The Use of Computer Simulation For Directional FM Pattern Studies

Presented By:
John L. Schadler

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Acknowledgement

S. Merrill Weiss

President, Merrill Weiss Group LLC

Preparation of the Petition for Rule Making (PRM)

Allow the use of computer modeling to demonstrate a FM DA performs as authorized

For his contributions to the subject matter

Today's Presentation

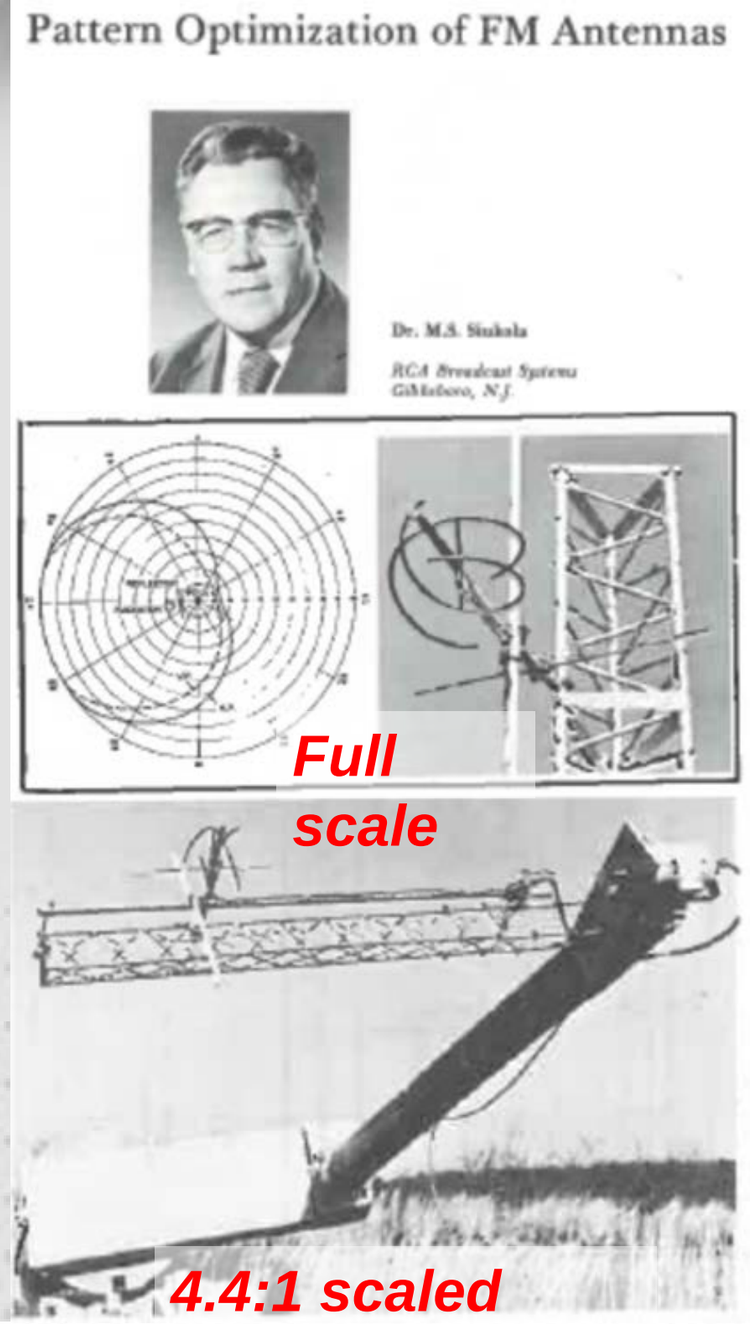
- Filed for PRM in early June
- Why?
  - History and background
  - Benefits
    - Accuracy
    - Efficiency
    - Optimization

Background - History

- Approximately 900 class A FM DA's
- Currently as found in the FCC Rules for licensing a FM DA: (Part 73.316)
  - "Applications for license upon completion of the antenna construction must include a tabulation of the measured relative field pattern"
  - Implies measurement must be done after installation
  - Rule adopted in 1963
  - Impractical
  - Wording has never been changed but at the time interpreted mean measure on a full scale range before shipment

