Advanced RF Design and Measurement Tools

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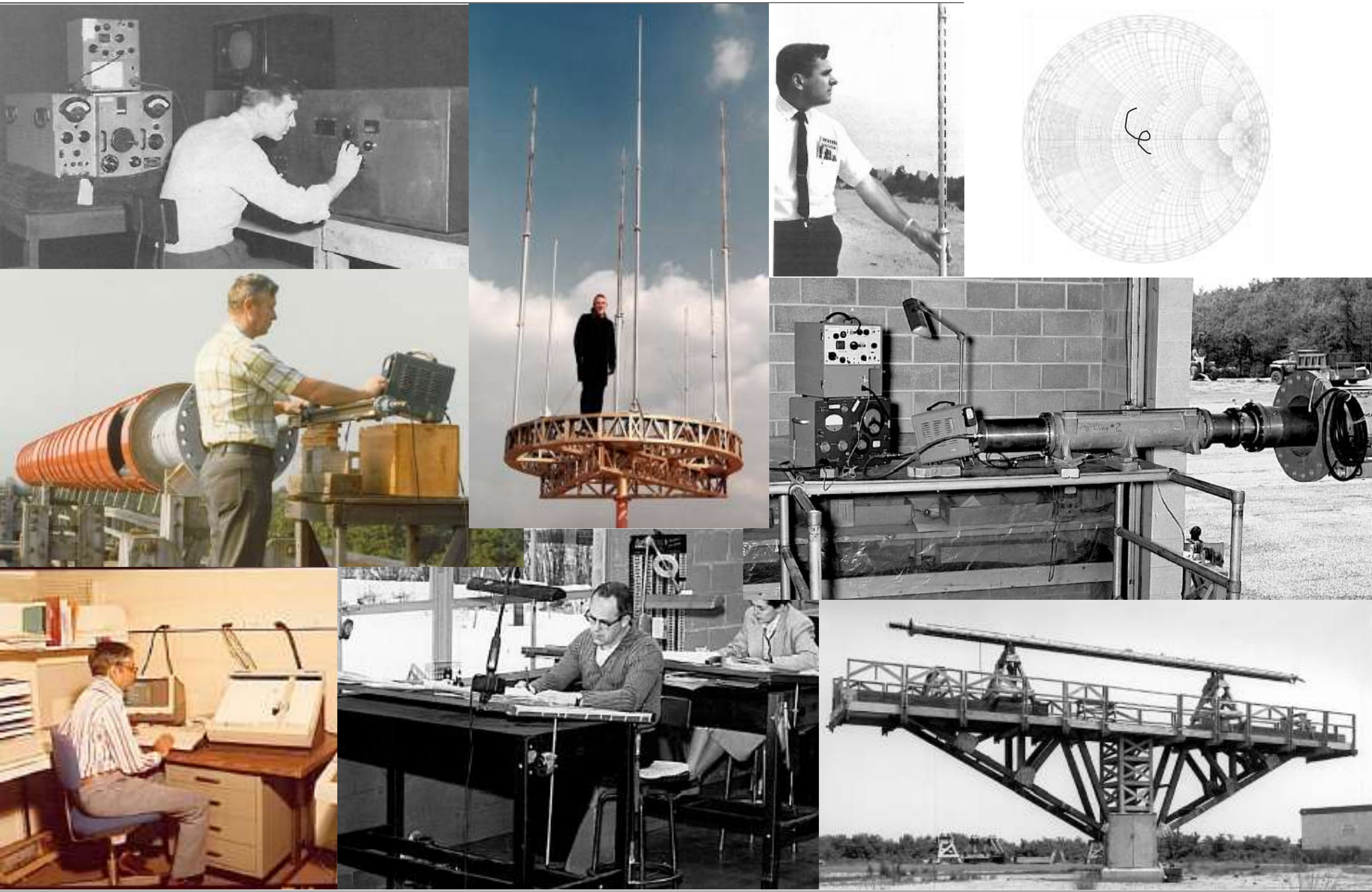
GLOBAL INFRASTRUCTURE X PROCESS EQUIPMENT X DIAGNOSTIC TOOLS

Who remembers these days?



Today’s presentation

- Advanced measurement tools
  - Near field
    - Indoor
    - Outdoor
- Advanced RF design tools
  - Simulation

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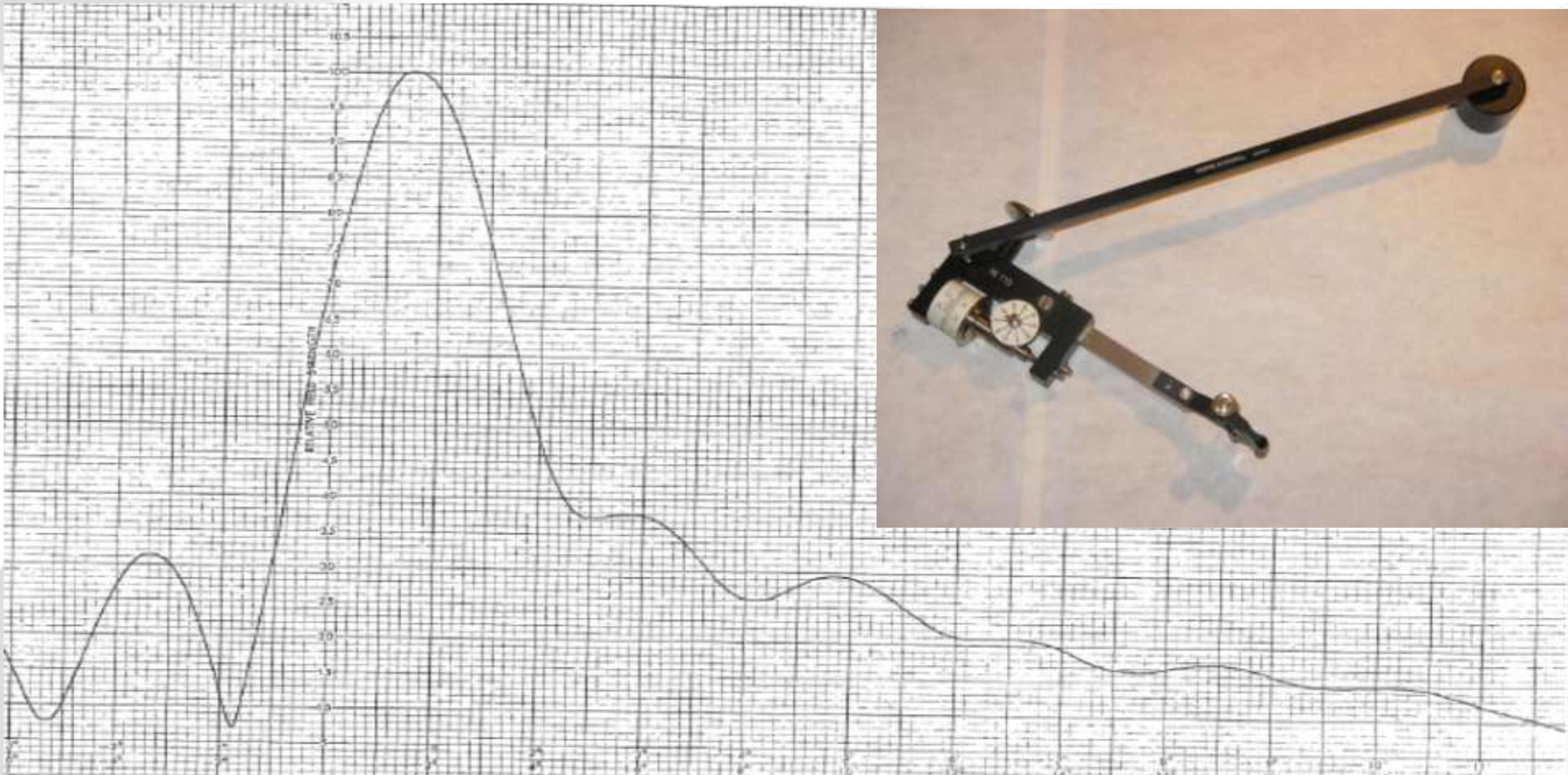
Antenna test and measurement tool trivia question

What is this and why would it be needed for testing antennas?

