

2D Traveling Wave Array Employing a Trapezoidal Dielectric Wedge for Beam Steering

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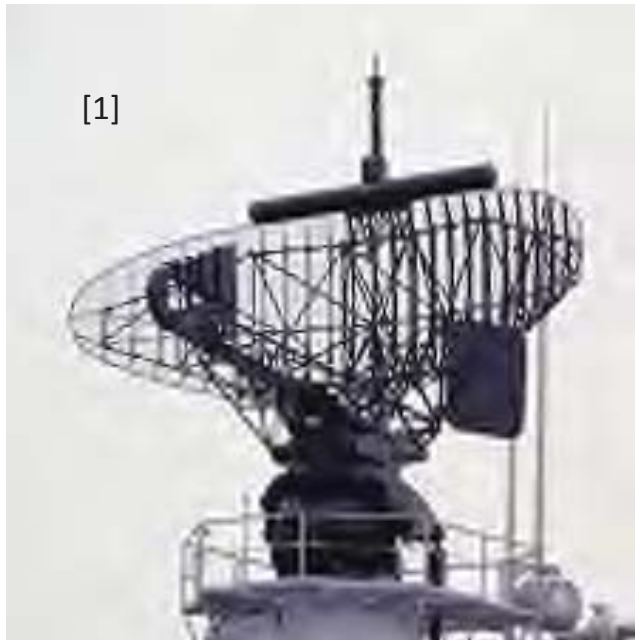
This presentation addresses the progress made so far in the development of an antenna array with reconfigurable transmission line feeds connecting each element in series. In particular, 2D traveling wave array employing trapezoidal Dielectric Wedge for Beam Steering will be discussed. The presentation includes current status of the effort and suggested future work. The work is being done as part of the NASA Office of the Chief Technologist's Space Technology Research Fellowship (NSTRF).

Acknowledgement

This work was supported by a NASA Office of the Chief Technologist's Space Technology Research Fellowship (NSTRF),
NASA Grant #NNX11AN16H



Mechanically Scanned



- Simple
- Inexpensive
- Slow
- Rudimentary capabilities



Electronically Scanned



- Advanced capabilities
- Fast
- Expensive
- Complex

[1] <http://www.aviationweek.com/Blogs.aspx?plckBlogId=Blog:27ec4a53-dcc8-42d0-bd3a-01329aef79a7&plckPostId=Blog:27ec4a53-dcc8-42d0-bd3a-01329aef79a7Post:6339e6b9-1484-4eed-89b5-f6236600cd8a>

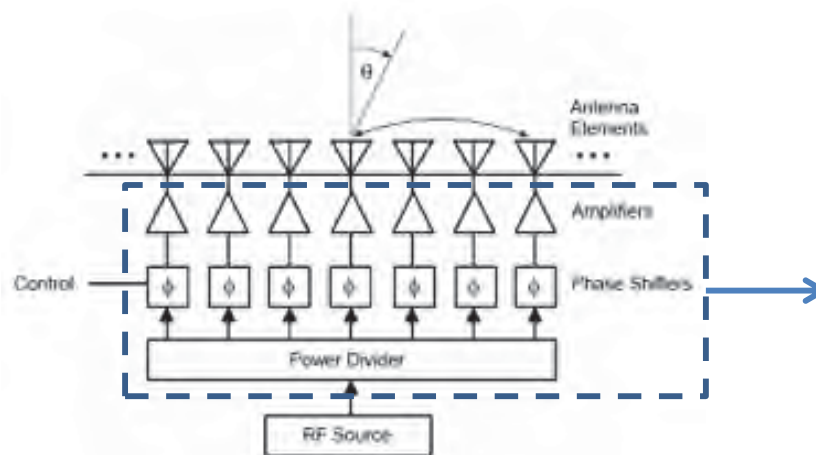
[2] <http://archive.nrc-cnrc.gc.ca/eng/projects/hia/phased-array.html>

Design Goals:

- *Reduce Complexity*
- *Reduce Weight*
 - Large contributions for both come from the backend
- *Reduce Cost*

Methodology:

- *Replace backend with simpler feeding mechanism*



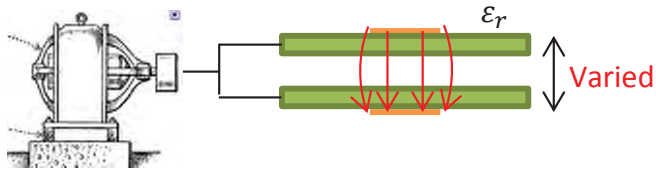
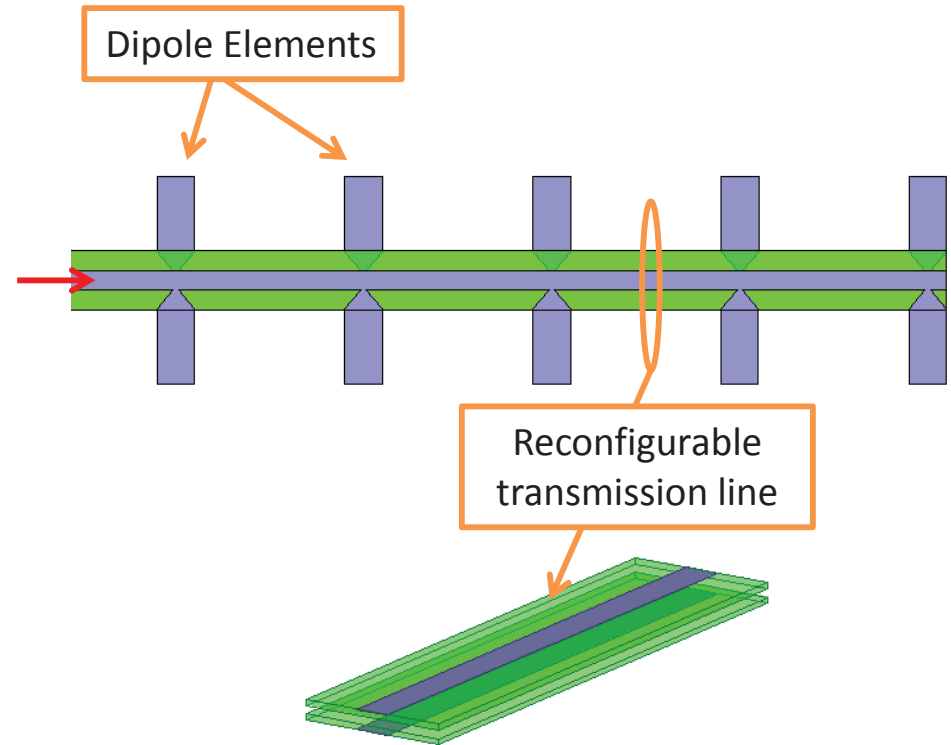
Replace with simpler mechanism

Replace Backend With Simpler Mechanism

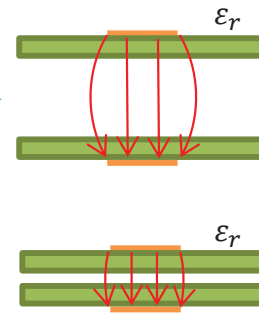
- *Get rid of all splitters, phase shifters, and amps*

Use Series Fed Array:

- *Array fed at one point (side)*
- *Magnitude at each element controlled by varied mismatch at element terminals*
- *Beam Steering will be accomplished by a controllable propagation constant between elements*
 - A motor can bring two fixed sheets closer to change the effective dielectric constant



Motor to move sheets closer or farther apart

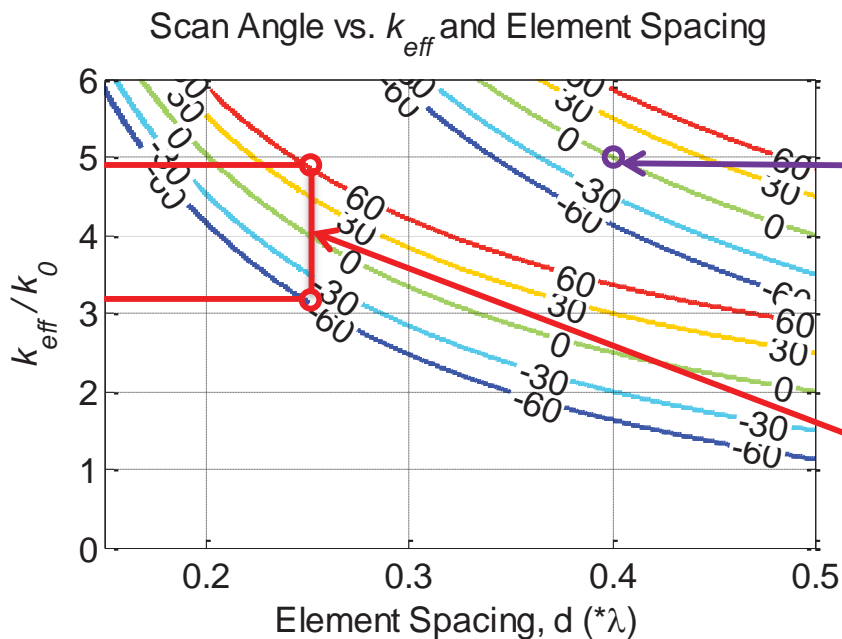
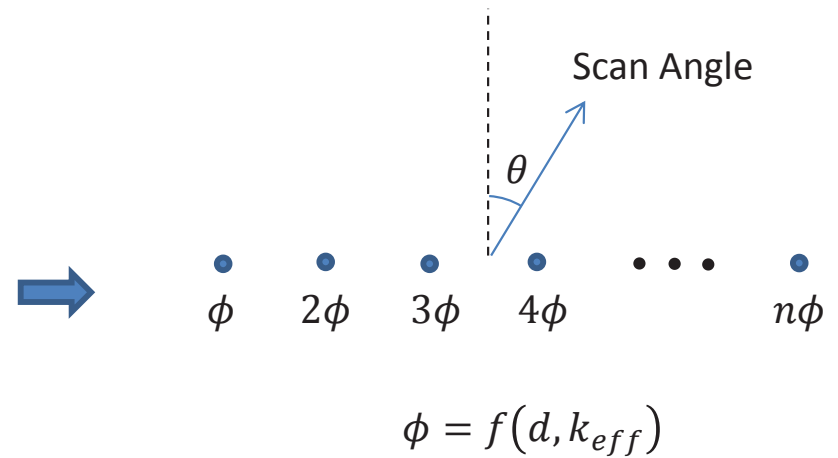
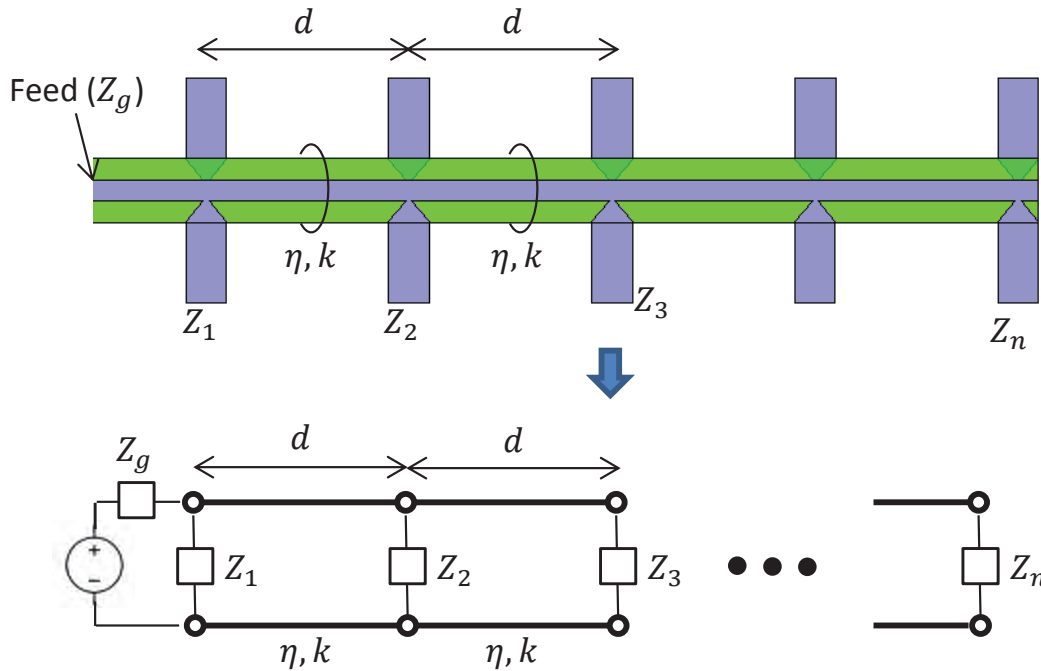


