a few degrees.





microstrip circuit

No longer an option in HFSS !

Rambabu, Thiart, Bornemann, Yu, Trans. AP, Dec. 2006

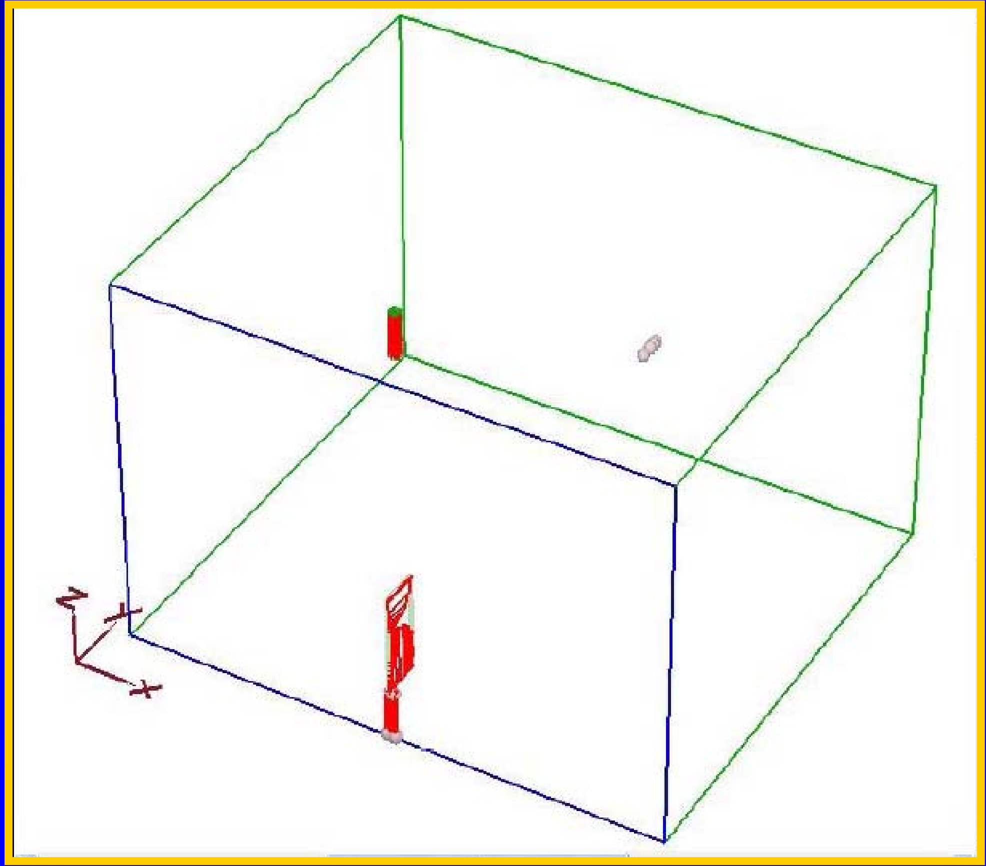
Group Delay Calculations

Time domain

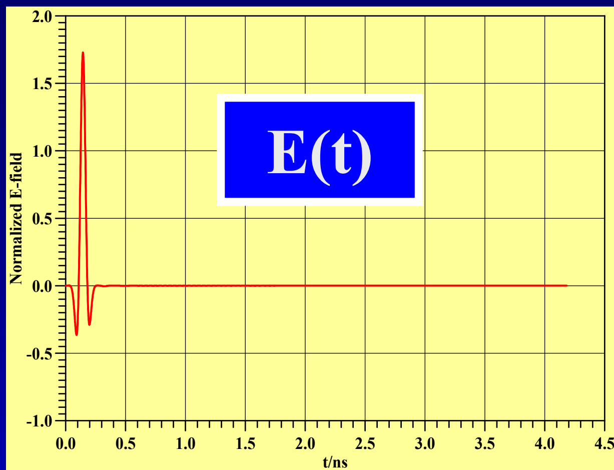
- Generate a pulse covering the respective frequency spectrum.
- Excite antenna and detect radiated pulse.
- Fourier transform both pulses and record phase response.
- Calculate the group delay from the derivative of the phase response.

