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

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Abstract

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

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Current Technologies

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

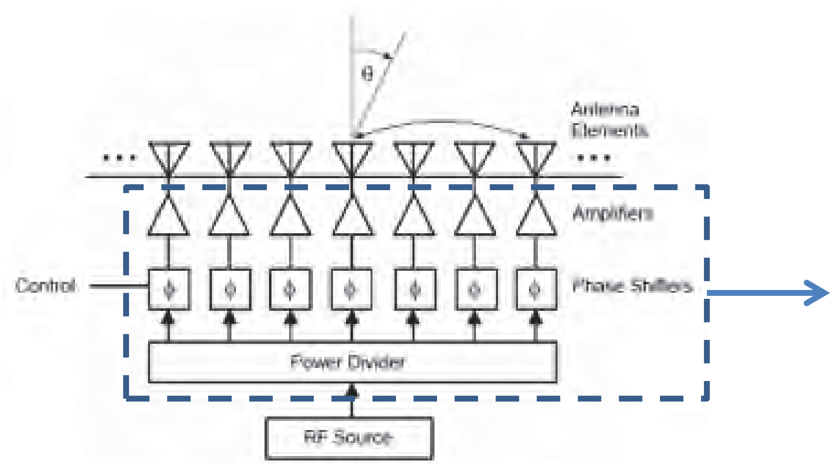
Novel Aspects

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

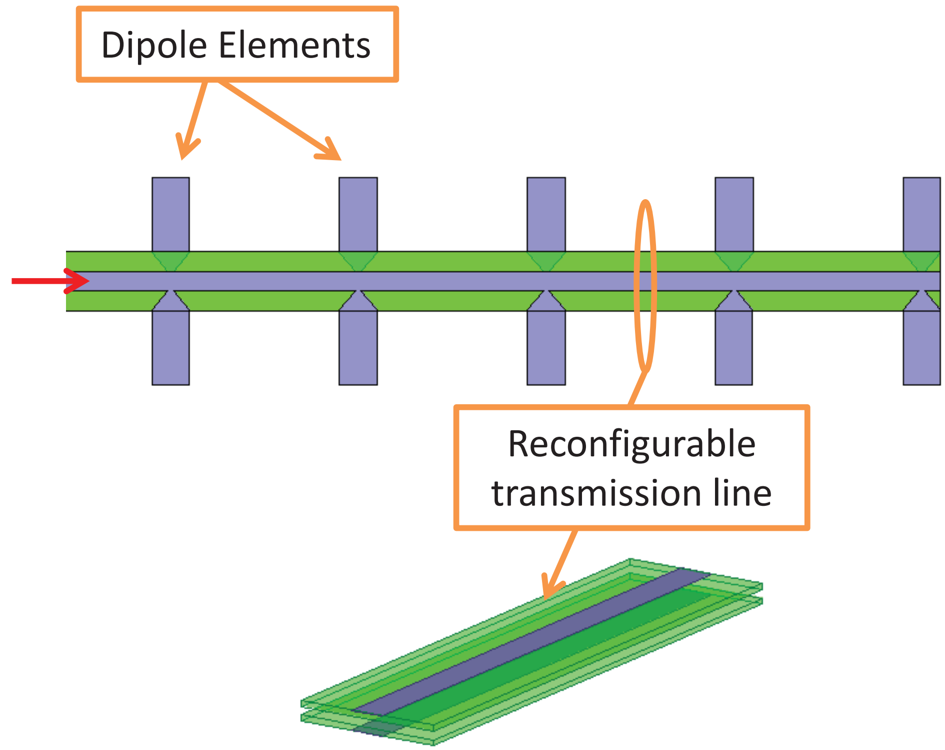
Approach

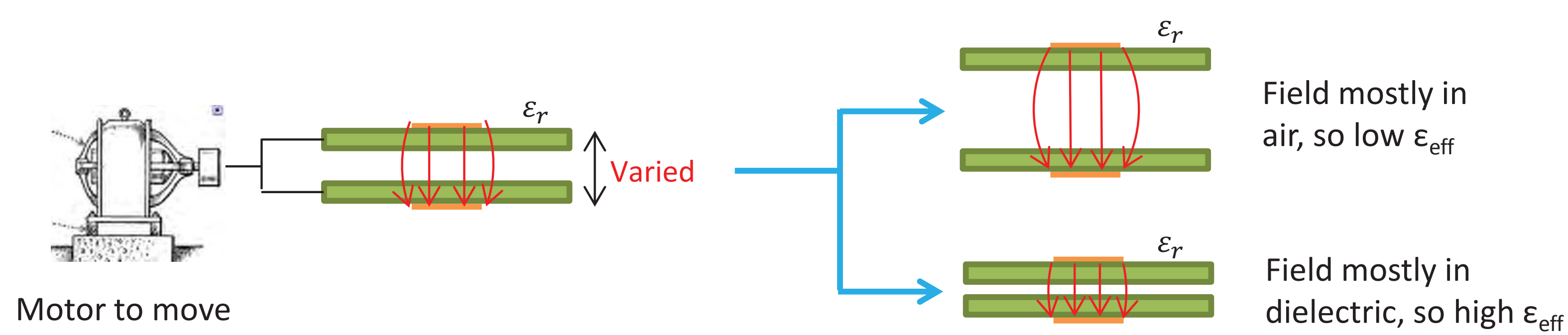
Replace Backend With Simpler Mechanism

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

Use Series Fed Array:

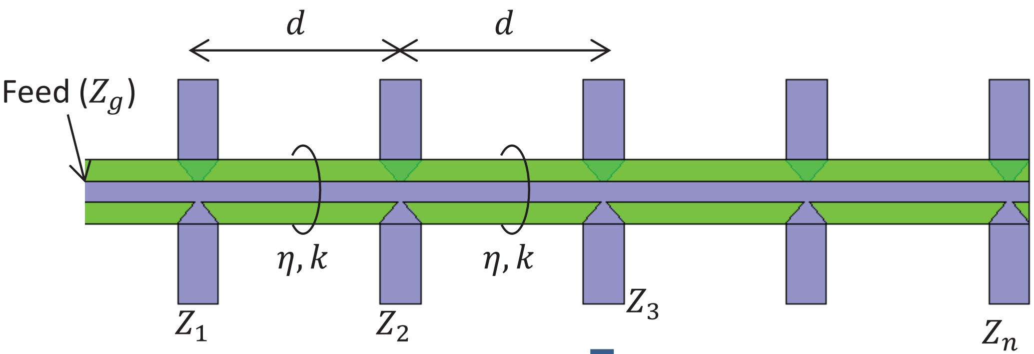
- *Array fed at one point (side)*
- *Magnitude at each element controlled by varied mismatch at element terminals*
- *Beam Steering will be accomplished by a controllable propagation constant between elements*
  - A motor can bring two fixed sheets closer to change the effective dielectric constant

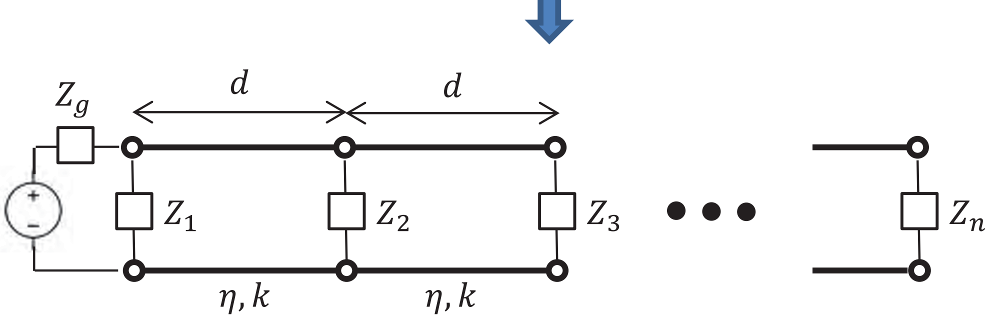


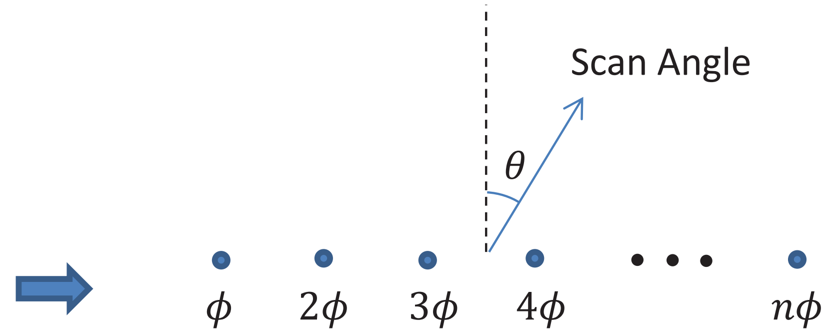


By changing ϕ (through change of k_{eff}) scanning is accomplished:

