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
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


3.1 - 10.6 GHz Variations ≈ 300 ps
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

**Frequency domain 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.

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No longer an option in HFSS!
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

$E_\theta(\theta, \pi/2)$

$E_\theta(\pi/2, \phi)$

$E_\theta(\theta, 0)$

$E_\phi(\pi/2, \phi)$
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

Amplitude Variation (3.1-10.6 GHz):
\[ \Delta |E_\theta| < 8.7 \text{ dB} \]
\[ \Delta |E_\phi| < 23 \text{ dB} \]

Group Delay Variation (3.1-10.6 GHz):
\[ \Delta (E_\theta) < 163 \text{ ps} \]
\[ \Delta (E_\phi) < 620 \text{ ps} \]

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)

HFSS (incl connector)
MEFiSTo (no connector)
measured (incl connector)
Note:

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

<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>Coplanar Antenna</th>
<th>Microstrip Antenna</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 – 10.6 GHz</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VSWR</td>
<td>2.03</td>
<td>3.7</td>
</tr>
<tr>
<td>Group Delay Variation</td>
<td>&lt; 163 ps</td>
<td>&lt; 231 ps</td>
</tr>
<tr>
<td>Amplitude Variation</td>
<td>&lt; 8.7 dB</td>
<td>&lt; 8.8 dB</td>
</tr>
</tbody>
</table>

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.