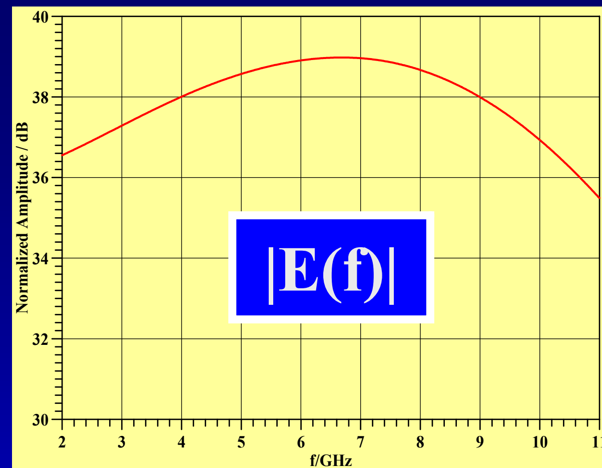
Setup in MEFiSTo-3D ➔

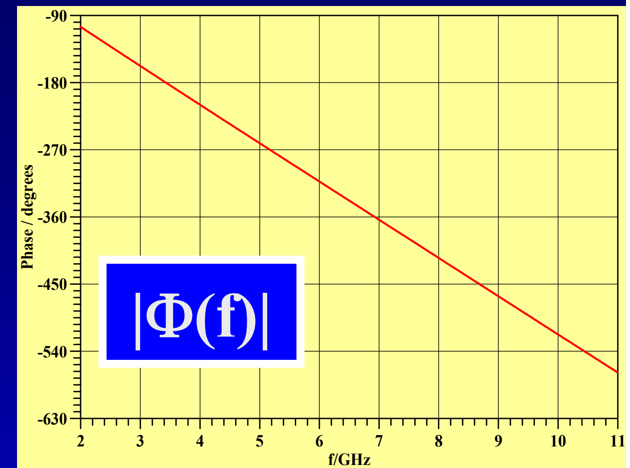
Note that the model includes the coax-to-CPW transition.