Field mostly in air, so low ϵ_{eff}

Field mostly in dielectric, so high ϵ_{eff}

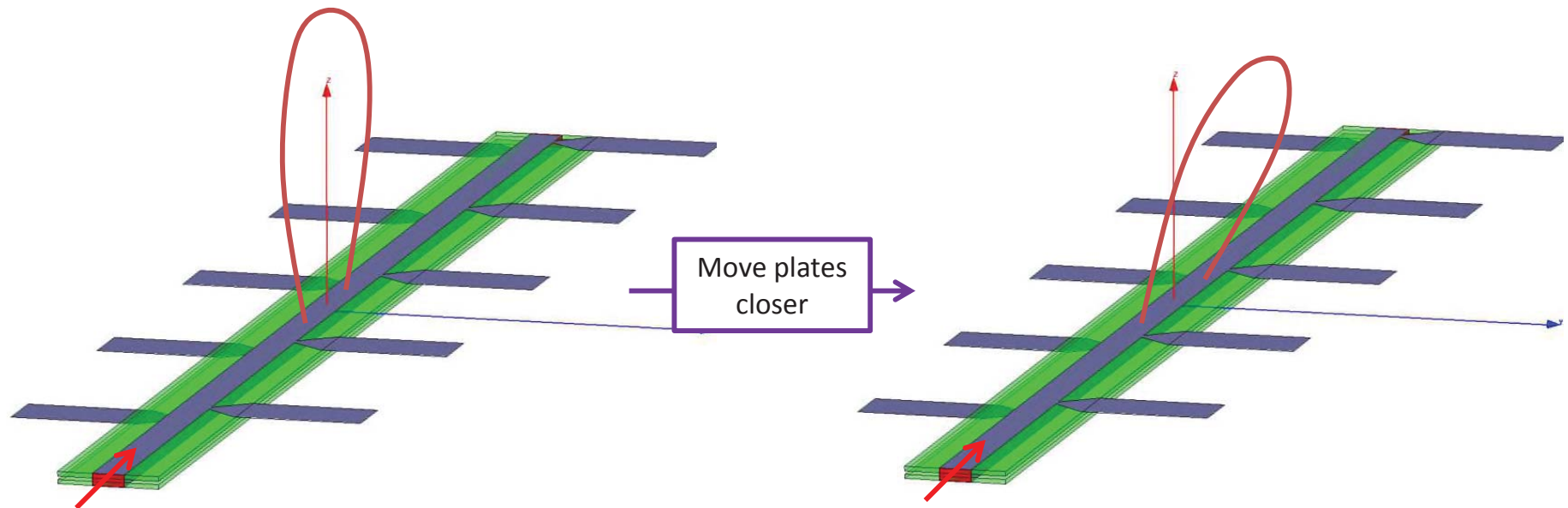
By changing ϕ (through change of k_{eff}) scanning is accomplished:

Needed Transmission Line Agility



For $d = 0.4\lambda$ and $\frac{k_{eff}}{k_0} = 5 \Rightarrow \theta = 0^\circ$

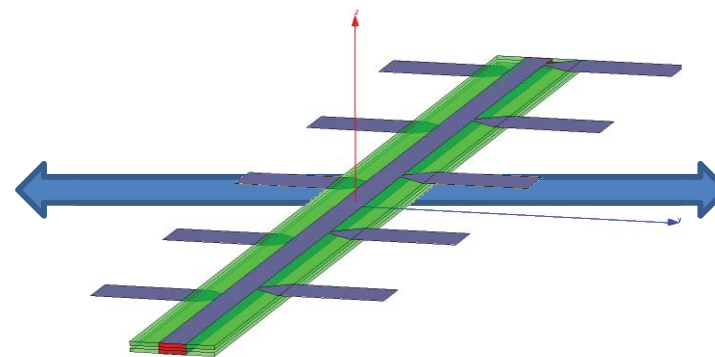
For $\theta = -60$ to 60 at $d = 0.25\lambda \Rightarrow \text{Need } 3.1 \leq \frac{k_{eff}}{k_0} \leq 4.9$



Scanning is achieved with one mechanical motion and no phase shifters



- Simple
- Inexpensive
- Slow
- Rudimentary capabilities



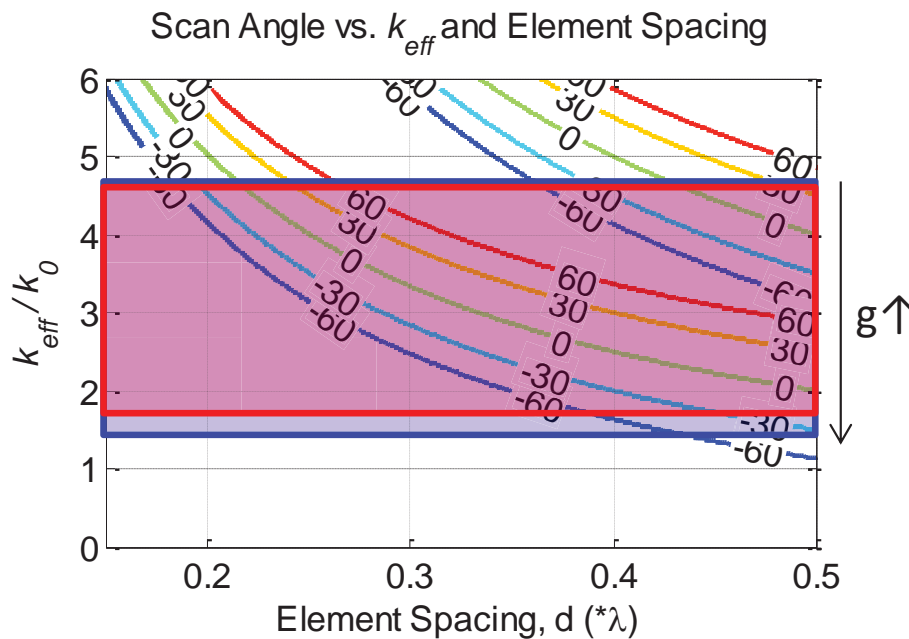
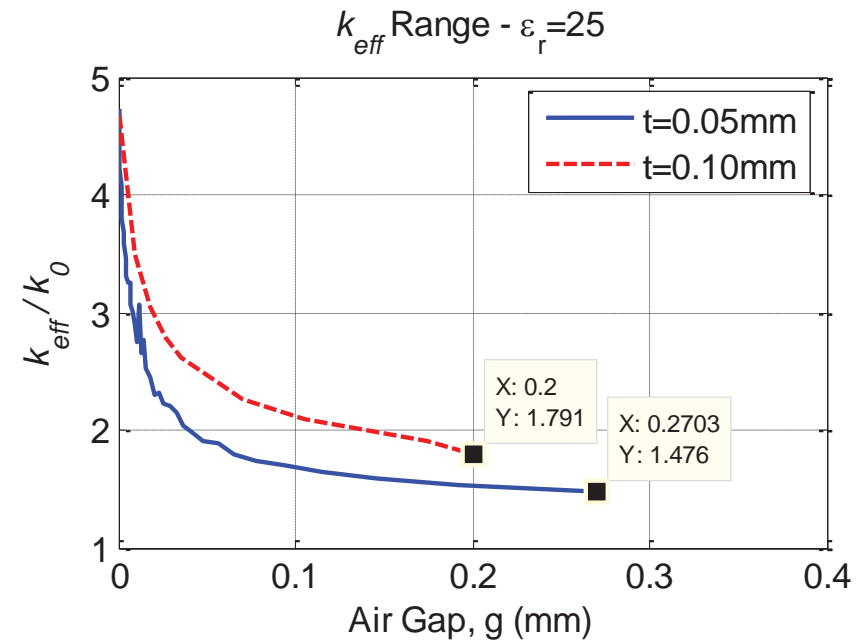
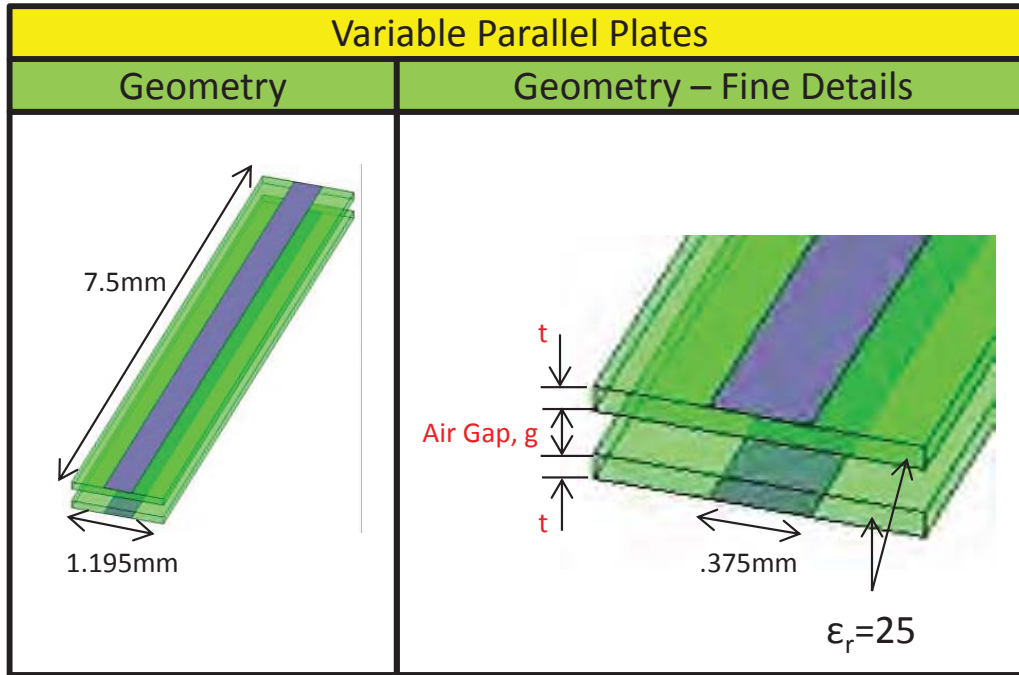
- Simple
- Inexpensive
- Fast



