Changing the Landscape of FM Broadcast Pattern Studies and Combiners

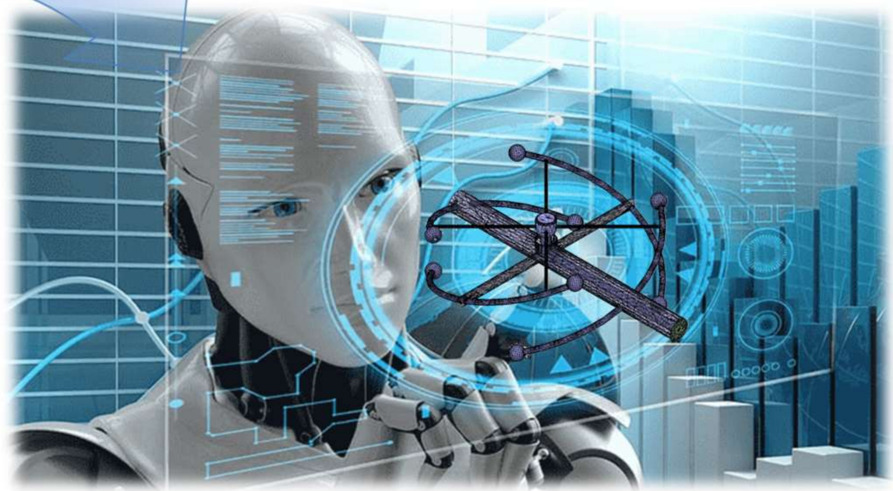
PRESENTED BY DAVE BENCO

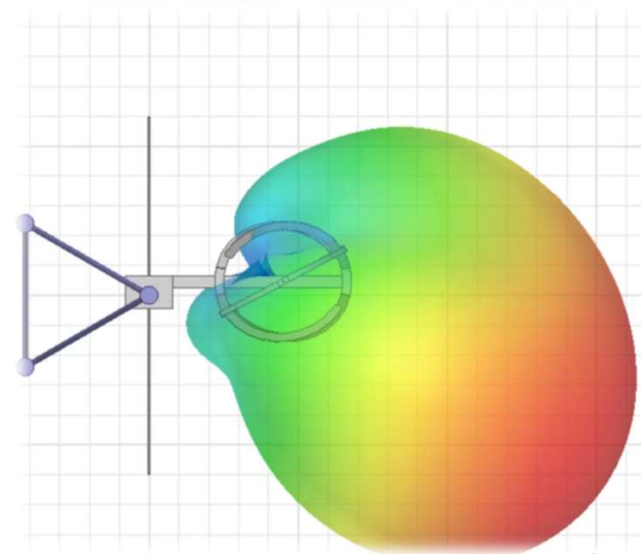
SEPTEMBER 28, 2023

TODAY'S PRESENTATION

- Use of AI Optimization to develop FM Directional Patterns
  - Recent FCC Rule change and timeline
  - History of the technology used to develop patterns
  - Field verification with Drone measurement
- Reconfigurable Manifold Combiner
  - Accommodate future expansion
  - Reduced loss/increased power handling
  - Leverage computer design tools

BRINGING FM INTO MODERN TIMES





RANGES

Harris / Dielectric Far Field Range – Palmyra MI

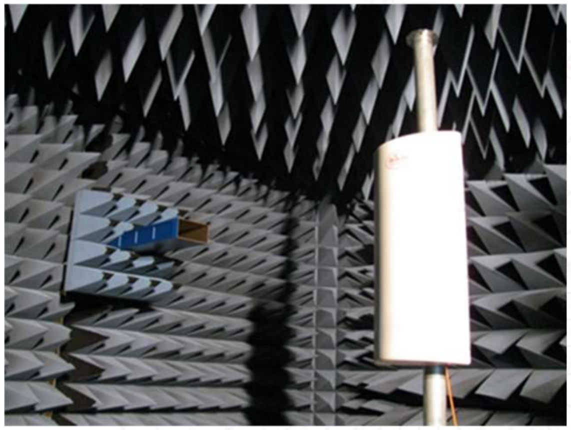
RCA / Dielectric Gibbsboro NJ Antenna Engineering Center

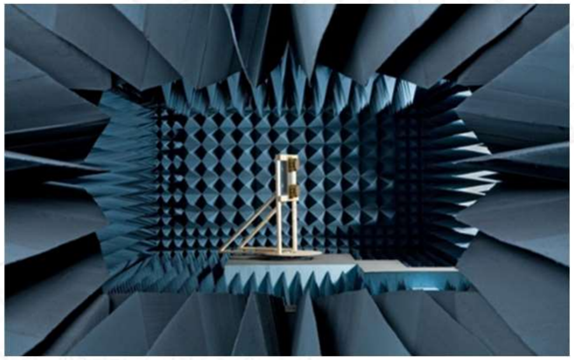
RANGES

Dielectric – Raymond, ME

60’ Tapered anechoic chamber

Outdoor 100’ cylindrical near field range – Largest in the US.





Indoor cylindrical near field model range

OLD SCHOOL STUDIES

- Need to build a model
  - Find (or build) a similar Tower section to verify performance

OLD SCHOOL STUDIES

- Tune Bay
  - Add Small metal rods and tie wrap them in place.

Lots of Metal Tape

FCC RULE CHANGE TIMELINE AND UPDATE

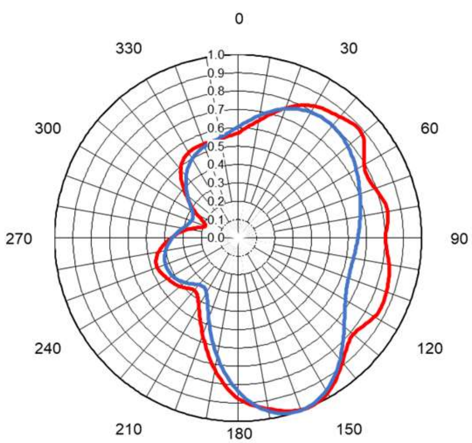
- June 2021 - Filed a PRM with the FCC to allow the use of computer simulation to verify performance of directional FM antennas
- November 2021 - Unanimous decision by the FCC to move forward with the NPRM
- FCC strong support - Public comment period reduced to only 30 days
- Public comments tally
  - 18 in favor – 1 opposed
  - Strong support from the broadcast community
- May 2022 – FCC adopted the rule change

Ruling states : *"To verify a particular antenna model for simulation, the broadcast station must submit to the Commission both the results of the computer modelling and the measurements of either a full-size or scale model of the antenna demonstrating a reasonable correlation"*

DIELECTRIC VERIFICATION UPDATE

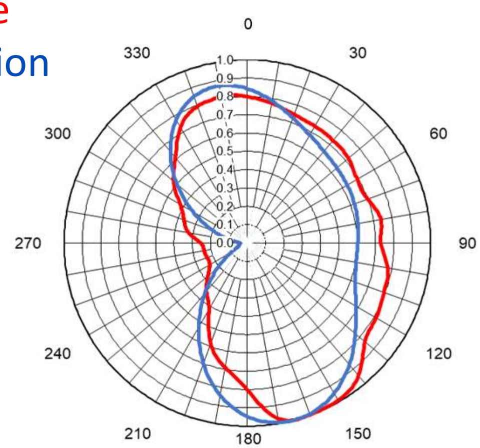
- Defined verification report template – submitted first in Dec 2022 (WLPR)
- Reasonable correlation?
  - Figure of merit – correlation coefficient
    - Statistical measure of the relationship between two data sets
    - Correlation of 1 shows perfect match