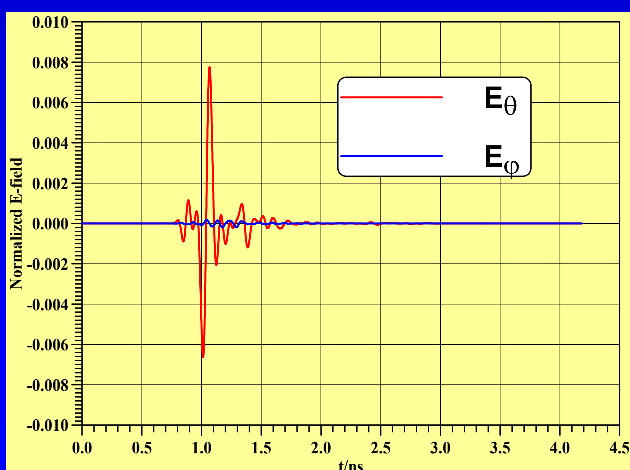
Input pulse

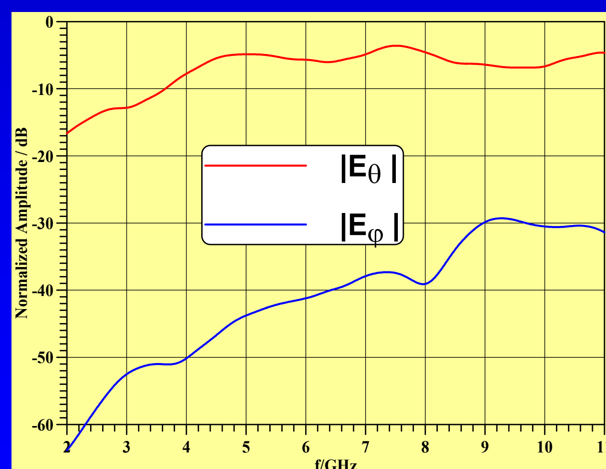


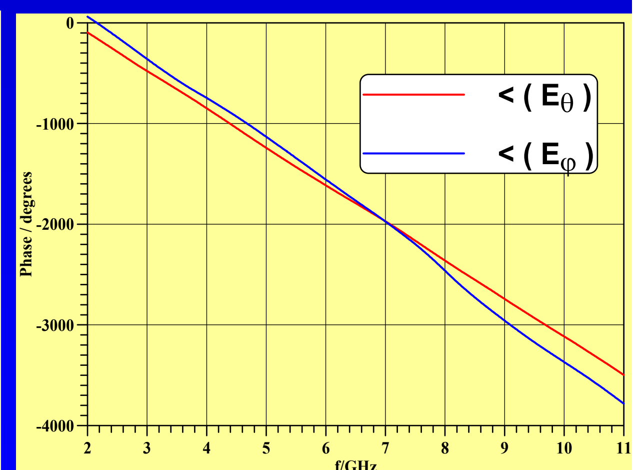