Background - History

- 1976 – Matti Siukola “Pattern Optimization of FM Antennas” – NAB Symposium
  - Proposed the use of parasitic elements behind a ring style FM broadcast antenna used as directors and reflectors
    - Yagi principal
  - Proposed the use of the more economical scale modeling for antenna measurement
    - 4.4:1 scaling factor
    - Became an accepted measurement method for pattern authorization



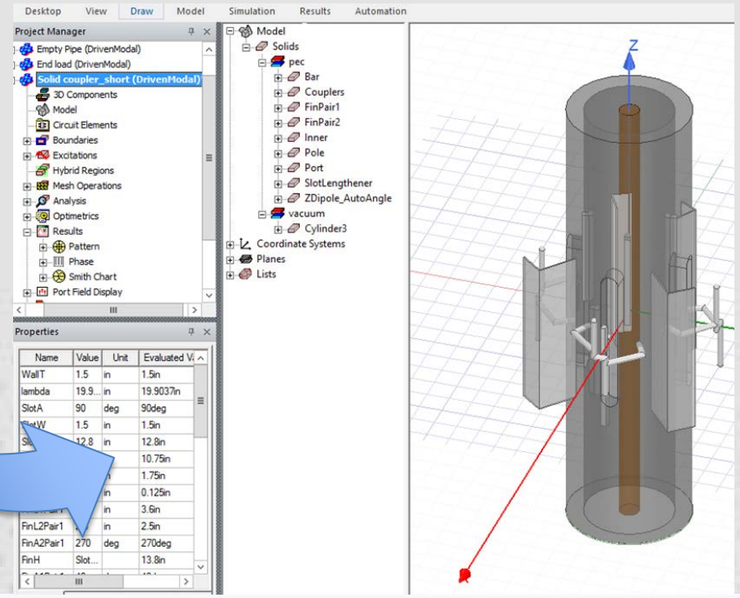
Background - History

- It has now been 58 years and basically nothing has changed regarding FM antenna verification
- Interestingly….. Commission has history of accepting computer modeling
- Characterization of azimuth patterns has greatly evolved services
  - AM Broadcast (MoM)
  - TV Broadcast (Flexible)
  - RF Exposure (Flexible)
    - Handheld devices
    - Medical devices

Directional FM is the only service left with the burden of building physical models and collecting measured data