Needed Transmission Line Agility

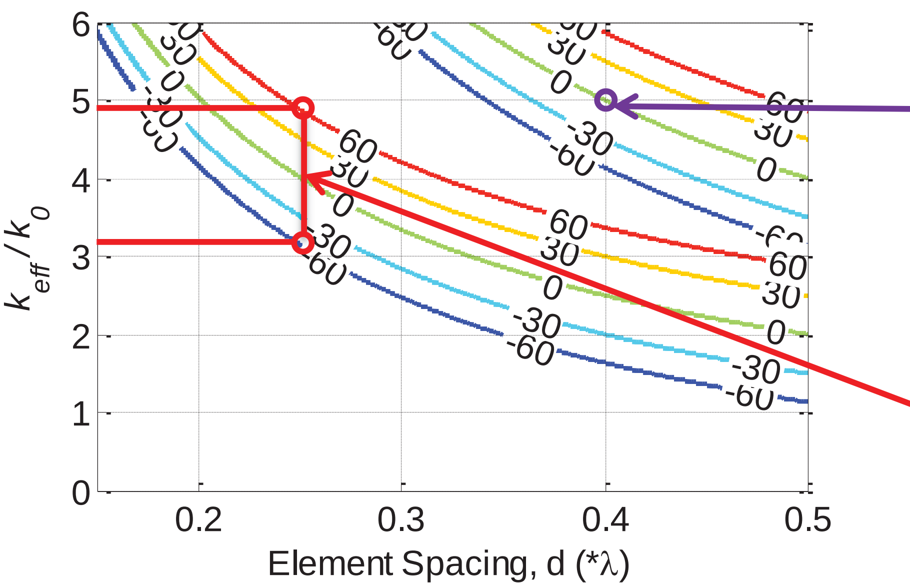






$$\phi = f(d, k_{eff})$$

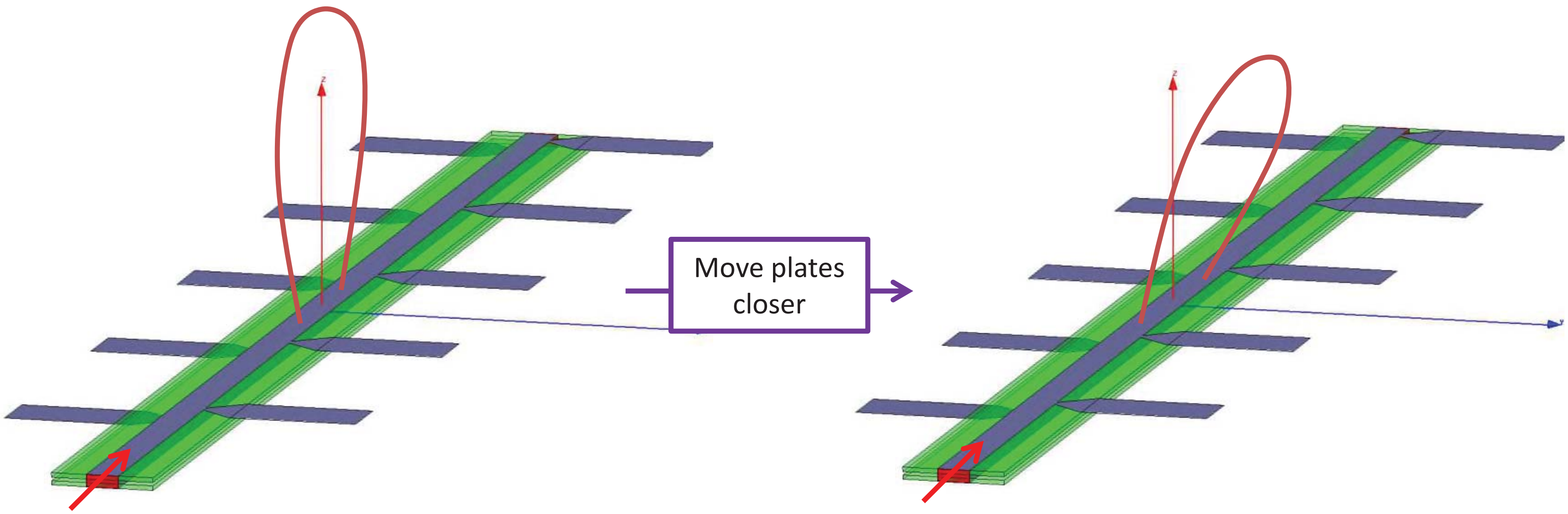
Scan Angle vs. k_{eff} and Element Spacing



For $d = 0.4\lambda$ and $\frac{k_{eff}}{k_0} = 5$ ⇒ $\theta = 0°$

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

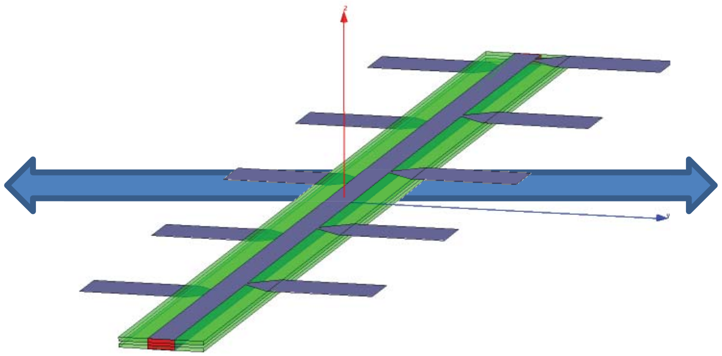
Achieving Scanning



Scanning is achieved with one mechanical motion and no phase shifters

Comparison of Technologies

- 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 - $\varepsilon_r = 25$

<table>
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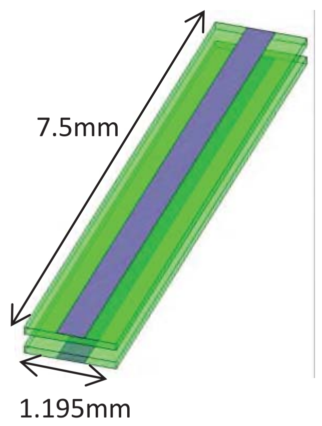
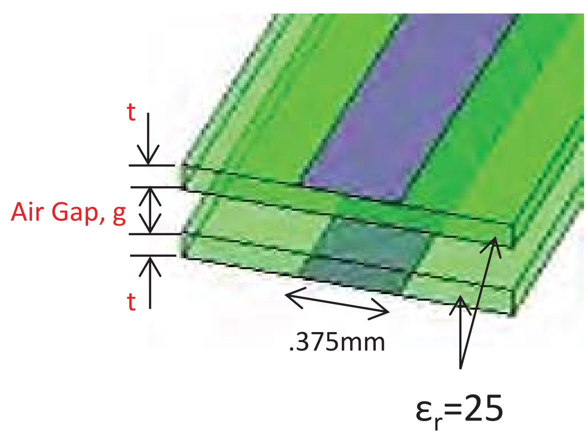
<tr><th>Geometry</th><th>Geometry – Fine Details</th></tr>
<tr><td>
</td><td>
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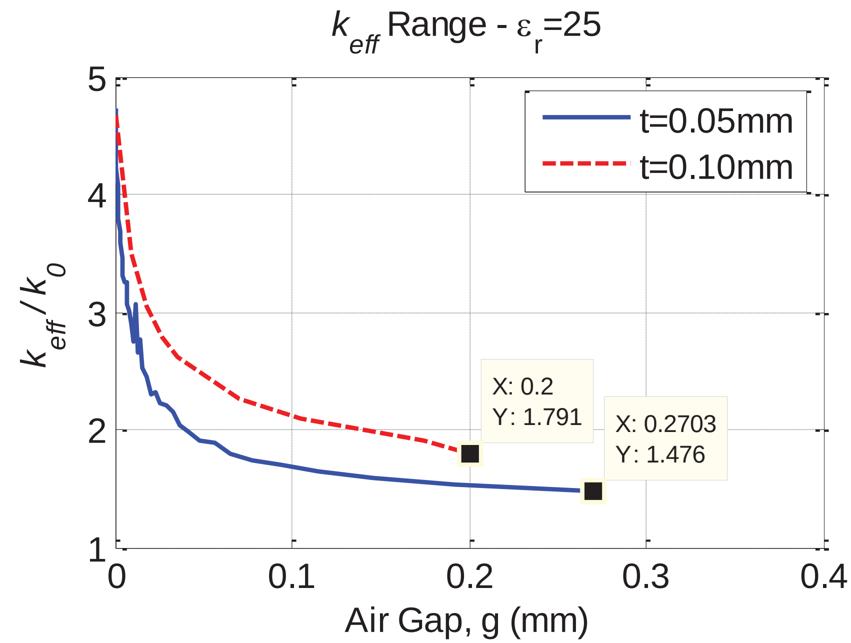
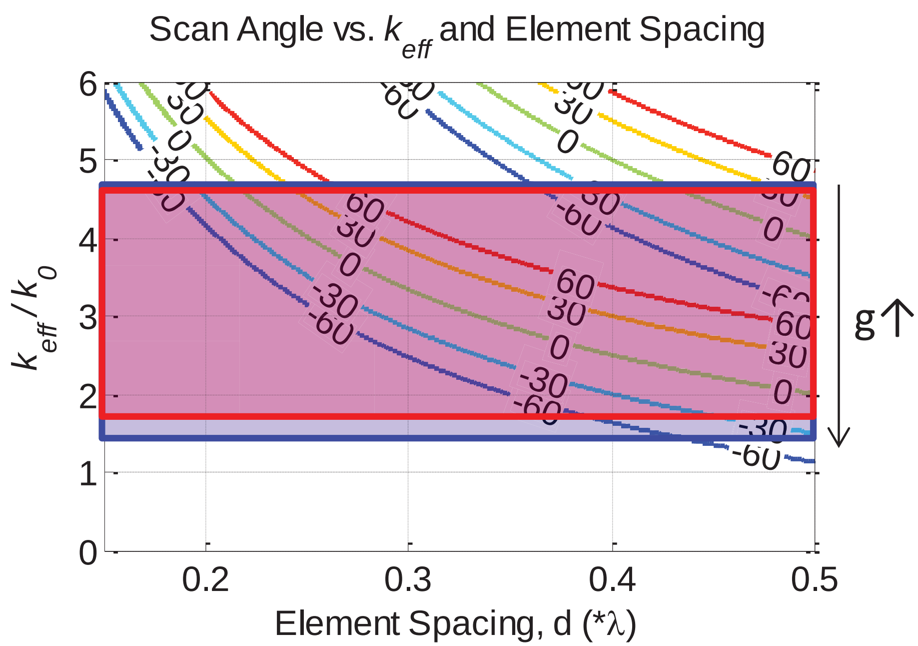
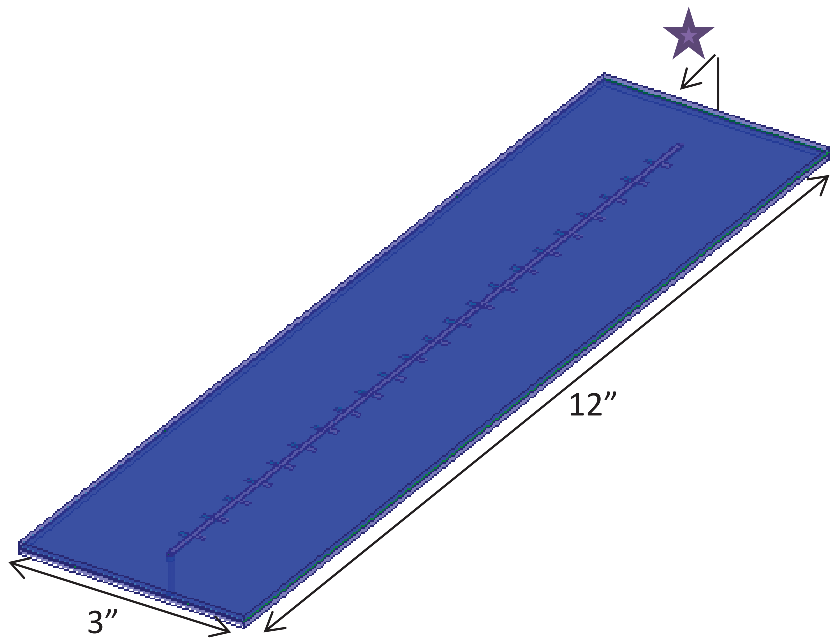
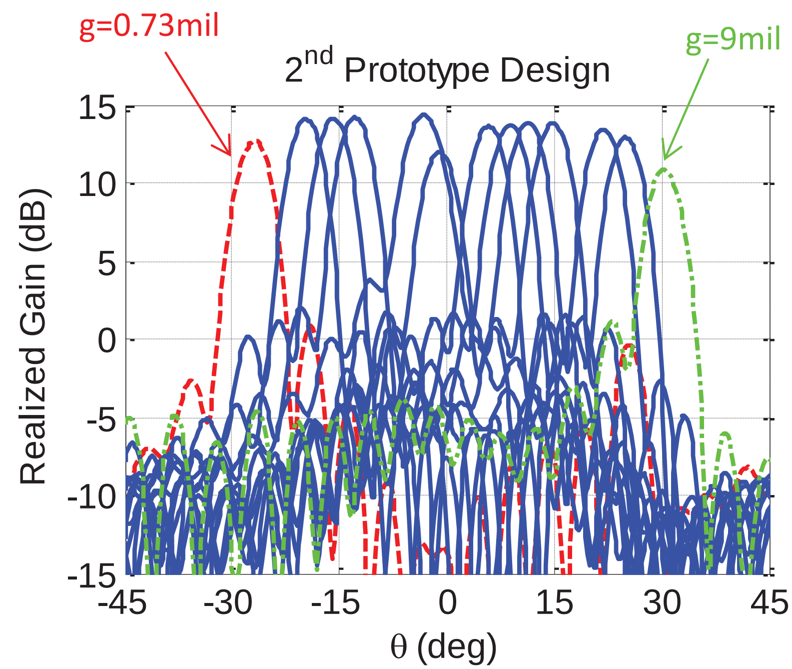