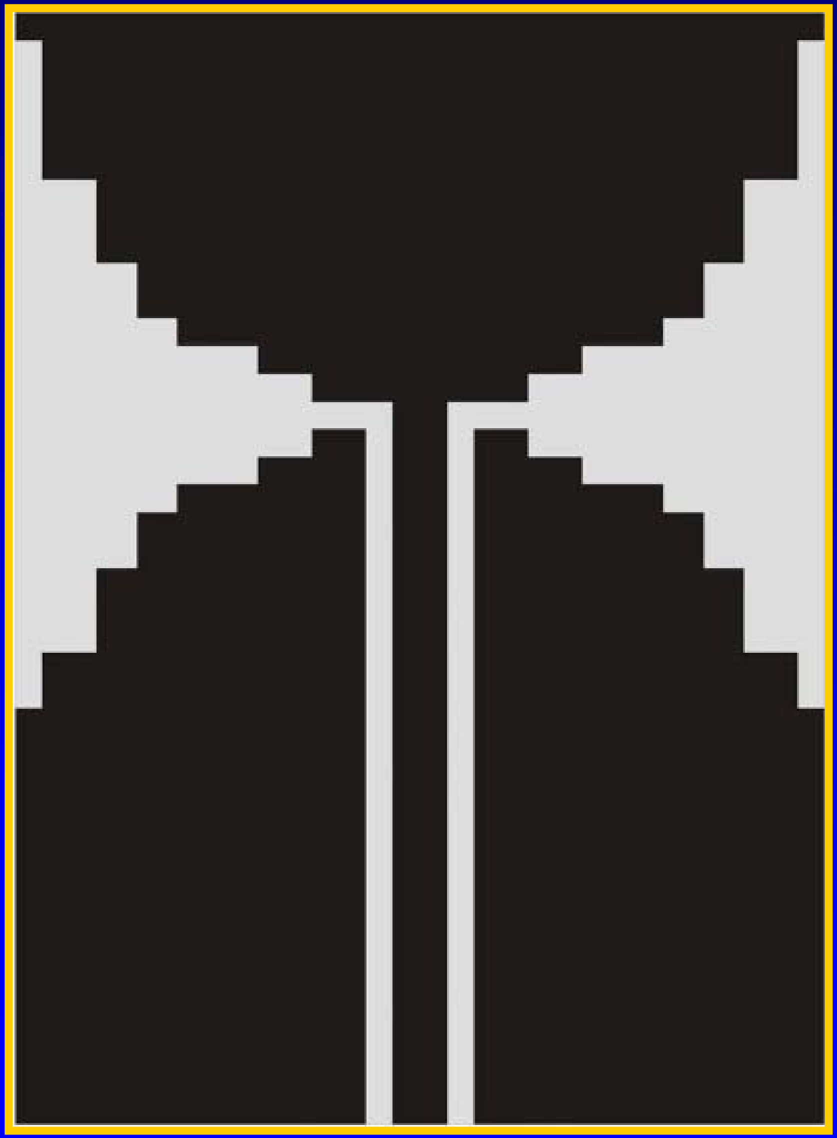
Radiated pulse

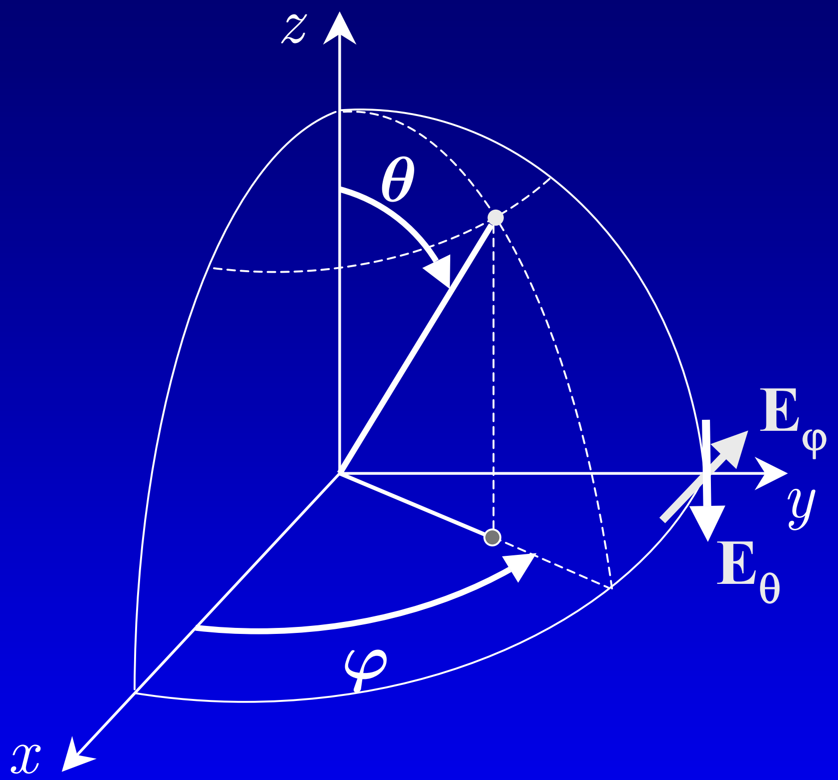






Coplanar UWB Antenna