Computer Modeling – TV Repack

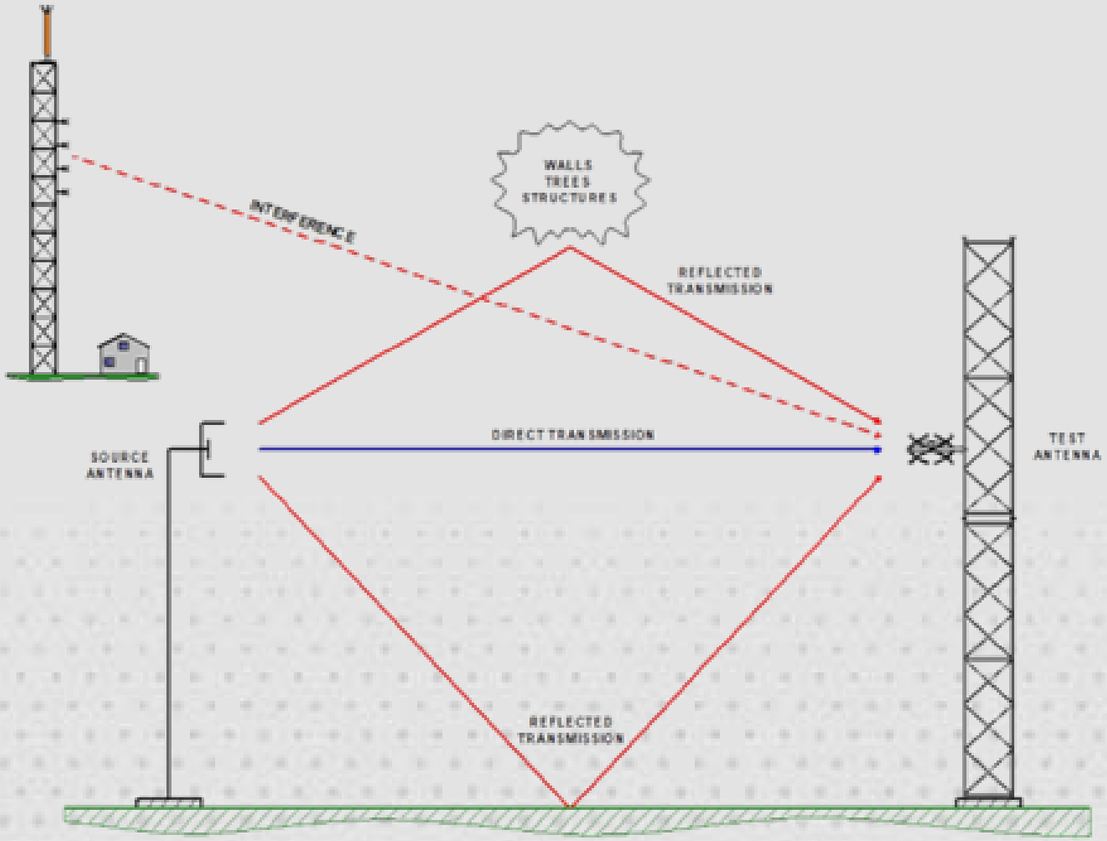
- Created a unique situation in the industry
- Aggressive timeline
- Dielectric replaced physical modeling with computer modeling in 2017
- We have shipped over 1000 antennas based on virtual designs
  - Process:
    - Reduced lead time
    - Reclaimed manufacturing space
    - Proved more accurate - Reduced test time
- Left with a new crop of engineers – “HFSS super users”



Safe to say that it would have been impossible to design, manufacture and test over 1000 antennas needed to successfully complete the Post- Incentive Auction Spectrum Repack in the time allowed without computer modeling

Range Measurement Accuracy

- Range accuracy depends on:
  - Alignment
    - Mechanical bore sighting
  - Reflectivity
    - Reflections
      - Range surface
      - Surrounding objects
      - Positioner
      - Cables
  - External interference

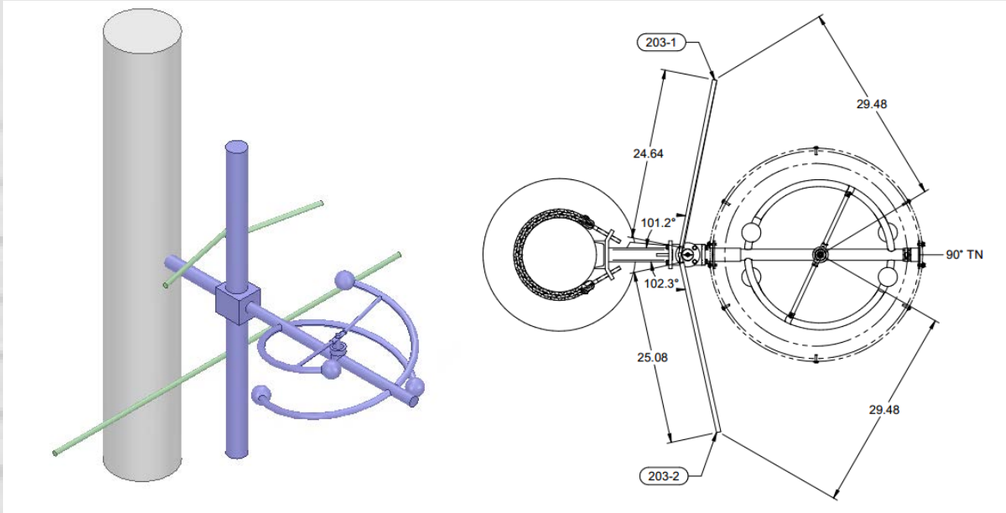


Range measurement accuracy limitations are removed with the use of computer simulation