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

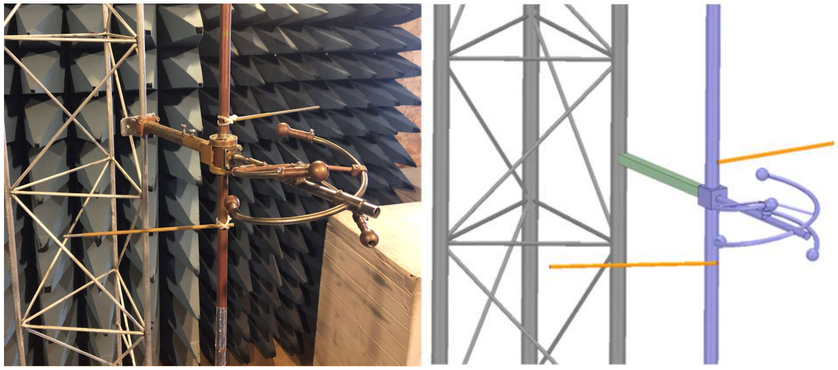


HPOL Correlation = 96%

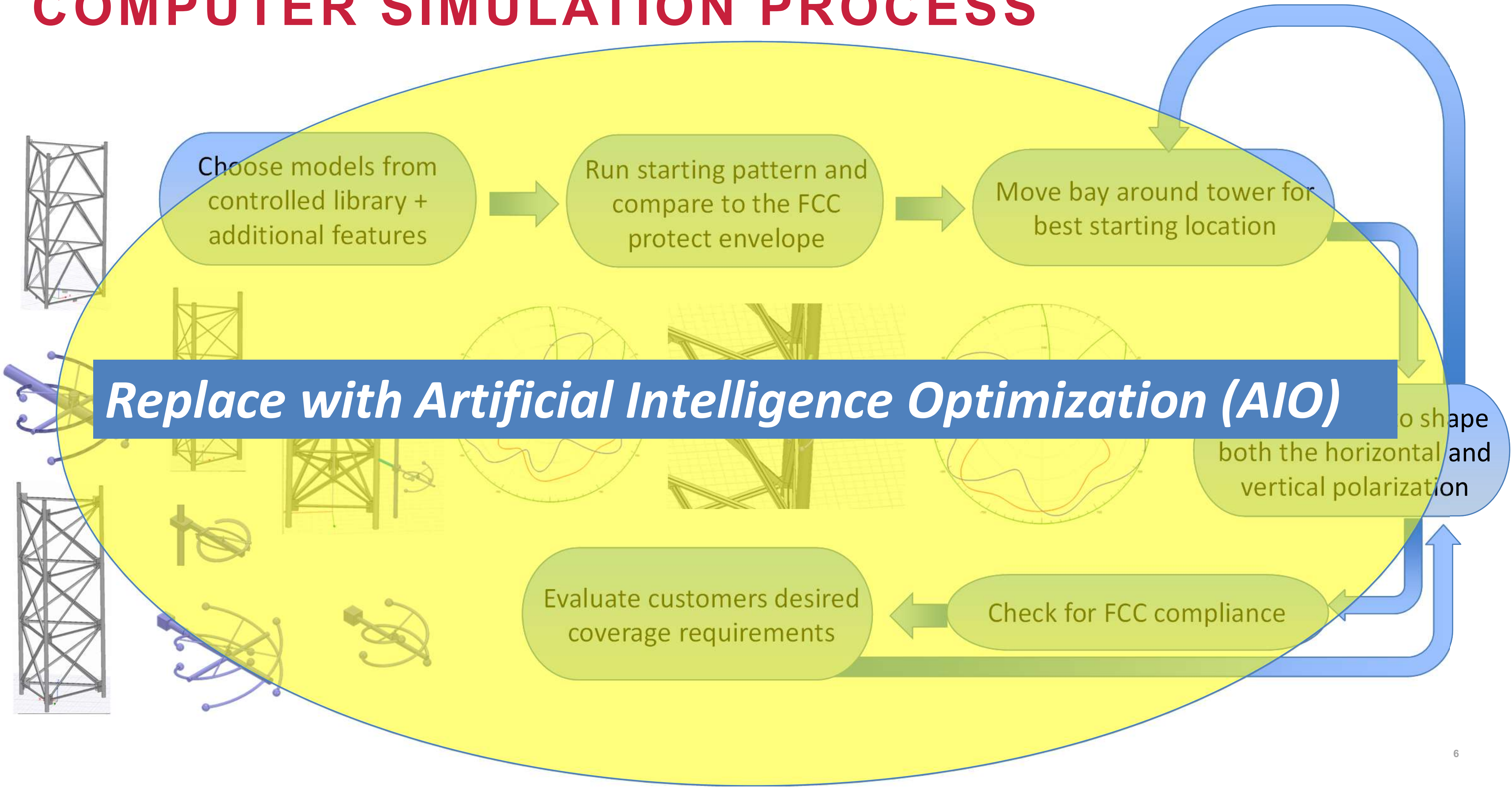
Range
Simulation



VPOL Correlation = 95%

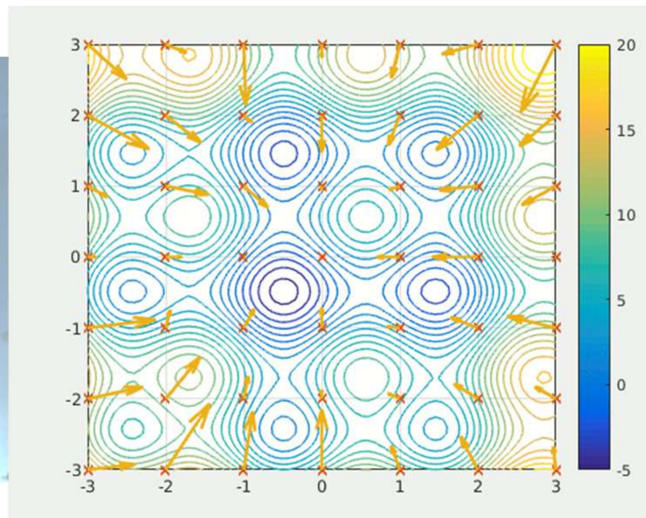


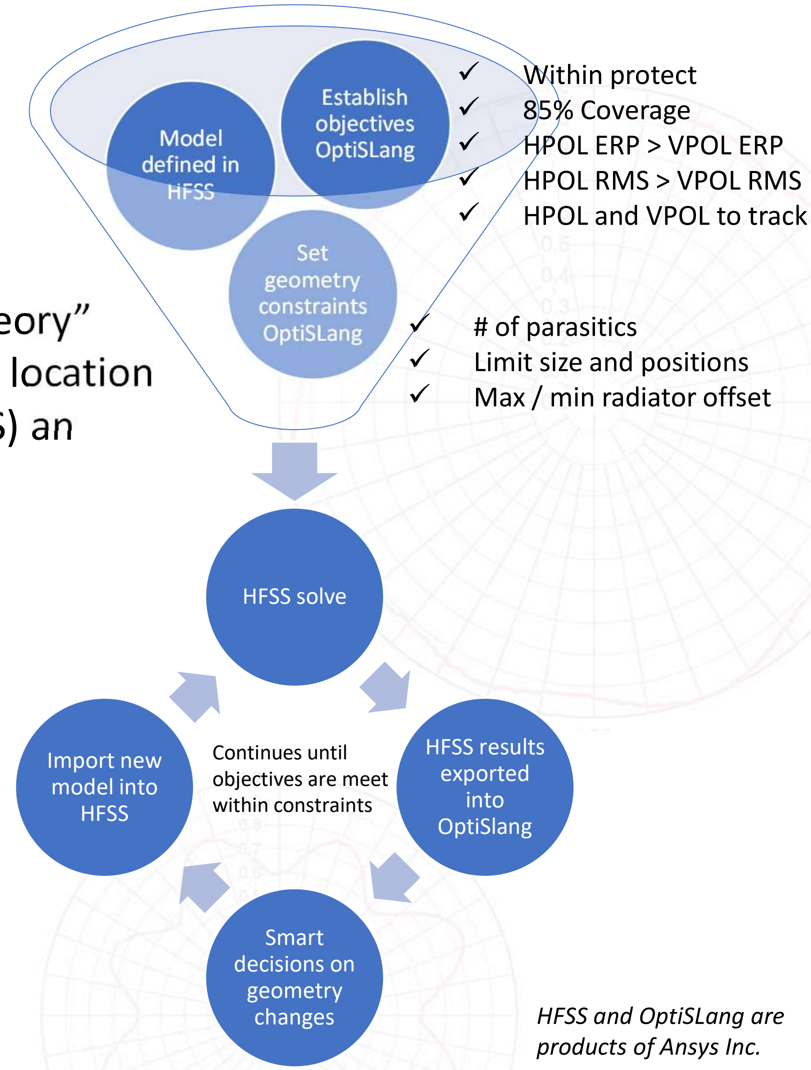
COMPUTER SIMULATION PROCESS



PATTERN STUDY – AI OPTIMIZATION (AIO)

- Many types of Optimizers – Chose "Particle Swarm Optimization Theory"
- Process modeled after how bees swarm and converge to a common location
- Intelligent decision making outside of the simulation software (HFSS) an done in an optimetric language (OptiSLang)



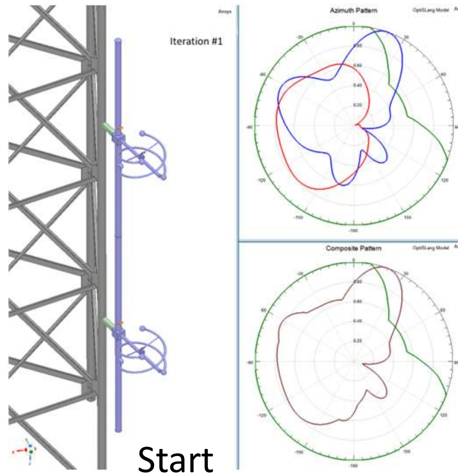


HFSS and OptiSLang are products of Ansys Inc.

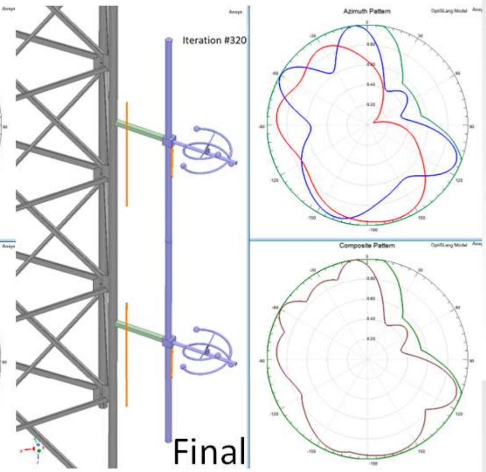
FM-AIO

HPOL – Blue
VPOL – Red
FCC Protect – Green
Composite - Brown

- AIO Example
  - C- Bay on a 6 ½’ tower
- 320 Iterations
  - Final – meets all objectives - nice pattern congruency, composite fills 89%
- First 100 iterations - patterns very erratic
  - Geometry variables spread out
  - “Bees looking for a direction”
- Last 50 iteration - small pattern changes
  - Geometry variable beginning to cluster
  - “Bees now swarming”
- AIO completed in only 21 hrs.



Start



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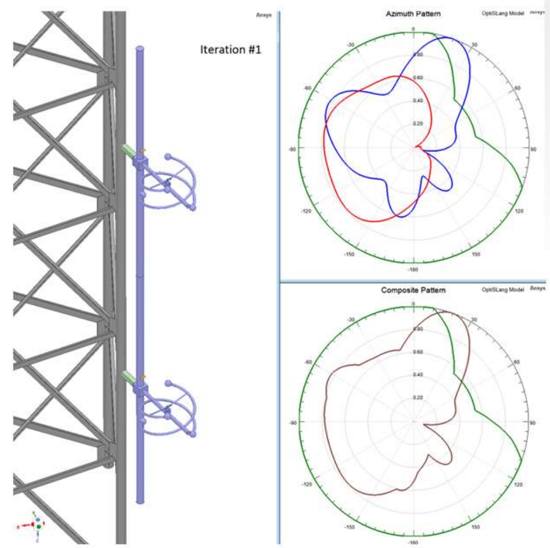
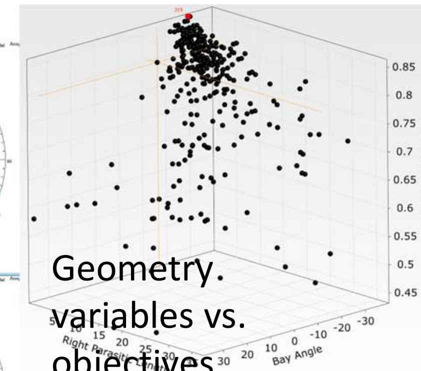
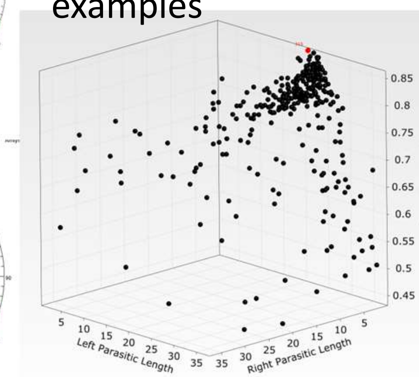
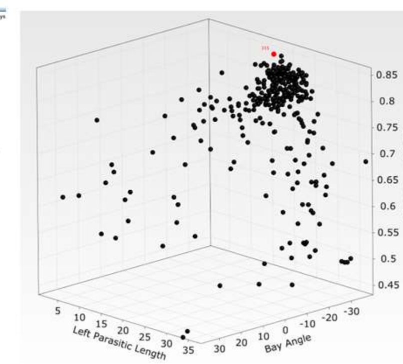