Planimeter

- Measures area within an arbitrary two dimensional shape
- Antenna gain is inversely proportional to the normalized area within the radiation pattern

$$D = \frac{1}{\frac{1}{4\pi}\int_0^{2\pi}\int_0^{\pi}\left|F(\theta,\phi)\right|^2 \sin\theta d\theta d\phi}$$



Far field

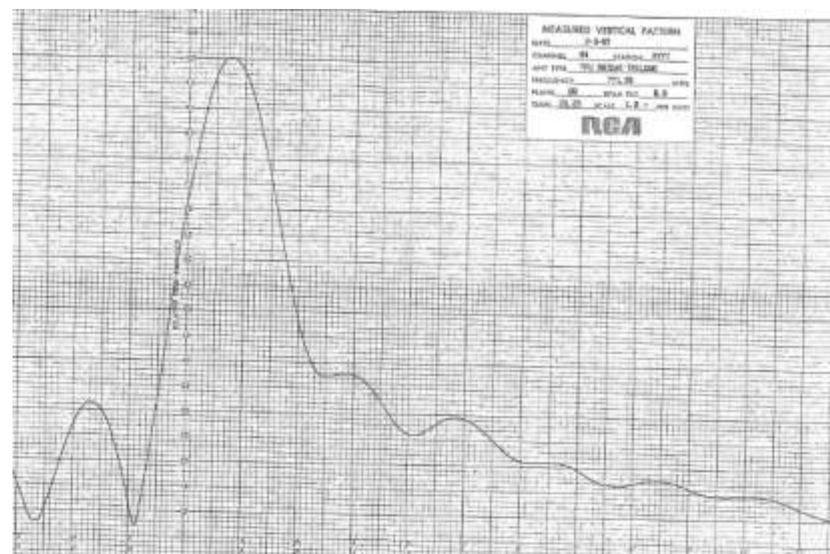
For 40 years RCA depended on far field testing to measure the patterns of broadcast antennas


Far field range RCA / Dielectric Voorhees NJ

Limitations

- Required remote Tx site
  - FF of typical UHF broadcast antenna is approx. 1 mile
- Single cut measurements
- Provided no information to help tune or diagnose a problem

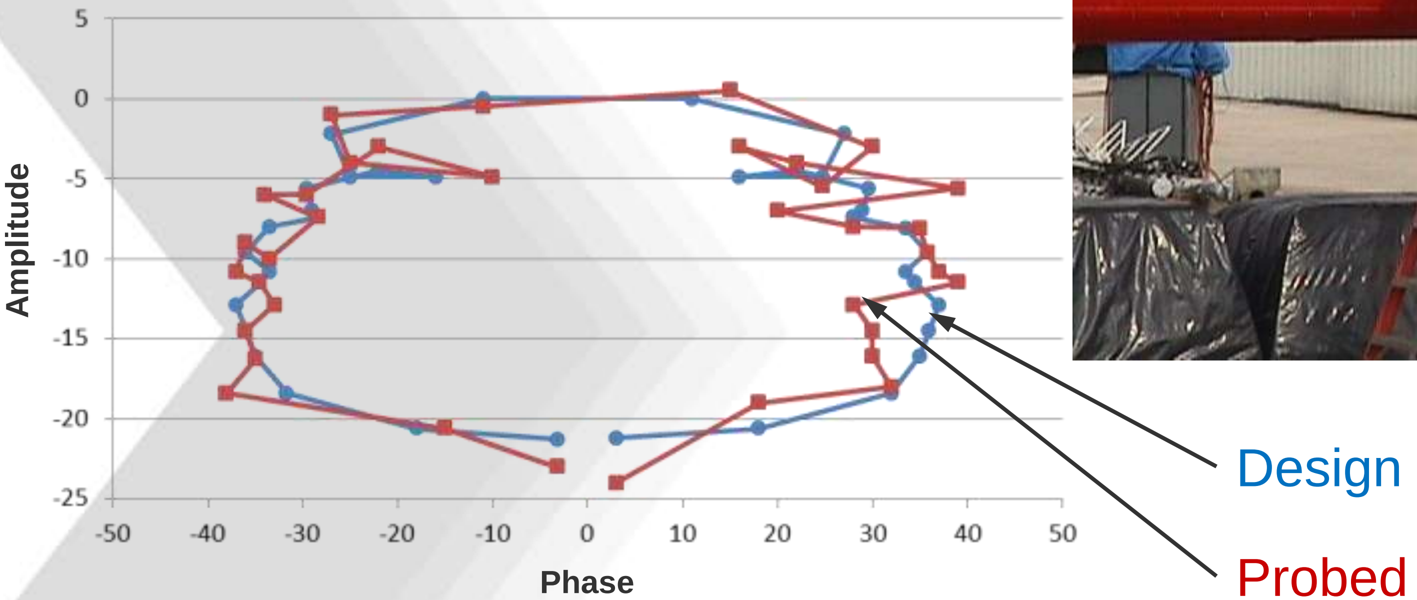
Tuning procedure – Trial and error



Aperture probing

Far field replaced with aperture probing

- Samples the radiated amplitude and phase along the aperture and uses array theory to calculate the far field pattern
- Provides data that can be used for analysis and tuning



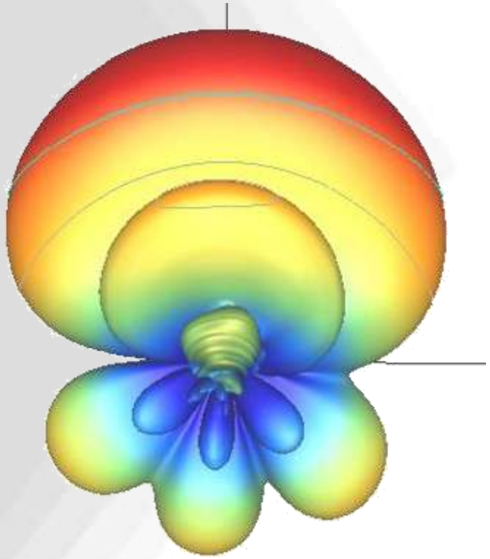
Limitations

- Simple plane analysis
- Limited to elevation plane analysis

The need for complete characterization

Simple single cut approaches may be accurate enough for most applications and studies, but in some cases, more careful antenna planning is necessary to limit contours or prevent interference.

- Distributed transmission systems
- Radiation exposure
- Effect of mechanical tilt
- Elevation patterns of asymmetrical antennas

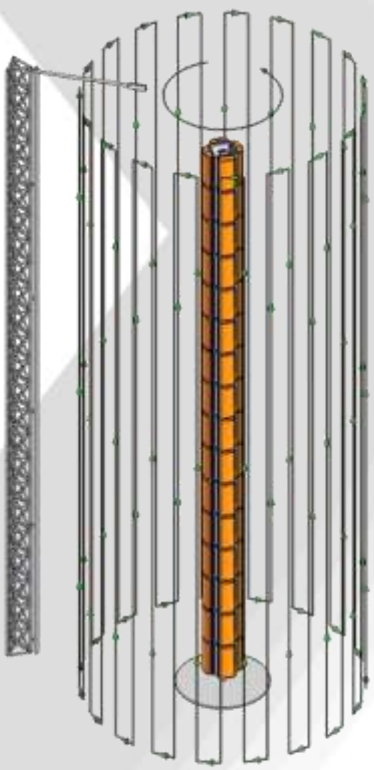


Not all side lobes lie in a principle plane, therefore a 3D understanding of the antenna's radiation pattern may be desired.

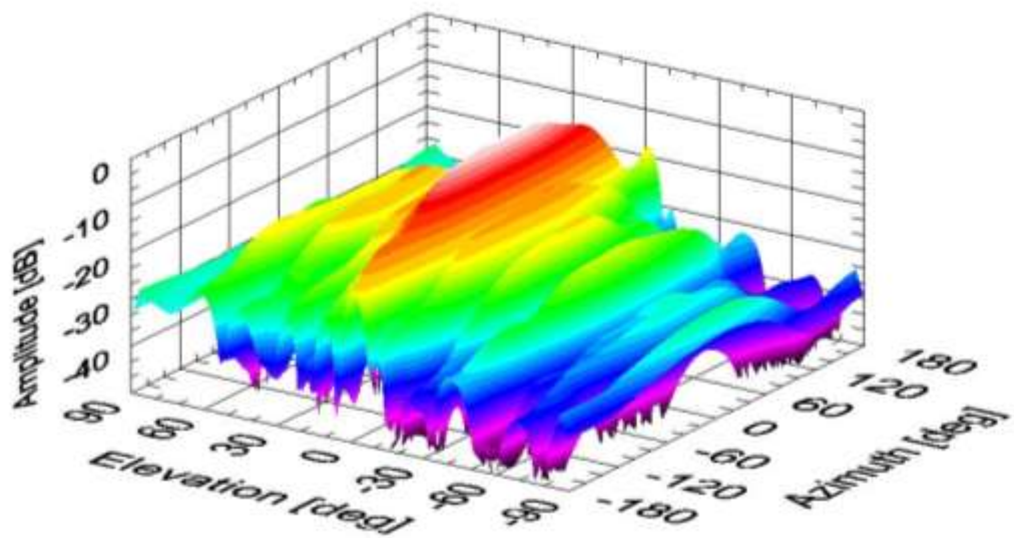
Near field testing

A cylindrical near field system measures the energy in the radiating near field region and converts the measurements by Fourier transform into the far field.

