Very-Near-Field Solutions for Antenna Measurement Problems
Chamber on your Desktop

- **EMxpert**
  - EMC diagnostic tool to rapidly diagnose and solve EMC/EMS/EMI problems with real-time PCB emission analysis

- **RFxpert**
  - APM tool enabling to quickly evaluate performance and optimize designs with real-time antenna performance characterization
Fundamentals

- High-density planar antenna array
- High-speed electronic switching
- Very-near-field measurements
- Far-field calculation
- “Real-time” real-fast
- No chamber
RFxpert

Introduction to Near-Field Theory
Existing Solutions

- **Anechoic Chamber**
  - Slow testing
  - High CAPEX and OPEX
  - Real-estate
  - Qualified personnel

- **Reverberation Chamber**
  - Fast testing
  - No pattern
  - Qualified personnel
What is Near-Field?

- Anything not in the far-field
- Far-field is where the pattern is not changing with the distance
- Common definitions
- Usually stay out of the reactive region
Functionality

- **300 MHz to 6.0 GHz**

- **Far-field patterns and bisections**
  - EIRP / TRP / TIS Proxy
  - Circular and linear polarization

- **Very-near-field insights**
  - Amplitude
  - Phase
  - Polarity

- **Gain and efficiency**

- **DLL programming**
RF Test Solution

- Typically looking for far-field parameters
  - Gain, efficiency, pattern are basic measures
  - More complex applications such as Envelope Correlation, Axial Ratio and Beam Forming
- Debugging via near-field
Far-Field Measurements

- Far-field site far and demanding a large area
- Open-air-test-site (OATS) avoids reflections
  - Almost impossible in an urban environment
- Anechoic Chambers
Near-Field to Far-Field Transformation

- **Near-field measurement**
  - Smaller footprint
  - Can be as accurate as far-field

- **Near to Far projections**
  - Plane Wave/Modal Expansion
  - Magnetic currents
  - Genetic algorithms and more
Planar Near-Field Theory

- The radiation of the antenna can be described in terms of angular spectrum of waves
- Based on Huygen’s principle
- Fourier transform from near-field space to propagation vectors in far-field

Image: www.schoolphysics.co.uk
Planar Near-Field Theory

- An antenna can propagate in all directions
- The phases and amplitudes in each direction will vary
- In the near field all elements are interdependent
Planar Near-Field Theory

- Sample near field elements along a planar surface
- Measure amplitude and phase in each point
- Combination of phase fronts
Planar Near-Field Theory

- Use sampled points to reconstruct new phase fronts
- No difference between this and the original phase front that was sampled
Planar Near-Field Theory

- Separate the various phase fronts or plane waves based on their weightings.
- This set of plane waves in all directions is the plane wave spectrum.
Planar Near-Field Theory

Based on Maxwell’s equations and a source-less boundary condition we can construct the following equations

\[
E(x, y, z) = \frac{1}{2\pi} \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} A(k_x, k_y) e^{-jk\cdot r} \, dk_x \, dk_y
\]

\[
H(x, y, z) = \frac{1}{2\pi} \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} k \times A(k_x, k_y) e^{-jk\cdot r} \, dk_x \, dk_y
\]

The term \( k \) may be called the wave number vector and the terms in the integration represent a uniform plane wave propagating in the \( k \) direction

\[
A(k_x, k_y) e^{-jk\cdot r}
\]
And $A(k_x, k_y)$ can be determined by,

$$A_x(k_x, k_y) = e^{jk_z z_t} \frac{1}{2\pi} \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} E_x(x, y, z_t) e^{j(k_x x + k_y y)} \, dx \, dy$$

$$A_y(k_x, k_y) = e^{jk_z z_t} \frac{1}{2\pi} \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} E_y(x, y, z_t) e^{j(k_x x + k_y y)} \, dx \, dy$$
Planar Near-Field Benefits

\[ E(x, y, z) = \frac{je^{-jkr}}{r} k_z A(k_x, k_y) \]

- Simple Fourier transform
- Easy to calculate quickly
- Easy to sample data
A Very-Near-Field Implementation
Very-Near-Field Challenges

- Coupling unavoidable so make it predictable
- Static array has constant effect for each sample
Very-Near-Field Implementation

- Array of probes
- Addressable array of probes makes very-near-field sampling very fast and repeatable
- Small loops not sensitive but very broadband, with good isolation and polarization specifications
- Reference channel for phase measurement of active devices
Very-Near-Field Implementation
Results with Ideal Data

- Still have limitations of finite planar scans
- Hemispherical results
- Limited angular coverage
- $E$-theta always reduces to zero at horizon
Aggregate Node

- Combined scan results for full spherical far-field view
- User defined elevation for asymmetrical devices
Very-Near-Field Benefits

- Visualizing interference in the near-field
  - Resonance and mutual coupling
Very-Near-Field Benefits

- Antenna position
- Loading and field perturbation
Very-Near-Field Benefits

- Effects of Surrounding Material
Aggregated Very-Near-Field

- Multiple planar measurements combined together to provide larger effective scan area