Progression

Geometry variables vs. objectives examples







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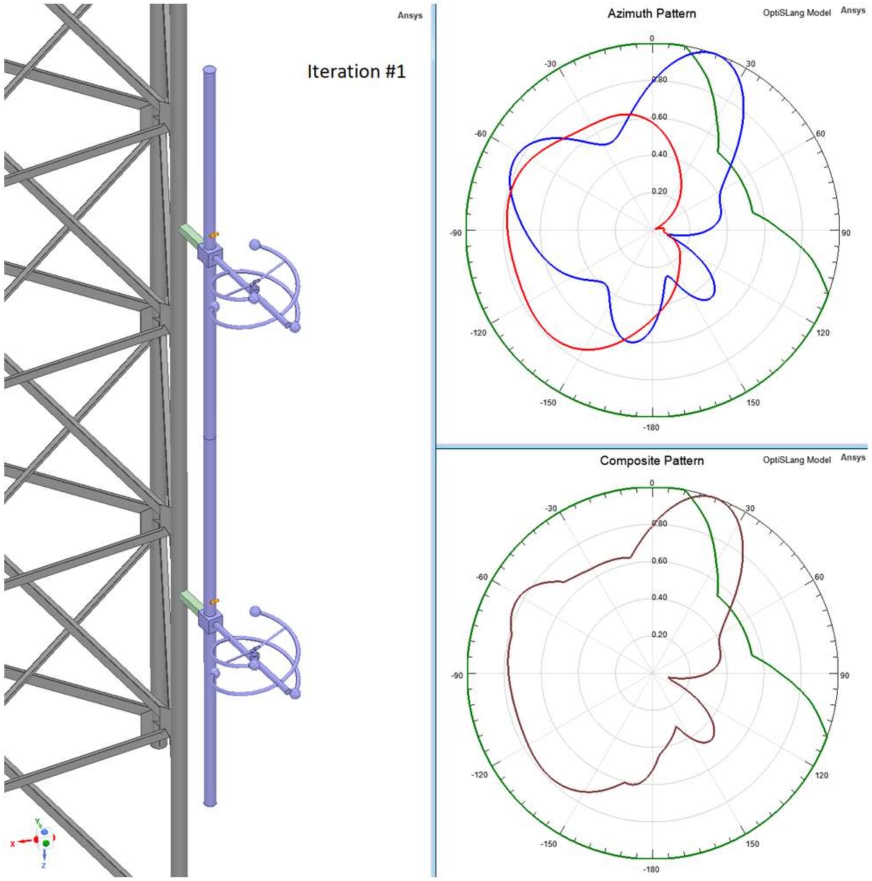

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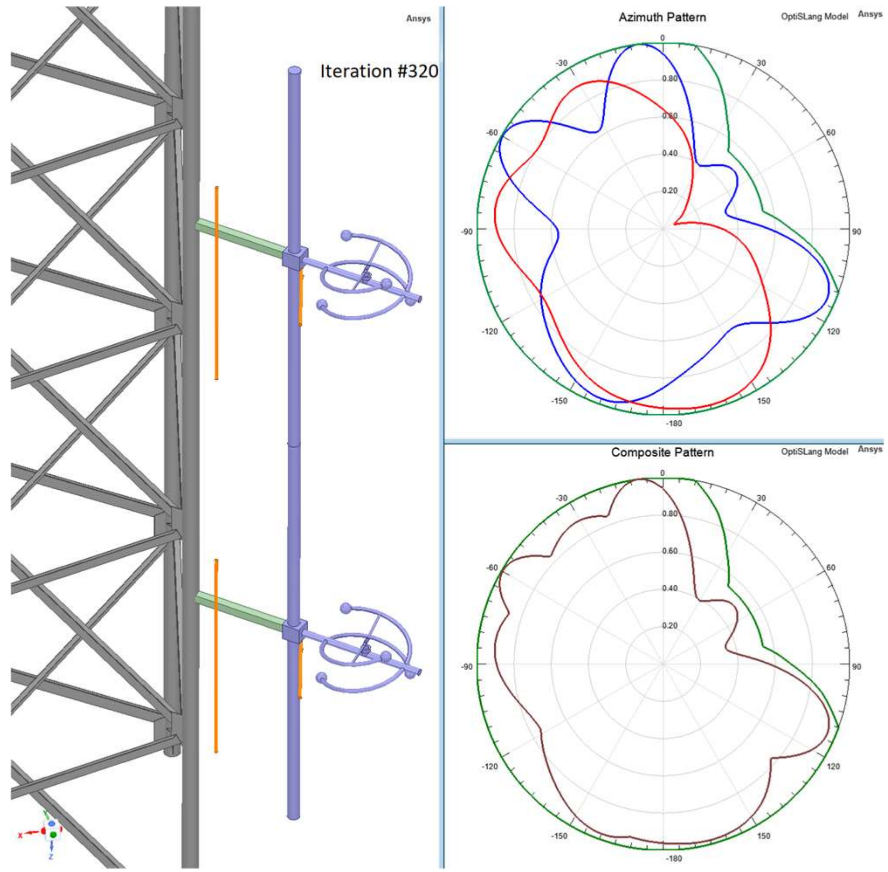

FINAL

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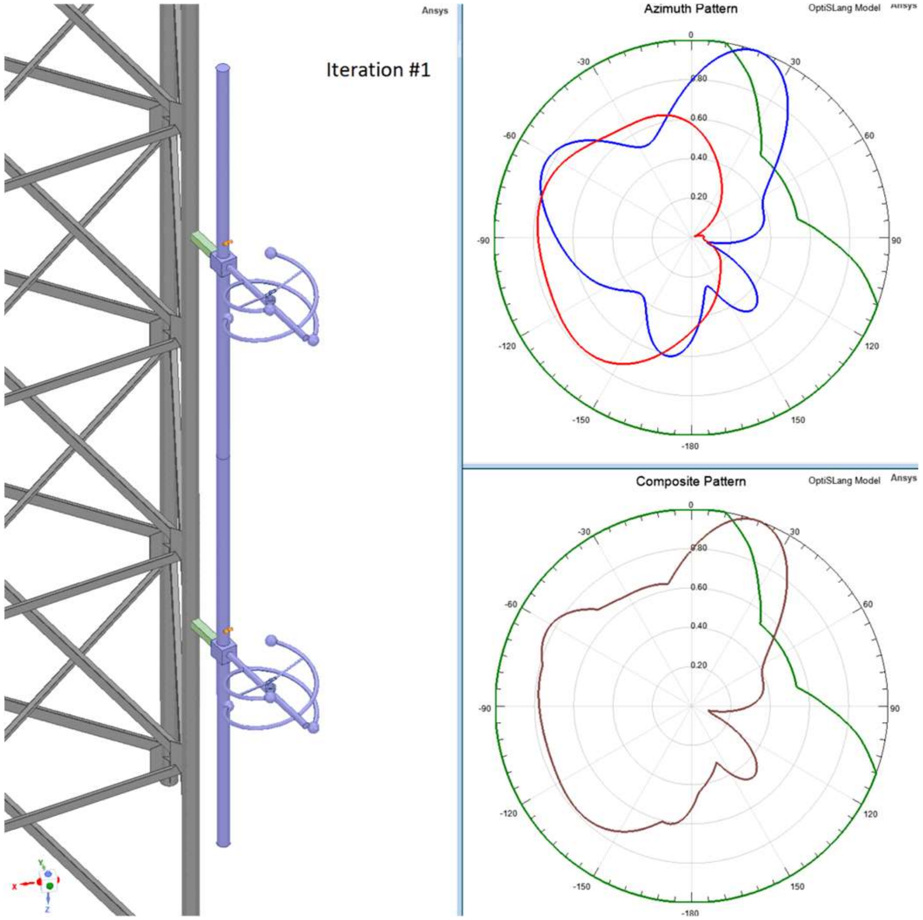

PROGRESSION

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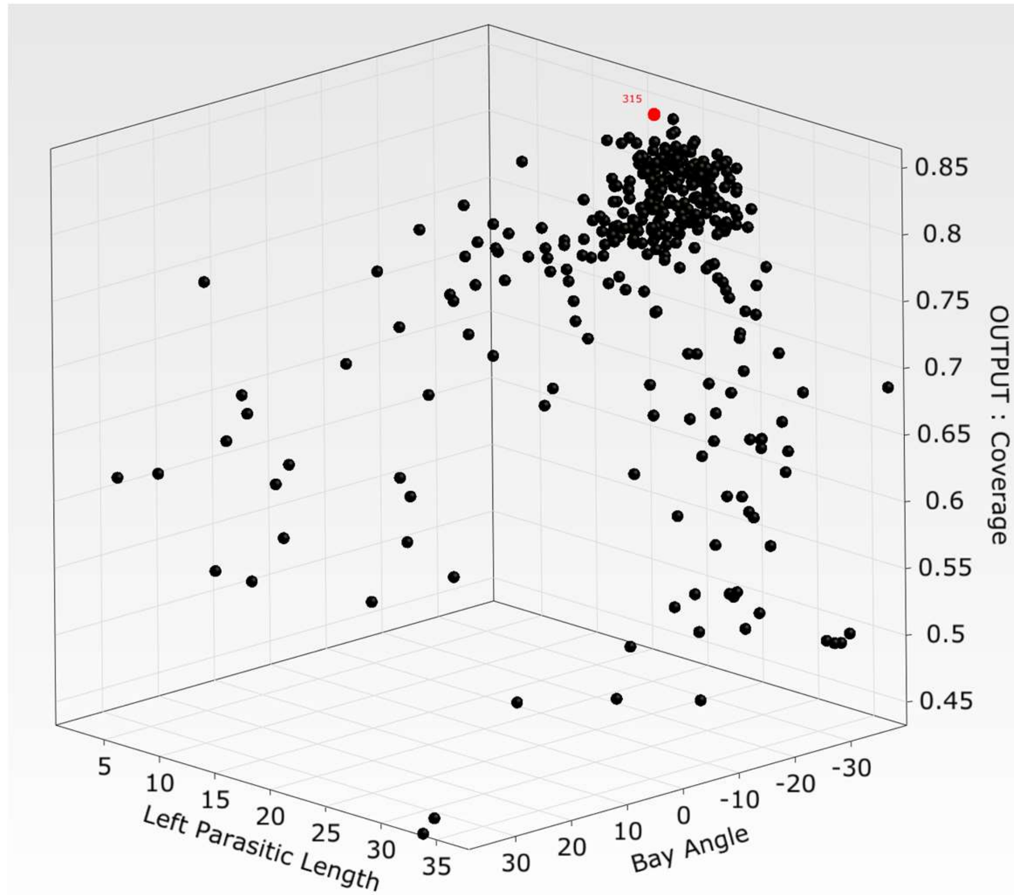