- Advanced capabilities
- Fast
- Expensive
- Complex

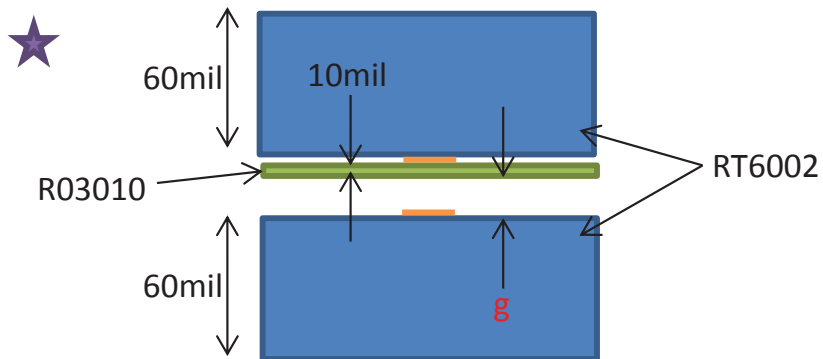
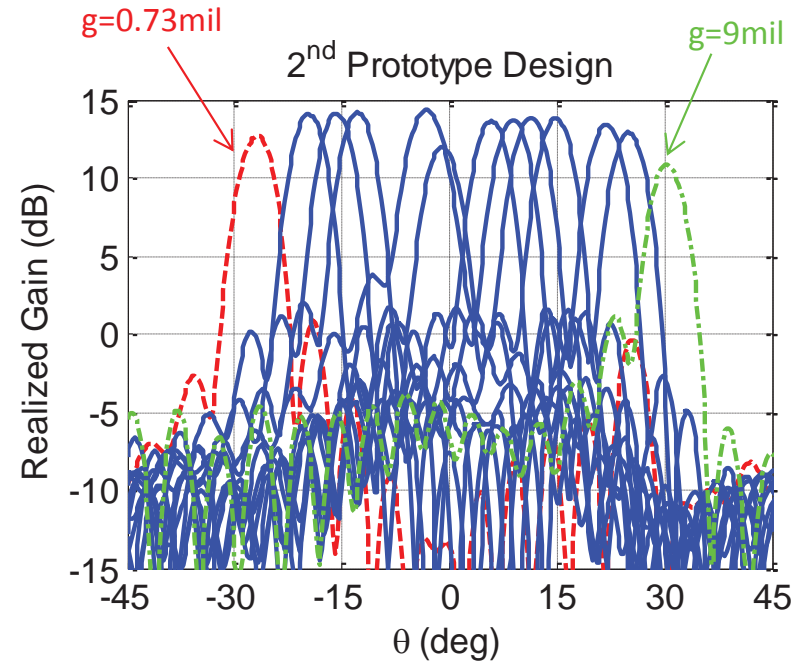
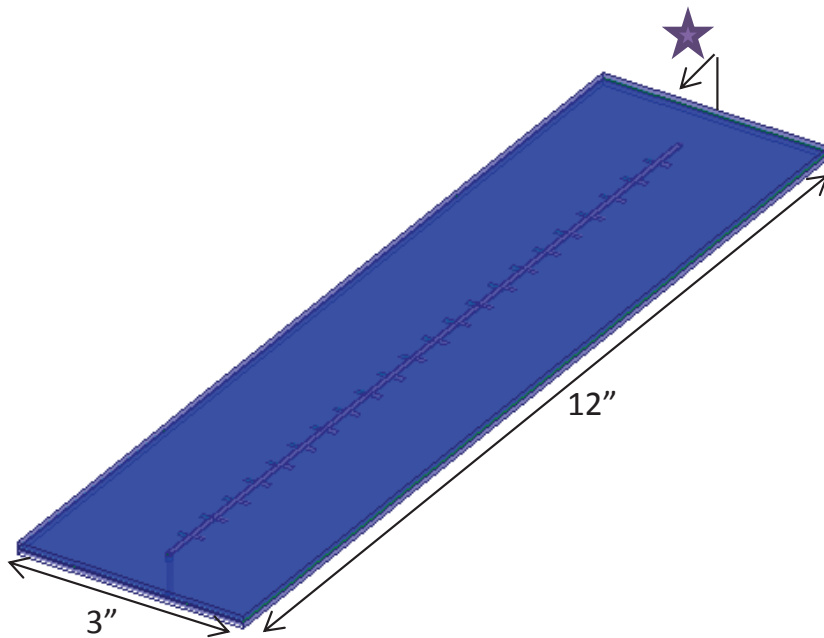
The technology is a compromise between **capability** and **cost**

Achievable k_{eff} Range - $\epsilon_r = 25$



- Strip Spacing $\leq 0.40\text{mm}$ ($\lambda/20$ @ 40GHz)
 - $t=0.1\text{mm}$ case \rightarrow lower max g
- $t=0.05\text{mm}$
 - Larger $\epsilon_{eff}\mu_{eff}$ range
 - More precision needed
- $t=0.10\text{mm}$
 - Smaller $\epsilon_{eff}\mu_{eff}$ range
 - Less precision needed

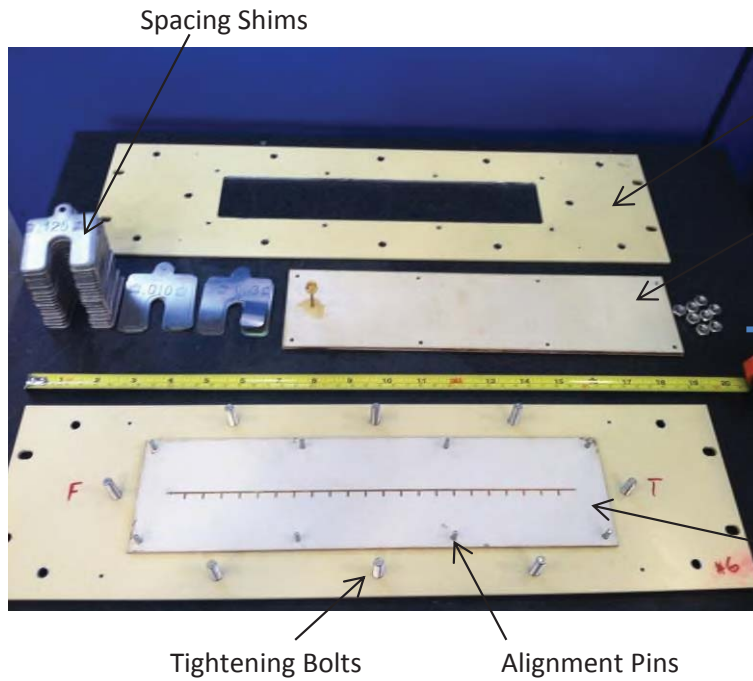
22 Element Prototype Design



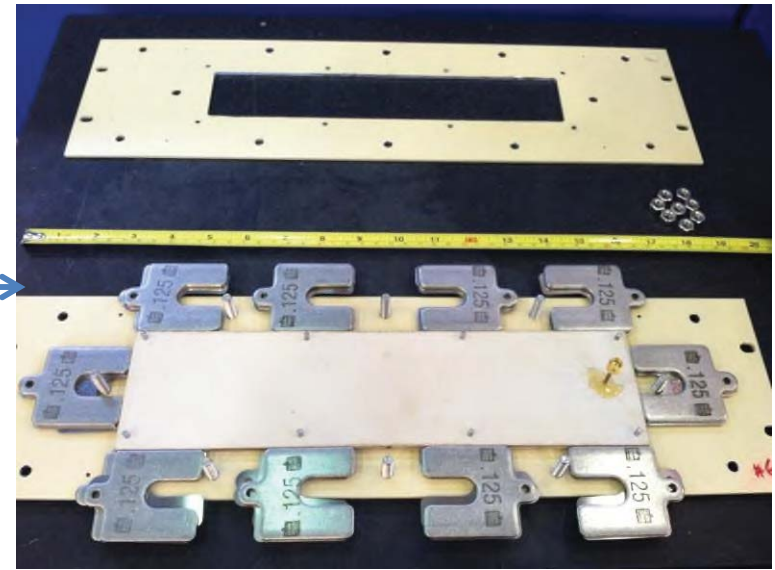
Practical Transmission Line Design

- Circuit printed on two 60mil thick RT6002 boards
 - R03010 becomes ripply when unsupported
- R03010 material bonded to inside of one of boards

Assembly of Prototype



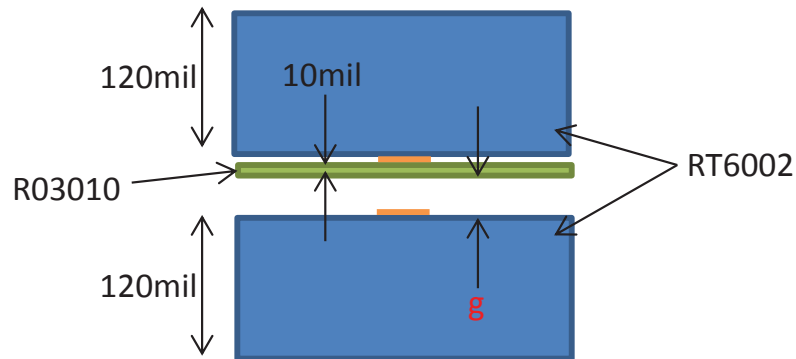
Fit top dielectric on with shims as spacers



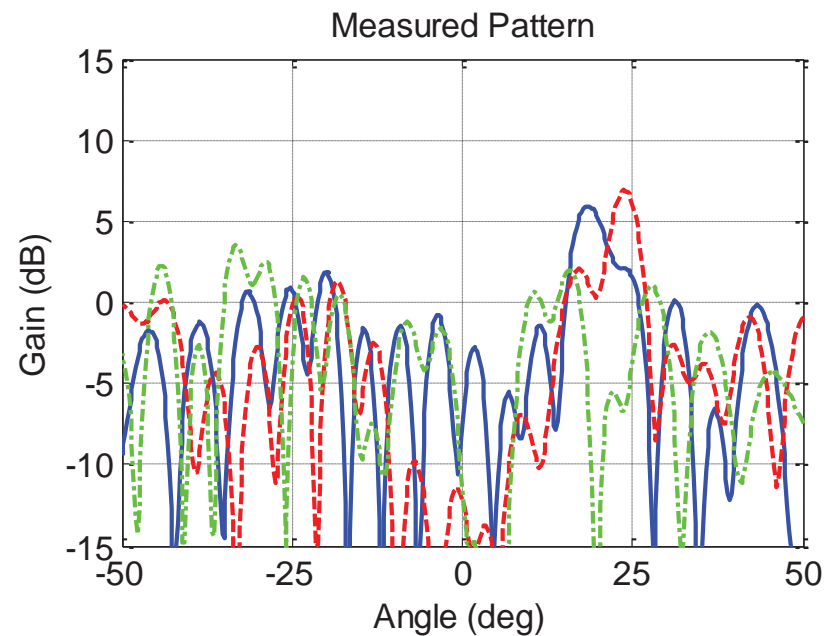
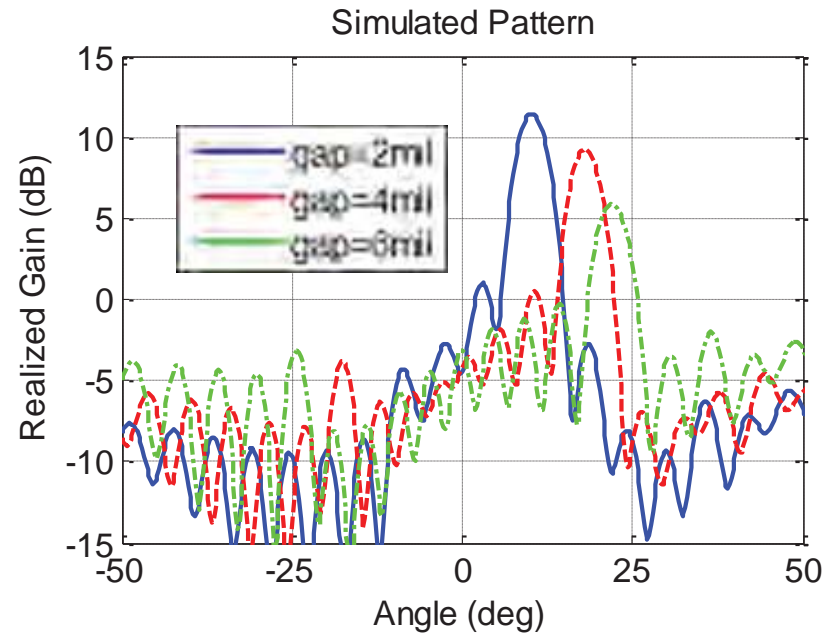
Pinch together two boards with metal frames