Collect data on an imaginary cylinder



Transform data to the far field and fully characterizes the 3 dimensional radiation pattern



Advantages of near field measurements

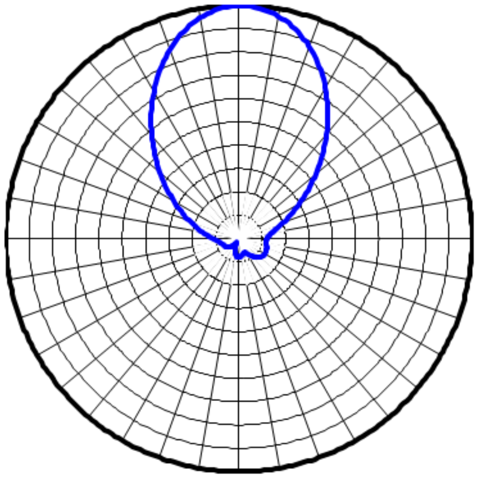
- Near field only requires one site location and less real estate
  - Elevation cuts are made with antenna standing upright
- Near field is not susceptible to multipath

Far field range RCA / Dielectric, Voorhees NJ

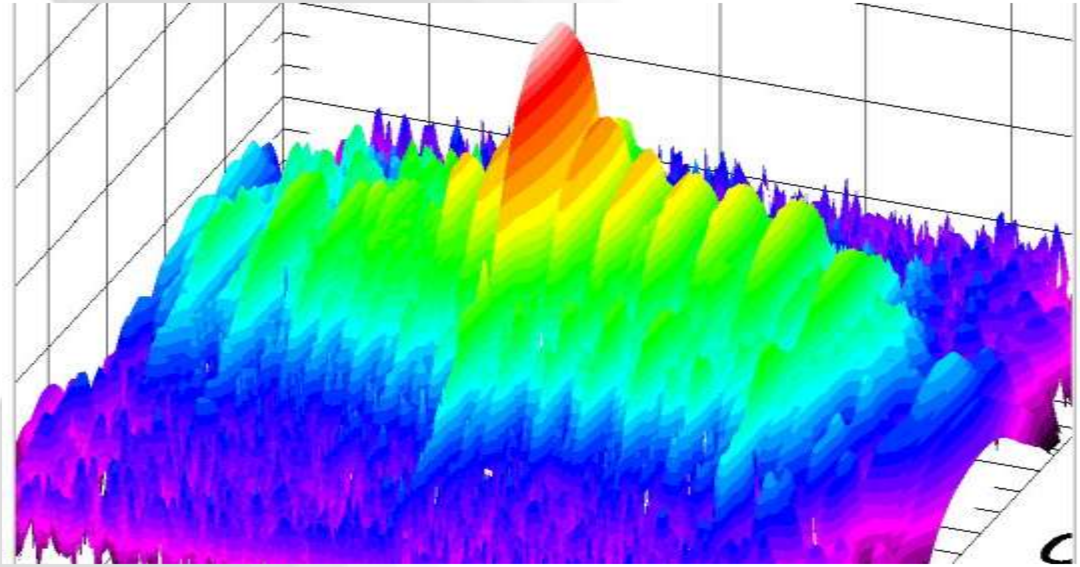
Near field range SPX / Dielectric, Raymond ME

Advantages of near field measurements

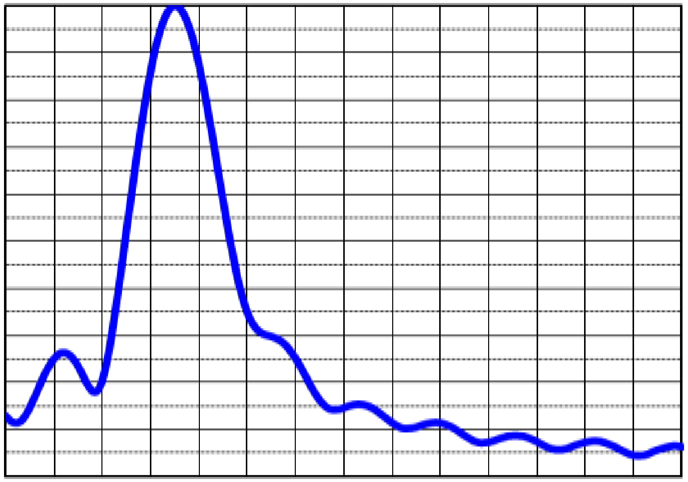
- Complete pattern and polarization information
- Any cut can be extracted from the 3 dimensional pattern
- Back projection
  - Detection of anomalies
- Field can be calculated at any distance from the antenna



Azimuth pattern cut



3D radiation pattern



Elevation pattern cut

Near Field Ranges

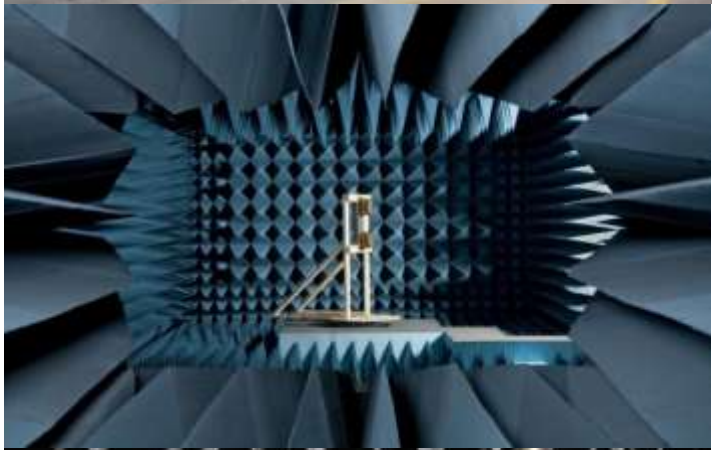
GLOBAL INFRASTRUCTURE **X** PROCESS EQUIPMENT **X** DIAGNOSTIC TOOLS

SPX indoor range

60’ Tapered Anechoic Chamber

- Far field and near field capability
- Frequency range 400 MHz to 6 GHz
- 6’ quiet zone
- VPOL <-36 dB of reflectivity
- HPOL <-40 dB of reflectivity
- Aperture sizes < 8’ X 6’

Excellent for characterizing individual panels



SPX outdoor range

85’ scanner capable of measuring apertures up to 15’ in diameter and weighing over 10 tons

- Frequency range 400 MHz to 6GHz
- Probe tolerance +/- ¼”
    - Sidelobe lobe error < +/-2dB at -30 dB level

Largest cylindrical near field range in the US.
Second largest in the world!

Near Field Measurement Example

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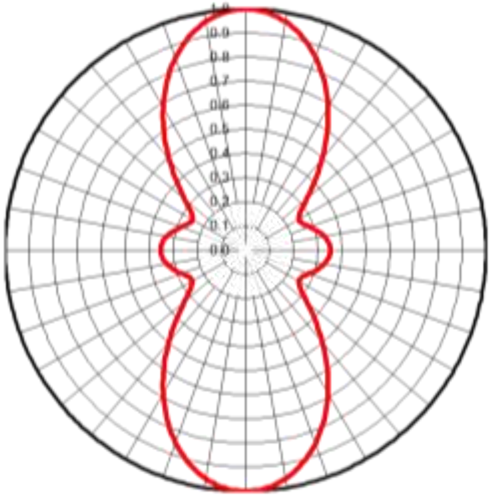
TFU – 8 DSB/VP P270 Ch. 25