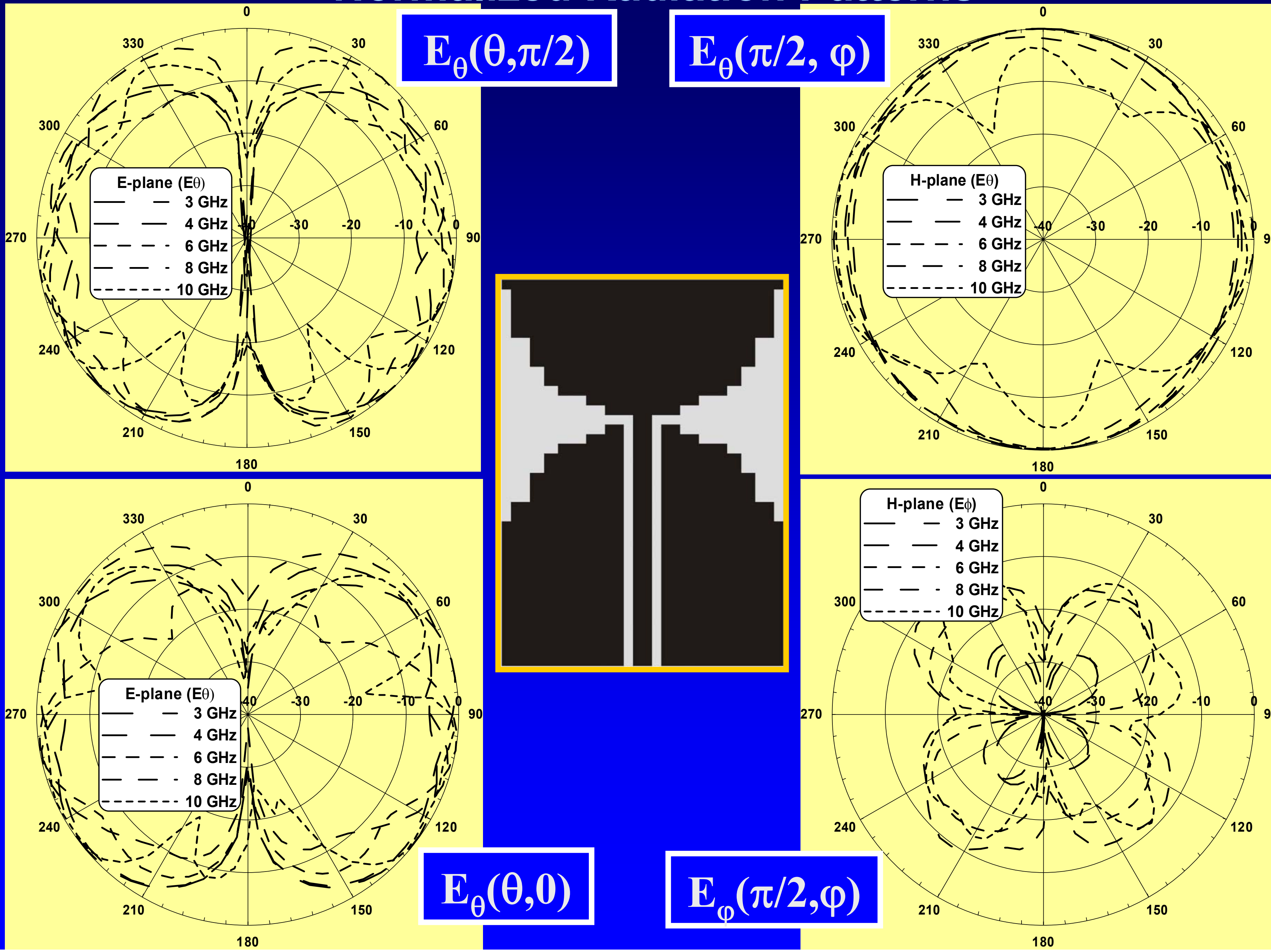




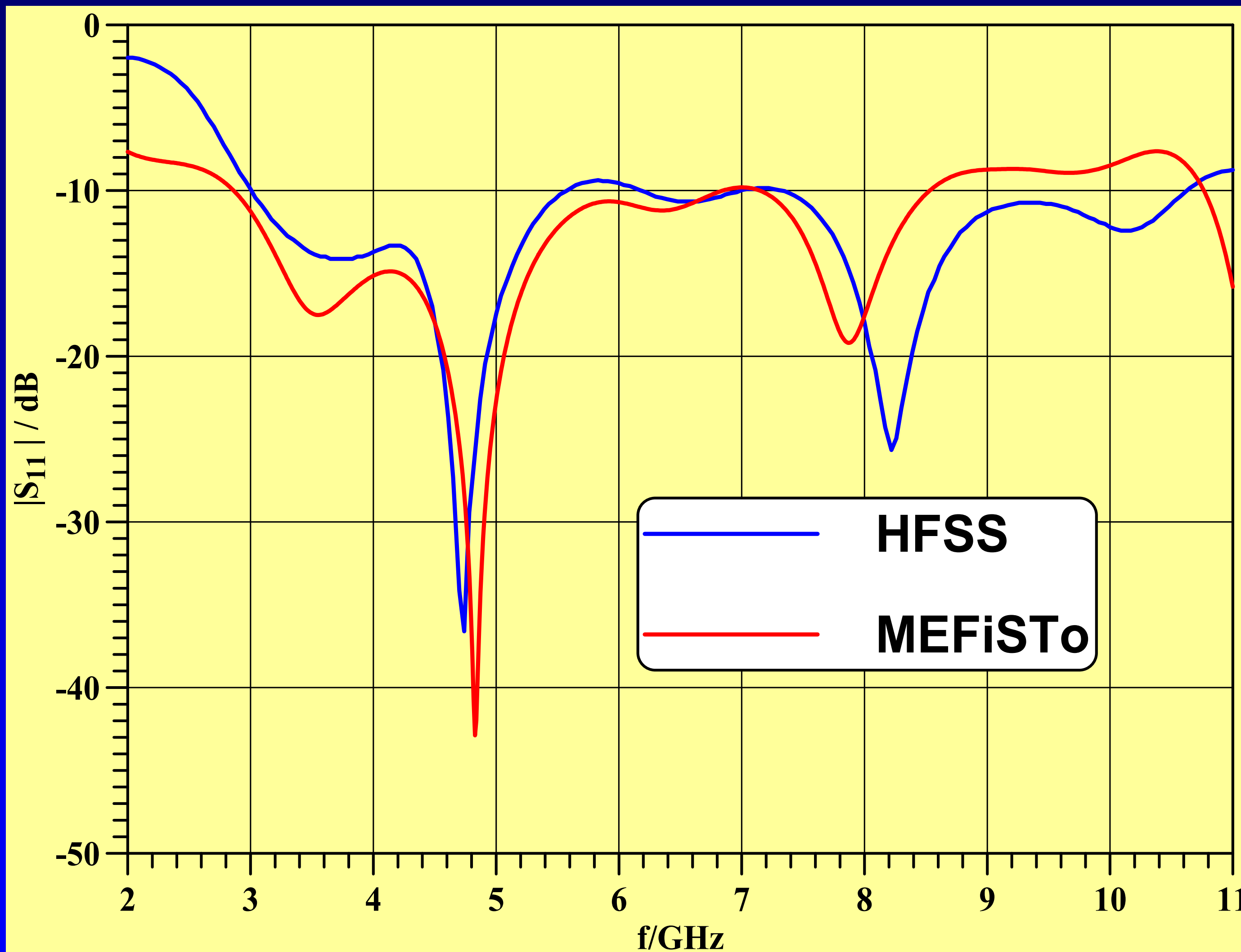
New CPW UWB antenna
for 3.1- 10.6 GHz band