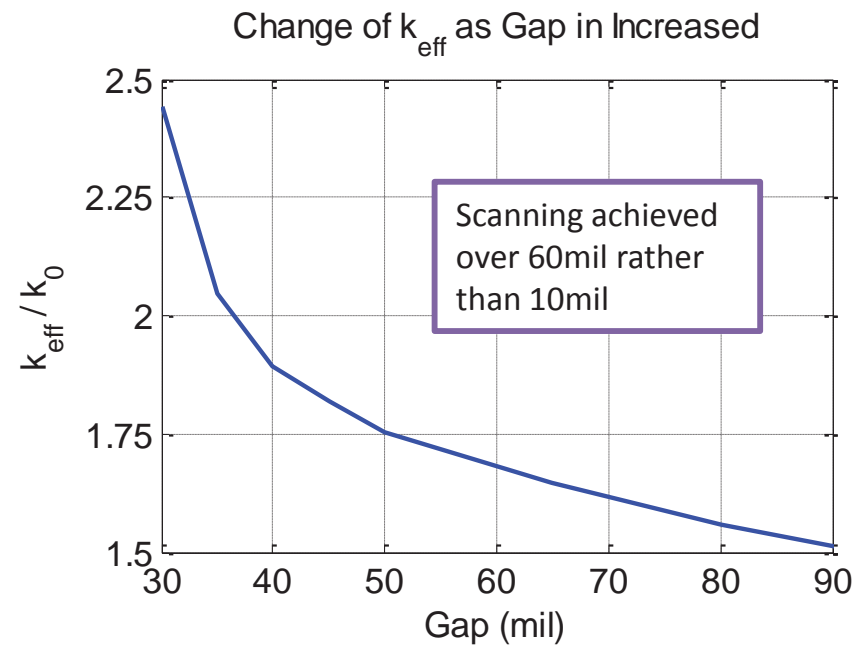
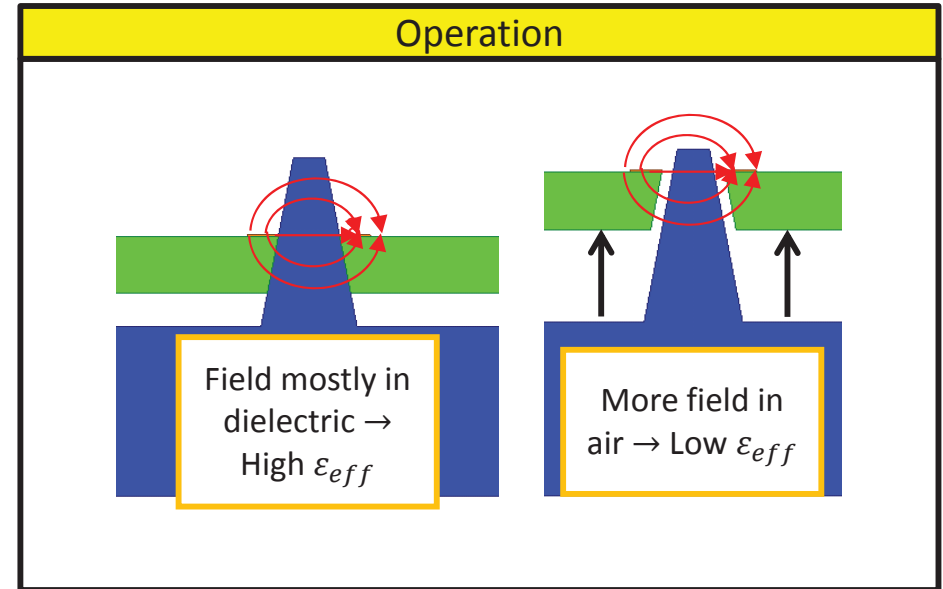
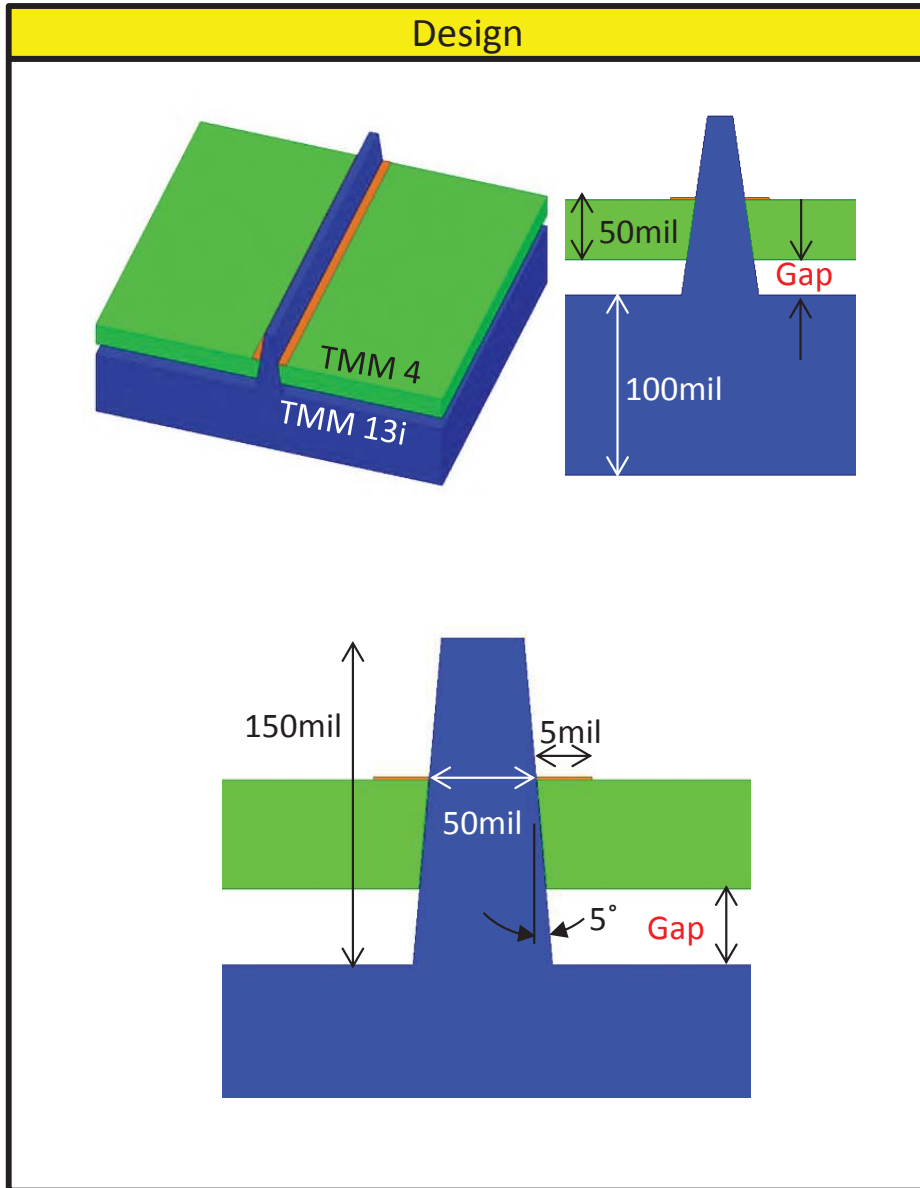


- Metal plates used to ensure rigidity
- Bolts used to squeeze together
- Spacers to achieve gap

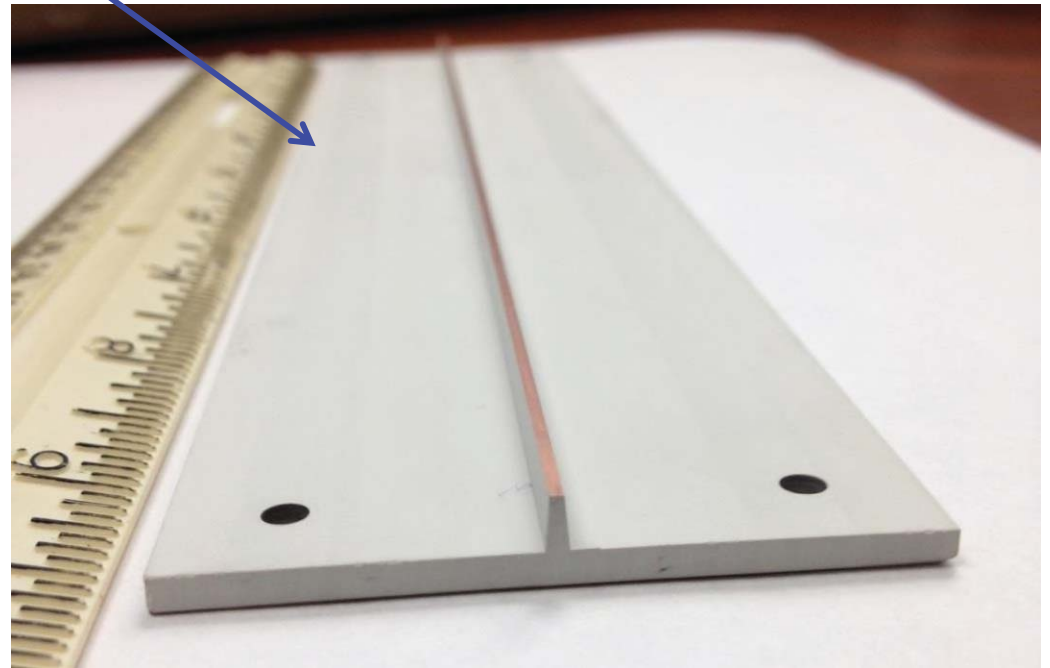
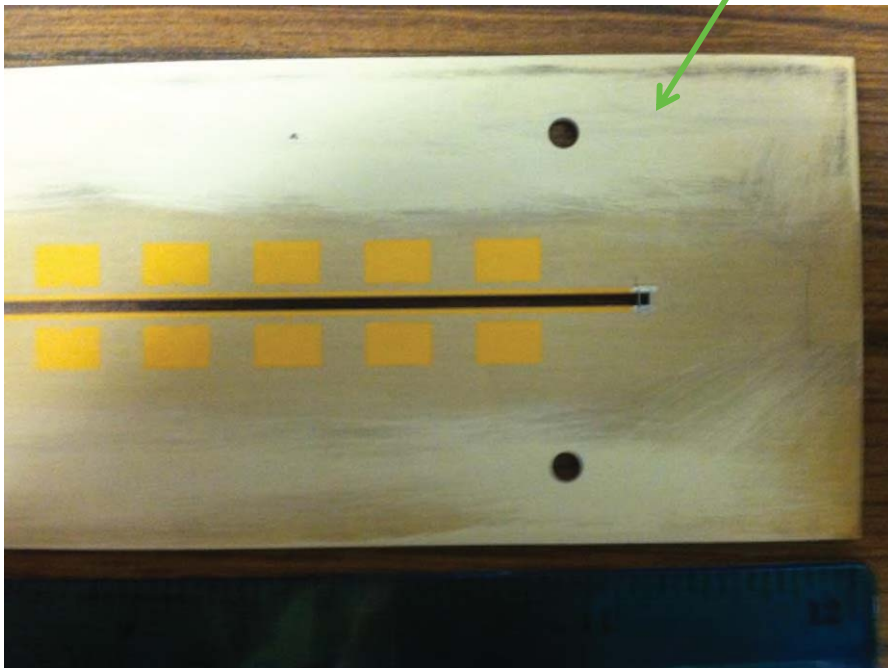
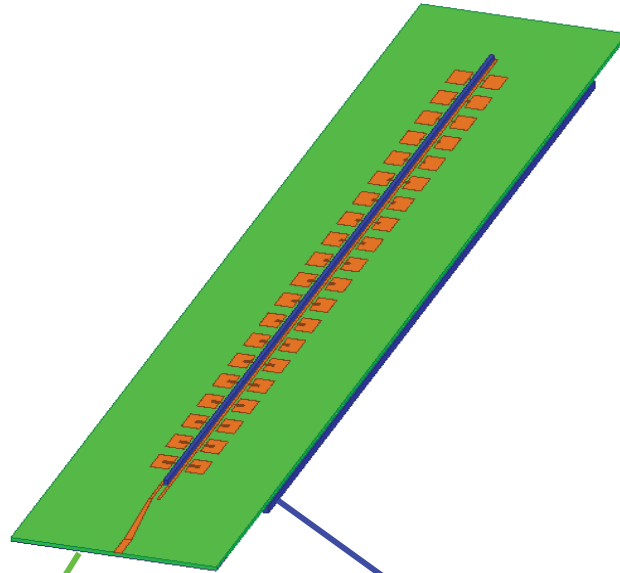


- Scanning Observed
- Achieving gap imprecise
 - Patterns shifted
 - Gain Lowered