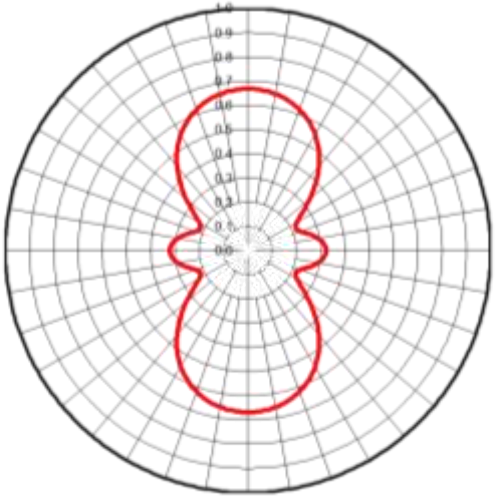
SPX

Proposed performance

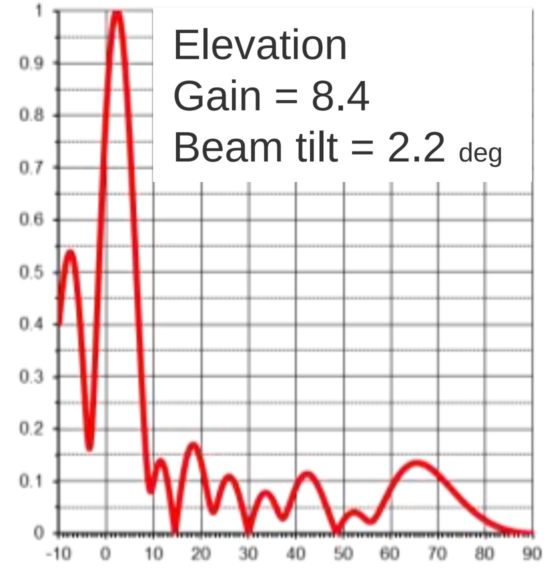
Azimuth - Hpol
Gain = 2.7



Azimuth - Vpol
Gain = 2.1



H/V split 63% / 37%
Hpol gain = 11.58 dBd
Vpol gain = 8.1 dBd

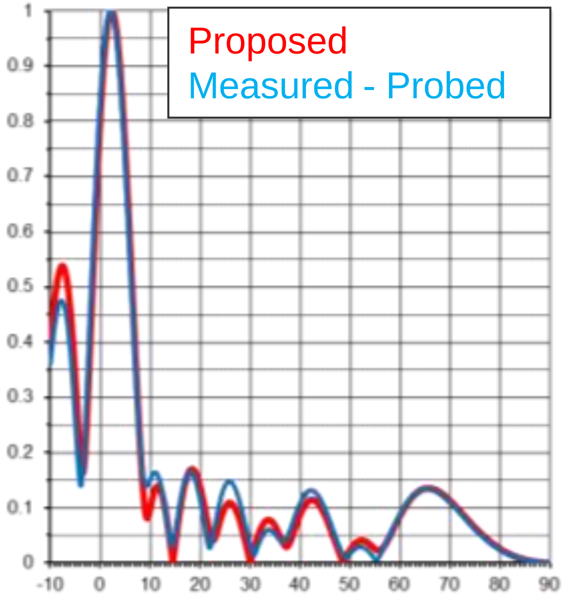


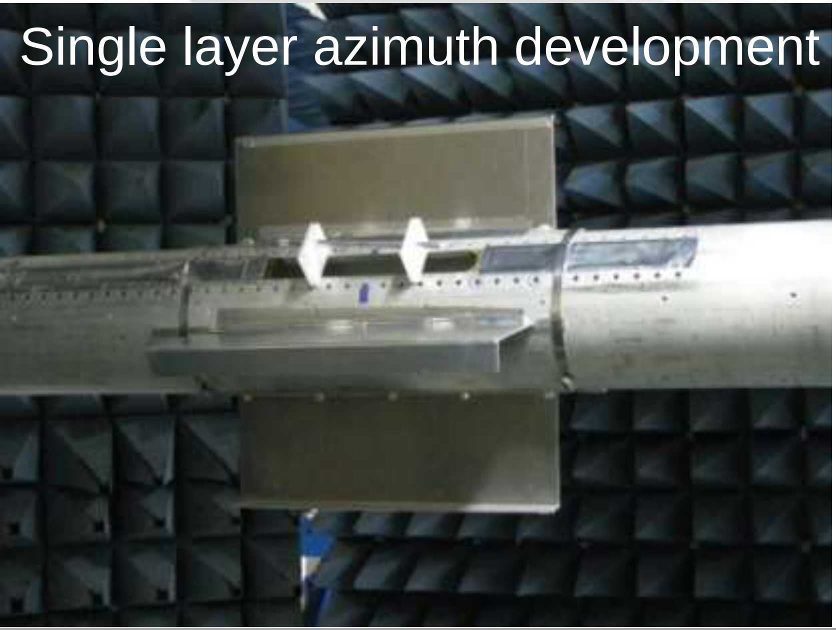
TFU – 8 DSB/VP P270 Ch. 25

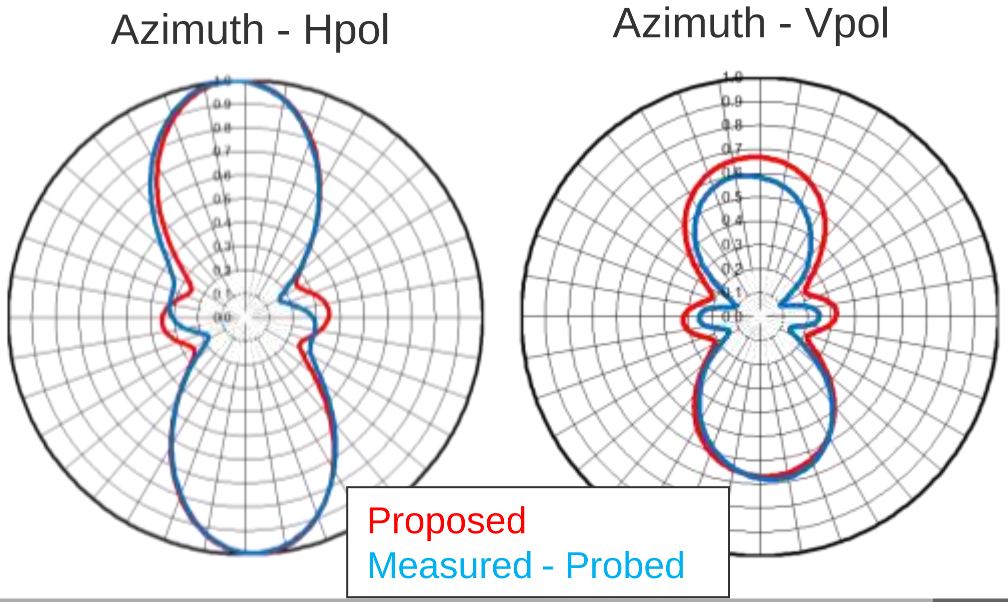
Conventional testing
Principle plane

Elevation gain = 8.59
Beam tilt = 2 deg
Az Hpol gain = 2.74
Az Vpol gain = 2.74
H/V split = 68% / 32%

Hpol gain = 11.97 dBd
Vpol gain = 8.62 dBd





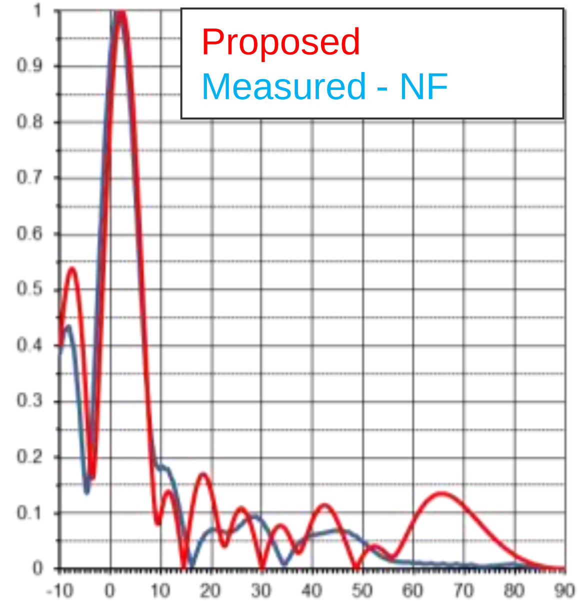


TFU – 8 DSB/VP P270 Ch. 25

Near field testing
Principle plane

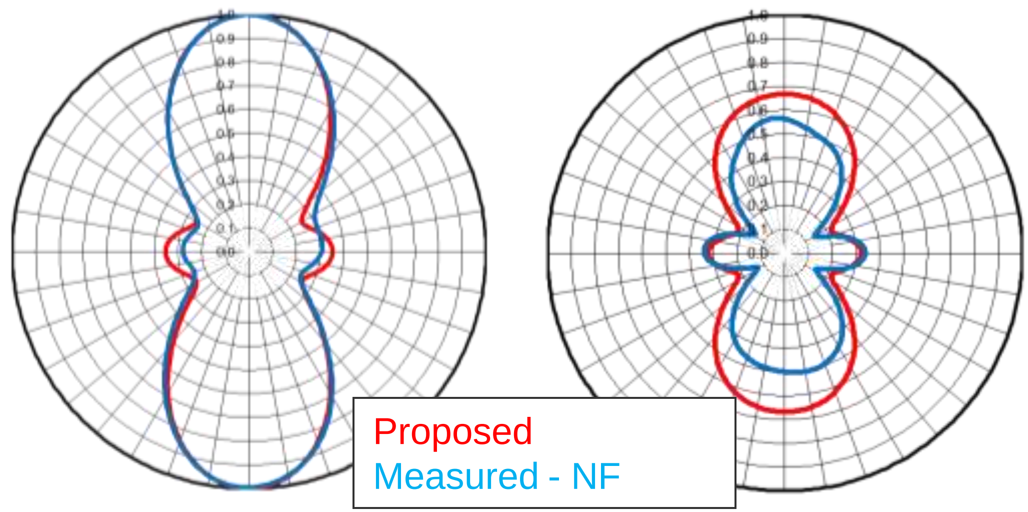
Elevation gain hpol = 8.81
Elevation gain vpol = 8.70
Beam tilt = 2 deg
Az Hpol gain = 2.72
Az Vpol gain = 2.33
H/V split = 71% / 29%