GEOMETRY VARIABLES VS OBJECTIVE

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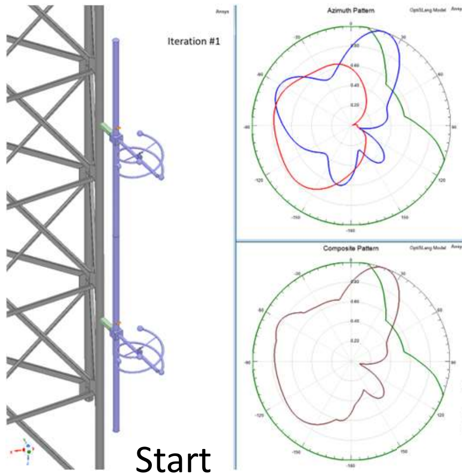

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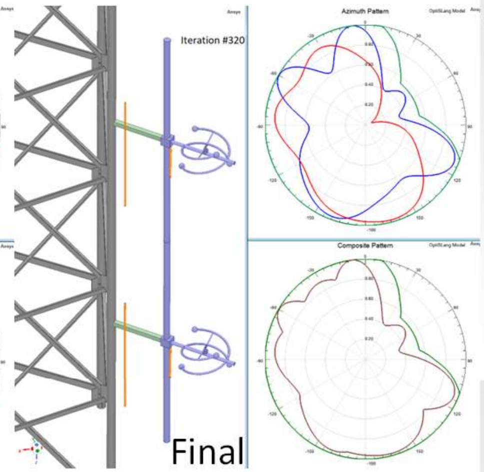

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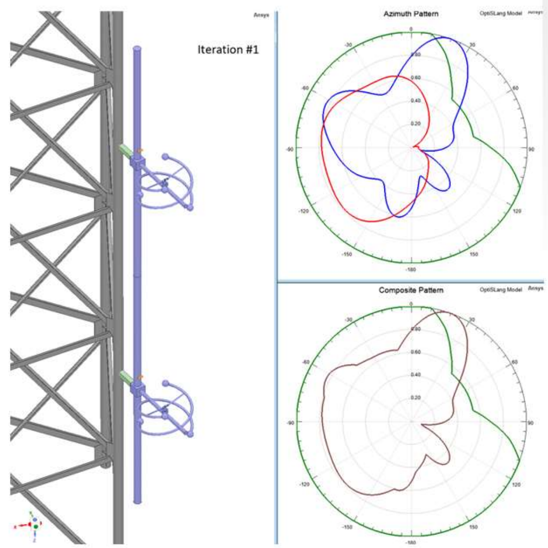

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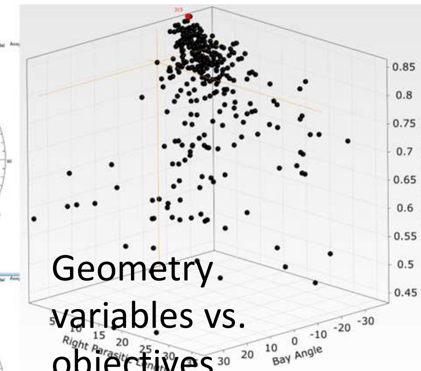

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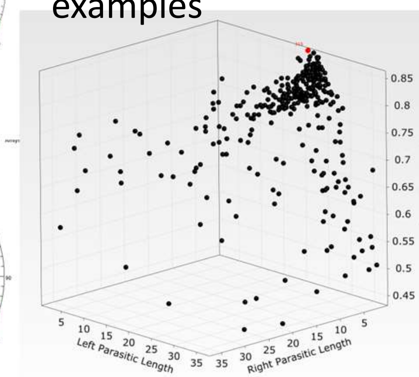
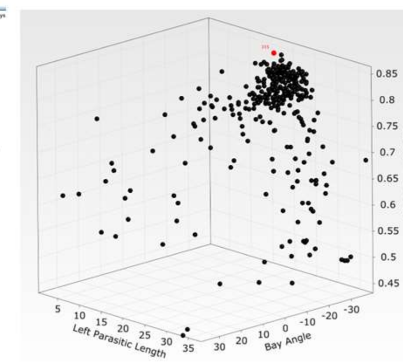


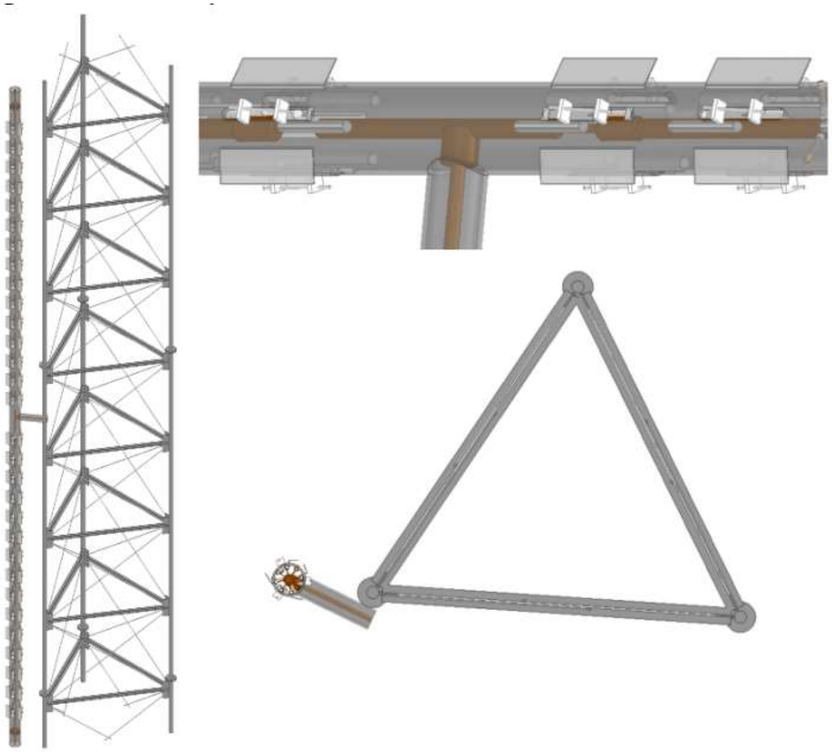


HOW DO WE FURTHER APPLY THIS APPROACH?

- HFSS Modeling
  - Design 100 of new products at Dielectric
    - Eliminates Proto-types
    - Saves time
    - Saves cost
  - Designed patterns for TV Antennas
    - Validated with 100’s of older models made
    - Drone Studies later in time

APPENDIX

Example of drone measurements vs. HFSS calculations



VHF AND UHF REPACK ANTENNAS DESIGNED BY HFSS SIMULATION AND VERIFIED BY FIELD DRONE MEASUREMENTS

TFU-30DSC/VP-R 3BP260

***Side Mount Antenna. Tower info in aperture available to Dielectric was limited, so discrepancies are expected but the drone measurement shows the overall pattern is intact.**

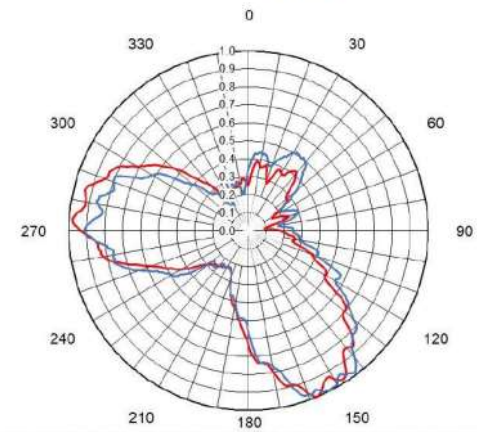


Figure 1: Horizontal polarization azimuth pattern. Red- simulation. Blue – drone measurement

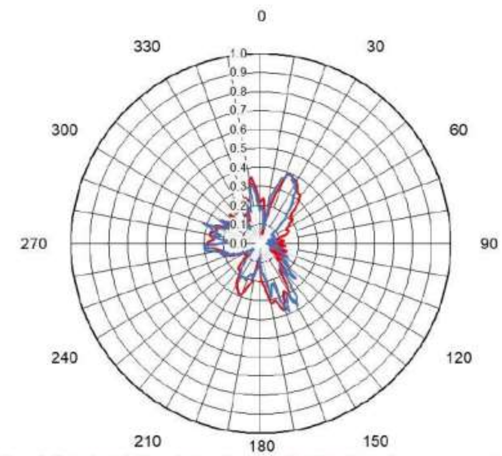


Figure 2: Vertical polarization azimuth pattern. Red- simulation. Blue – drone measurement