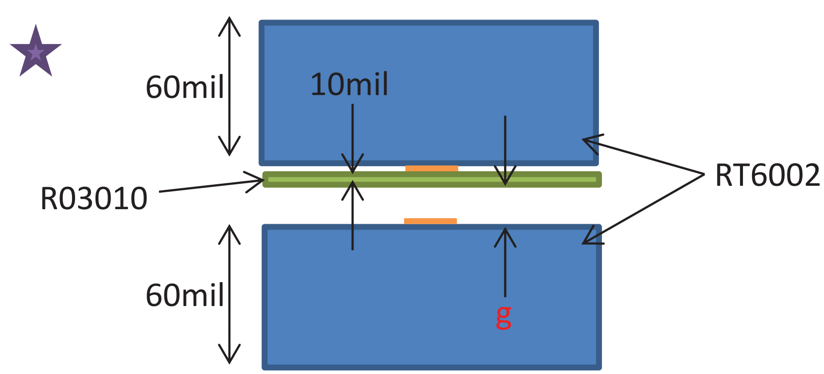


- Strip Spacing ≤ 0.40mm (λ/20 @ 40GHz)
  - t=0.1mm case → lower max g
- t=0.05mm
  - Larger $\varepsilon_{eff}\mu_{eff}$ range
  - More precision needed
- t=0.10mm
  - Smaller $\varepsilon_{eff}\mu_{eff}$ range
  - Less precision needed

22 Element Prototype Design







Practical Transmission Line Design

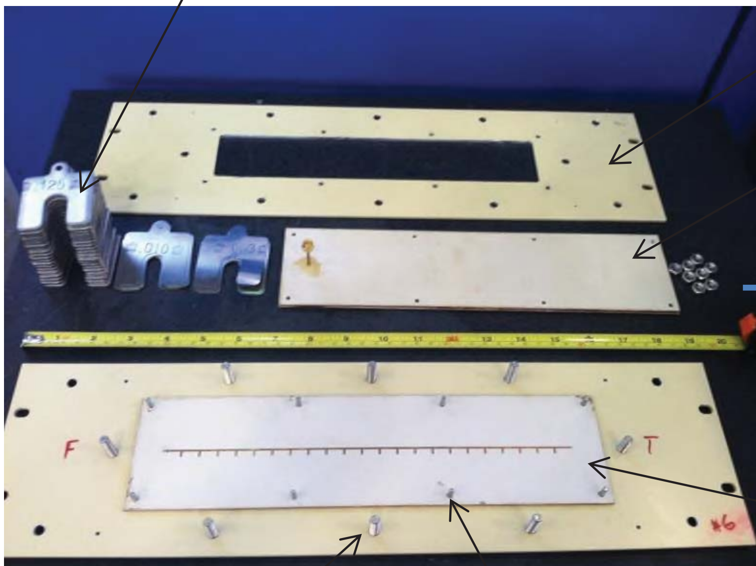
- Circuit printed on two 60mil thick RT6002 boards
  - RO3010 becomes ripply when unsupported
- RO3010 material bonded to inside of one of boards

Assembly of Prototype

Spacing Shims

Compressing Frame

Bottom Dielectric

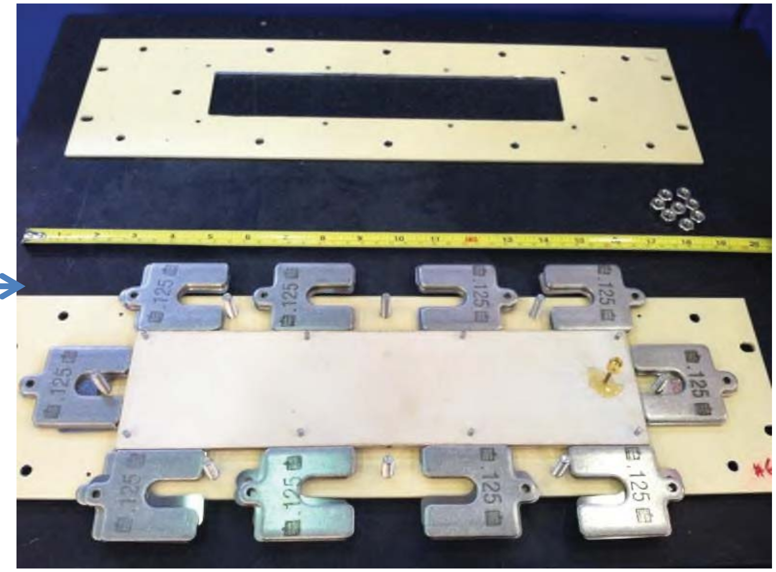


Top Dielectric

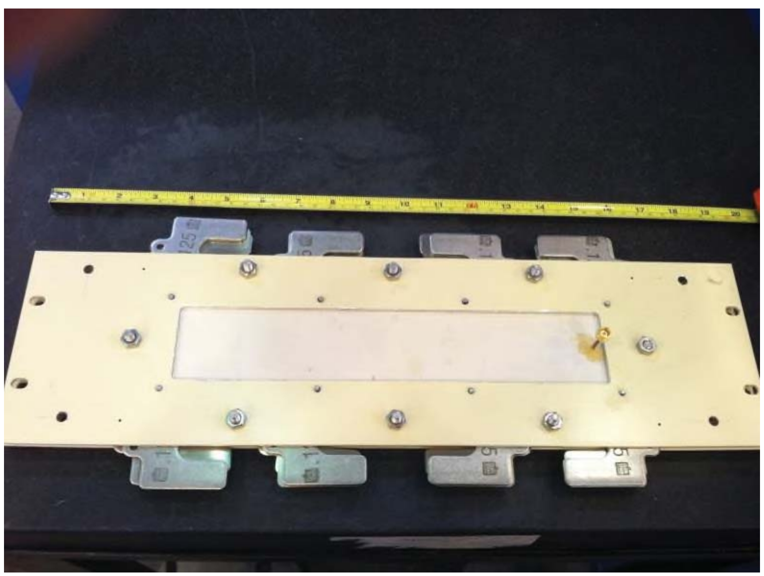
Tightening Bolts

Alignment Pins

Fit top dielectric on with shims as spacers

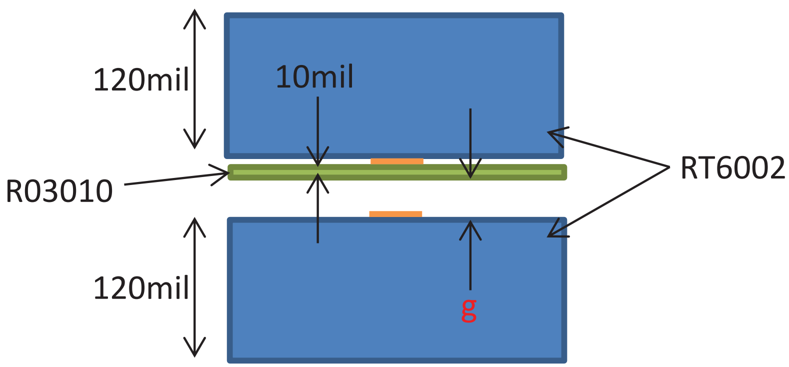


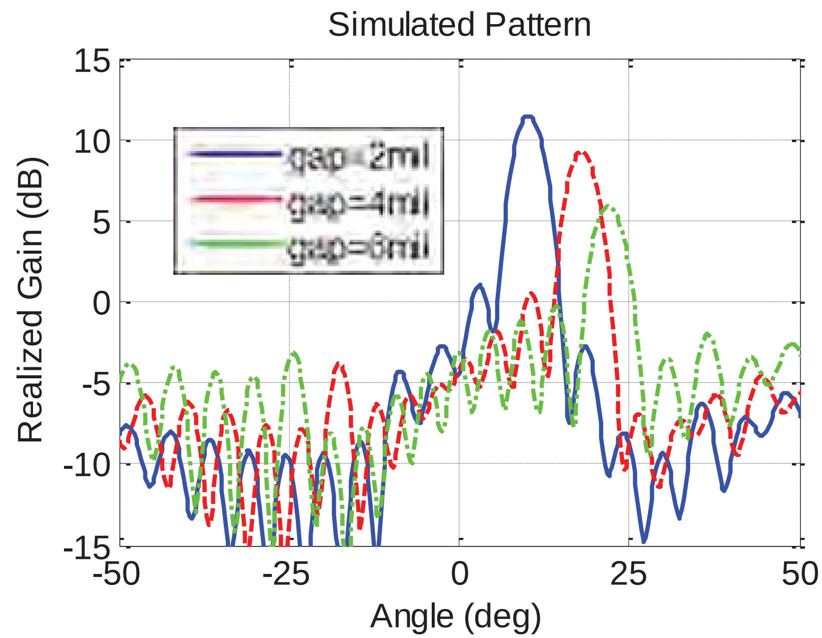
Pinch together two boards with metal frames

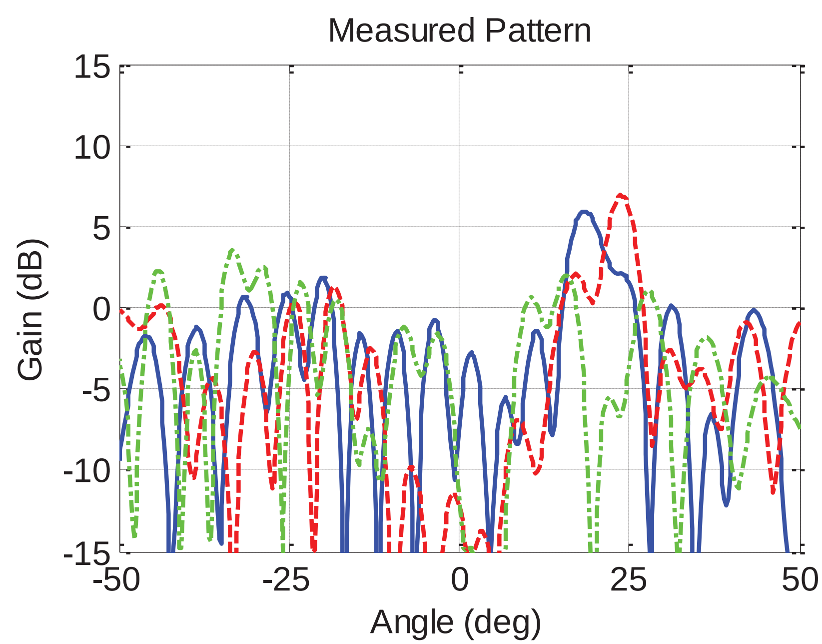


- Metal plates used to ensure rigidness
- Bolts used to squeeze together
- Spacers to achieve gap