Hpol gain = 12.3 dBd
Vpol gain = 7.6 dBd



Azimuth - Hpol

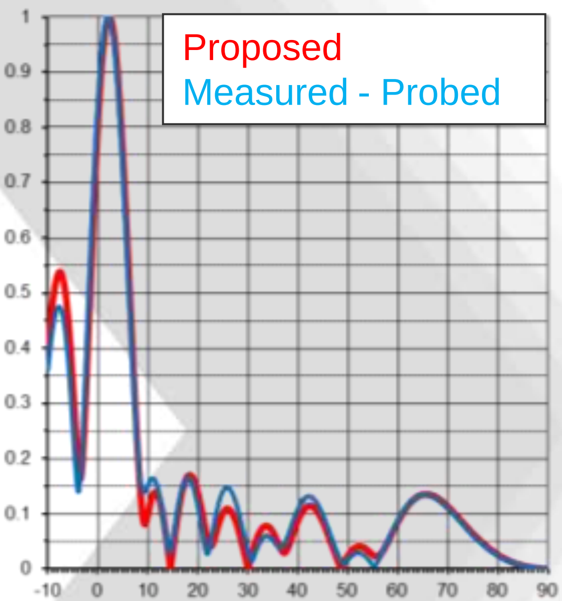
Azimuth - Vpol

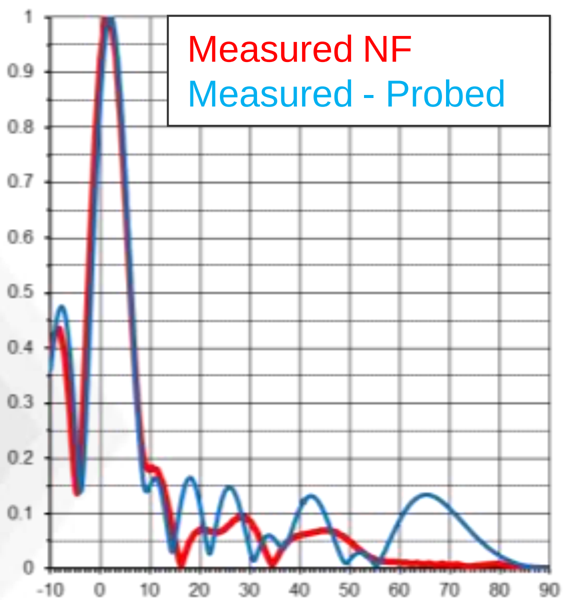


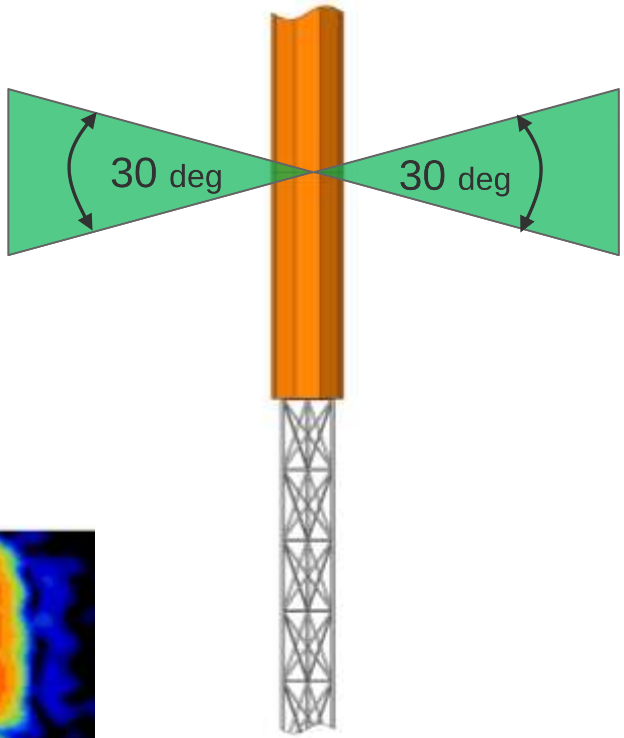
Near field measurements

Observation

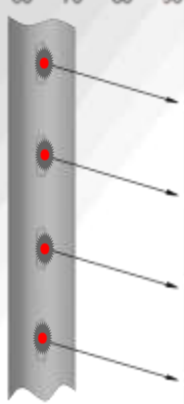
- Techniques using simple array theory are sufficient for predicting and testing typical broadcast antenna performance from -15 to 15 degrees.



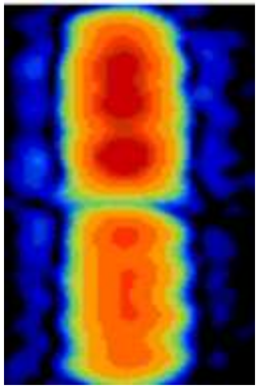




Array theory assumes point sources separated by a distance



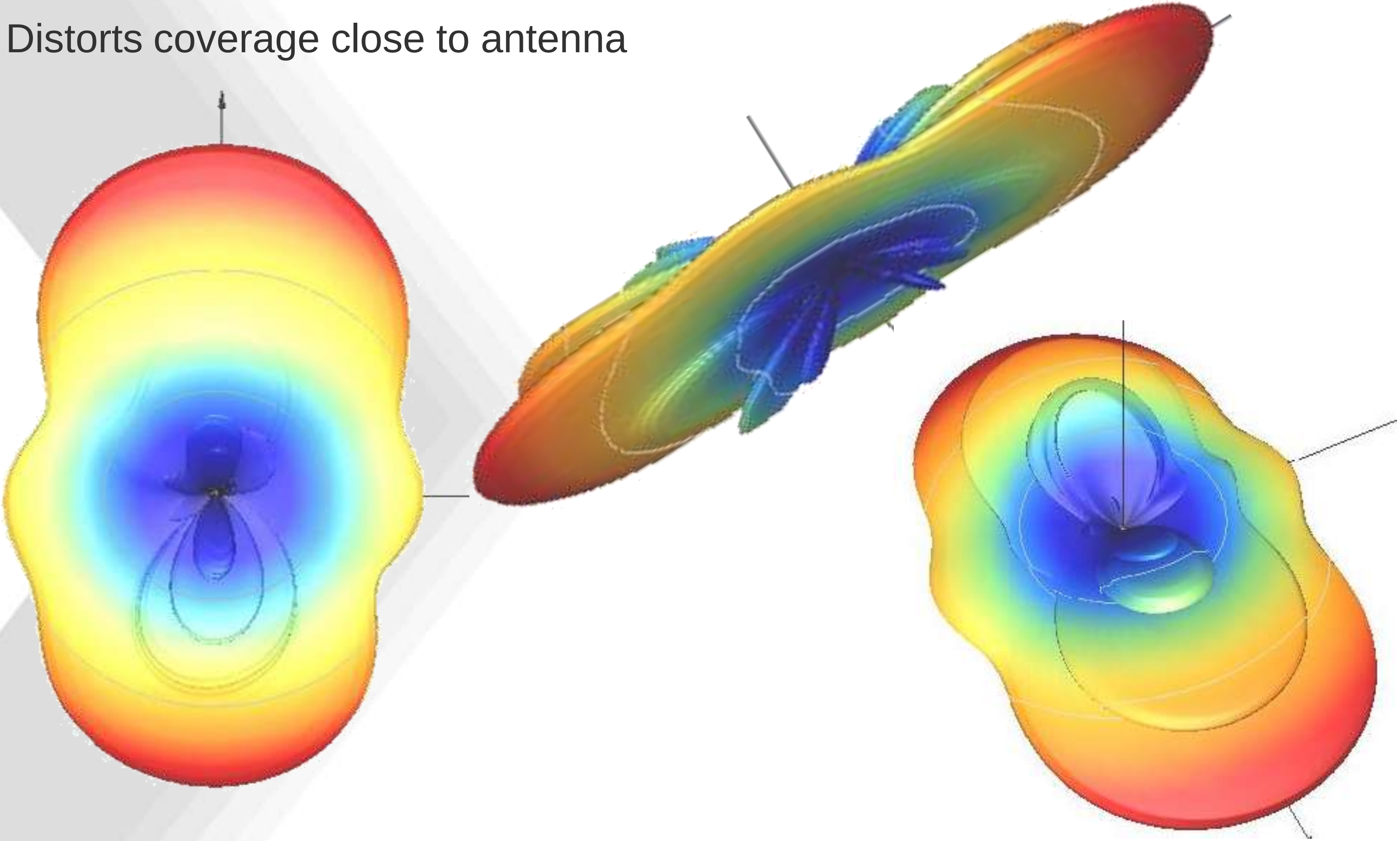
NF uses actual current distribution along the entire aperture