Lam, Bornemann, EMC Symp., July 2007

Normalized Radiation Patterns



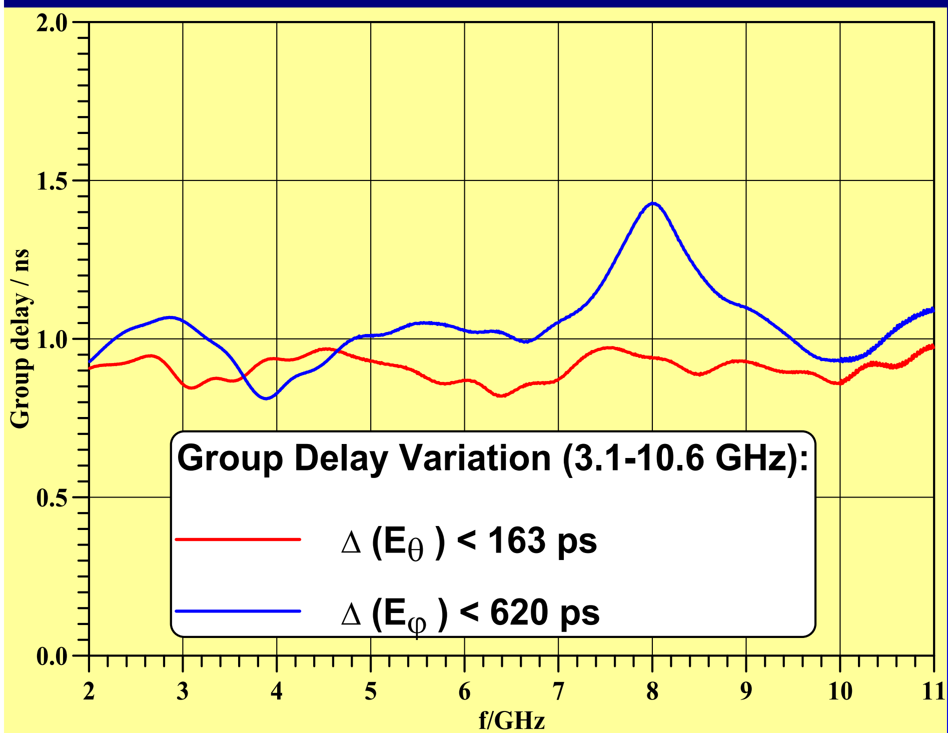
Input Return Loss ($|S_{11}|$)