Validation



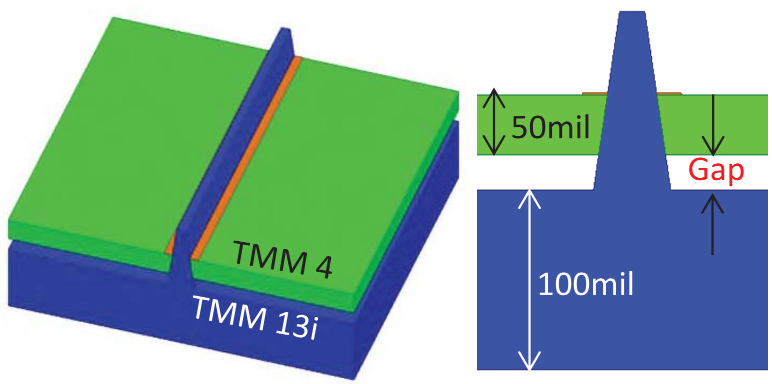


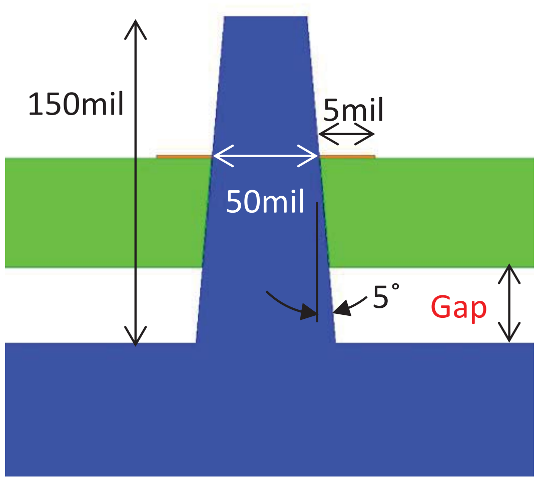


- Scanning Observed
- Achieving gap imprecise
  - Patterns shifted
  - Gain Lowered