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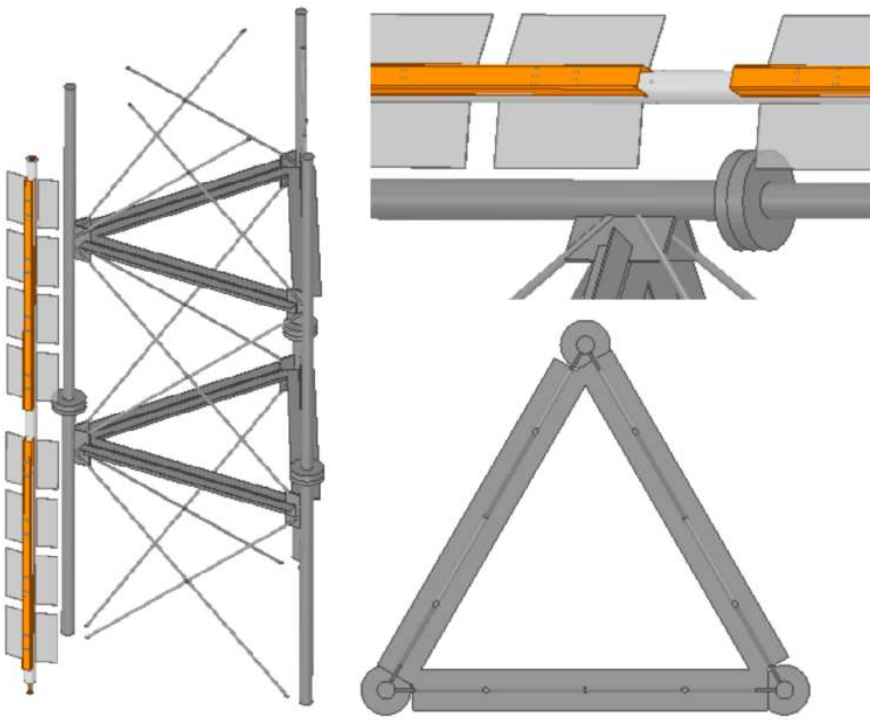
Example of drone measurements vs. HFSS calculations



VHF AND UHF REPACK ANTENNAS DESIGNED BY HFSS SIMULATION AND VERIFIED BY FIELD DRONE MEASUREMENTS

TLP-8M/VP

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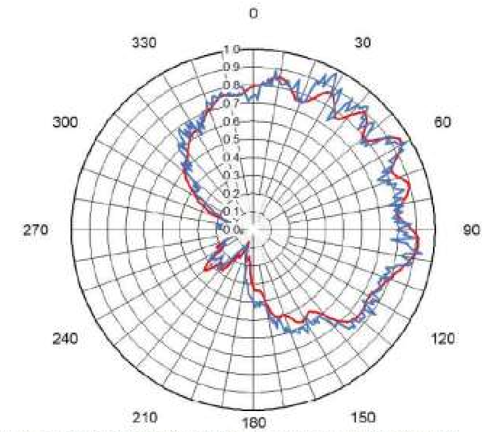
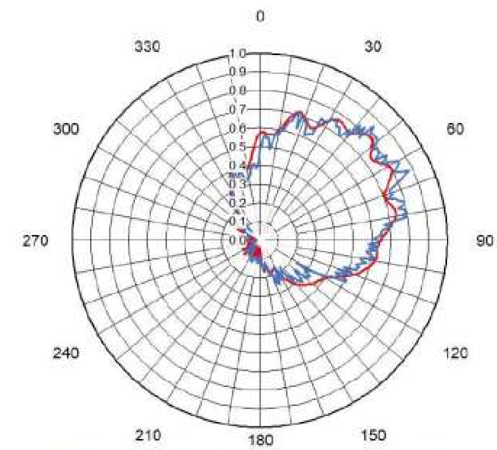


Figure 1: Horizontal polarization azimuth pattern. Red- HFSS. Blue – drone measurement



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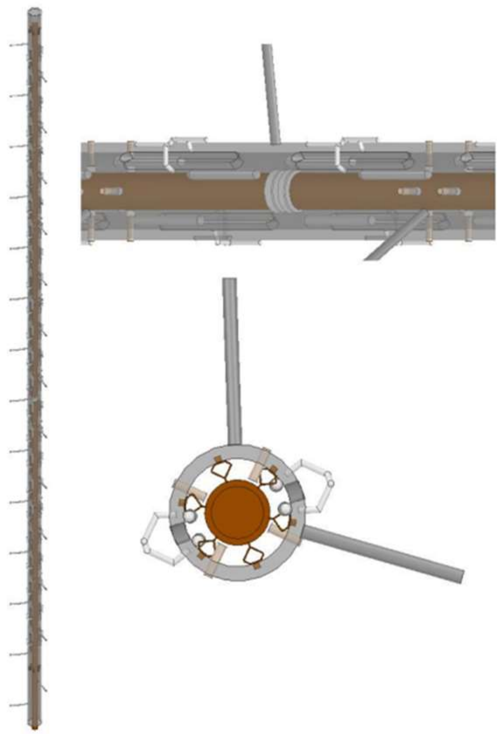

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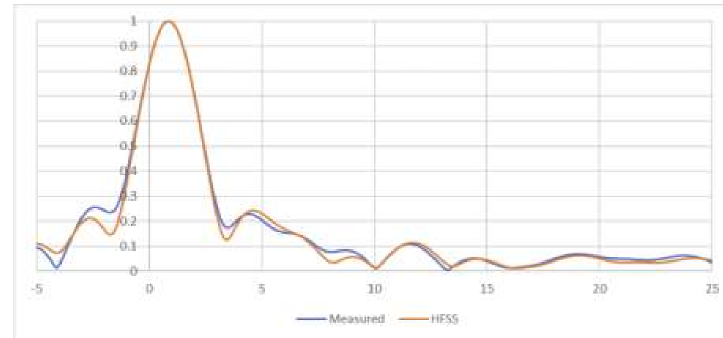

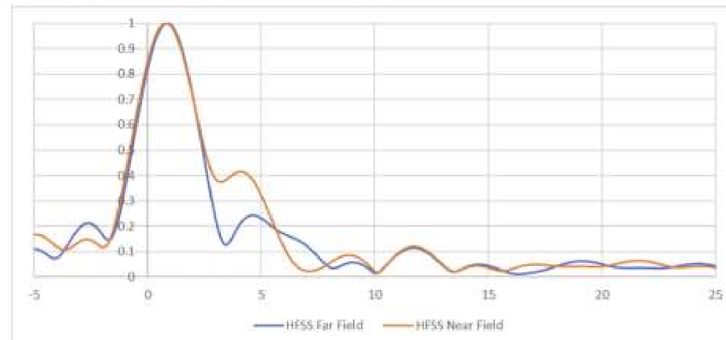

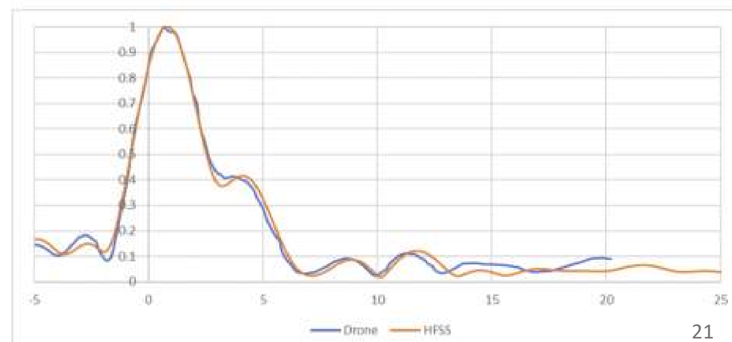

TFU-24JTH/VP-R P216

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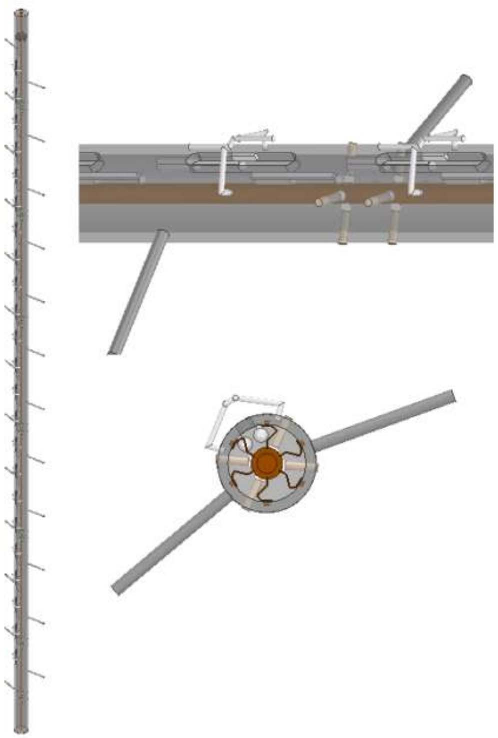

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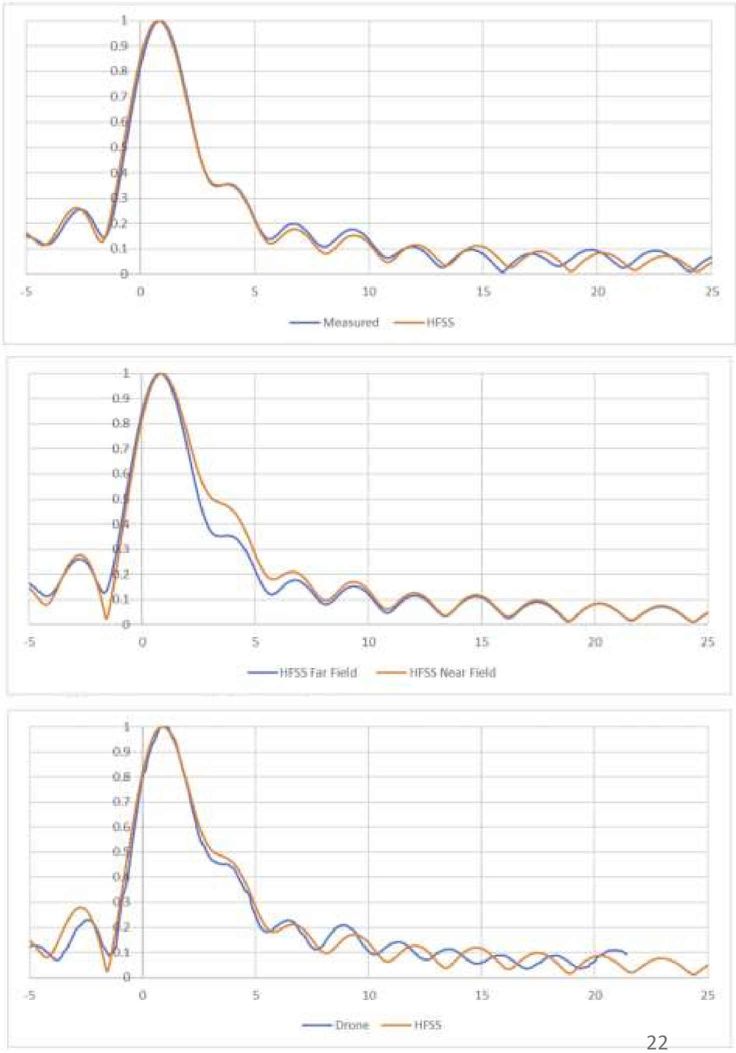
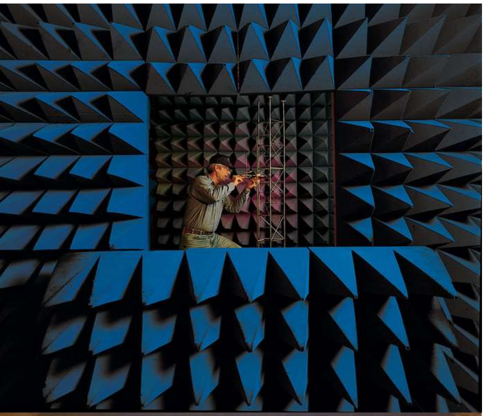