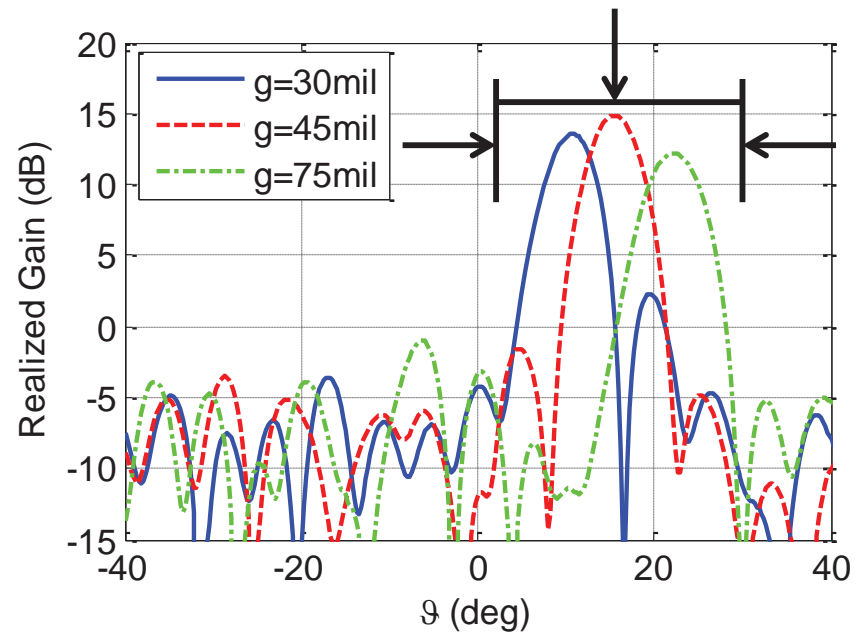
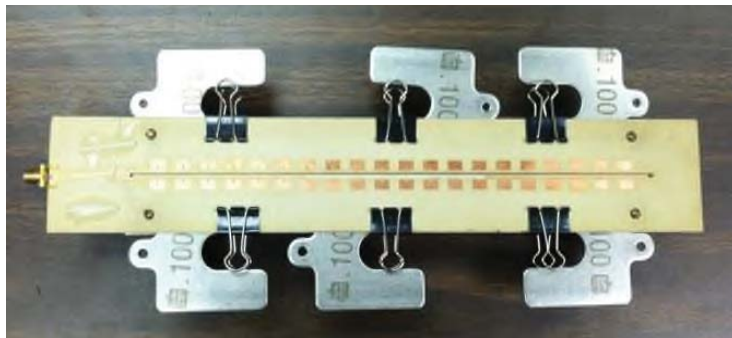
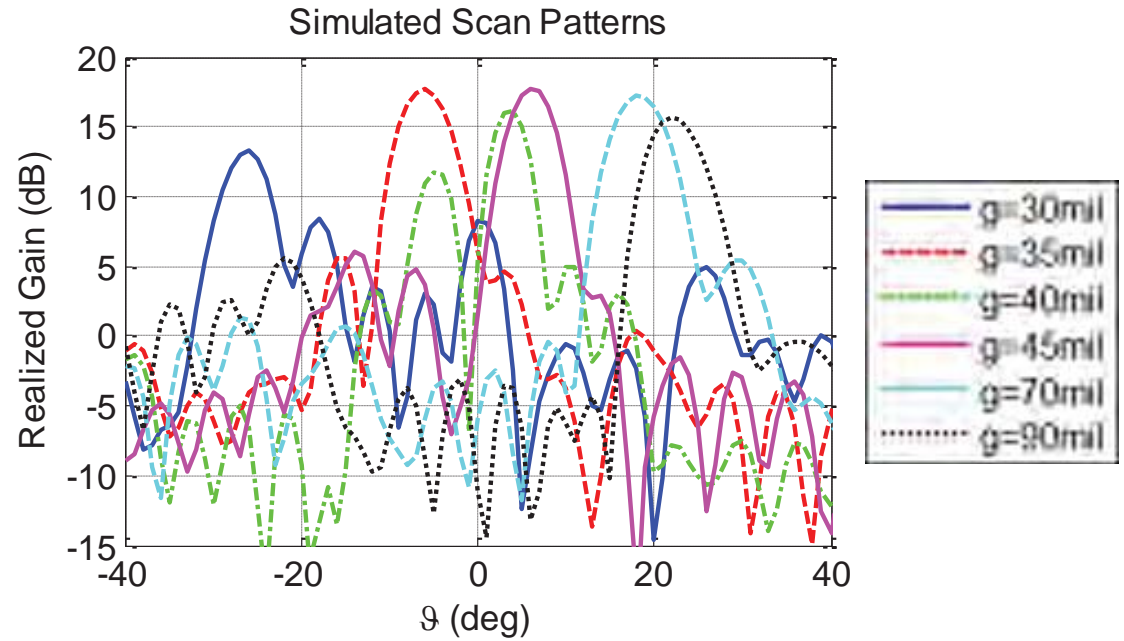
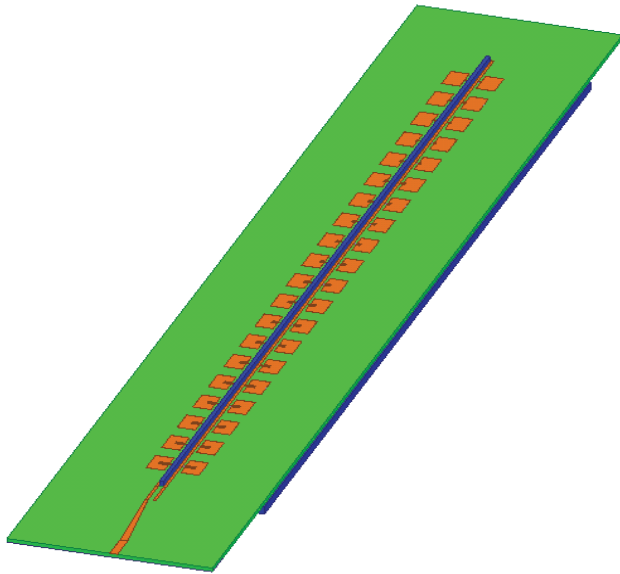


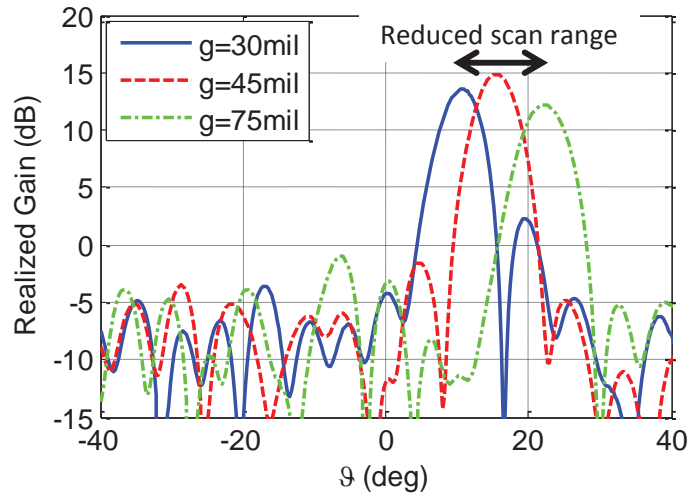


Prototype Pieces



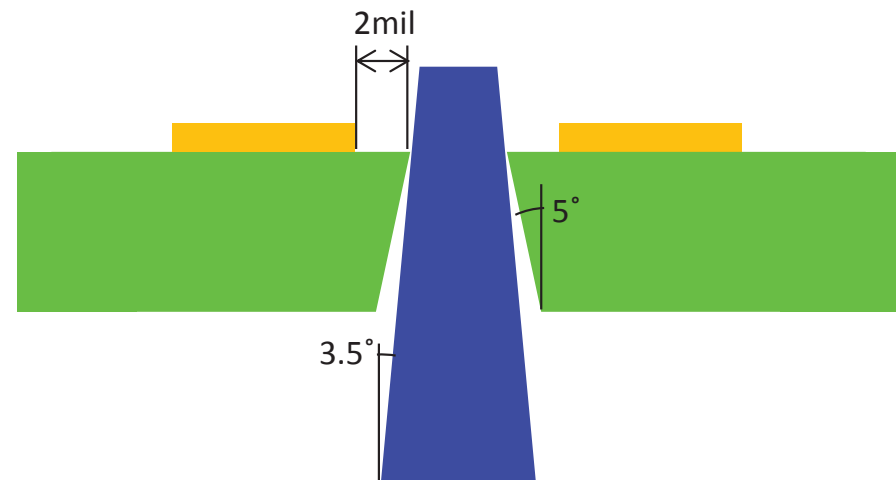
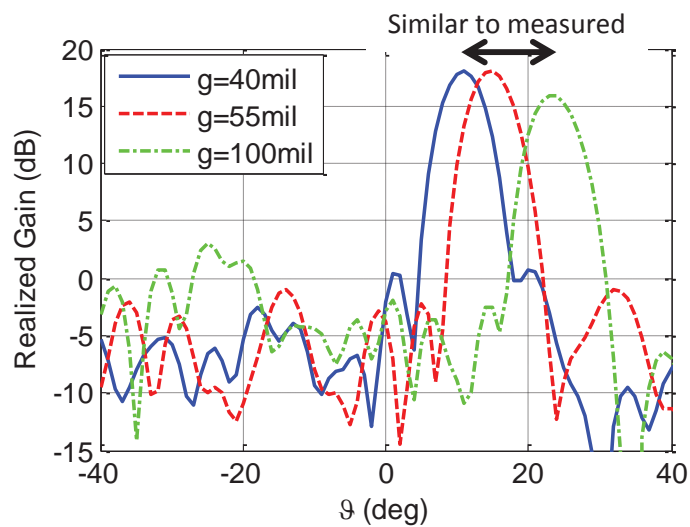
Simulated vs. Measured

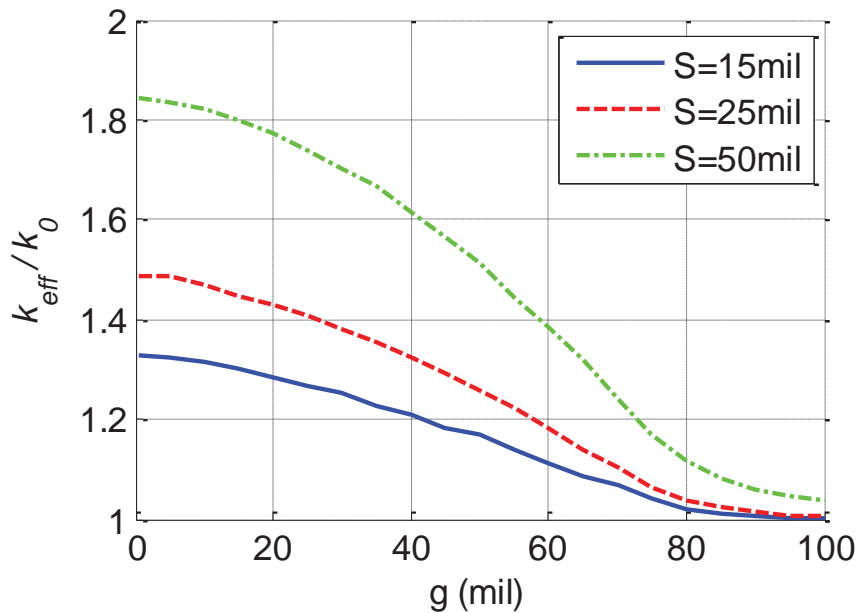
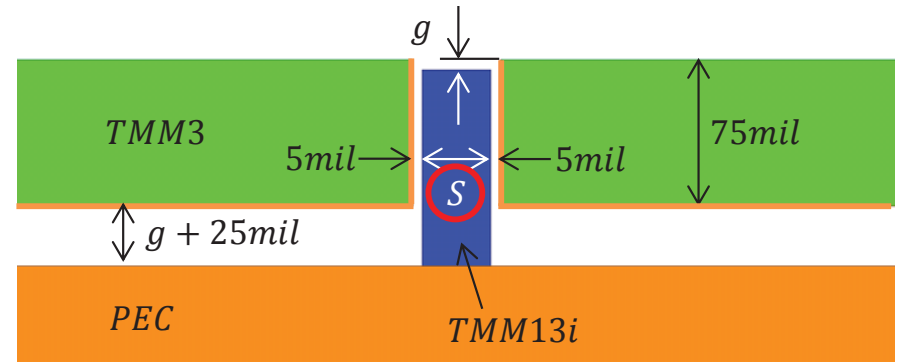
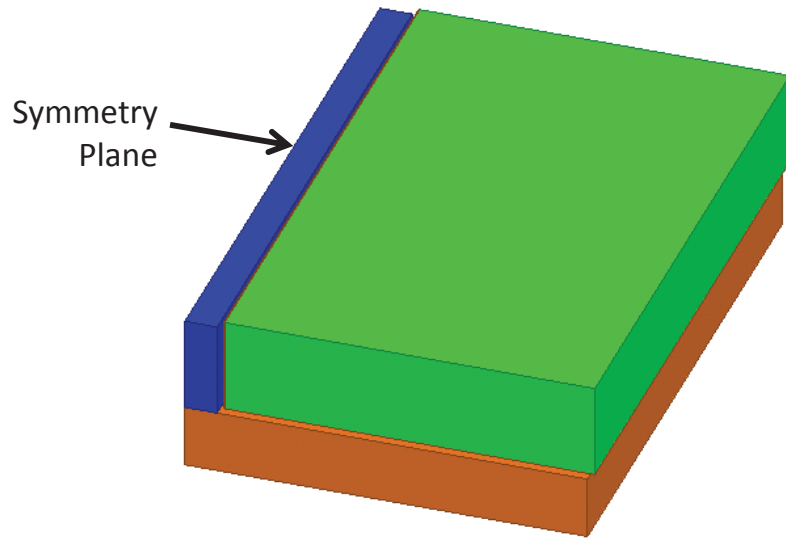