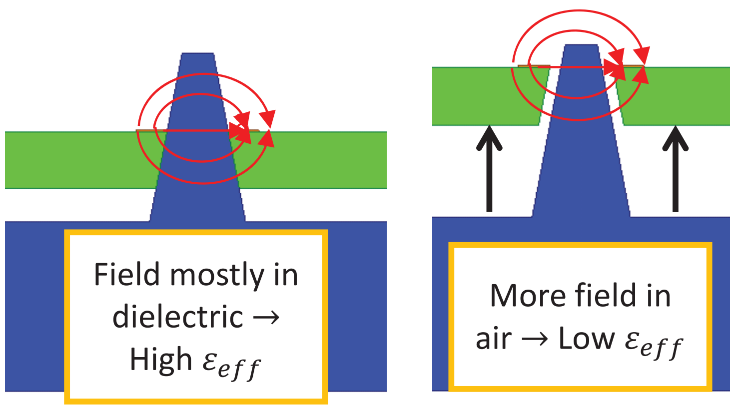
CPS Line

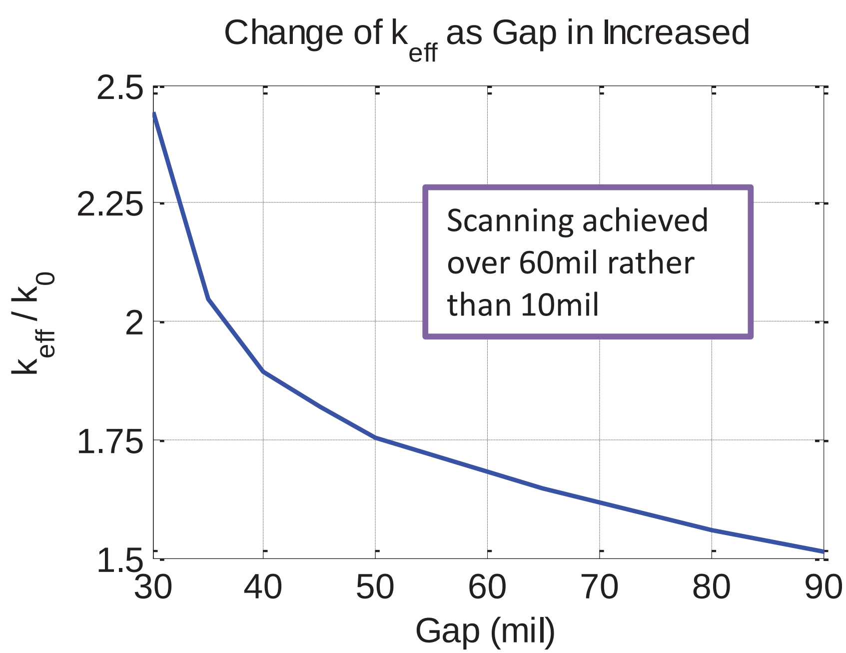
Design



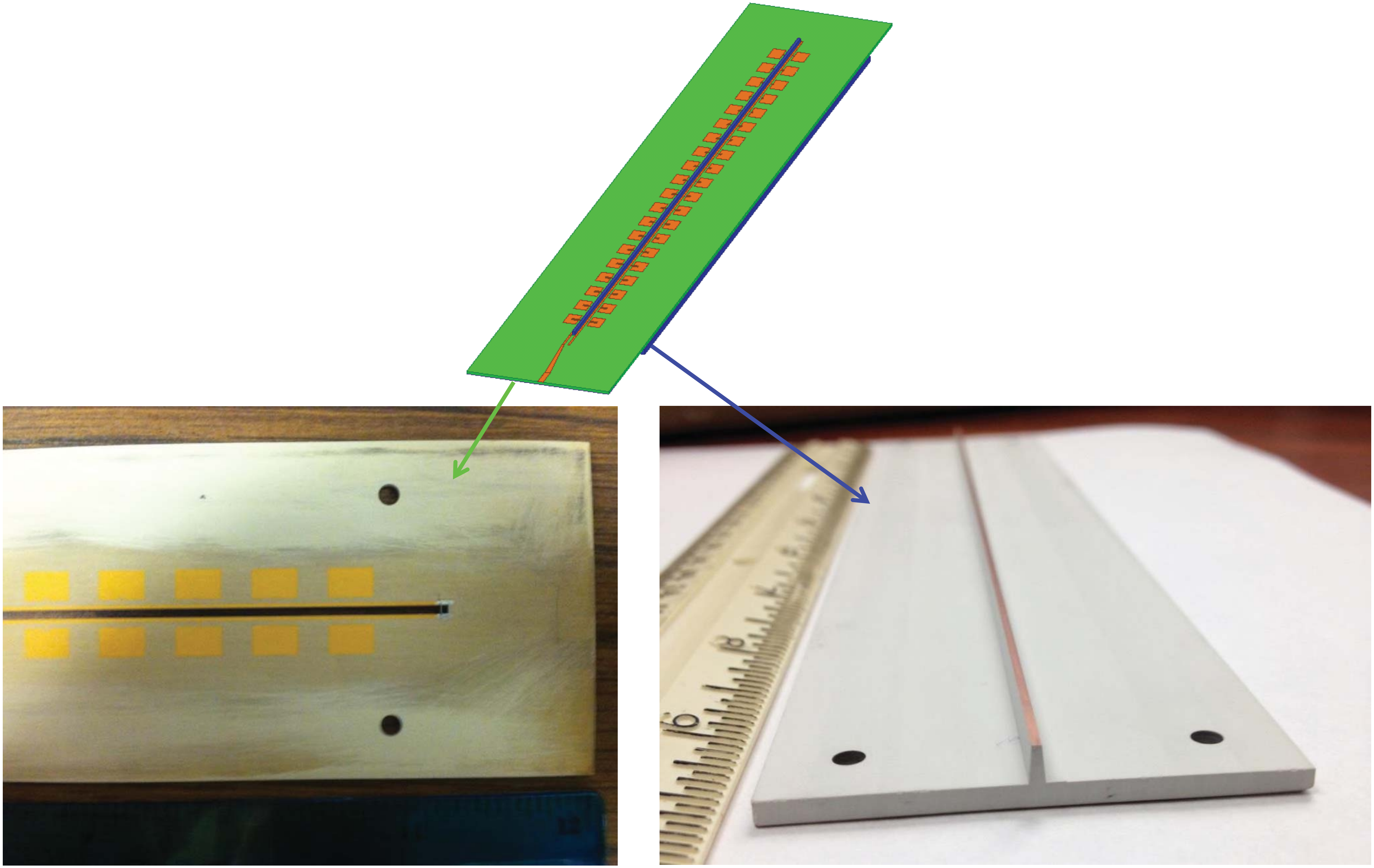


Operation

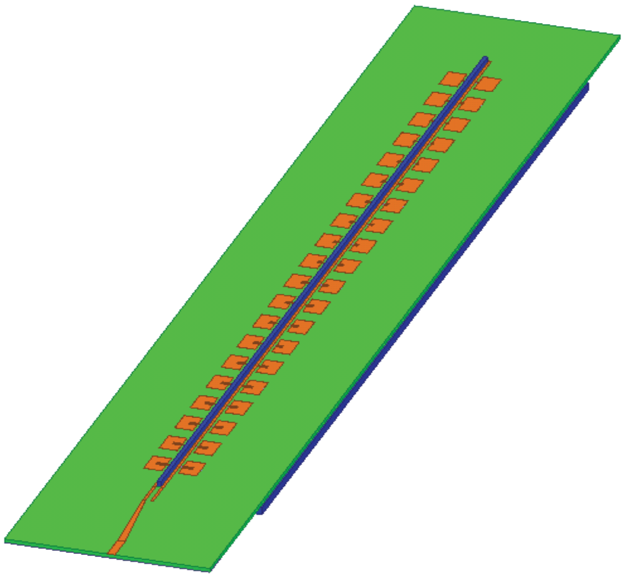


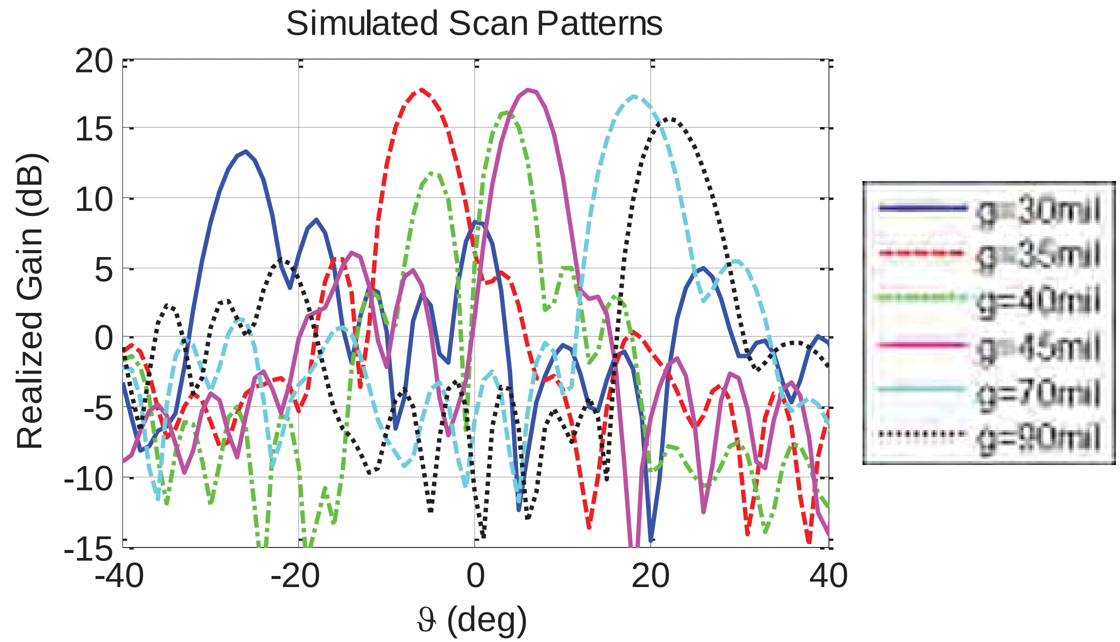


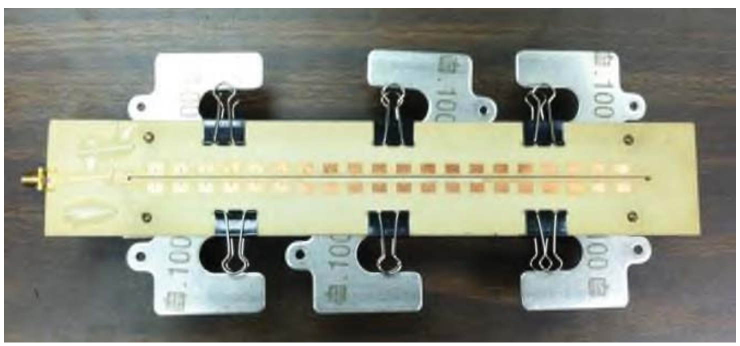
Prototype Pieces

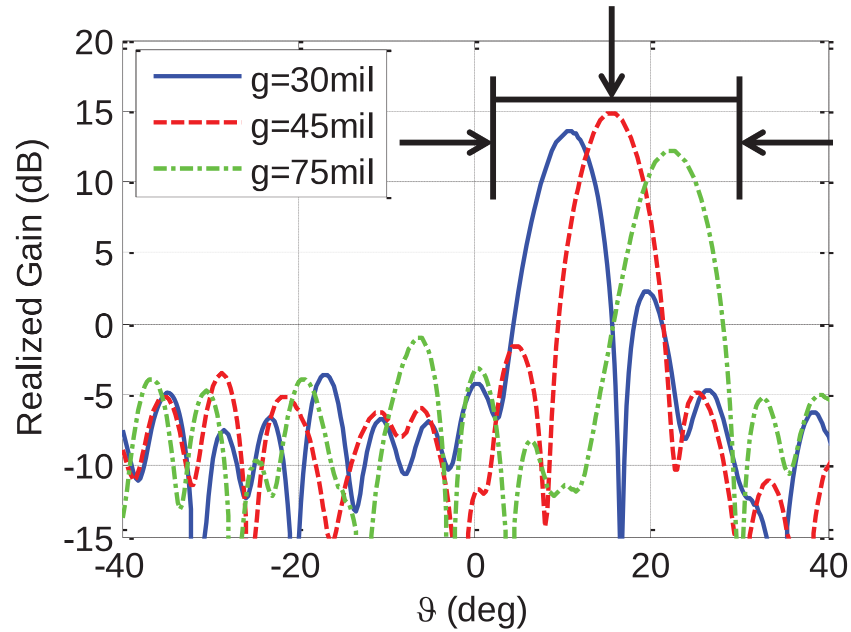


Simulated vs. Measured

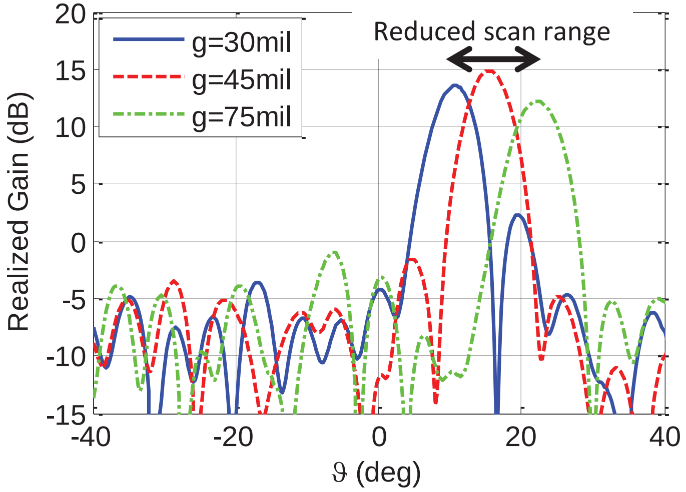






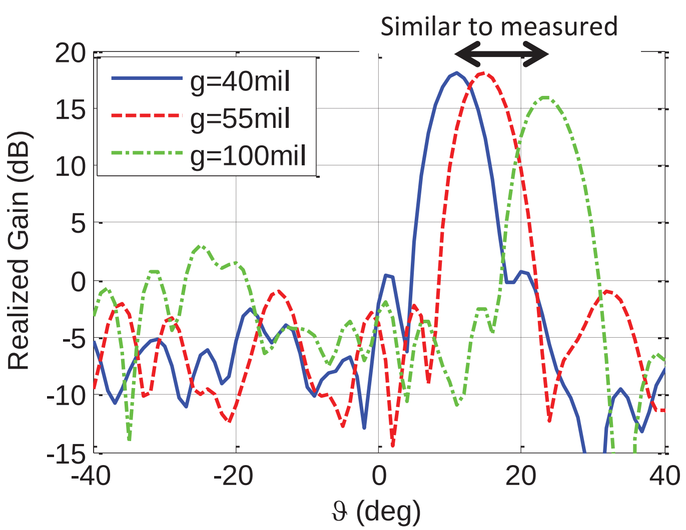


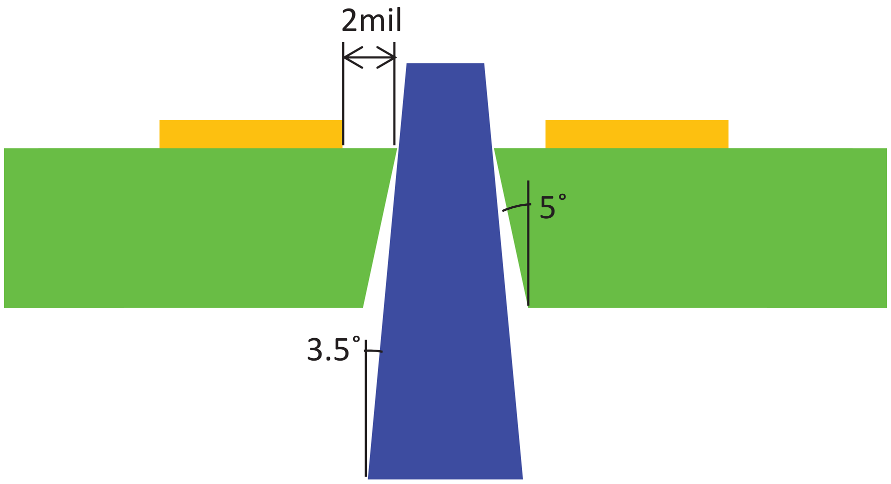
Simulating Known Differences



