On the determination of the impulse response of Ultra-wideband antennas

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Each path of the impulse response between two antennas can be separated:

\[ h_{tx}(t, \phi_{tx}, \theta_{tx}) \quad h_{ch}(t, \phi_{tx}, \theta_{tx}, \phi_{rx}, \theta_{rx}) \quad h_{rx}(t, \phi_{rx}, \theta_{rx}) \]

Knowledge of the directional antenna impulse response (IR) allows for:

- Derivation of different antenna parameters, e.g. gain, group delay
- more realistic simulations e.g. in a raytracing environment
- design of more efficient receivers
Motivation

Antenna receive IR relates the incident E-field with the signal at the antenna feeding port by:

\[ \frac{u_{RX}(t)}{\sqrt{Z_C}} = \vec{h}_{RX}(t, \phi_i, \theta_i) \ast \frac{\vec{E}_i(t, \phi_i, \theta_i)}{\sqrt{\eta_0}} \]

Antenna transmit IR relates the signal at the feeding port with the transmitted E-field by:

\[ \frac{\vec{E}_{TX}(t, r, \phi_i, \theta_i)}{\sqrt{\eta_0}} = \frac{1}{r} \ast \delta(t - \frac{r}{c_0}) \vec{h}_{TX}(t, \phi_i, \theta_i) \ast \frac{u_{TX}(t)}{\sqrt{Z_C}} \]

Antenna transmit and receive IR relation given by Lorentz reciprocity:

\[ \vec{h}_{TX}(t, \phi_i, \theta_i) = \frac{1}{2\pi c_0} \frac{d}{dt} \vec{h}_{RX}(t, \phi_i, \theta_i) \]

\[ \Rightarrow {\text{Transmit Simulation in CST Microwave Studio can be used to characterize a passive antenna}} \]
A new method, the GTEM method, is presented using an easy setup to determine the receive IR:

\[ u_{tx,TG}(t) = \sqrt{\frac{\eta_0}{Z_C}} u_{tx,TG}(t) * \frac{h_{tx,TG}(t)}{\alpha r} \]
Outline

- Introduction of the cone antenna

- Simulation of the antenna IR using CST MWS
  - Simulation Setup
  - Deconvolution
  - Presentation of the CST / MATLAB framework
  - Results and Comparison

- Measurement of the antenna IR using the GTEM Method
  - Pulse propagation in GTEM Cells
  - Method description
  - Results and Comparison

- Conclusion
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Introduction of the cone antenna

UWB cone antenna

- mechanically simple to guarantee identical antennas
- nearly omnidirectional pattern
  => **single** impulse response to characterize azimuth plane
- low cross polarization
- compact size (20 mm x 20 mm x 20 mm)
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Simulation Setup

**Determine antenna transmit IR:**
- Extract E-field component in farfield condition
- Extract excitation signal
- Deconvolve both signals

**E-field probes (farfield)**
- Time consuming to define all probes

**Broadband Farfield Monitor**
- Check Farfield/RCS
- Check Transient farfields
Deconvolution

Applying a Wiener filter in the FD leads to the following deconvolution (see also [1]):

\[ H_{AUT,tx}(\omega) = \sqrt{\frac{Z_C}{\eta_0}} \frac{E_{tx}(\omega)U_{tx}^*(\omega)}{|U_{tx}(\omega)|^2 + \lambda} \]

\( \lambda \) aims to bound \(|U_{tx}(\omega)|^2 \) in case of low SNR.

Identify signal+noise and noise parts of the energy spectral density \( \Phi_{u_{tx},u_{tx}}(\omega) \)

\[ \int_{-\omega_s}^{\omega_s} \Phi_{u_{tx},u_{tx}}(\omega) d\omega = \gamma_{nn} \Phi_{u_{tx},u_{tx}}(\omega) \]

\( \lambda \) can be calculated with the “noise“ part which is limited by \( \omega_s \):

\[ \lambda = \max(\Phi_{u_{tx},u_{tx}}(\omega > \omega_s)) \]

- Framework allows for conversion of Antenna Farfield to MATLAB (time & freq dependent)
- Extraction of different parameters in MATLAB e.g. antenna impulse response, Gain
- Macro in CST includes GUI
- MATLAB script is guided in command line (GUI in next version)
- Downloadable soon (May 2010 after evaluation) at:
  http://www.ikt.uni-hannover.de/software.html
Results

- Plane wave to indicate to Lorentz reciprocity
- Perfect matching between all three extraction methods
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Pulse propagation in GTEM cell

absorber

septum

resistor network

input port
Simulation of pulse propagation in GTEM cell

- TEM waveguide developed 20 years ago
- frequently used measurement device in EMC for immunity and emission measurements
Measurement of pulse propagation in GTEM cell

- downtime \( t_D \) defines the time interval until reflections occur at the measurement position.
- Reflections are related to the rear end of the cell.
- IR of GTEM cell can be modelled by a **weighted dirac impulse response** (see also [2]).

As has been shown the impulse response of the GTEM cell can be modeled by a weighted Dirac impulse within downtime $t_D$.

$\Rightarrow$ applying time gating techniques, the IR can be modeled by:

$$\bar{h}_{TG}^{GTEM}(t) = \left(0, \frac{\eta_0}{Z_C} \frac{1}{\alpha d} \delta(t - \frac{t}{c_0}), 0\right)^T$$

$$\Rightarrow u_{tx,TG}(t) = \sqrt{\frac{\eta_0}{Z_C}} u_{tx,TG}(t) \star \frac{h_{rx,TG}(t)}{\alpha r}$$

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CST User Group Meeting 2010

S. Sczyslo
GTEM method: Tradeoff in antenna placement

- Respective downtime at AUT position
- Excitation pulse width
- GTEM cell
- Expected AUT’s impulse response length
- TEM field distortion by AUT’s size
GTEM method: Measurement Setup

Pulse Generator: $A = -1.9 \text{ V}$
$t_{\text{FWHM}} = 22 \text{ps}$

Oscilloscope:
$\text{av}_\text{cycle} = 1024$
$t_{\text{scale}} = 500 \text{ ps/div}$
$N_{\text{points}} = 405 \text{ pts/div (interpolation)}$
Results using a cutoff frequency $f_c = 15\text{GHz}$

- nearly perfect match between CST simulation and measurement with GTEM method
- slight oscillations for $t > 0.3 \text{ ns}$
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Conclusion

• It was shown how to determine the impulse response of an antenna by simulation and measurement

• A new framework taking advantage of CST MWS’s farfield monitor and MATLAB was presented

• GTEM method was presented as an efficient method to measure the antenna impulse response

• A nearly perfect match between both methods could have been achieved
Thank you for your attention