Simulated with known differences

- Ridge dimensions
- Overetch





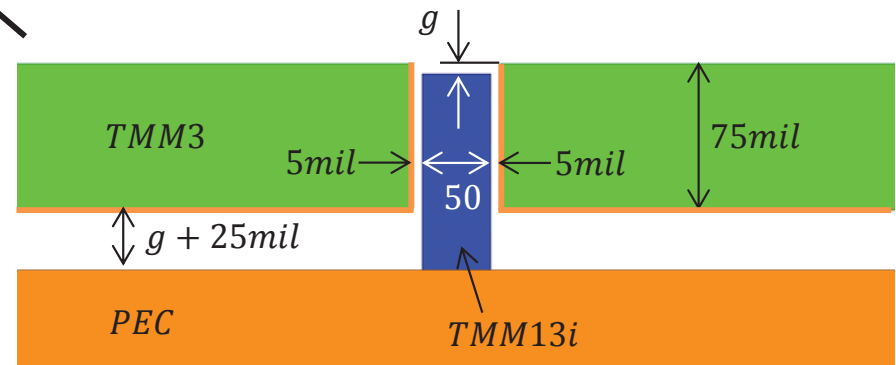
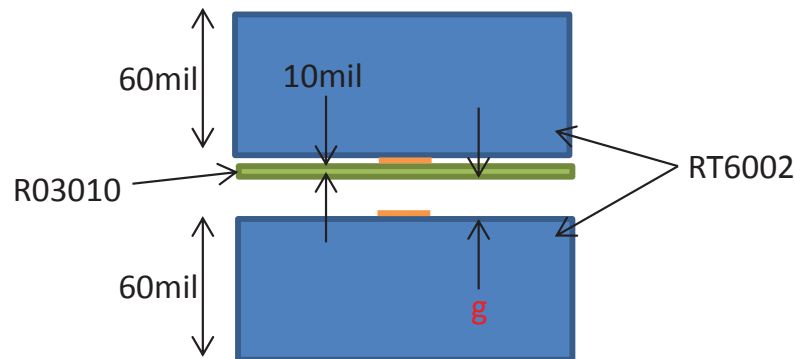
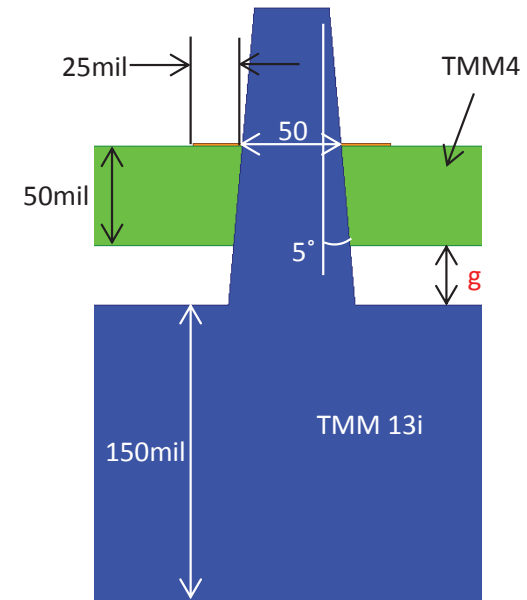
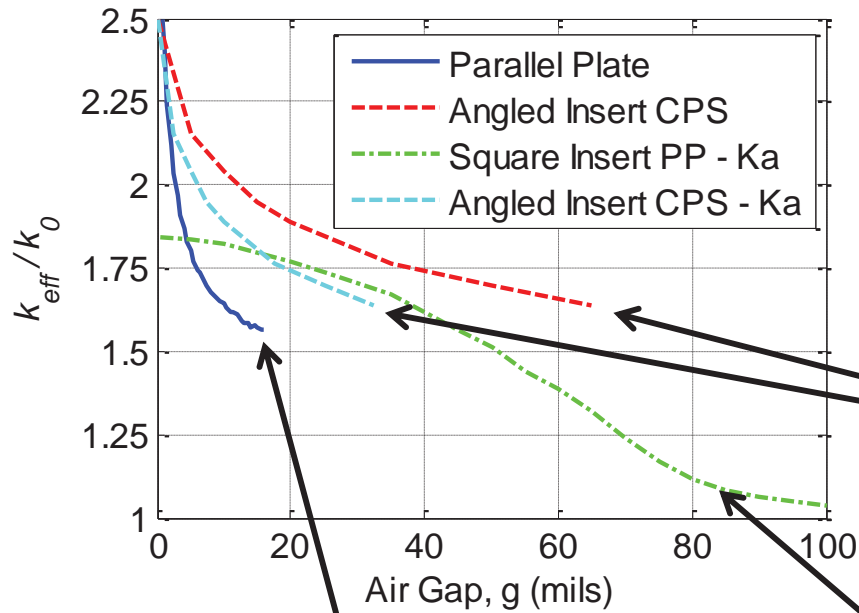
Improvements

- Simpler fabrication
- Built in insert clearance
- Increased k_{eff} control

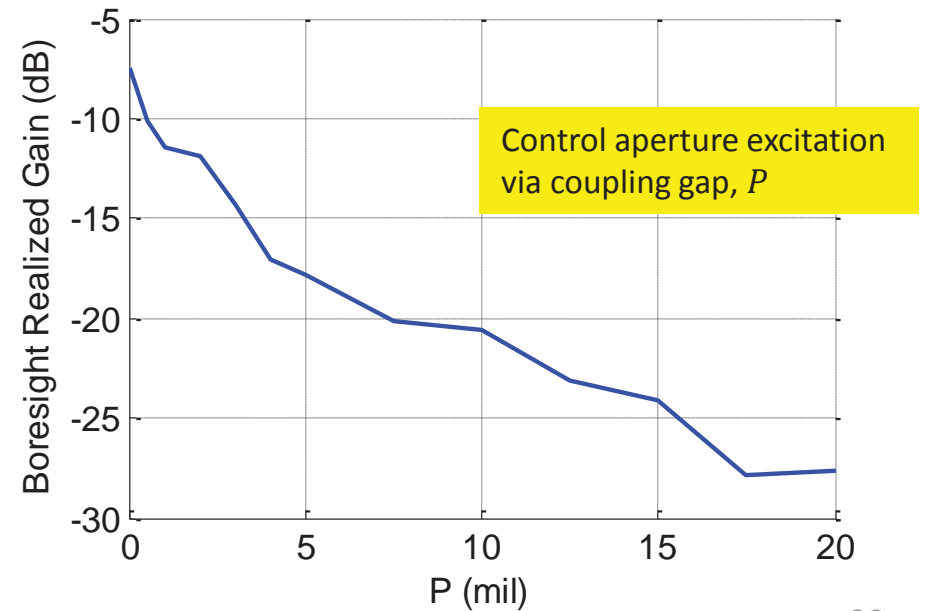
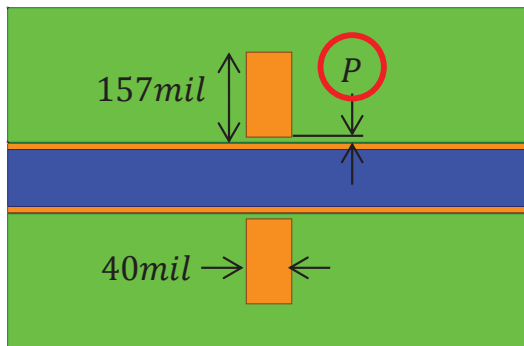
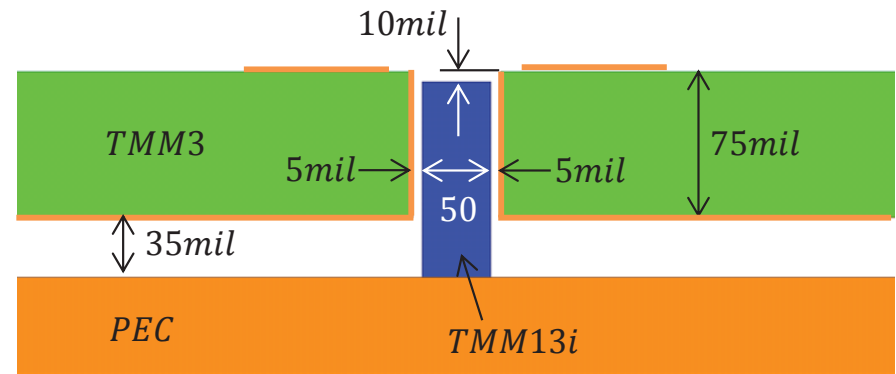
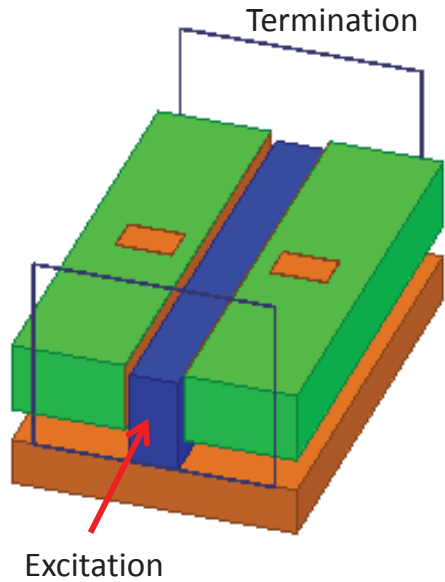
Operation

- k_{eff} dependent on air to dielectric ratio
- Insert is retracted to induce scanning