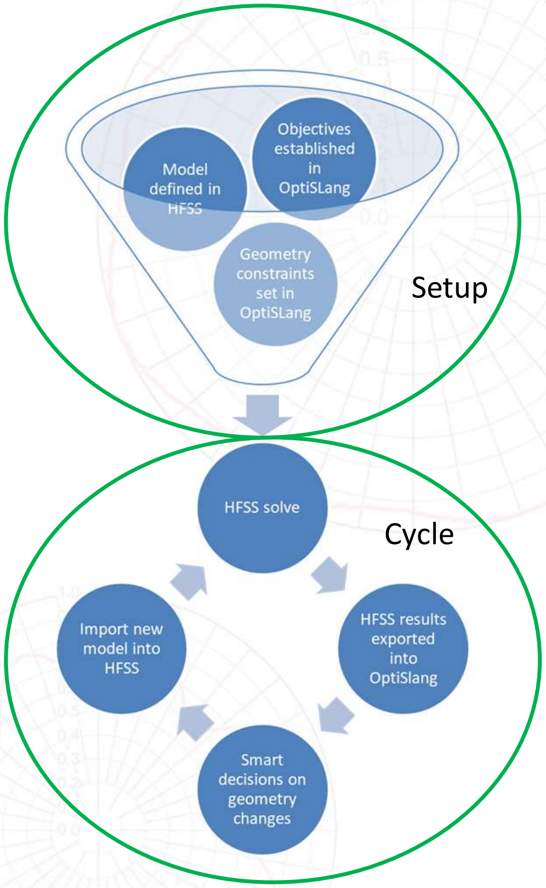
TFU-23ETT/VP-R S200 SP

MODERNIZE WITH USE OF SIMULATION SOFTWARE



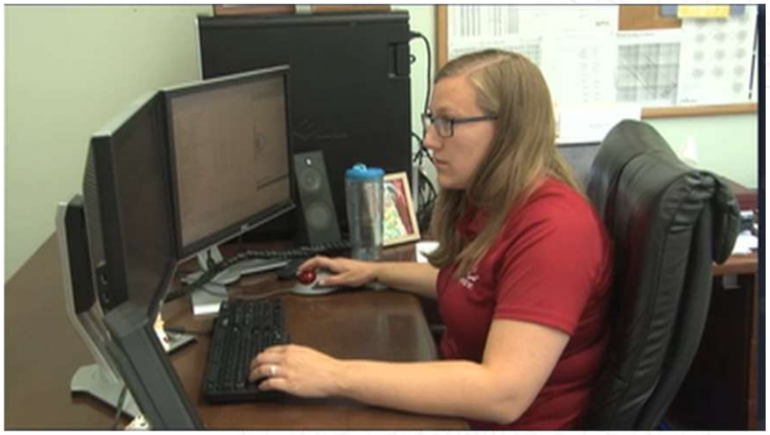
- Range (4.4:1 scale model range)
  - 4 hr. Setup time
  - Pattern/adjustments - 20 min
  - 1 Week range time
  - Total lead time = 5 days
  - 120 Iterations
  - Man hours = 40

- AIO
  - 1 hr. Setup time
  - 20-30 hr. Cycle time
  - 300-400 Iterations
  - Total lead time = 2 days
  - Man hours =1



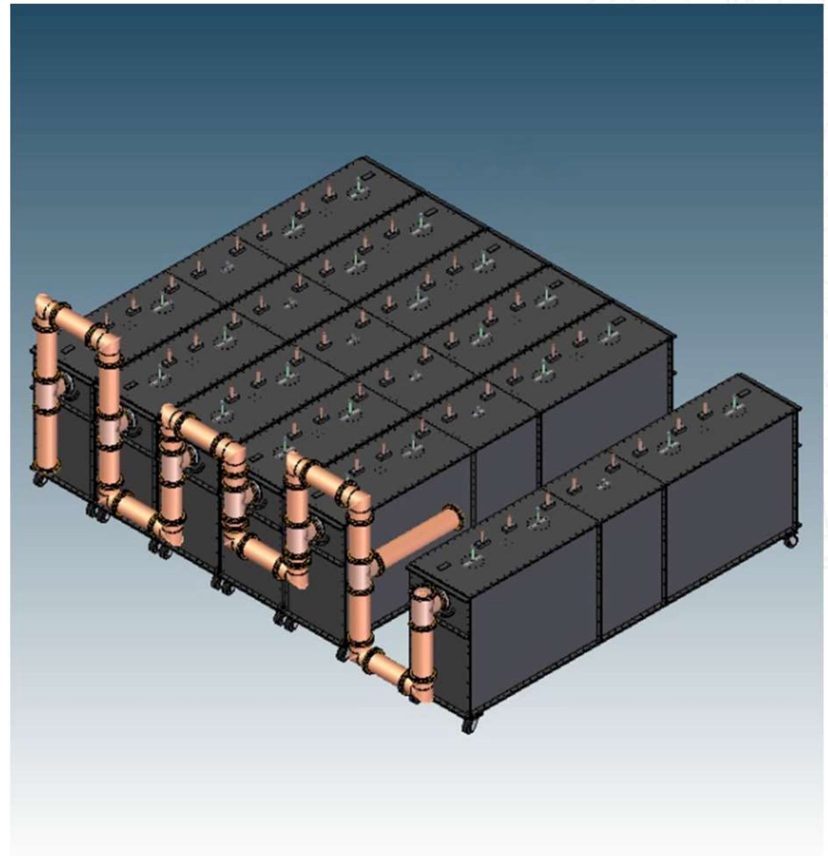
MODERNIZE WITH USE OF SIMULATION SOFTWARE

- Simulation has many benefits over traditional range measurements
  - Cost advantage, reflection free environment, mechanical tolerancing, human error, complete optimization, time constraints, standardization, quality, reproducibility……



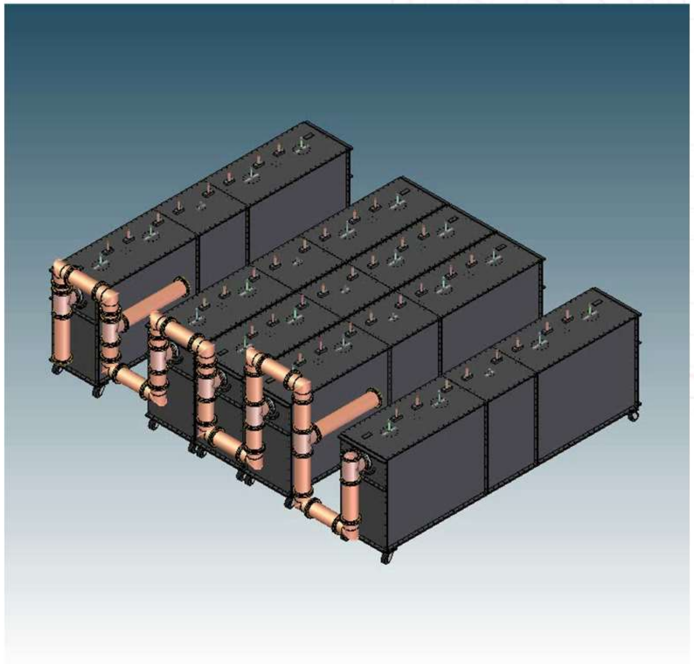
RECONFIGURABLE MANIFOLD

- What is a reconfigurable manifold combiner?
- New technology incorporates existing manifold combiner with new features
- Mechanical advantages – reduced size and higher reliability
- Walk through 7-channel design
- Electrical advantages – single filter per channel and expandable design
- Market analysis and real-world example



MECHANICAL ADVANTAGES

- **What is a reconfigurable manifold combiner?**
- Unique package that utilizes manifold spline
- Unused ports optimized for future expansion
- Analysis used to compute output spline line lengths
- Inputs/Outputs kept in the same location
- Smaller footprint and increased peak power rating over comparable designs



Patent Pending

MECHANICAL ADVANTAGES

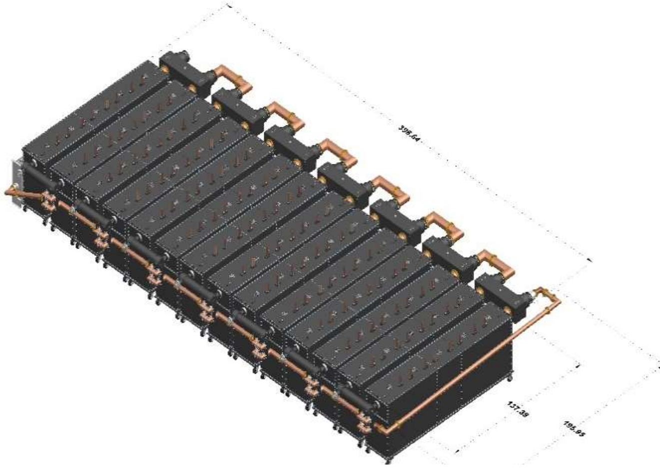
Footprint & Reliability

- Streamlined design footprint half the size of equivalent CIF
- Failure rate:

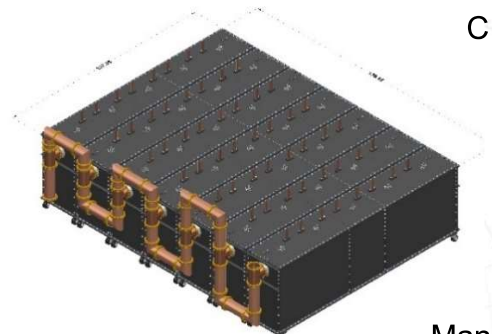
$$\lambda = \sum_{i=1}^{n} N_i \lambda_i \pi_{Qi}$$

- n: number of parts categories
- Ni: quantity of the ith part
- λi: failure rate of the ith part
- πQi: quality factor of the ith part

- Reliability directly proportional to parts count
- Manifold has 60% fewer components than equivalent CIF
- Simplicity = Reliability!