Mechanical Tolerancing and Human Error

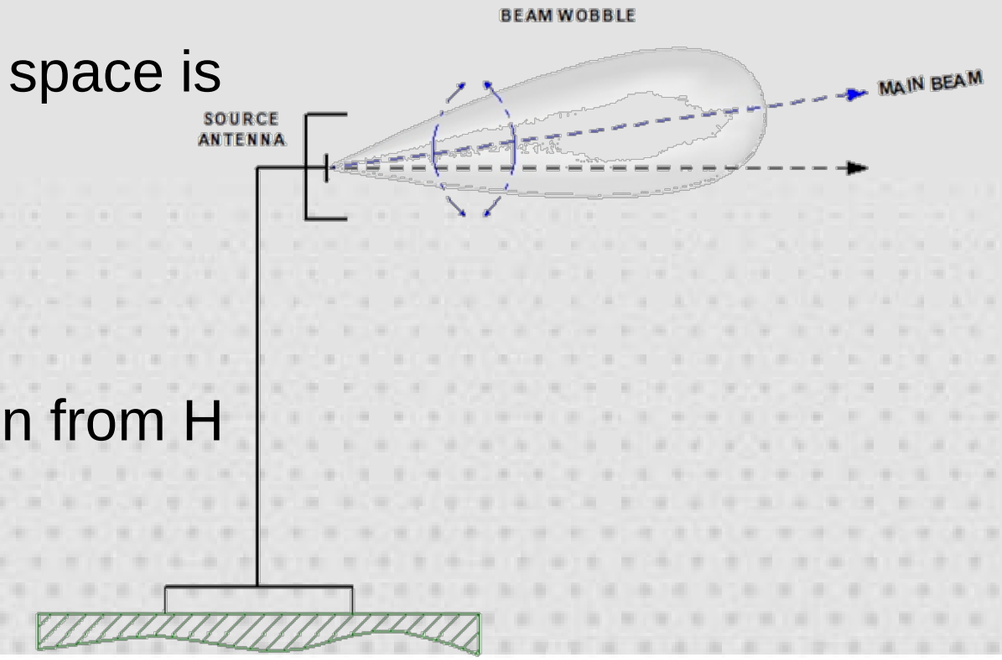
- Computer simulation eliminates:
  - Lengthy set-up and take down time
  - Mechanical tolerances of physical adjustments
  - Hand recorded information - Accuracy
    - Radiator location
    - Parasitic sizes and locations in space