- Multiple planar scans do not need to be co-planar
  - Can used to created 3D scan surfaces or even enclosed surfaces
Aggregated Very-Near-Field
RFxpert

- Fast measurements
  - Continuous “real-time”
  - Single scan < 1 second

- Compact tabletop instrument

- Cost effective solution

- Easy-to-use by any engineer
High Accuracy

- **Repeatability**
  - +/- 0.2 dB from one measurement to the next
  - +/- 0.5 dB within the white test zone

- **Relative accuracy**
  - +/- 0.5 dB comparative measurements
Absolute Accuracy Out-of-the-Box

- Aligned to the Atlanta CTIA Satimo chamber
- Re-align your RFxpert to your chamber
  - Portfolio of devices
  - $2\sigma = +/- 1.1\text{ dB at } 700\text{ MHz (better at higher frequency)}$
Absolute Accuracy Out-of-the-Box

- Aligned to the Atlanta CTIA Satimo chamber
- Re-align your RFxpert to your chamber
  - One device
  - $2\sigma = +/-0.54$ dB at 700 MHz

![Graph showing customized deviation between chamber and RFX2](chart.png)
Configuration

EMSCAN Application

VNA or BSE

RFxpert

Power Sensor

USB

GPIB

RF

USB
Frequency Scan

- Gain, efficiency, EIRP and TRP of a device at a discrete frequency and across a range of frequencies through remote control of a VNA

![Graph showing frequency scan results]

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Efficiency</th>
<th>Gain</th>
<th>EIRP</th>
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</thead>
<tbody>
<tr>
<td>1880.00</td>
<td>73.91</td>
<td>6.66</td>
<td>6.66</td>
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</table>
Circular Polarization

- LHCP / RHCP / AR over a range of ±30° from the center line
Aggregate Node

- Combined frequency scanning results for full spherical far-field view
- User defined elevation for asymmetrical devices
Very-Near-Field

- Insights into design issues
Comparison with Simulation
Simulation

Agilent EDA simulation

Toyo corporation (EMSCAN Representative)
Tokyo, Japan
June 19, 2012
4 ブランチアンテナ

位相重みづけ

3cm上方磁界強度　遠方界
<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
<th>Farfield (dBi)</th>
<th>mag (Hx)</th>
<th>mag (Hy)</th>
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<tbody>
<tr>
<td>Mode 1:</td>
<td>4つとも同位相</td>
<td>EMPro</td>
<td>EMPro</td>
<td>EMPro</td>
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<tr>
<td>Mode 2:</td>
<td>上下で逆相</td>
<td>EMPro</td>
<td>EMPro</td>
<td>EMPro</td>
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<tr>
<td>Mode 3:</td>
<td>左右で逆相</td>
<td>EMPro</td>
<td>EMPro</td>
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<tr>
<td>Mode 4:</td>
<td>斜め同士が</td>
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<td>EMPro</td>
<td>EMPro</td>
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</table>
Comparison with Chamber Results
Mobile Phone Efficiency

Note: Low band offset applied by customer
Mobile Phone Efficiency

Note: Low band offset applied by customer
Mobile Phone Efficiency

Note: Low band offset applied by customer
Patterns of Various Mobile Phones

CTIA

RFxpert
Passive Antenna Results

- 47 antennas measured in CTIA MVG Satimo chamber
  - 20 PIFAs, 10 Patch designed by EMSCAN
  - 17 acquired antennas are a mix of different sorts
PRAD Offset Table

Re-alignment process

<table>
<thead>
<tr>
<th>Band 5</th>
<th>Freq 1</th>
<th>Chamber</th>
<th>EMSCAN</th>
<th>Error</th>
<th>Applied Error</th>
<th>Adjusted</th>
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<td>-0.78</td>
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<td>-1.42</td>
<td>19.51</td>
<td></td>
</tr>
</tbody>
</table>
Cellular Phone

- Power and pattern measurements at a single channel or a series of channels through the remote control of a Base Station Emulator
IoT

- Fast pre-certification
Cellular Base Station Antenna
Testing of Large or Long Antennas
Phase Center
Wi-Fi

- Any customized pulse up to 60-second timeout
Phased Array Antenna

- Phase balancing

Picture from www.mathworks.com/
GPS Antenna

- Circular Polarization
MIMO

- Very-near-field for antenna diversity and mutual coupling
- Far-field for real-time tuning
- Correlation
  - Envelope and pattern correlation
    - Hemispherical RFX
    - Spherical RFX2
Smart Meters

- **Connectivity with**
  - GSM, Mobile
  - WLAN / WiFi
  - ZigBee
  - M-Bus
  - Custom
  - Others ...

- **Measurement of antennas**

- **Measuring active device with long timeout**
Conclusion
Very-Near-Field Benefits

- Ability to see surface currents
- Very fast scanning
- Repeatable
- No chamber
- Low maintenance
- Easy to use
RFxpert Advantages

- Interaction effects in real-time
- Very-near-field measurements
- Fast and repeatable
- Low CAPEX
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