CIF: 378.4 ft^2



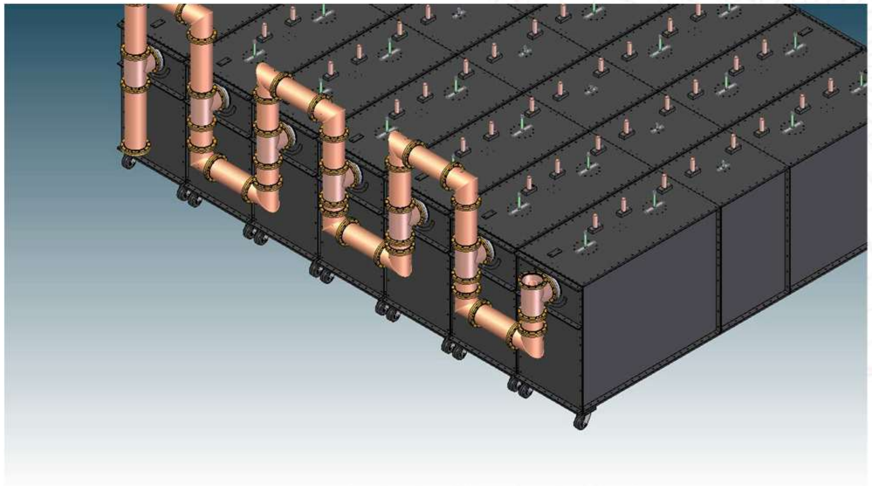
Manifold: 170.3 ft^2

Patent Pending

MECHANICAL ADVANTAGES

- **Adjustability & Stability**

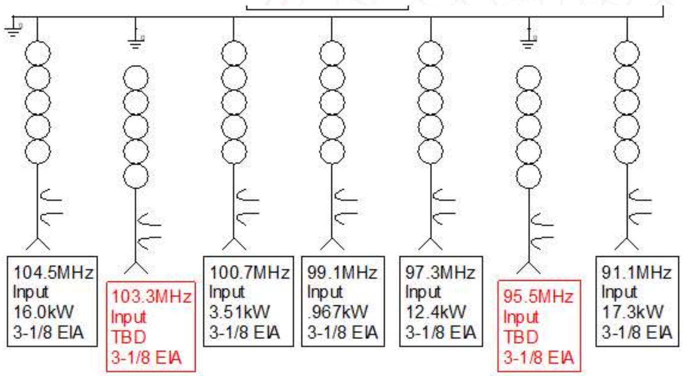
- Inputs/output remain stationary, no need to re-route TL
- U-links easily removed for phase modifications to the spline
- Each channel requires only one filter module
- Eliminates reject or ballast loads for combined system output
- Footprint of manifold combiner remains the same even with future channel addition



Patent Pending

7 CHANNEL DESIGN

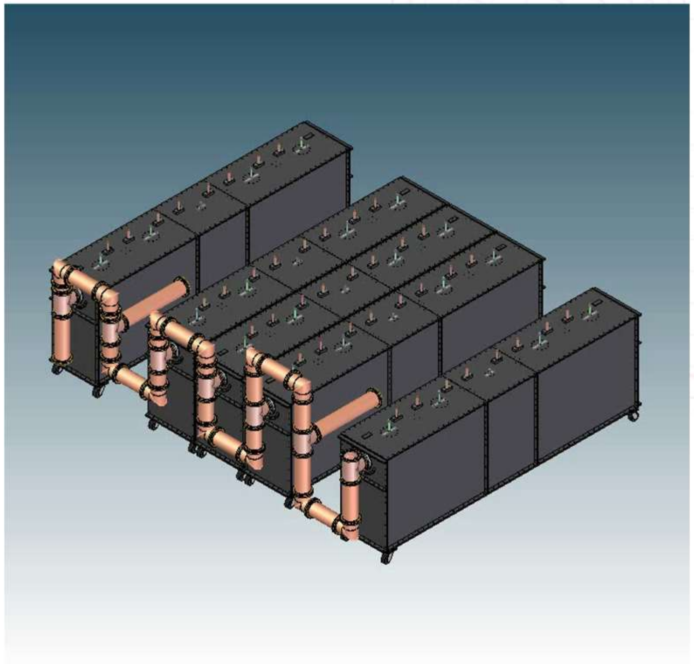
- **Ports for Future Channels**
- 7-channel manifold combiner
- 5 channels defined (black)
- 2 open ports for future channel expansion (red)
- Potential frequencies that could be added:
  - Slot 2: 102.9-103.5 MHz, 106.3 or 107.9 MHz
  - Slot 6: 94.9-96.3 MHz and 93.3 MHz



Patent Pending

7 CHANNEL DESIGN

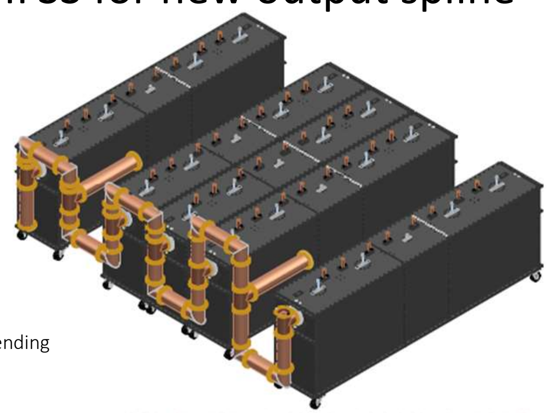
- **Spare Filters**
- All 7 filters incorporated in manufacturing and test
- Frequency matrix confirmed using HFSS based on known and anticipated channels
- Combiner installed with 5 known channel filters in place
- 2 shorts as placeholders for future channels
- 2 spare filters on site for future channels
- When a new channel is added combiner can be retuned in less than 4 hours, faster than adding a new CIF module into a CIF combiner
- Spare filters can also be swapped for a filter in the combiner that requires maintenance



Patent Pending

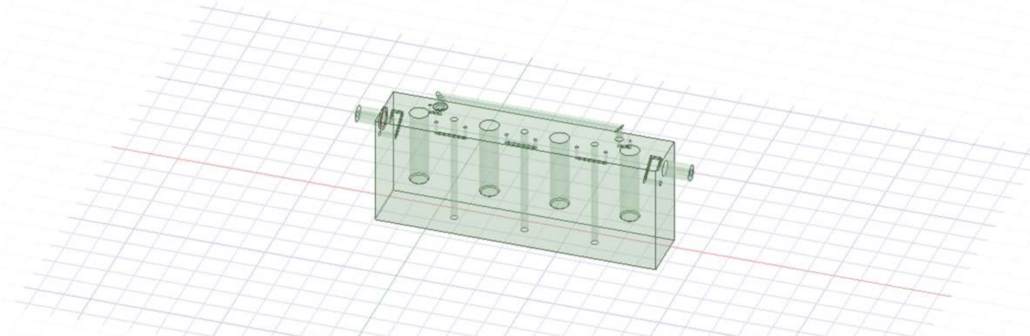
7-Channel Design

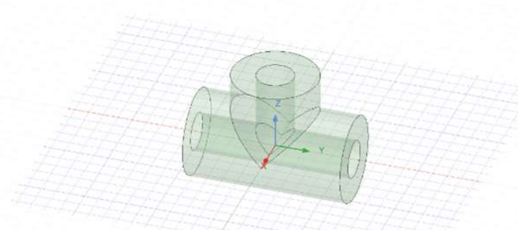
- **Electrical Shorts for Unused Ports**
- 2 unused ports are capped with electrical shorts
- For known future channel the short is equivalent to the electrical short of the filter for that channel
- Output spline is determined in original design and does not need to change
- For unknown future channels analysis is completed in HFSS for new output spline

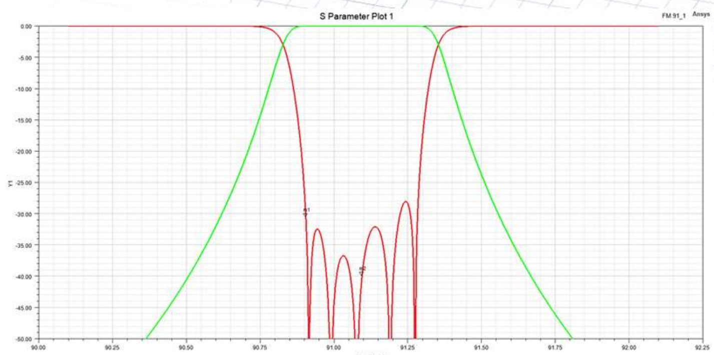


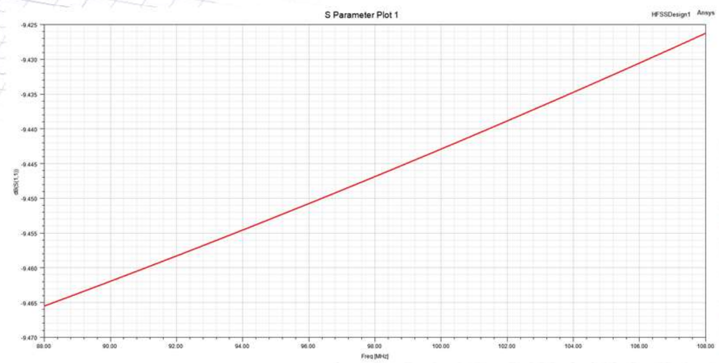
7 CHANNEL DESIGN

- **Defining the Spline in HFSS**
- HFSS determines S-parameters for each tuned filter and elbows/tees in the output spline