Replaced by simple exportation of the computer model



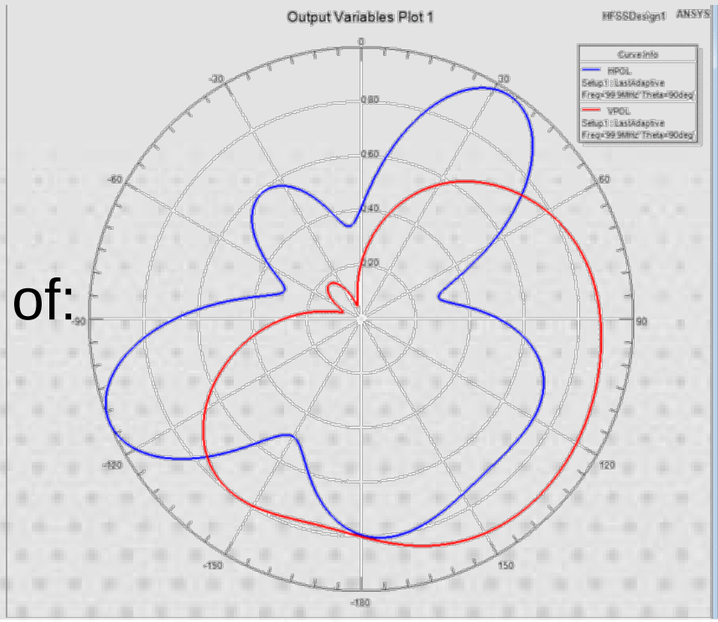
Significance of Polarization Ratio

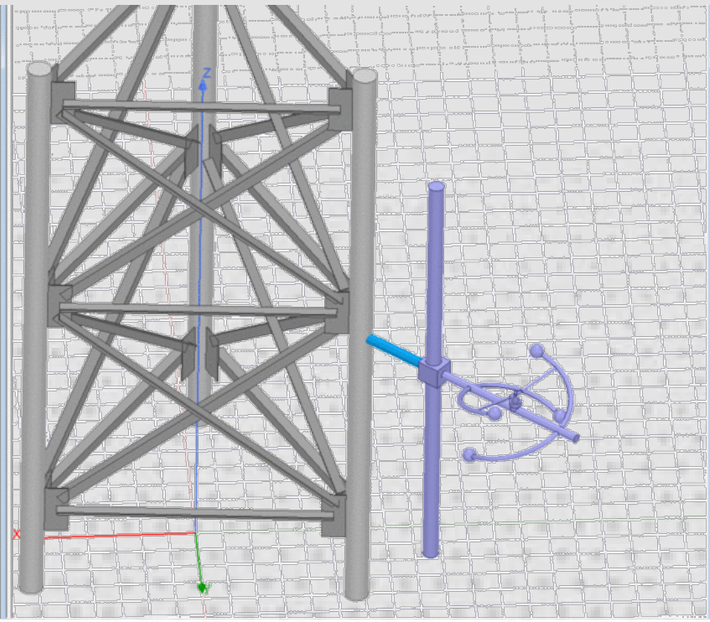
- Rules under 47 CFR 73.316 state that the supplemental VP ERP shall in no event exceed the ERP authorized
- Broadcasters consider VPOL more important than HPOL
  - Tend to maximize VPOL
- Accurate PR measurements are important
- Accurately range measuring the H/V ratio at any point in space is difficult
  - No range is reflection free
  - H and V waves reflect differently – Limits accuracy
  - Transmit antenna H/V pattern congruency
  - Source antenna beam tilt creating wobble when spun from H to V



Automated Optimization

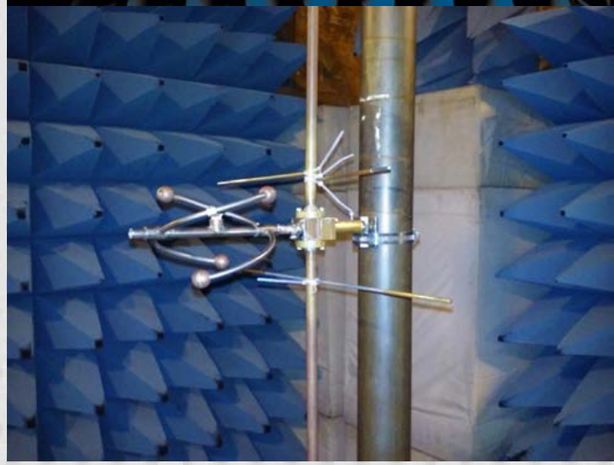
- Designing in a virtual environment leads to complete optimization
  - Not compromised by time, materials or tolerances
- Optimetrics replaces trial and error
  - Artificial intelligence
    - Establish desired criteria
      - FCC footprint
      - % of pattern fill (85% min)
      - VPOL < HPOL
      - Directions of interest
    - Simultaneously solve combinations of:
      - Pattern shapers
      - Parasitics
      - Radiator location and direction