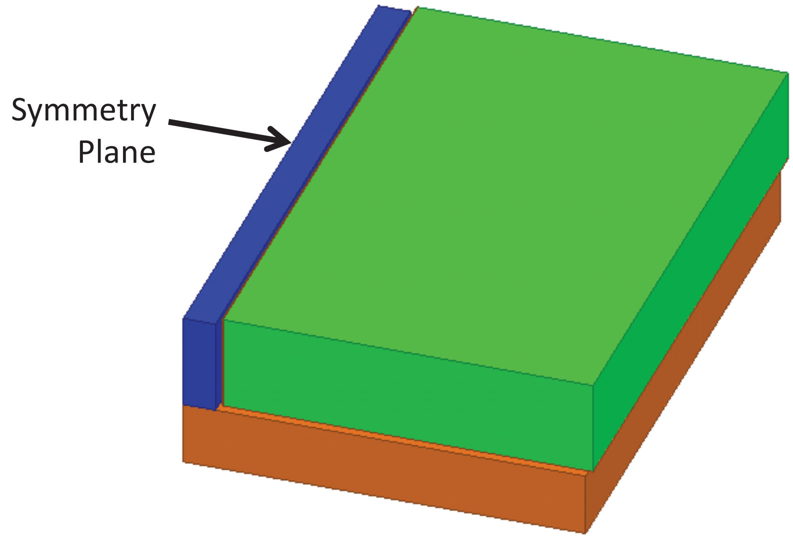
Simulated with known differences

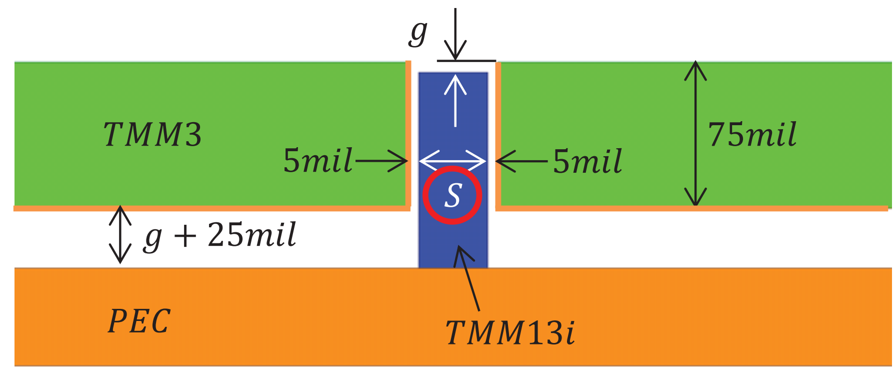
- Ridge dimensions
- Overetch

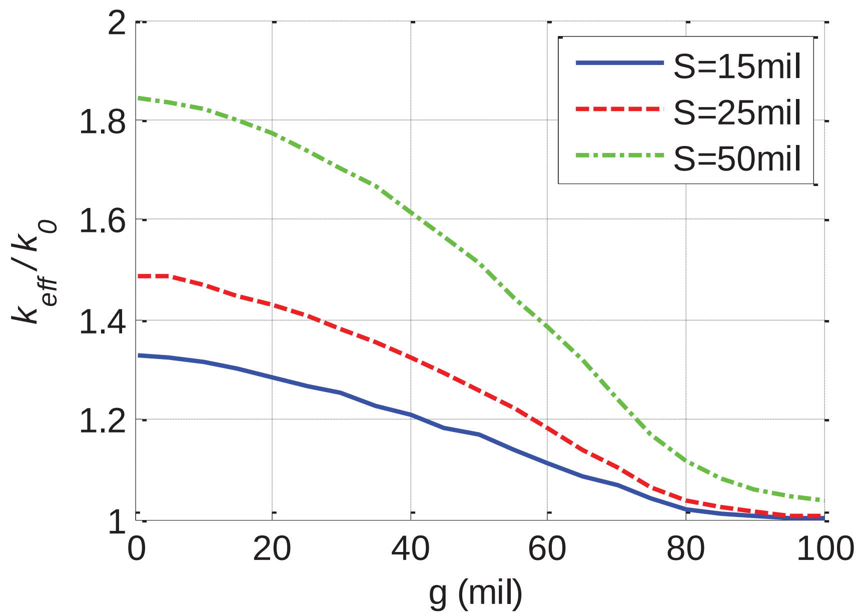




Square Insert Parallel Plate TL







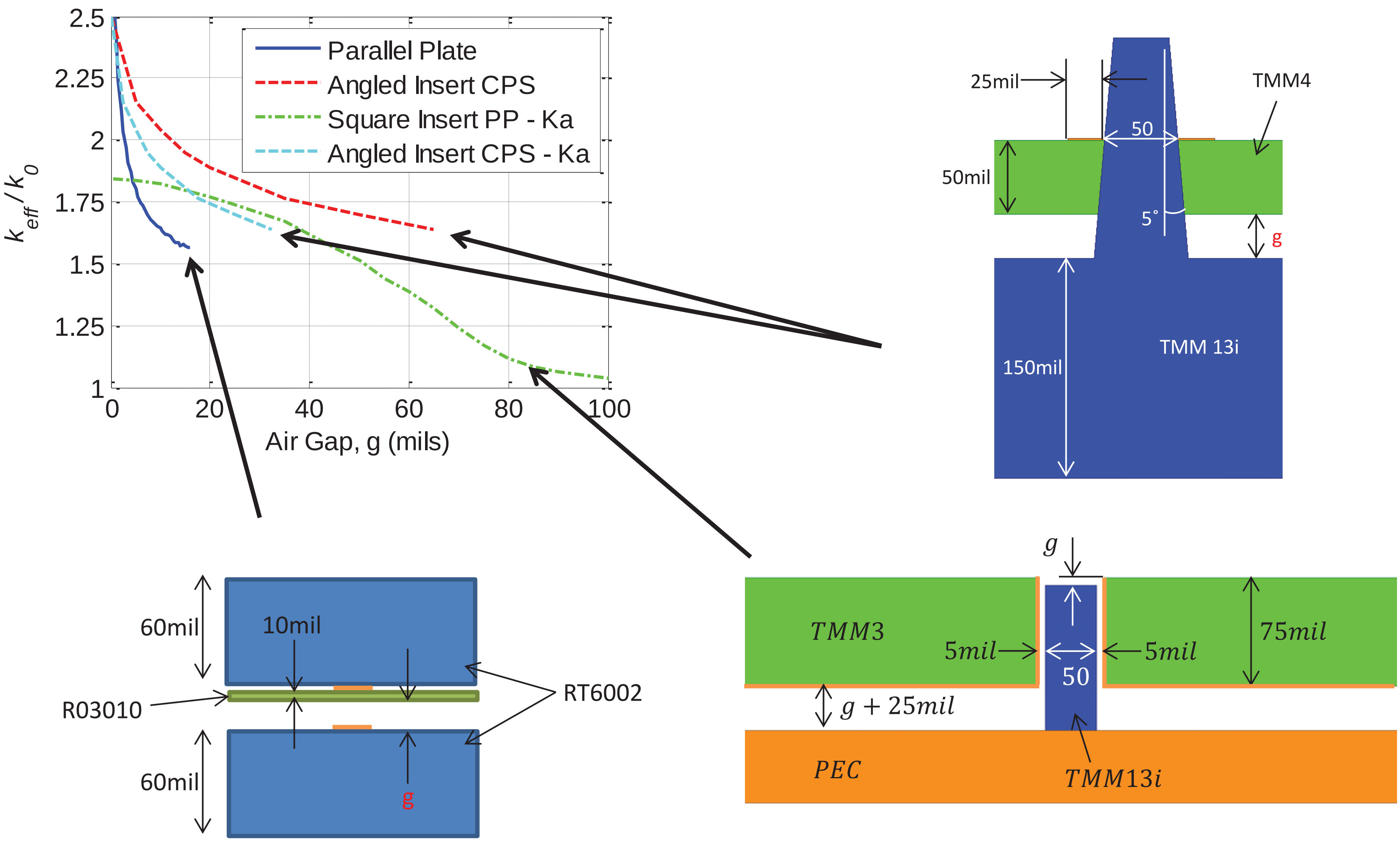
Improvements

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

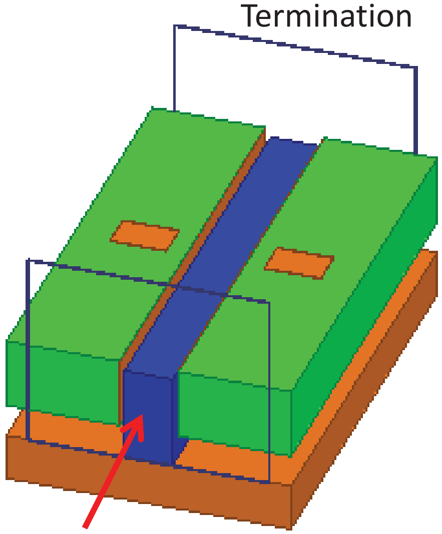
Operation

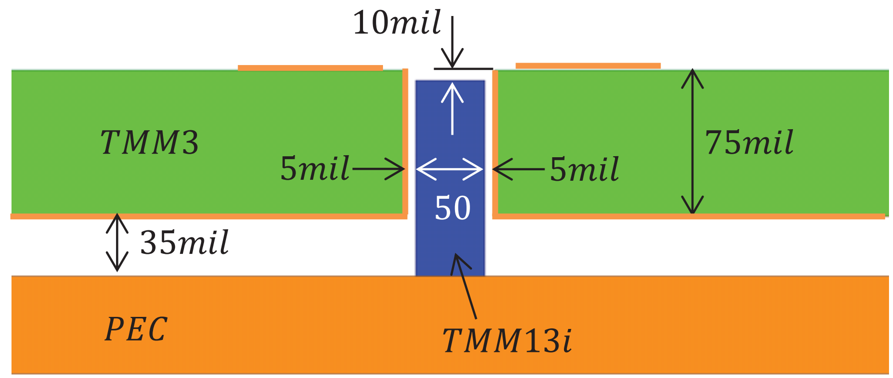
- k_{eff} dependent on air to dielectric ratio
- Insert is retracted to induce scanning