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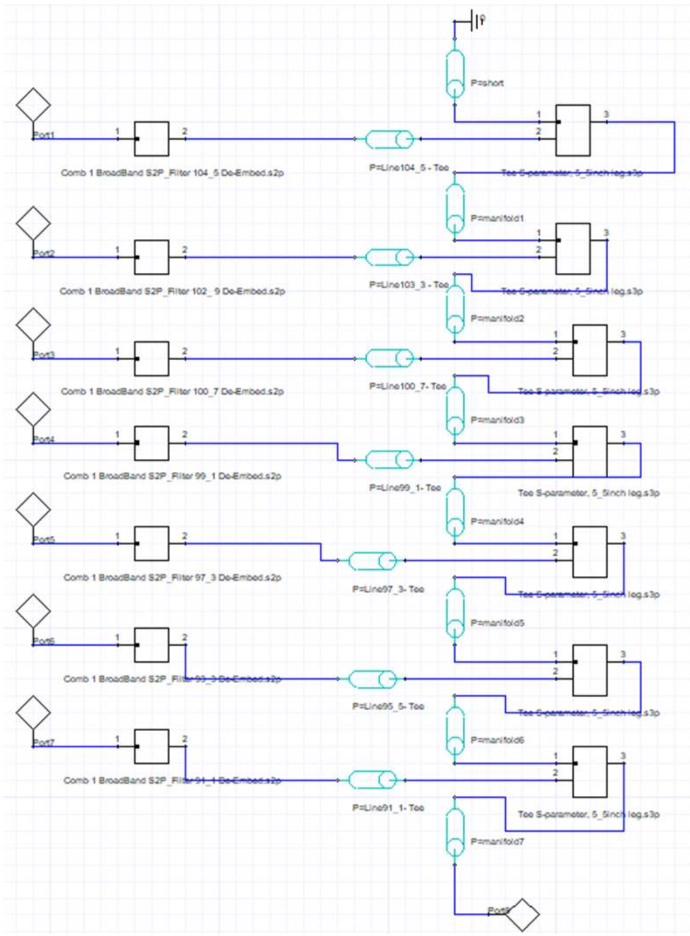
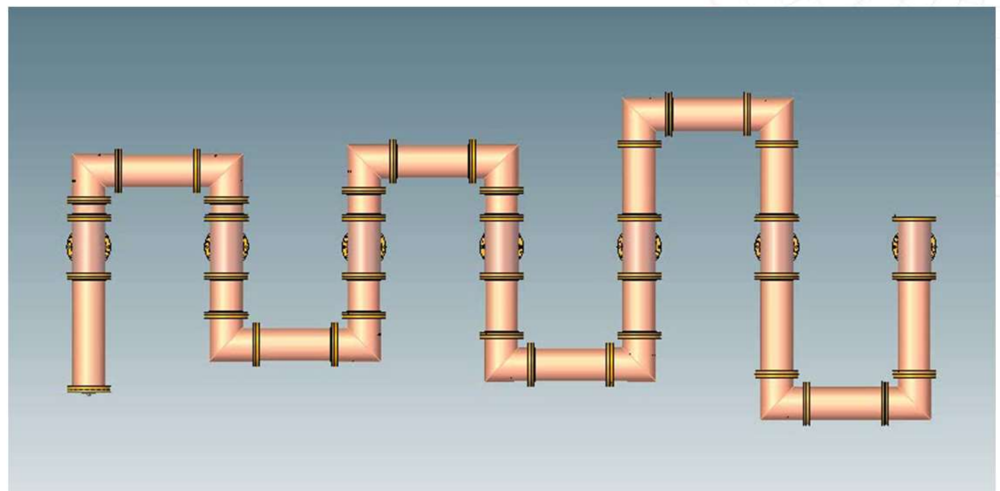
7 CHANNEL DESIGN



- **Defining the Spline in HFSS**
- S-parameter data entered into circuit simulator, line lengths are calculated for each configuration



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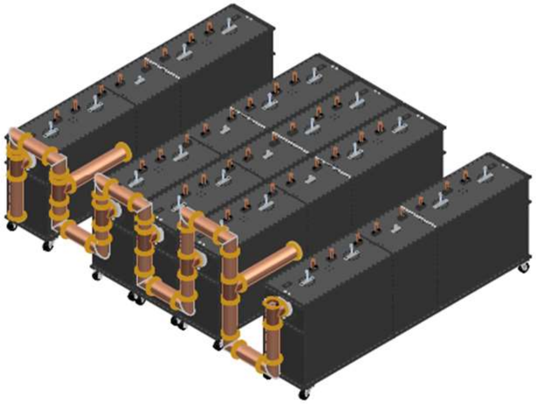
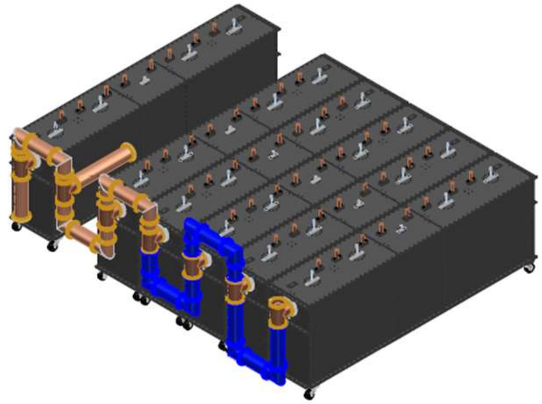
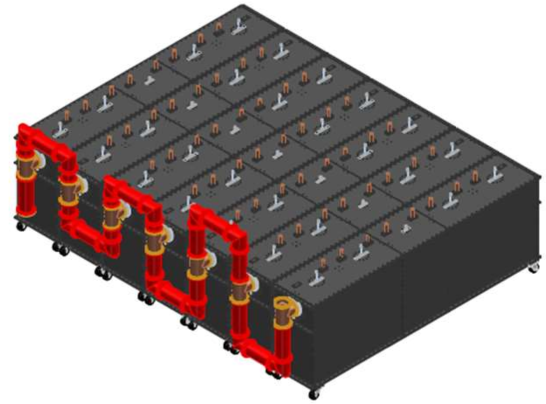
7 CHANNEL DESIGN

- **Defining the Spline in HFSS**
- When a new channel or channels are added some or all of the u-links in the output spline change







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ELECTRICAL ADVANTAGES

All positions are equal

Similar loss, VSWR, and group delay

Each station tuned to <1.06:1 regardless of position

Voltage limited by filters, mitigated by proper I/O sizing

Manifold Combiner			
Station	Freq, MHz	Loss, dB	Eff, %
1	104.5	0.43	0.91
2	TBD		
3	100.7	0.41	0.91
4	99.1	0.4	0.91
5	97.3	0.39	0.91
6	TBD		
7	91.1	0.36	0.92

- CIF Combiner

- CIF will have increased loss farther from antenna
- Station at ballast load has degradation over others
- Increased VSWR as you approach load side
- Hybrids are the weakest voltage link

CIF Combiner			
Station	Freq, MHz	Loss, dB	Eff, %
1	104.5	0.5	0.89
2	100.7	0.55	0.88
3	99.1	0.61	0.87
4	97.3	0.67	0.86
5	91.1	0.71	0.85
6	TBD		
7	TBD		

• Potential Market Size

- 100 stations on the FM spectrum with many combinations available for each market
- Even with streamlined analysis number of possibilities are daunting
- To determine the maximum number of stations in any market: $\frac{F(t)}{F(e)}$

- F(t): total number of stations available (100)
- F(e): number of stations eliminated when one is selected due to 800 kHz spacing (4)

- For any market, maximum number of stations is 25

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- **Boston**
- 21 potential stations
- Eliminating LP and directional patterns left with
- Assume 5 of 9 stations join a shared antenna system
- 7-channel manifold combiner could be utilized with 2 open ports for future expansion

Status	Calls	Freq	Power	City	State
LIC	WERS(FM)	88.9	4	Boston	MA
LIC	WGBH(FM)	89.7	100	Boston	MA
LIC	WJMN(FM)	94.5	9.2	Boston	MA
LIC	WBQT(FM)	96.9	22.5	Boston	MA
LIC	WBZ-FM	98.5	9	Boston	MA
LIC	WZLX(FM)	100.7	21.5	Boston	MA
LIC	WBGB(FM)	103.3	8.7	Boston	MA
LIC	WWBX(FM)	104.1	21	Boston	MA
LIC	WMJX(FM)	106.7	21.5	Boston	MA

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MARKET ANALYSIS

- **Boston - Continued**
- 5 known stations, leaves 2 of the remaining 4 stations able to join the system
- Ideally, each solution for the output spline would be calculated in HFSS
- To limit design time, need total possible combinations for Boston market

$$C(n,r) = n!/[r! * (n-r)]$$

- n: number of stations not included in the manifold
- r: number of spare ports available on the manifold

- In this case there are 6 possible solutions for the Boston market, simplifying the analysis

MARKET ANALYSIS

St. Louis

- 10 possible omni, high power stations
- Assume 4 of the 10 stations decide to join a shared antenna system
- Using a 7-channel combiner, 3 of the remaining 6 stations can join the system
- This leaves 20 possible output spline solutions to solve in HFSS

Status	Calls	Freq	Power	City	State
LIC	KDHX(FM)	88.1	42	St. Louis	MO
LIC	KWMU(FM)	90.7	100	St. Louis	MO
LIC	KSIV-FM	91.5	85	St. Louis	MO
LIC	WIL-FM	92.3	100	St. Louis	MO
LIC	KSD(FM)	93.7	74	St. Louis	MO
LIC	WFUN-FM	96.3	92	St. Louis	MO
LIC	KYKY(FM)	98.1	90	St. Louis	MO
LIC	KEZK-FM	102.5	100	St. Louis	MO
LIC	KLOU(FM)	103.3	90	St. Louis	MO
LIC	KSLZ(FM)	107.7	100	St. Louis	MO

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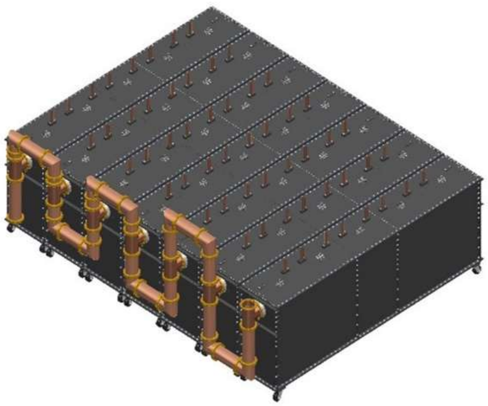
CONCLUSION

- Historically CIF combiners have been used for channel expansion of multi-channel systems
- Manifold combiner is a viable alternative:
  - Smaller footprint
  - Fewer parts, higher reliability
  - Equality in electrical performance across stations
- Advancement in simulation software allows for increased efficiency for all possible design scenarios
- Manifold provides a superior economical solution for future multi-station systems



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THANKS FOR YOUR TIME!
ANY QUESTIONS?

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