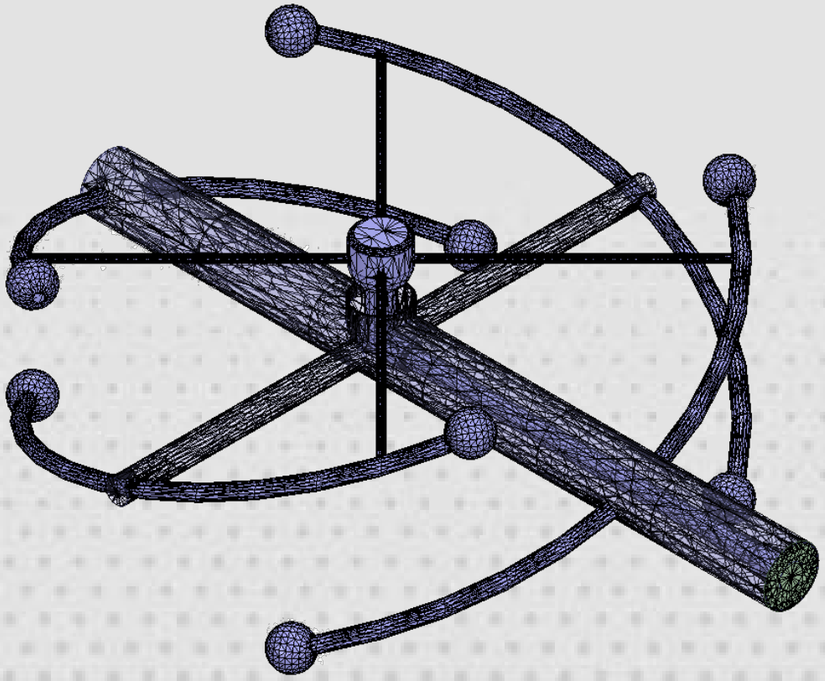
Physical Model Measurement vs. Simulation Example

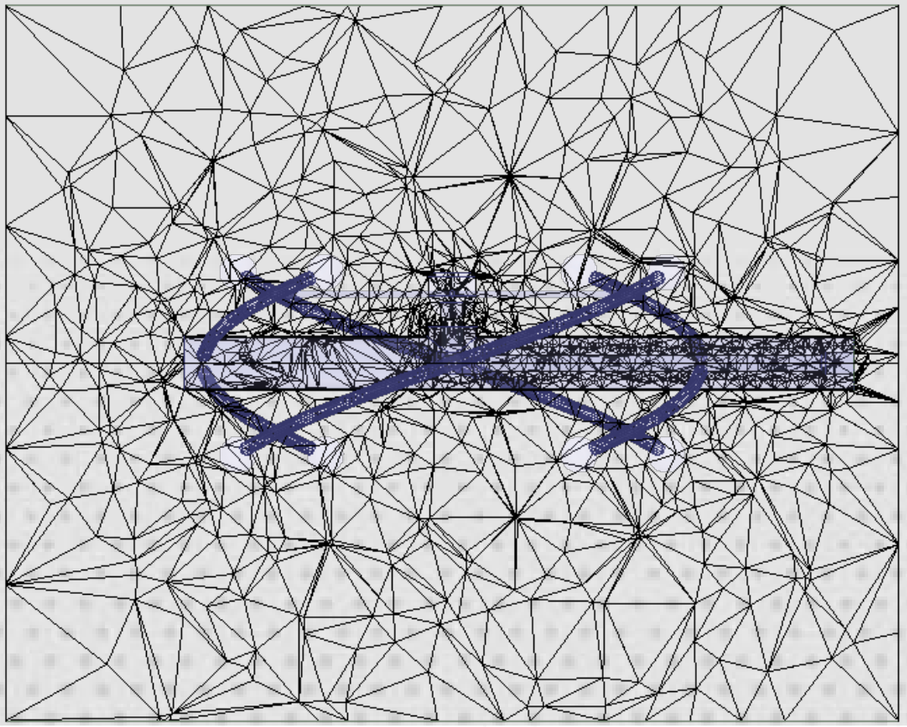
- Physical modeling and computational modeling of the same antenna are compared
- Physical modeling
  - 4.4:1 scale modeling
    - Scaled bay, antenna, tower
    - Scaled frequency (4.4X fundamental)
  - Anechoic chamber test range
    - Source antenna and scaled model mounted at same elevation at opposite ends of the chamber

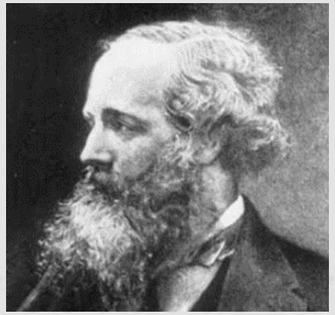


Physical Model Measurement vs. Simulation Example

- Computer modeling
  - ANSYS HFSS is a 3D electromagnetic (EM) simulation software tools for designing, simulating and evaluating high-frequency RF components.