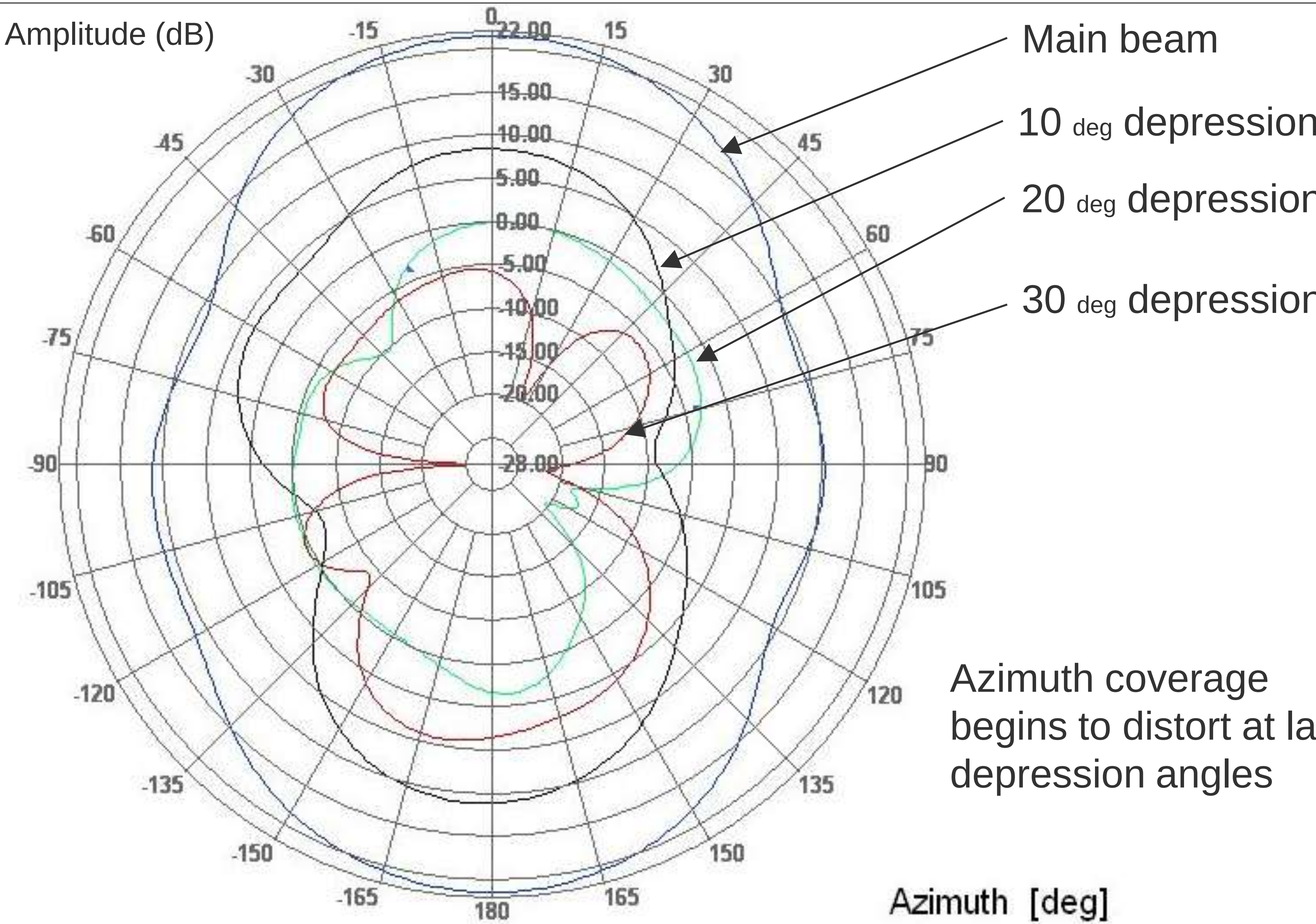
Near field measurements

3 dimensional view reveals non-symmetries at large depression angles

Distorts coverage close to antenna



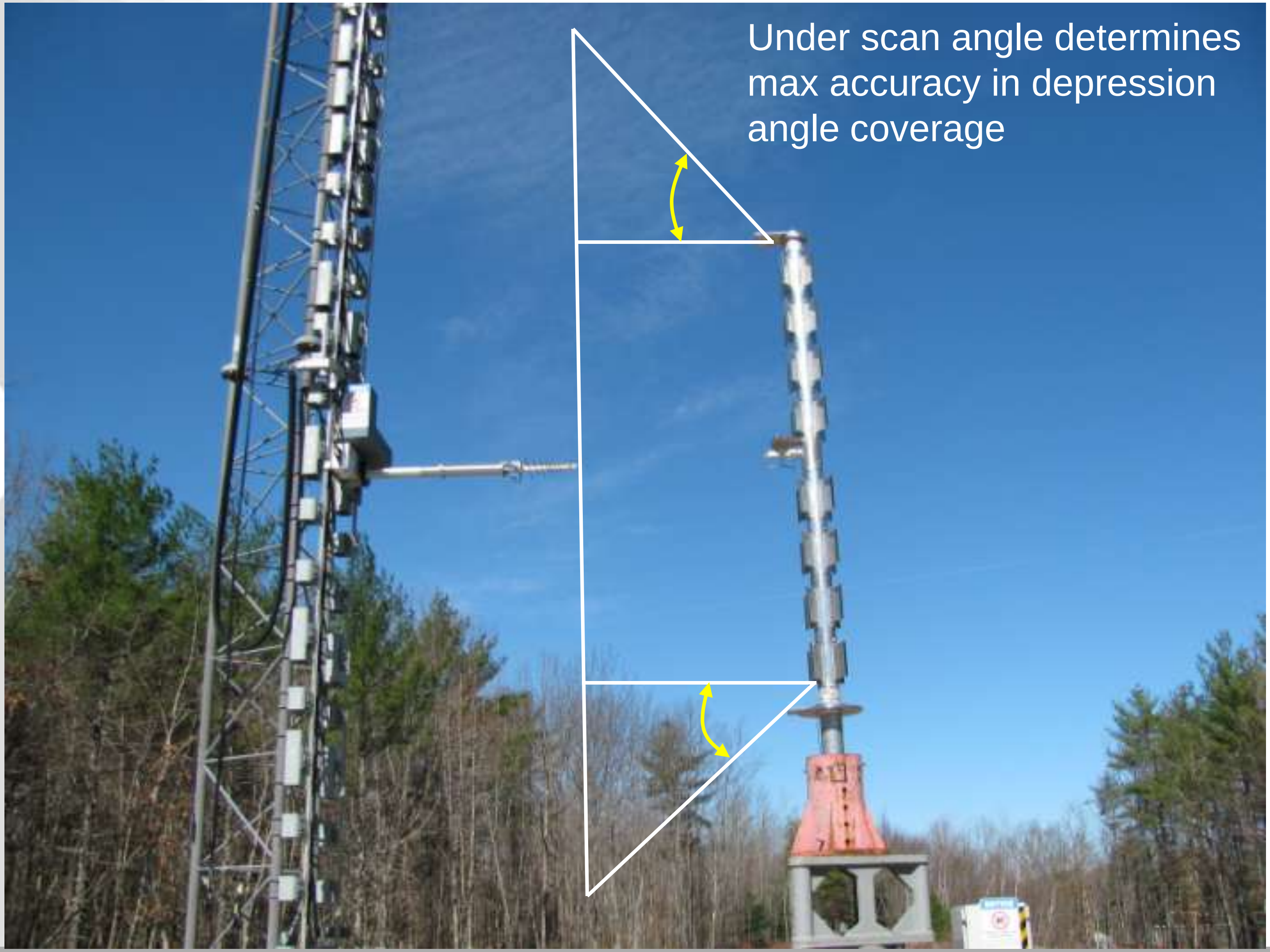
Near field measurements



Azimuth coverage begins to distort at large depression angles

Limitation of cylindrical near field

Accurate large depression angle measurements are limited by how much over and under scan can be achieved