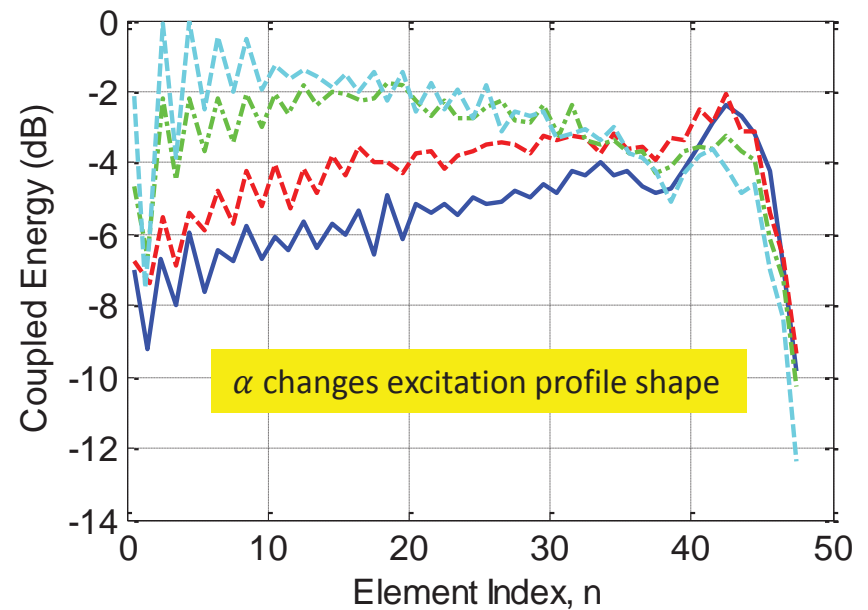
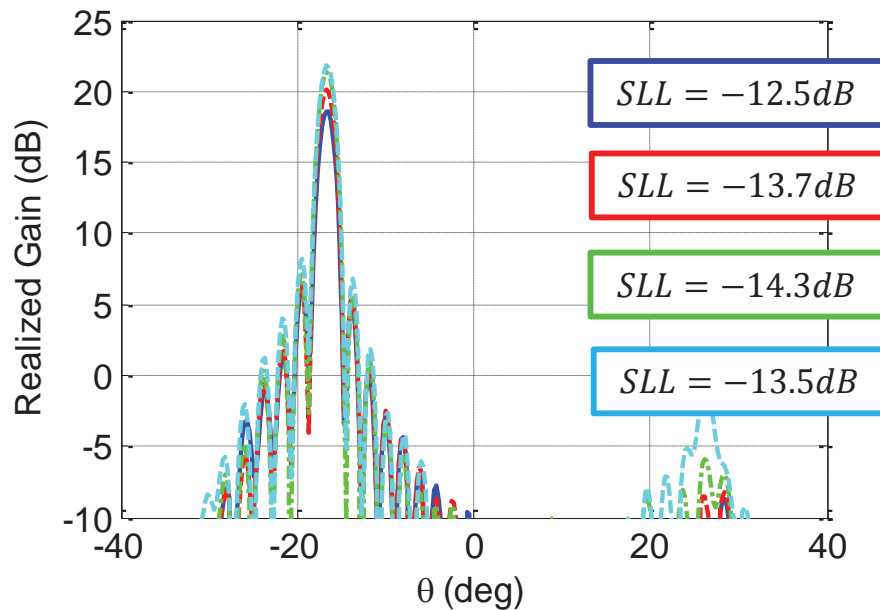
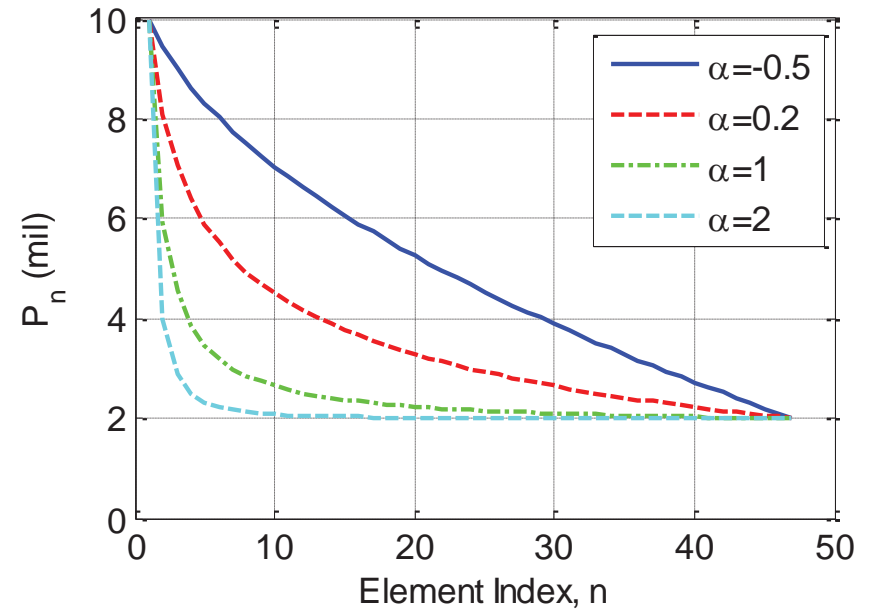
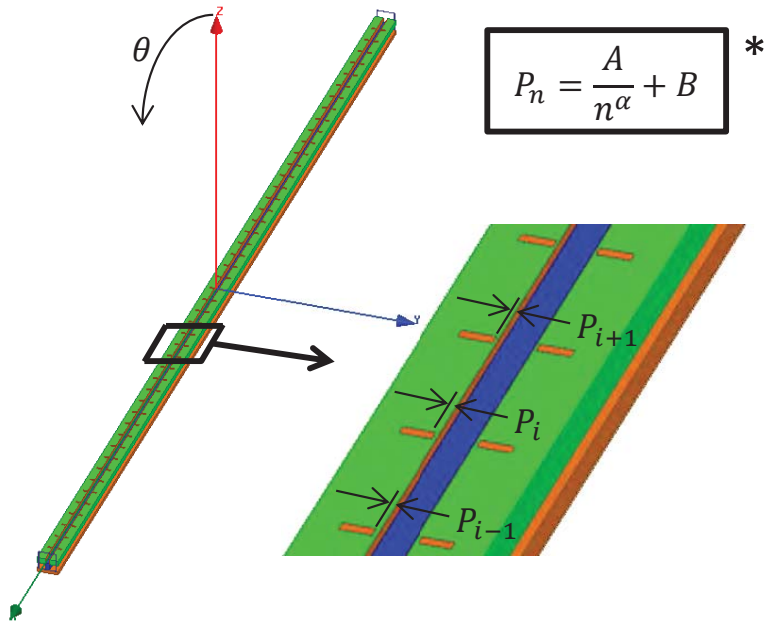
Comparison of TL Designs



Dipole Capacitive Coupling

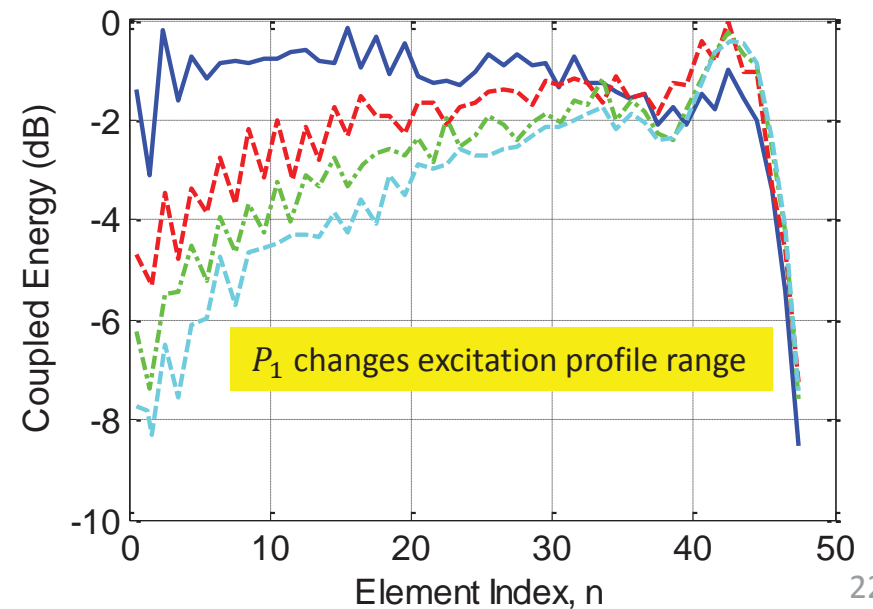
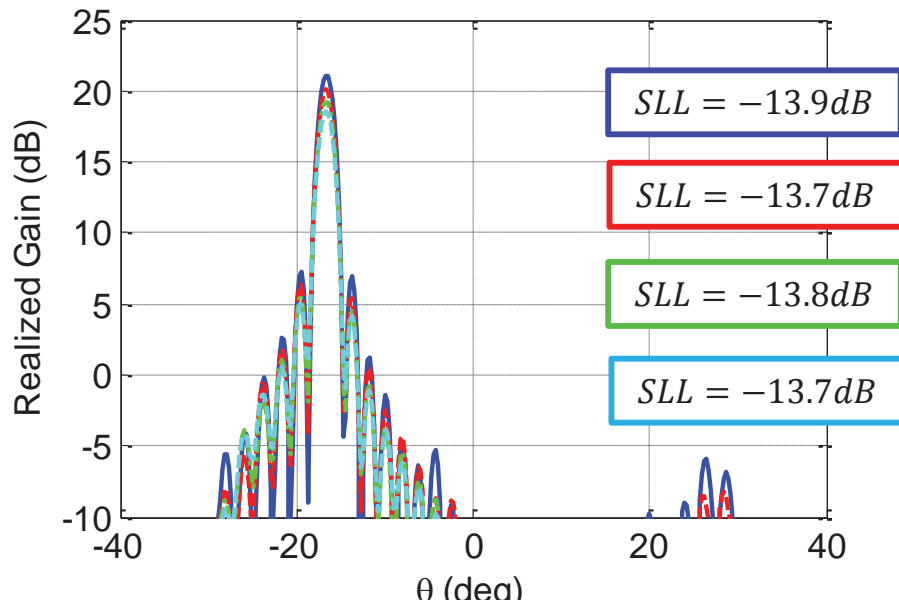
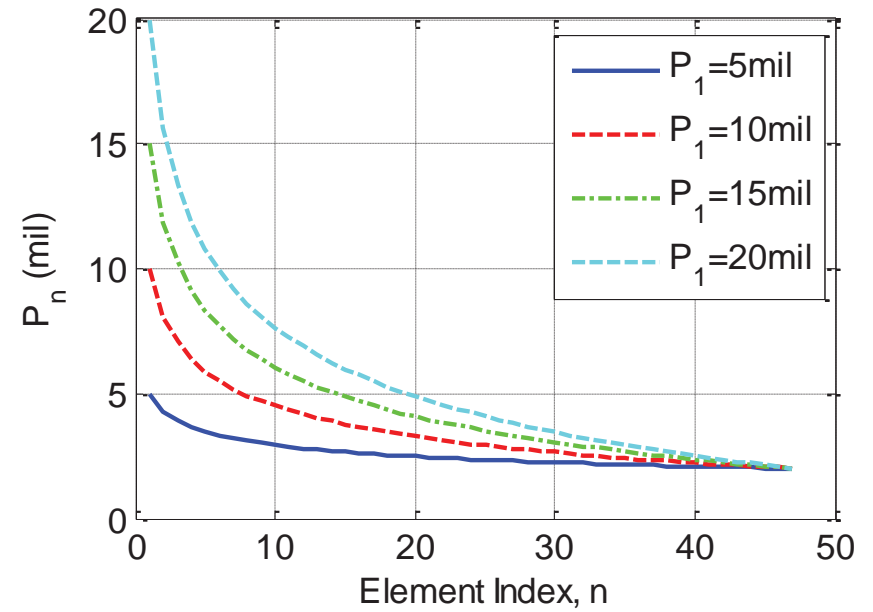
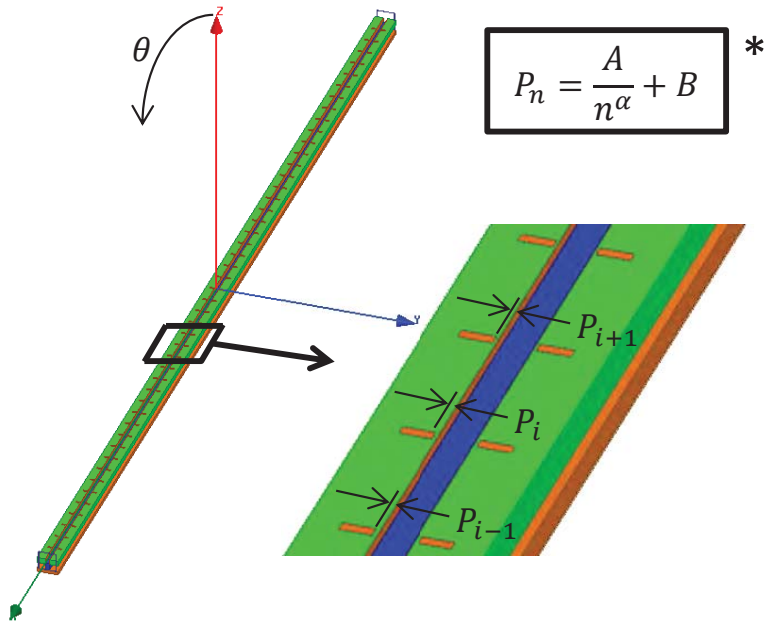