James Maxwell

Calculation is not an estimate, but an exact solution at every node in a mesh

Physical Model Measurement vs. Simulation Example

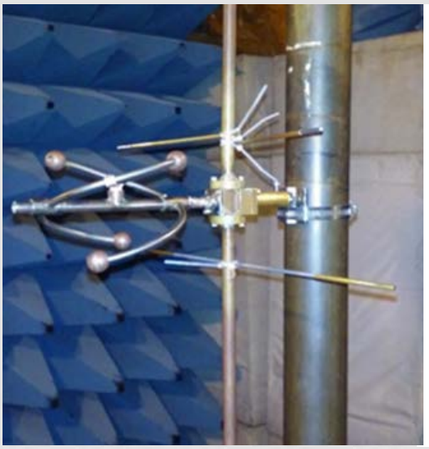
- Comparison figure of merit
  - Correlation coefficient
    - Statistical measure of the relationship between two sets of data
    - Correlation of 1 shows perfect correlation

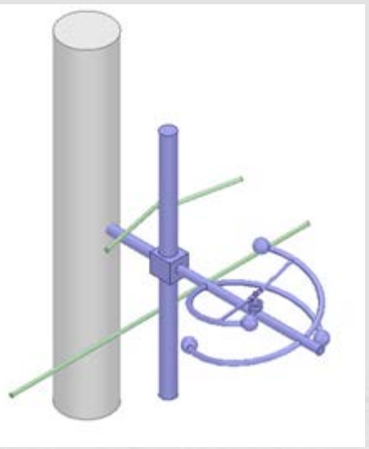
$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}}$$

$$x_i = x\ values\ in\ sample$$
$$\bar{x} = mean\ of\ the\ x\ value\ samples$$
$$y_i = y\ values\ in\ sample$$
$$\bar{y} = mean\ of\ the\ y\ value\ samples$$

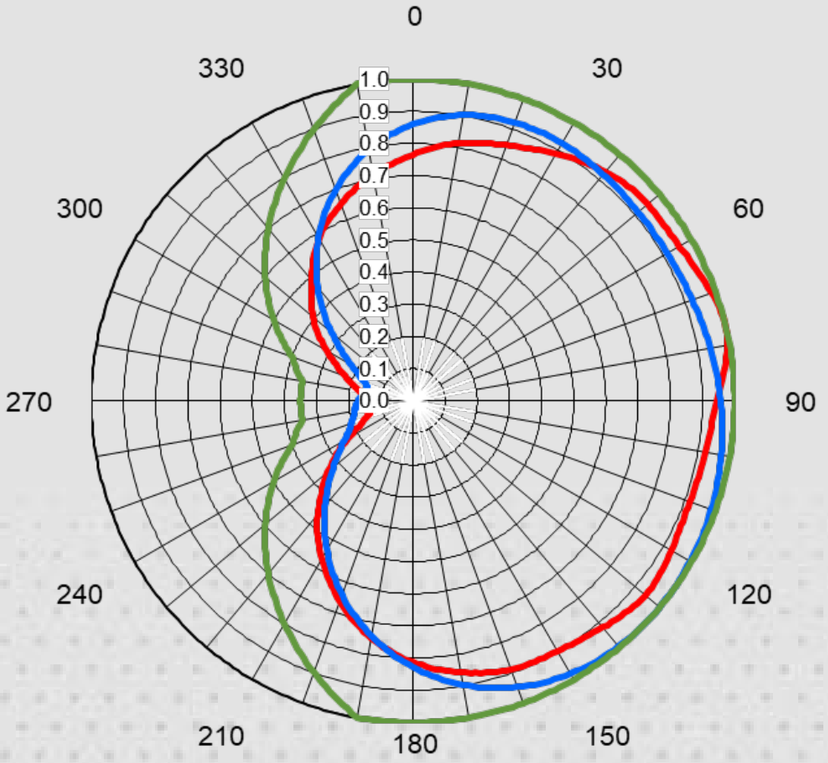
Physical Model Measurement vs. Simulation Example