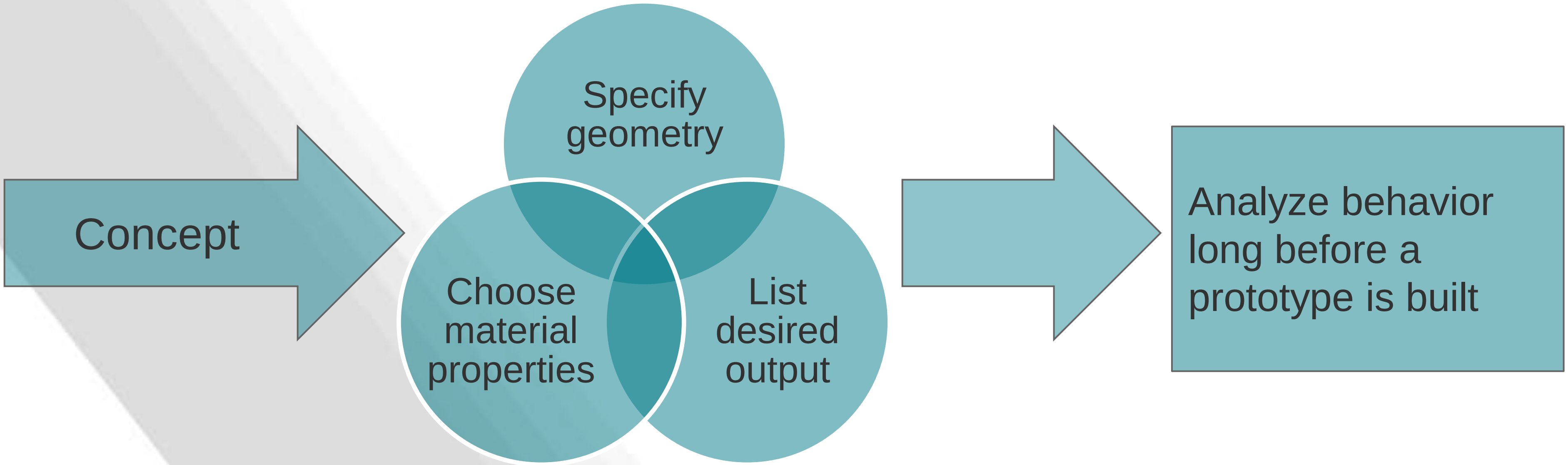


Electromagnetic Simulation

GLOBAL INFRASTRUCTURE X PROCESS EQUIPMENT X DIAGNOSTIC TOOLS

Electromagnetic simulation

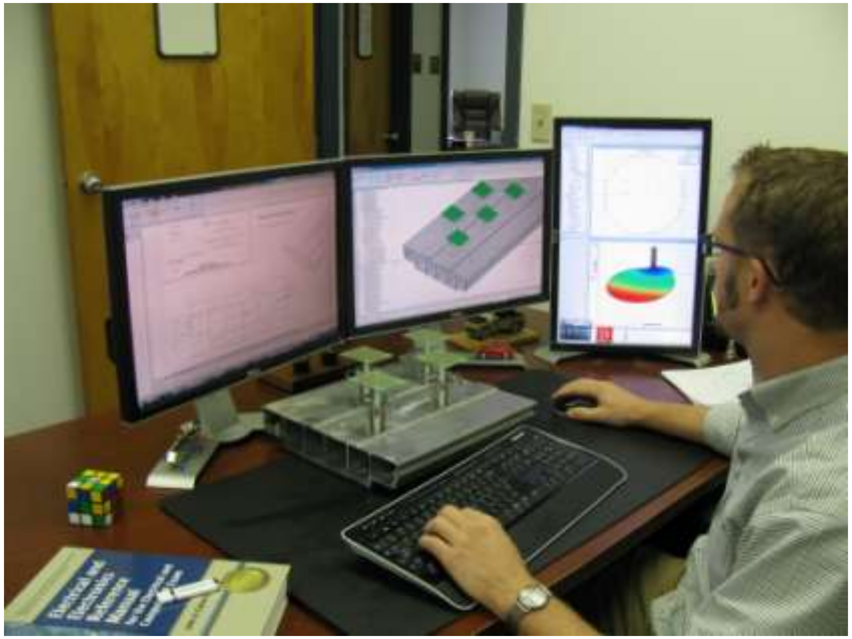
RF development in a virtual environment



- Commercial tool
  - HFSS – “High Frequency Structural Simulator”
    - Invested > $500,000
    - 7 Solvers
    - 9 Pre and Post Processors
    - 2 Designers

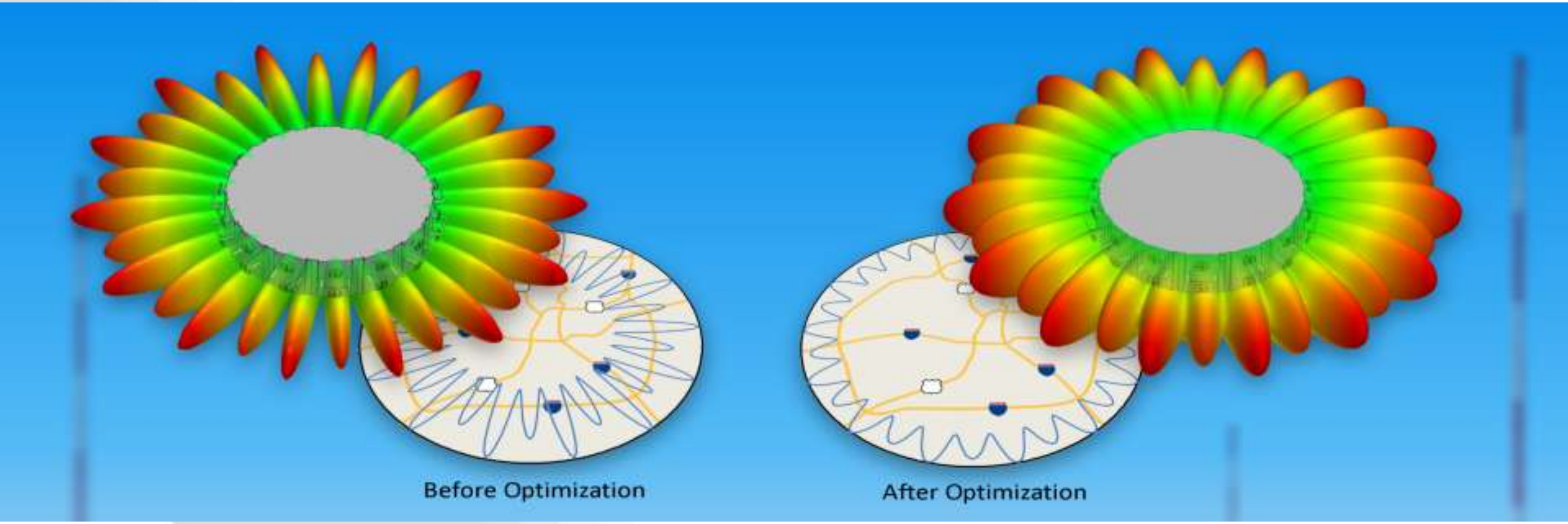
Advantages of electromagnetic simulation

- Design cost
- Design time
- Prototype cost
- Material choices
- Time to market



You don't have to cut chips until you know it works.

Broadcast applications



- Broadcast applications for electromagnetic simulation
  - TV / FM pattern optimization
  - TV / FM new product development
  - RF component design
    - Power dividers
    - Hybrids
  - TV / FM filter design
  - FM pattern studies

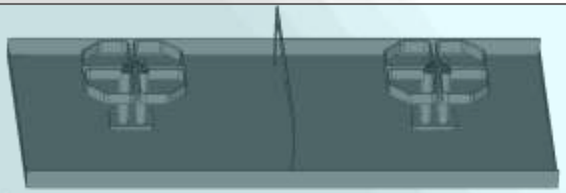
HFSS Design Examples

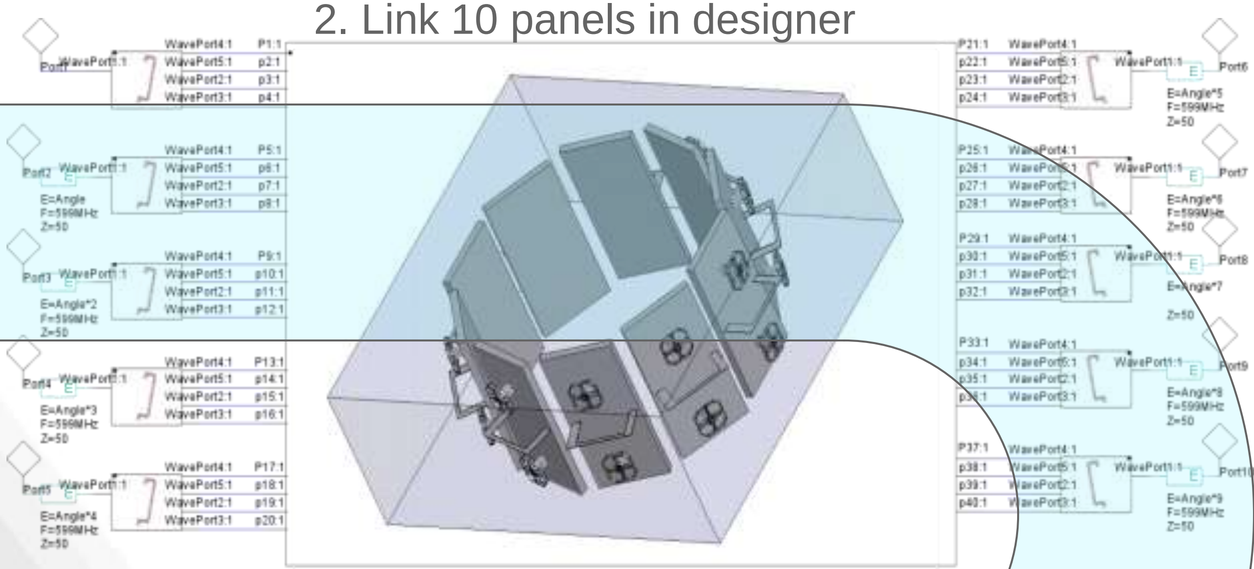
TUM Panels

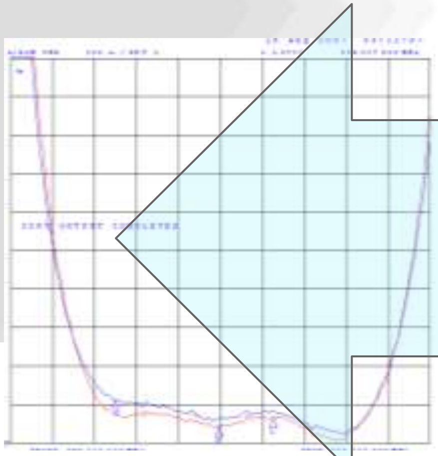
Design of a 10 around UHF TUM broadcast antenna system