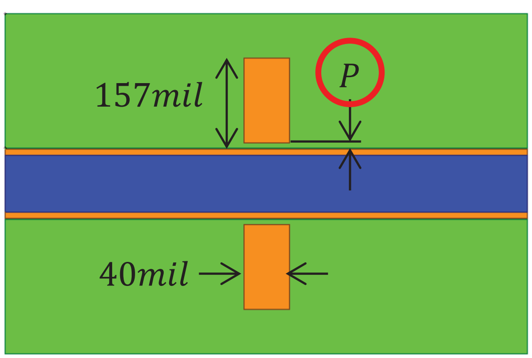
Comparison of TL Designs

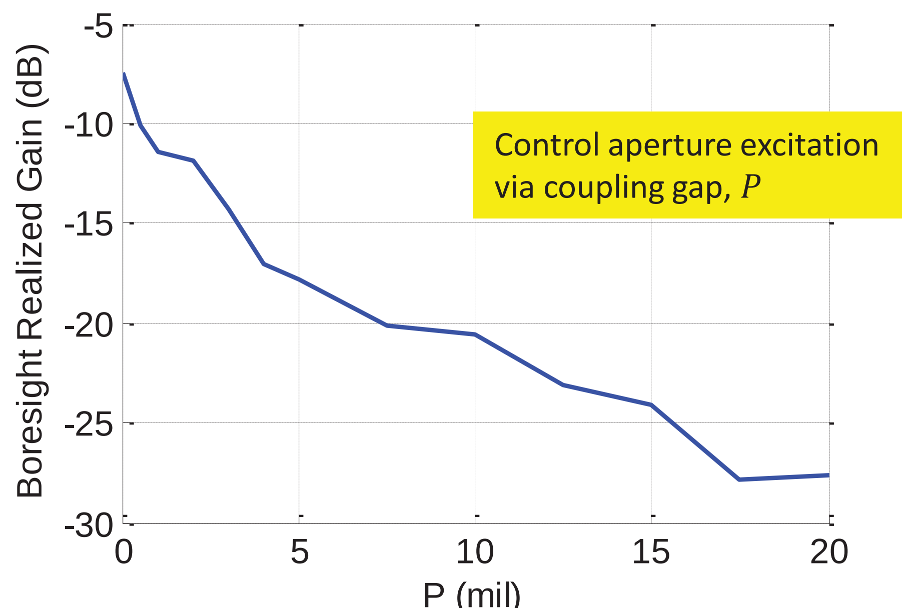


Dipole Capacitive Coupling

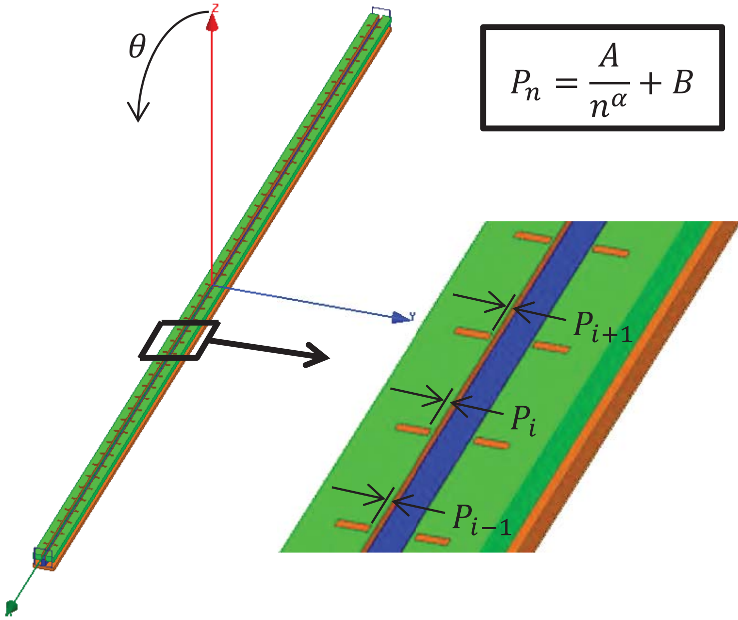




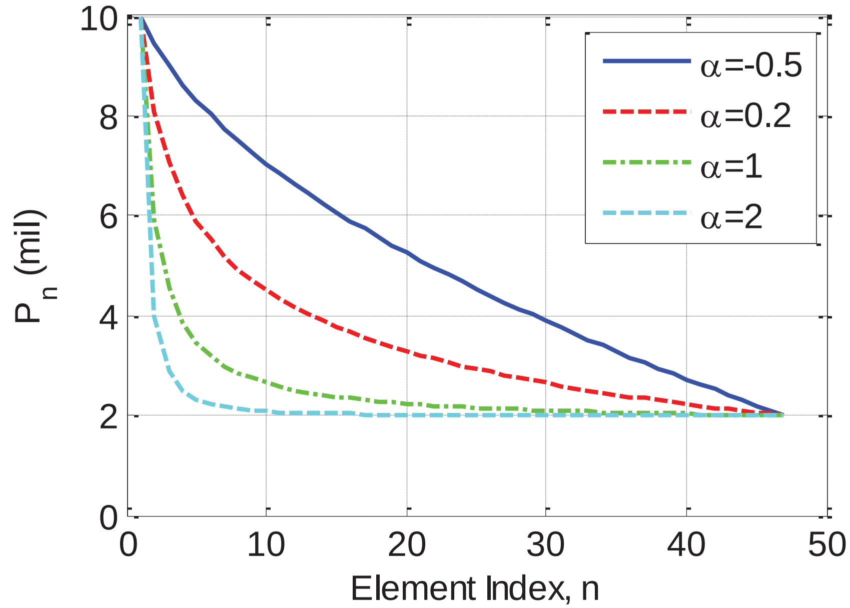


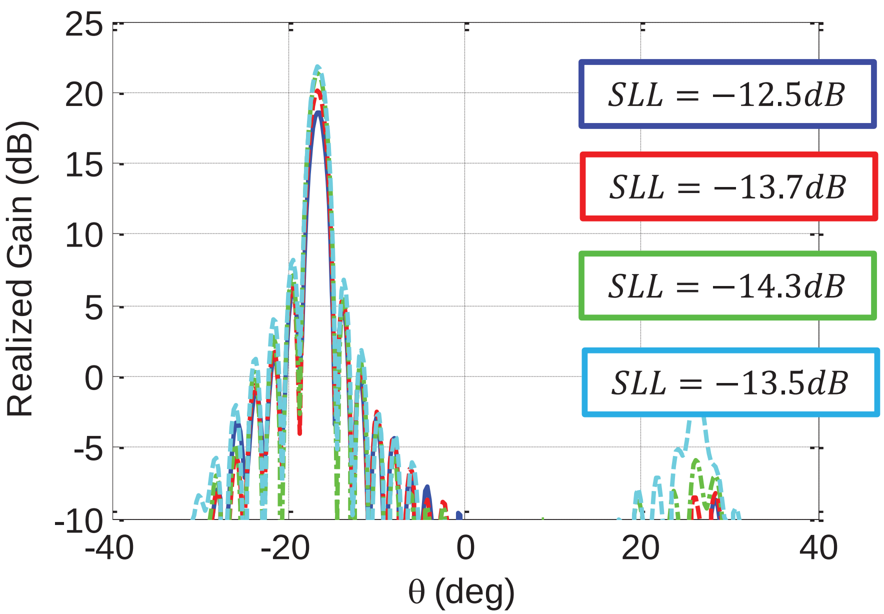


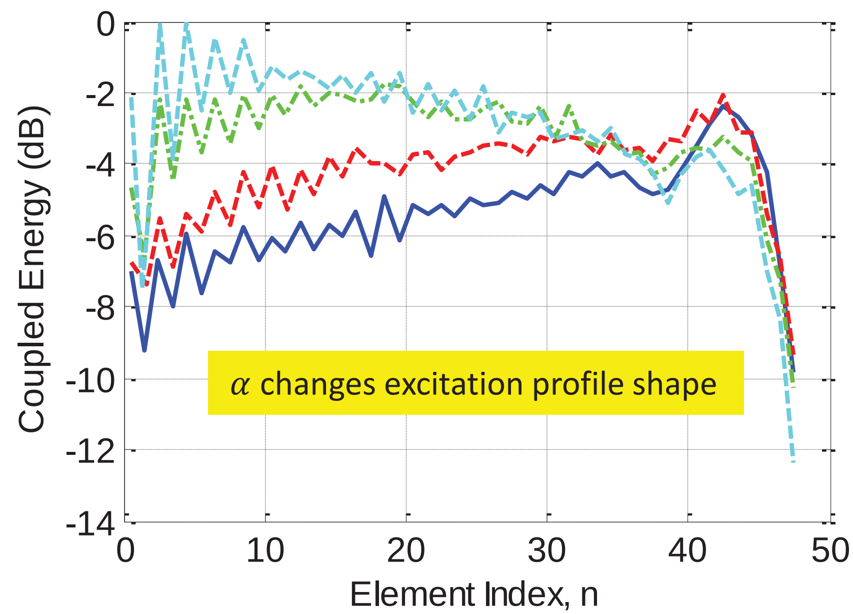
$P_1 = 10mil, P_{47} = 2mil$



$$P_n = \frac{A}{n^\alpha} + B$$ *



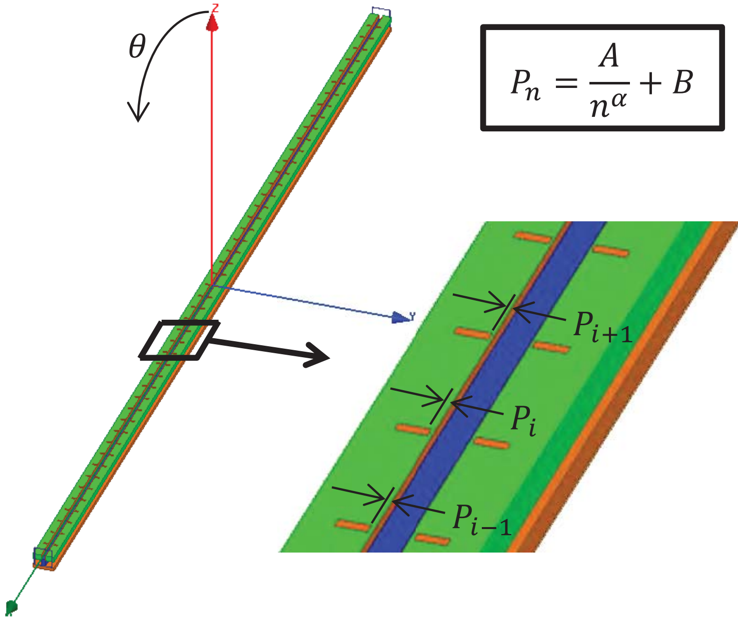


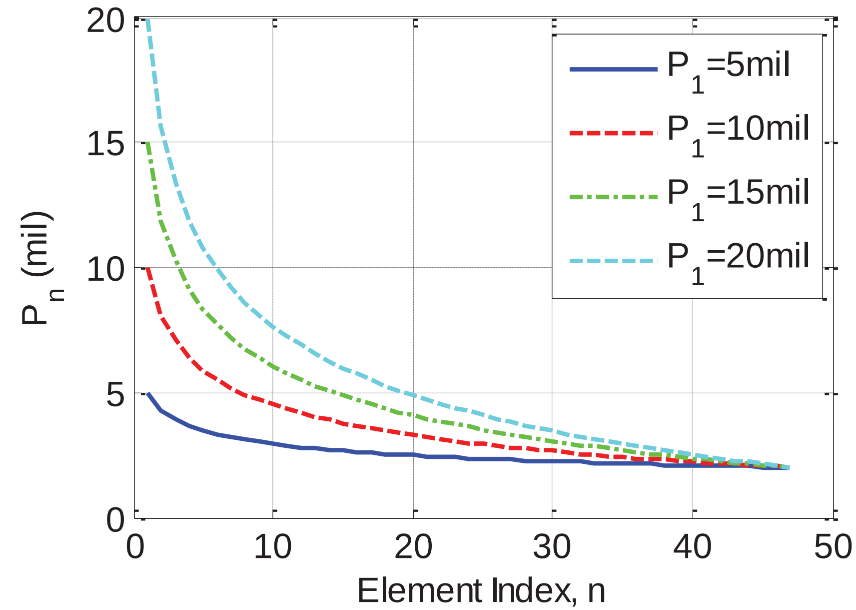


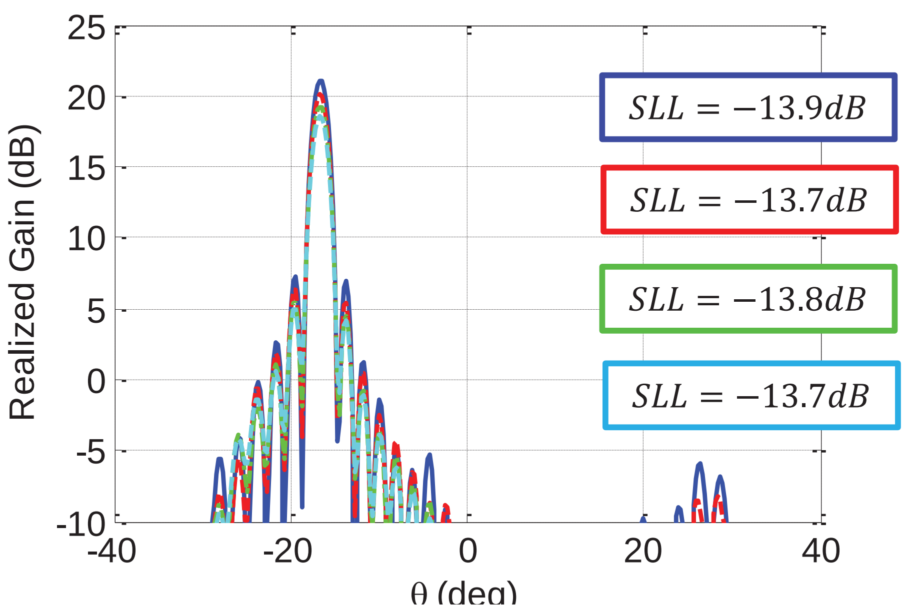
* A and B determined by choice of P_1, P_{47}, and α

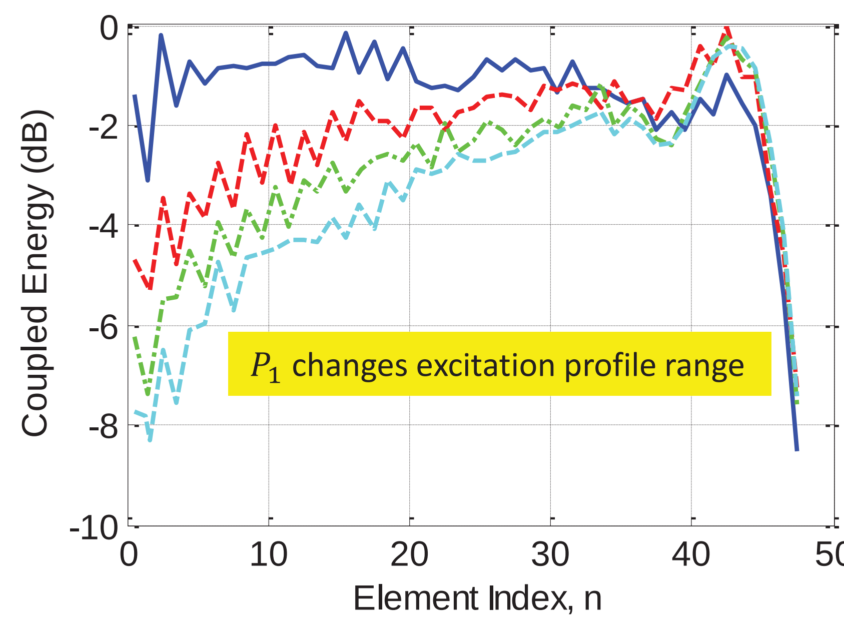
$\alpha = 0.2, P_{47} = 2mil$

$$P_n = \frac{A}{n^\alpha} + B \quad *$$



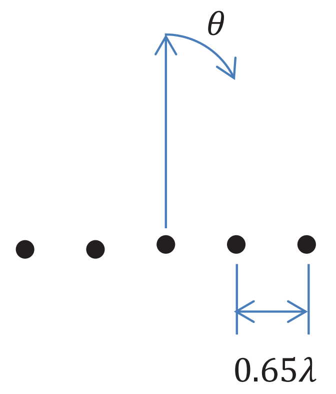






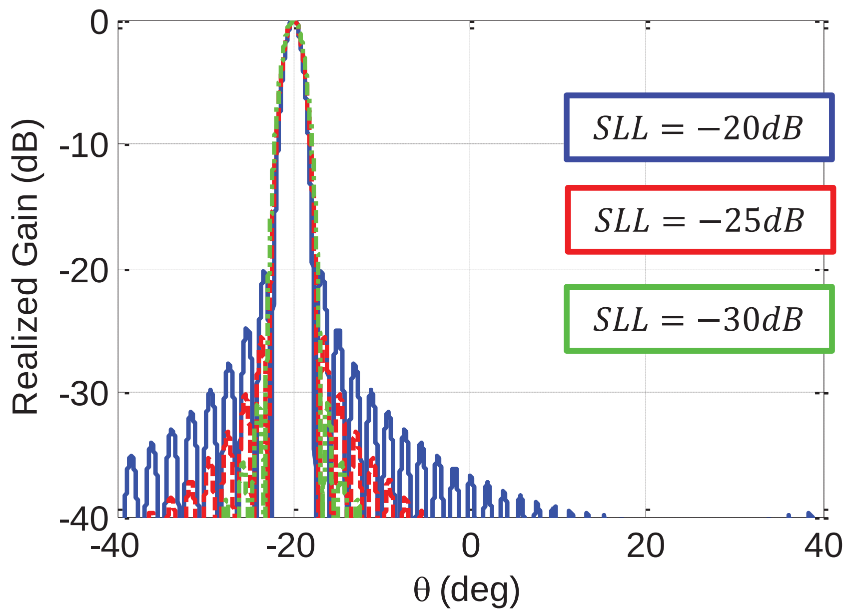
* A and B determined by choice of P_1, P_{47}, and α