WHEM 91.3 MHz – Eau Claire WI

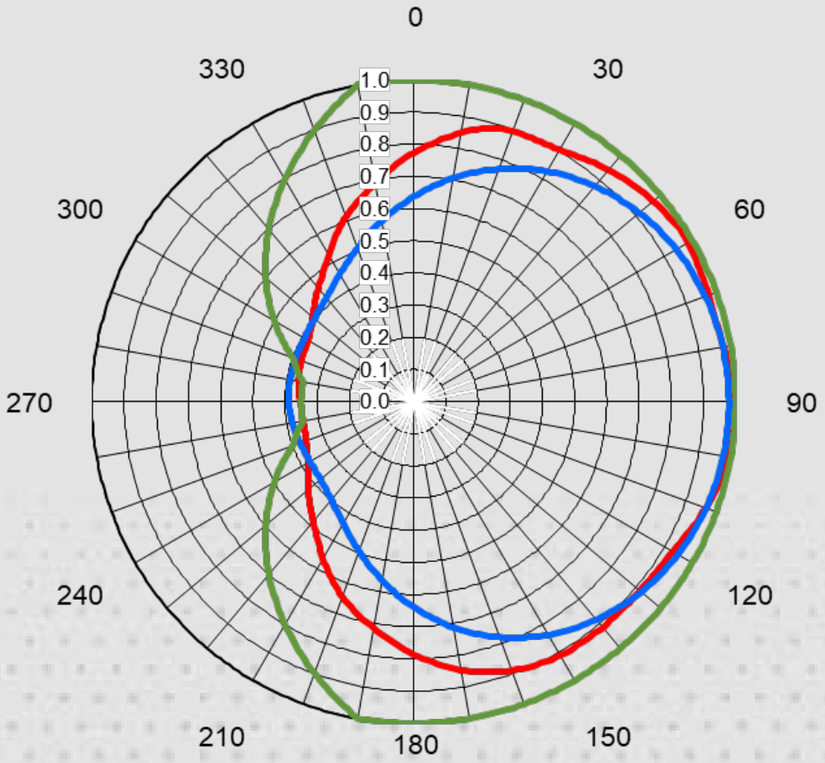




- Physical model study – 2014
- Recently replicated in HFSS
- Results closely match
- Correlation coefficient
  - HPOL .986
  - VPOL .960



HPOL

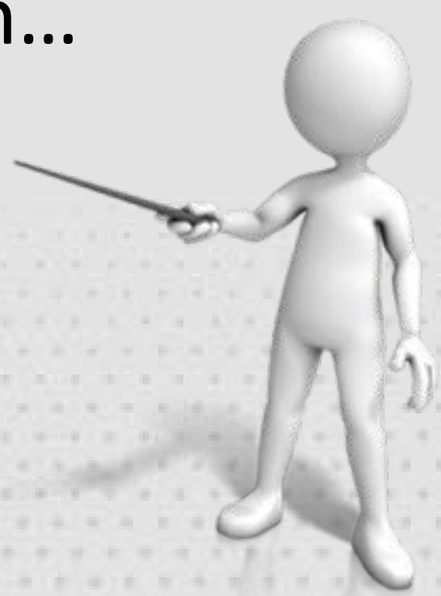


VPOL

Physical Pattern Study
HFSS Simulation
FCC Protect

Physical Model Measurements vs. Simulation Example

Examples are an exercise to validate how good range measurements are….not validate the use of simulation…



Conclusions

- 58 year old rules still mandate physical pattern measurements for directional FM licensing
- For decades, RF computational analysis has evolved
  - Accepted in all other broadcast services
- Simulation yields results that are superior to traditional range measurements
  - More reliable azimuth patterns – true fee space environment
- Virtual environment eliminates:
  - Mechanical tolerancing
  - Human data error
- Computer simulation allows geometry to be completely optimized – not compromised by time

LONG OVERDUE!

THANKS FOR YOUR TIME!

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