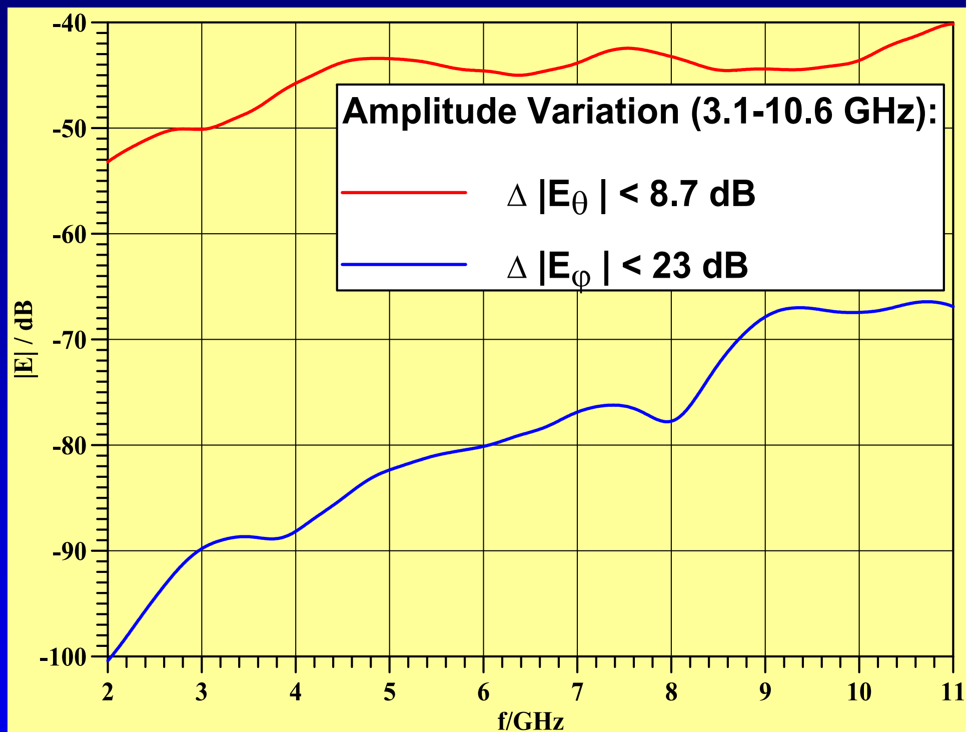


Input reflection coefficient: Comparison between HFSS and MEFiSTo

Note: Coax-to-CPW transition included in both models

Group Delay and Amplitude

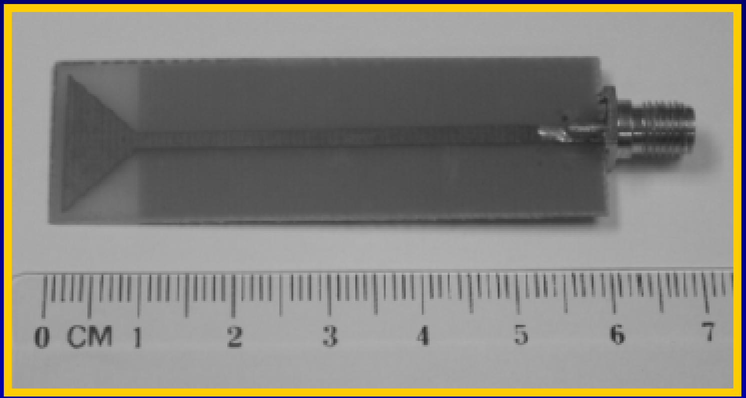




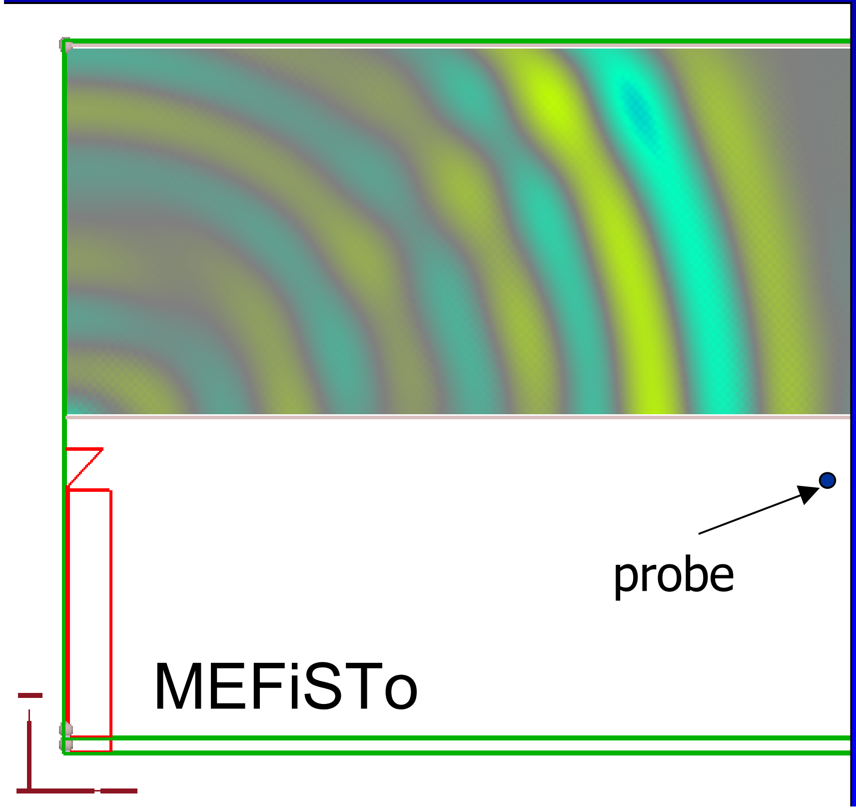
Note:

- Group delay variation in principal polarization is better than other published values.
- Variation in amplitudes are consistent with HFSS computations of radiation patterns.