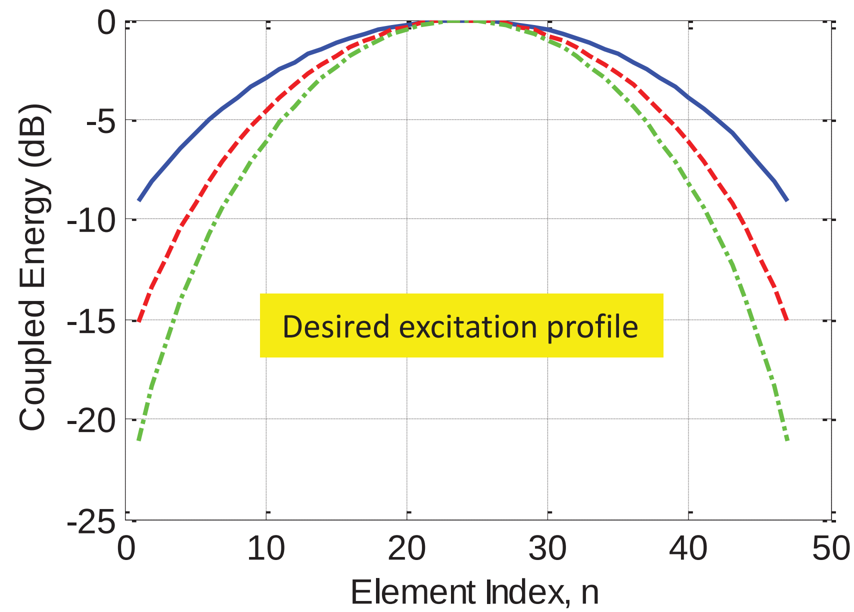
Mathematical Array Weighting



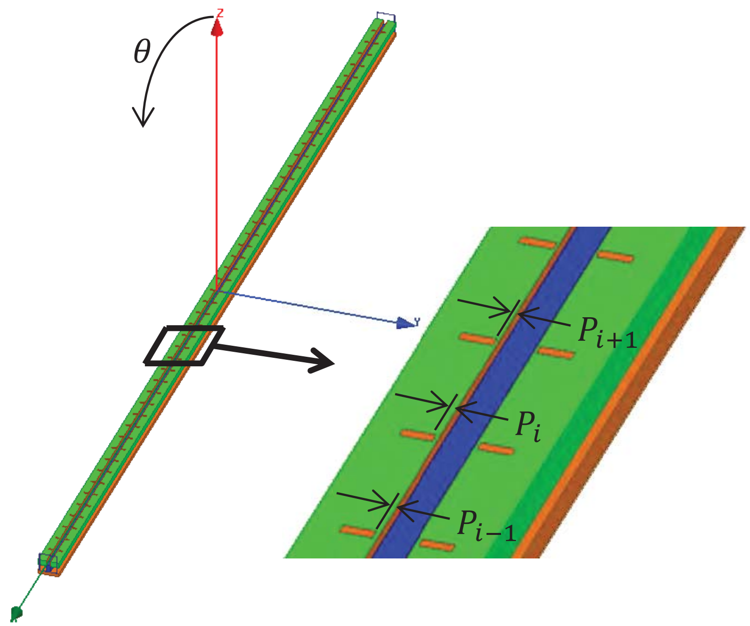
Array characteristics

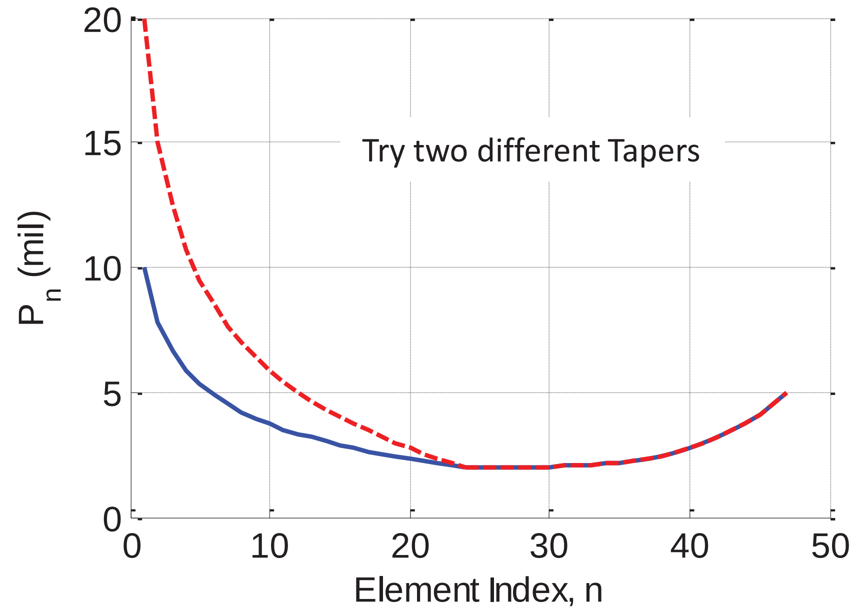
- Kaiser window used for weighting profile
- 47 Elements
- $\theta_{max} = -20°$

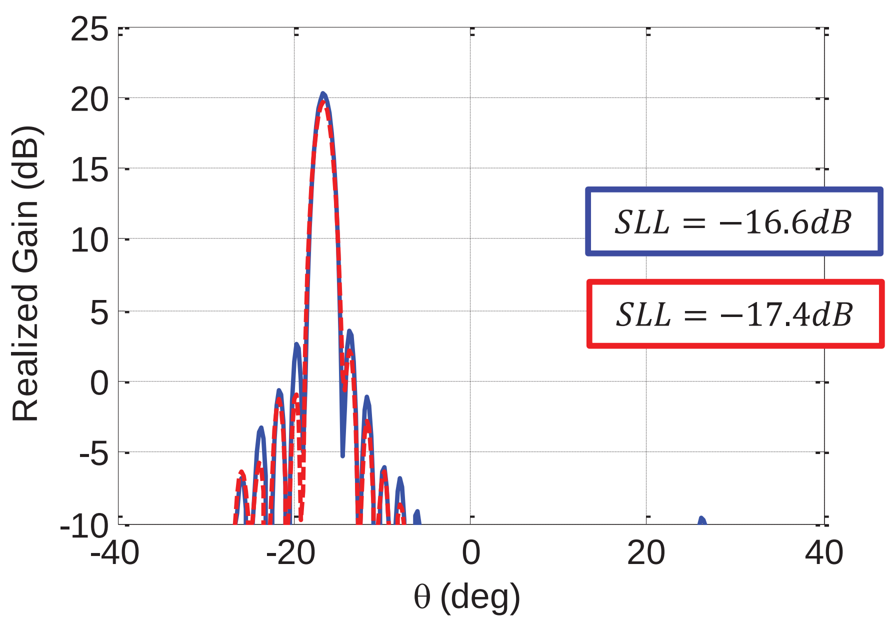


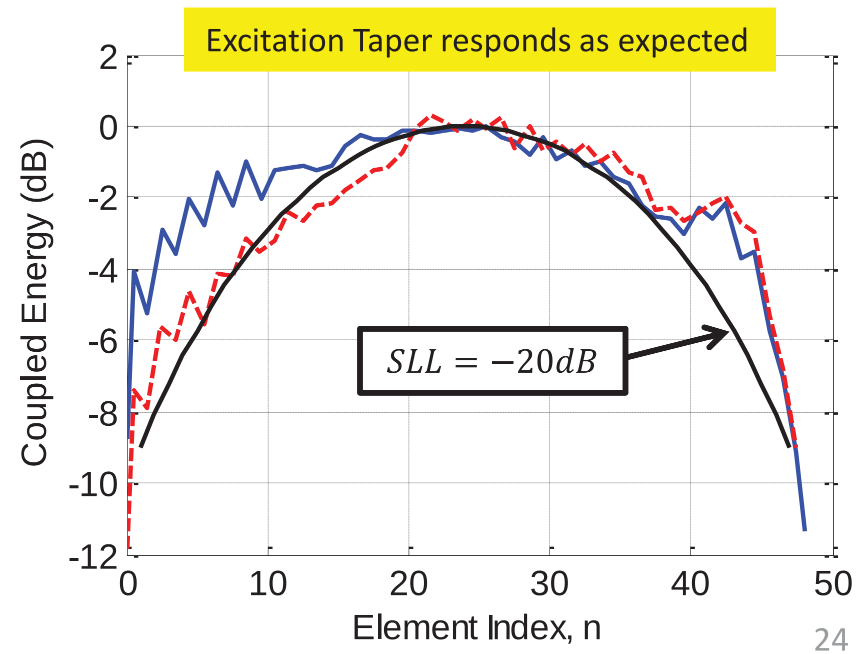


Double Equation Based Taper









Conclusions

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

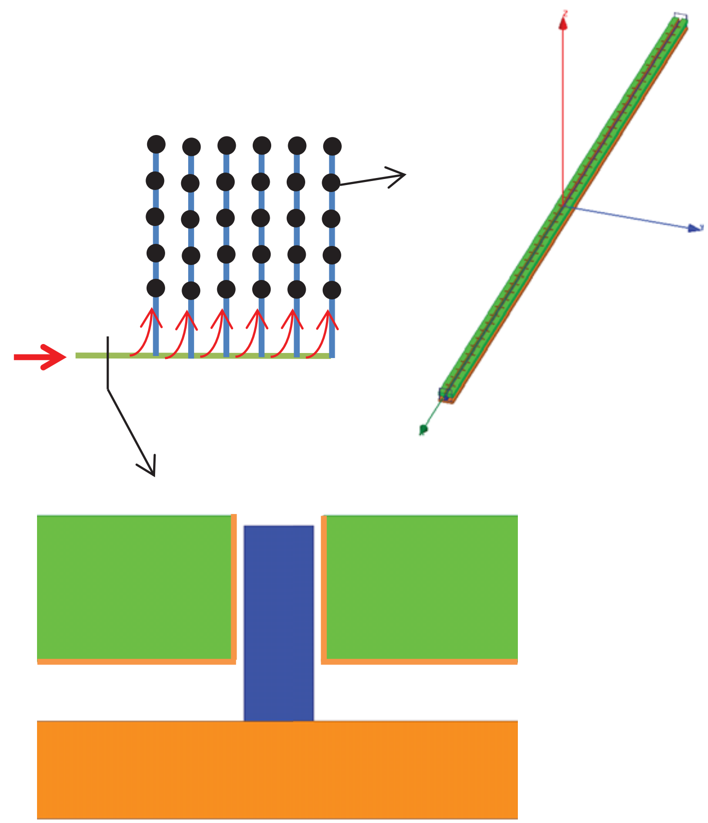
- *$\uparrow k_{eff}$ control*
- *Easier fabrication*
- *Sidelobe control*

Future Work

Finish planar array

- 47x47 element array
- Ka-Band (25.5-27GHz design frequency)
- Ability to scan in both elevation and azimuth directions
  - ±30˚ 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

<u>2-D Independent Scanning</u>



Questions?