$$P_1 = 10\text{mil}, P_{47} = 2\text{mil}$$

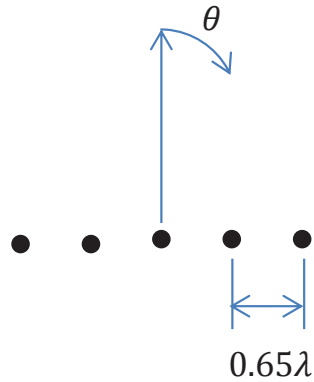


* A and B determined by choice of P_1, P_{47} , and α

$$\alpha = 0.2, P_{47} = 2\text{mil}$$

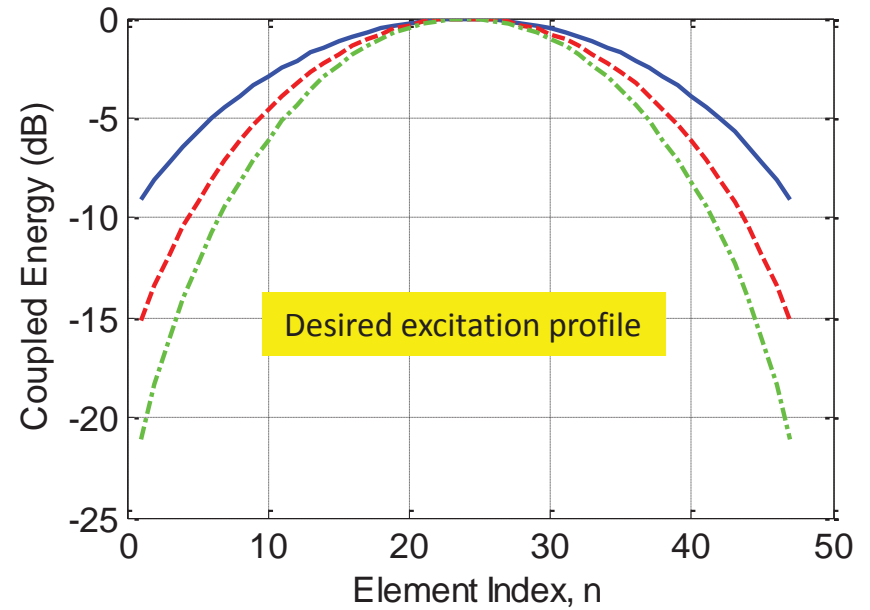
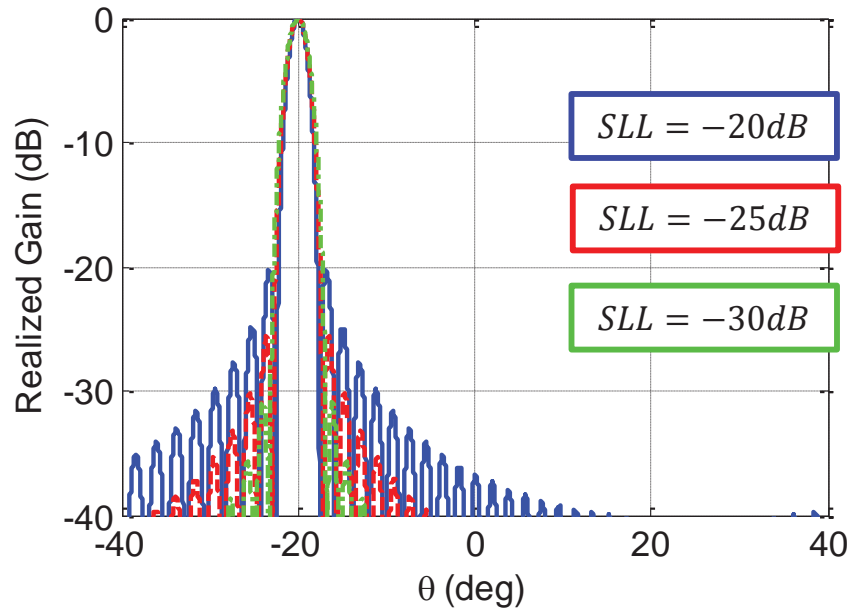


* A and B determined by choice of P₁, P₄₇, and alpha

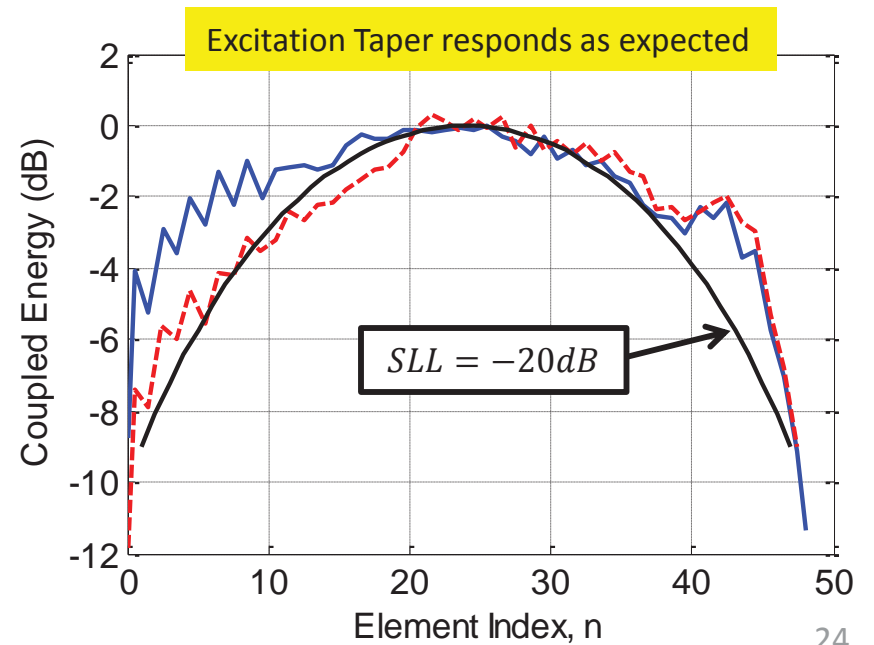
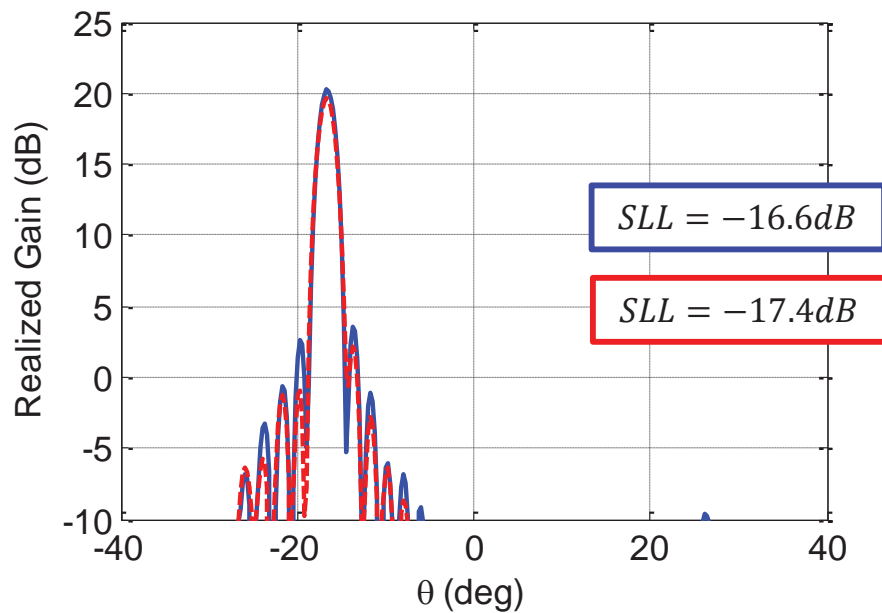
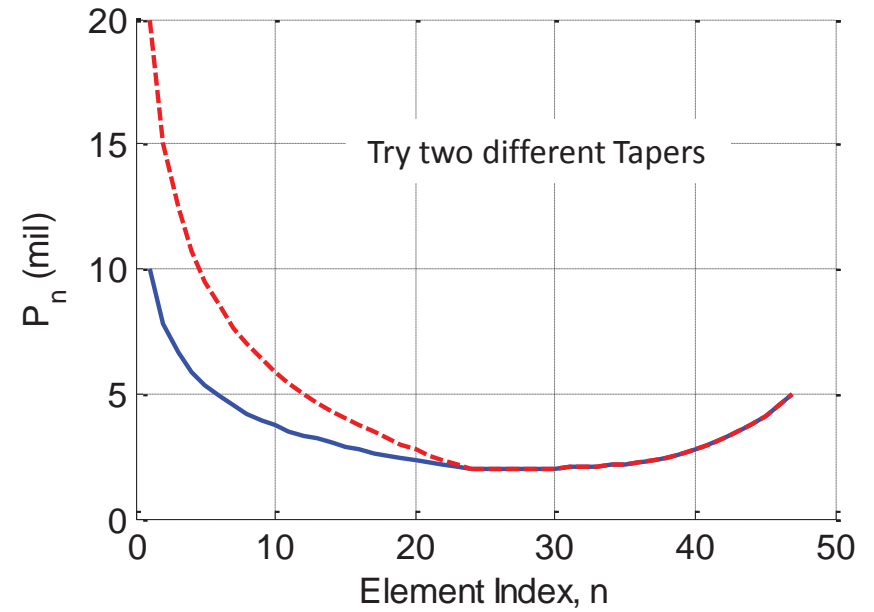
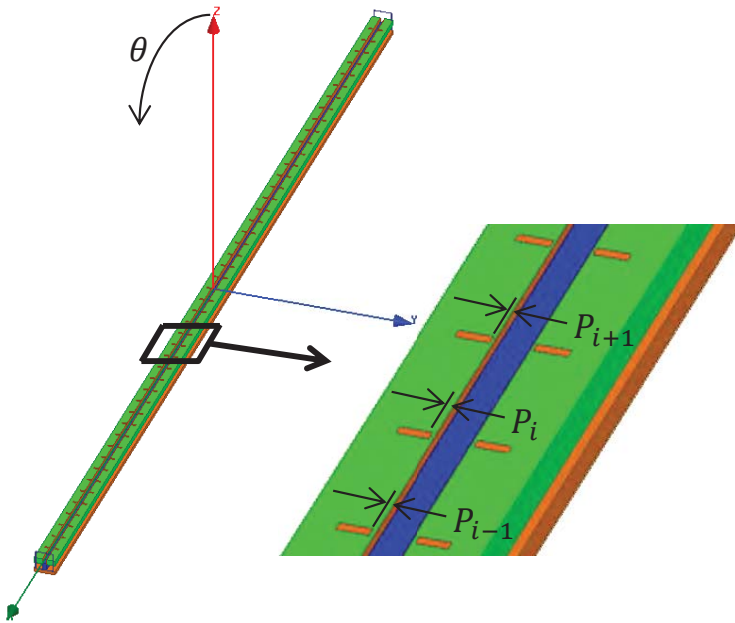


Array characteristics

- Kaiser window used for weighting profile
- 47 Elements
- $\theta_{max} = -20^\circ$



Double Equation Based Taper



Novel Phased Array Feeding Topology

- *Low Complexity*
- *Low Weight*
- *Low Cost*

Parallel Plate Transmission Line

- *Large k_{eff} range*
- *Great k_{eff} sensitivity*
 - *Degraded performance*

Coplanar Stripline

- *k_{eff} control*
- *Successful prototype*
 - *Smaller scan range*
 - *Manufacturing error*
 - *Simulation Validation*

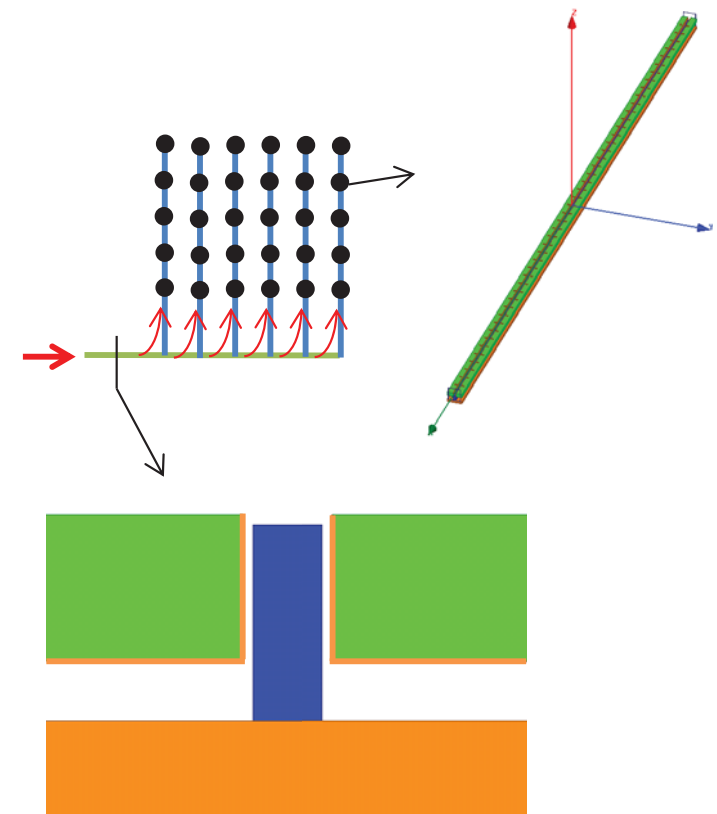
Square Insert PPTL

- *$\uparrow k_{eff}$ control*
- *Easier fabrication*
- *Sidelobe control*

Finish planar array

- 47x47 element array
- Ka-Band (25.5-27GHz design frequency)
- Ability to scan in both elevation and azimuth directions
 - $\pm 30^\circ$ in both directions
- Novel feeding scheme to reduce
 - Weight
 - 250 grams (not including excitation)
 - Complexity
 - 1 excitation and 2 independent phase controls
 - Cost
 - (1) 18"x12"x0.025" Roger's TMM 3 board
 - (1) 18"x12"x0.125" Roger's TMM 13i board
 - Actuators
 - Excitation

2-D Independent Scanning



Questions?