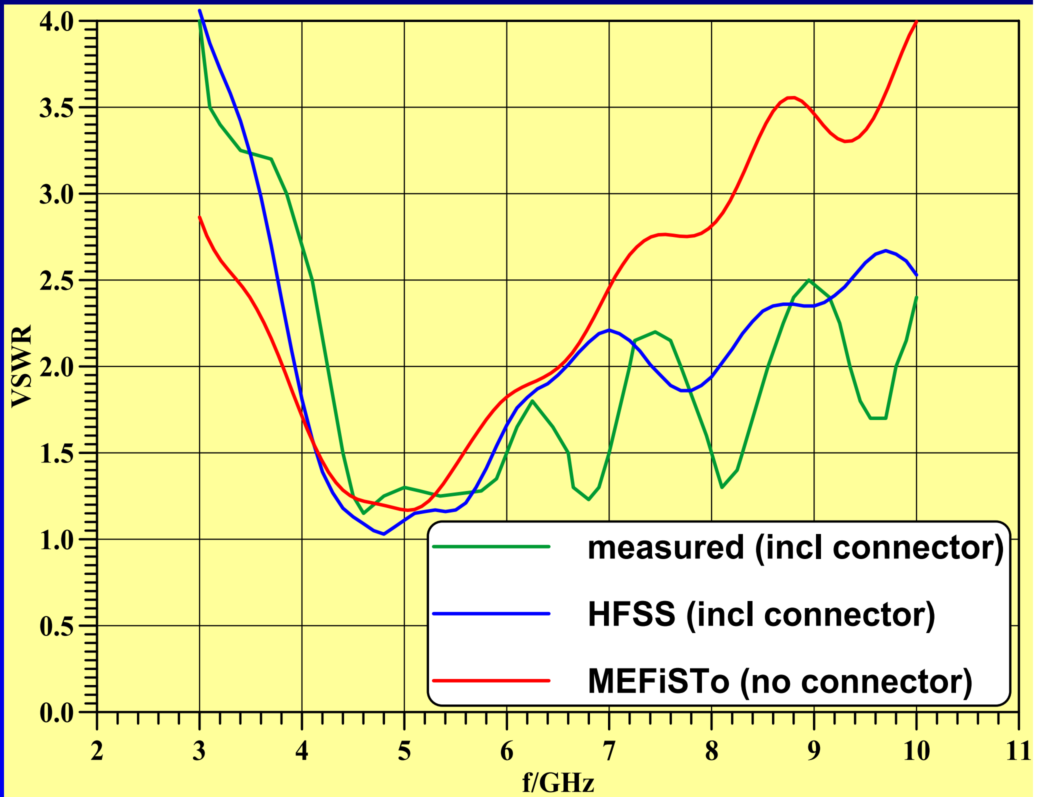
Microstrip UWB Antenna



Lin, Kan, Kuo, Chuang, MWCL, Oct. 2005

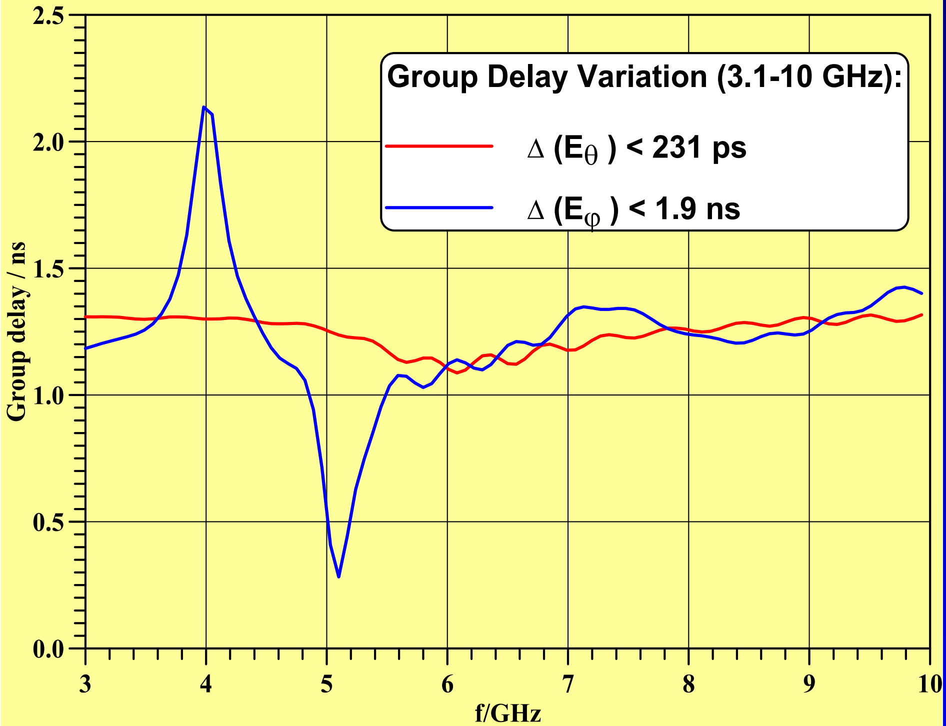


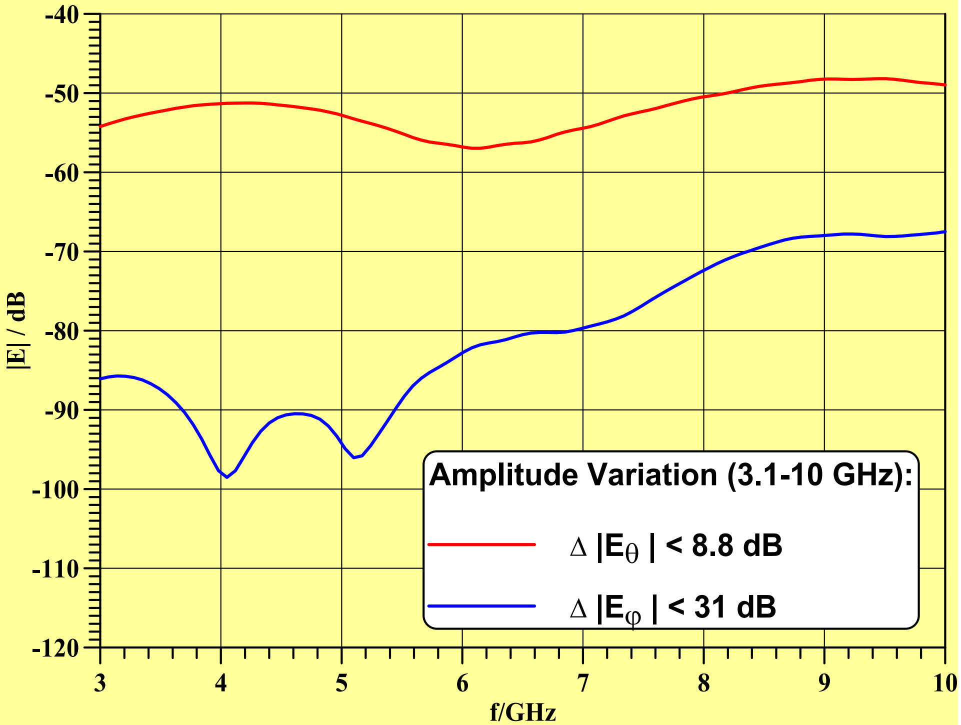
VSWR



Measured VSWR
< 3.7 (3.1 – 10 GHz)
< 2.5 (4.1 – 10 GHz)

Group Delay and Amplitude





Note:

- **Group delay variation is inferior to that of the CPW antenna.**
- **Amplitude variations in main polarization are almost identical.**

Comparison

3.1 – 10.6 GHz	Coplanar Antenna	Microstrip Antenna
VSWR	2.03	3.7
Group Delay Variation	< 163 ps	<231 ps
Amplitude variation	< 8.7 dB	< 8.8 dB

Note:

- Peak gain of CPW antenna: 1.7 – 5.1 dBi
- Comparable nearly omnidirectional radiation patterns; characteristic deteriorates towards 10 GHz.

Conclusions

- The Transmission-Line Matrix method in form of MEFiSTo-3D is applied to determine the group delay characteristics of printed-circuit UWB antennas.
- It is found that transient (time-domain) analysis has several advantages over frequency-domain phase center computations.
- The method is applied to two different printed-circuit UWB antennas, and their performances are compared.
- The design in CPW technology outperforms a comparable design using microstip circuitry.