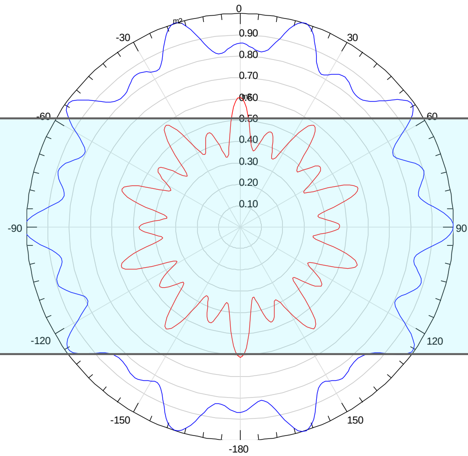
2. Link 10 panels in designer

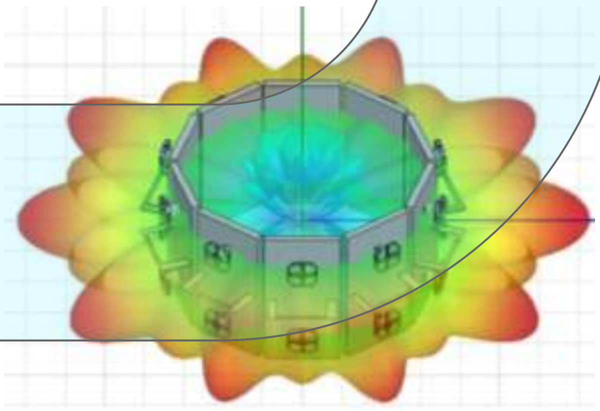
1. Model individual panel











5. Broadband panel with mutuals

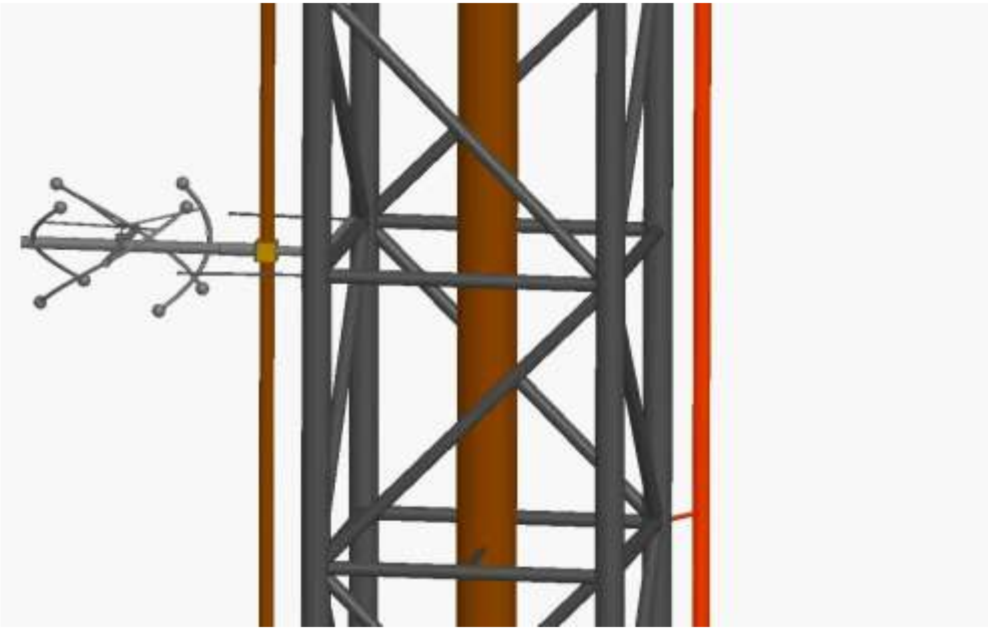
4. Design phasor pack for desired H/V ratio

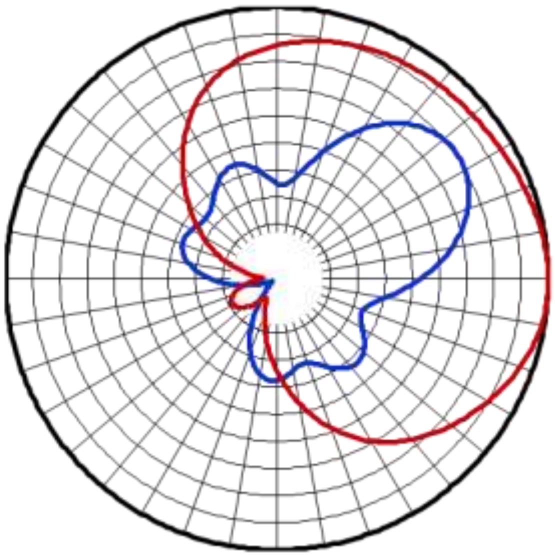
3. Optimize pattern for best circularity

FM pattern studies

Trial and error replaced by Optimetrics

- Reduces study time
- Simulation model exported directly into Solid Edge for mount design
  - Eliminates data transfer errors



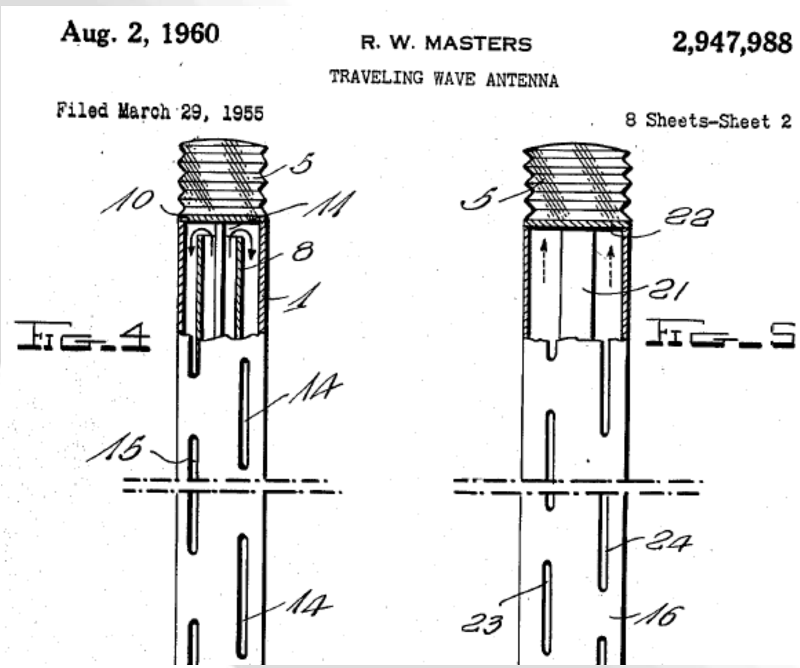


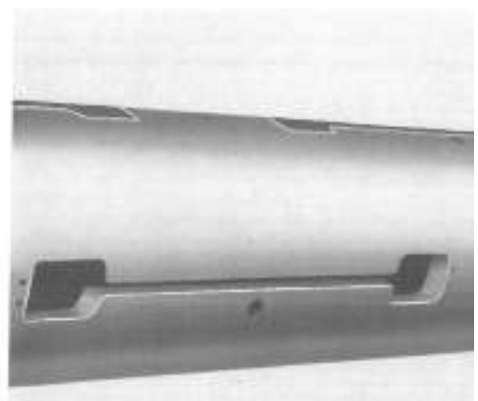
In closing……

One last antenna design trivia question….

- Traveling wave antenna
  - High band VHF 7-13
  - Slotted coaxial design
  - Very low windload
  - RCA shipped over 500

Antenna design trivia question





1957 RCA engineers make a breakthrough with the dog bone slot

In 1955, Masters filed for a patent on the traveling wave antenna.

Problem: For small pipe sizes, the resonate slot length is longer than a wavelength.

How did the top RCA antenna engineers come up with the dog bone slot and why didn't they patent the idea?

Dog bone slots were not so original

African tribes have been using this technique in drums for centuries to communicate over long distances.

Advanced design tools are essential for technical analysis, but they can not replace creativity.

Questions