Reconfigurable Wave Velocity Transmission Lines for Phased Arrays

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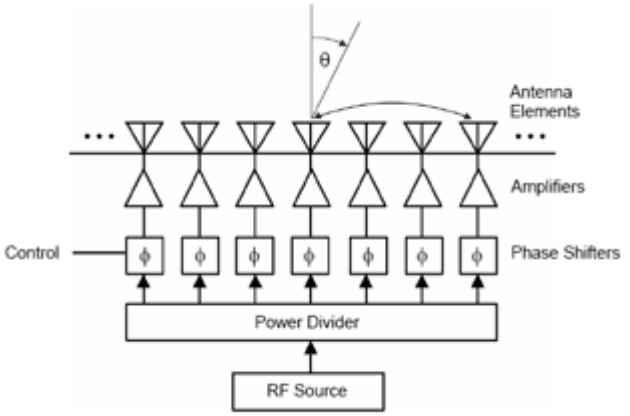
Current Technology

Phased Array Features:

- *Wideband*
  - Element Design allows for wideband operation
- *Beam Scanning Ability*
  - Element phase control allows for beam scanning

Phased Array Challenges:

- *Complex*
  - Backend used to achieve beam steering is very complex
- *Heavy*
  - The backend adds significant weight
- *Costly*
  - Components are very expensive



Addressed by our approach

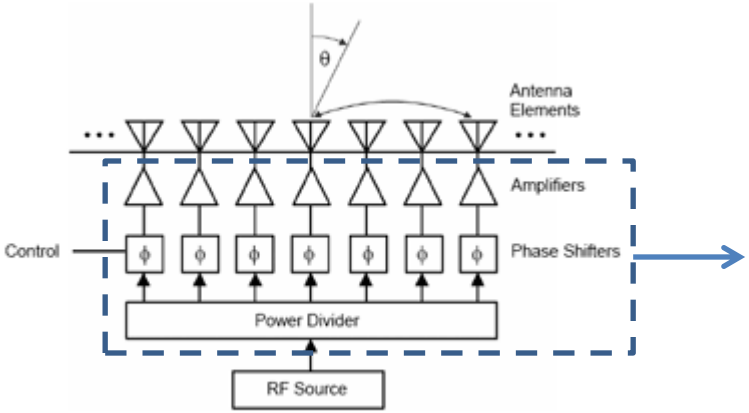
Novel Aspects

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

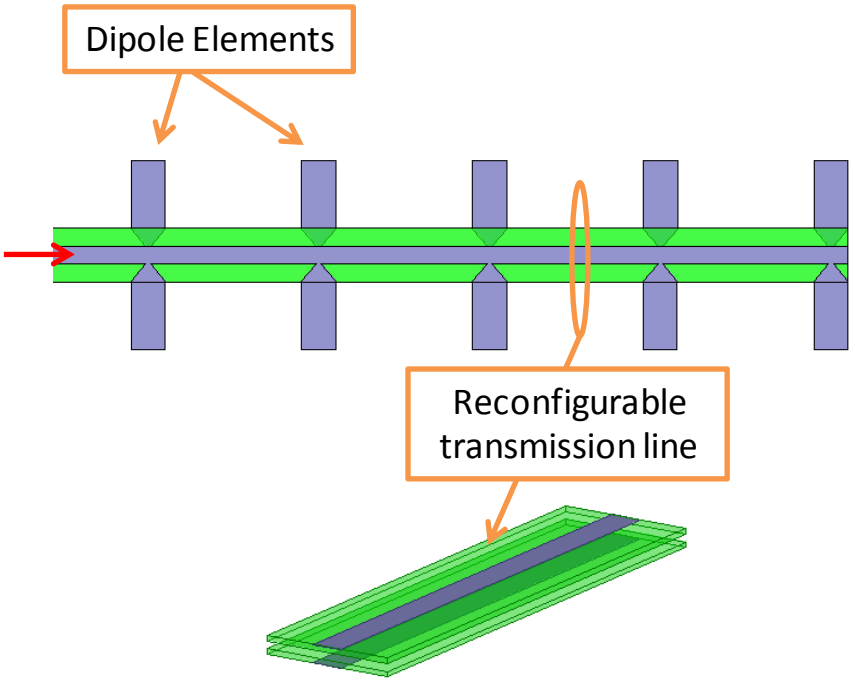
Approach

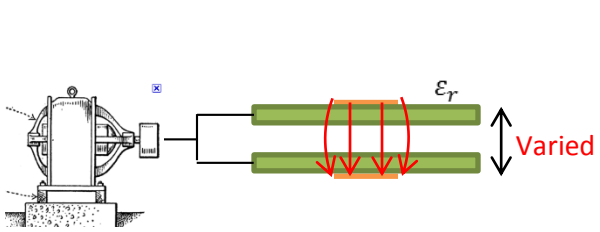
Replace Backend With Simpler Mechanism

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

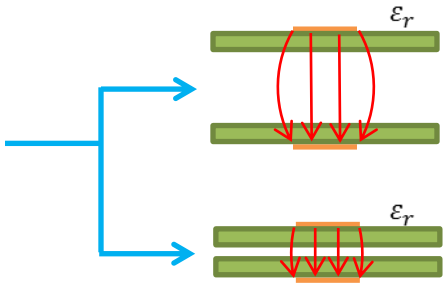
Use Series Fed Array:

- *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





Motor to move sheets closer or farther apart

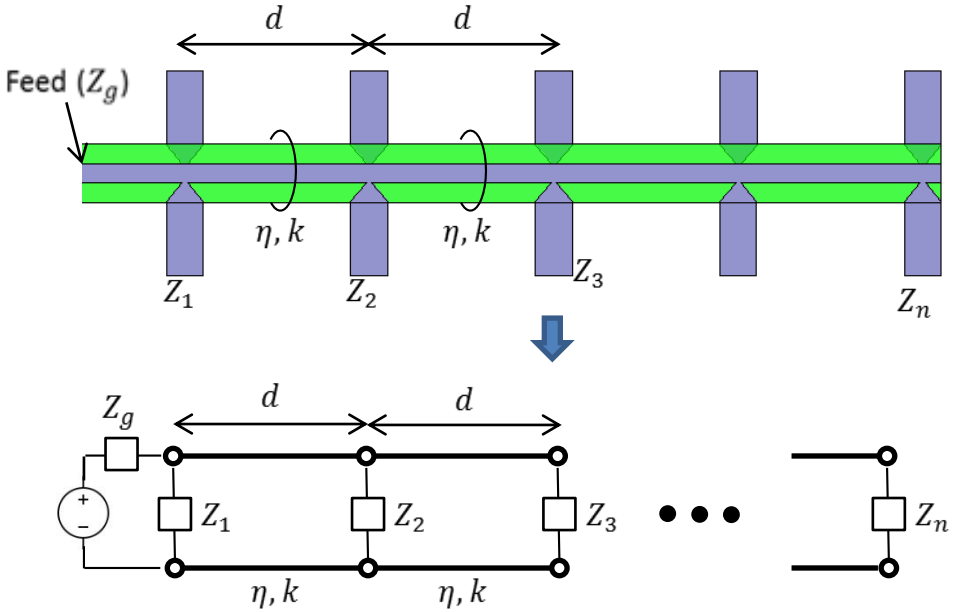


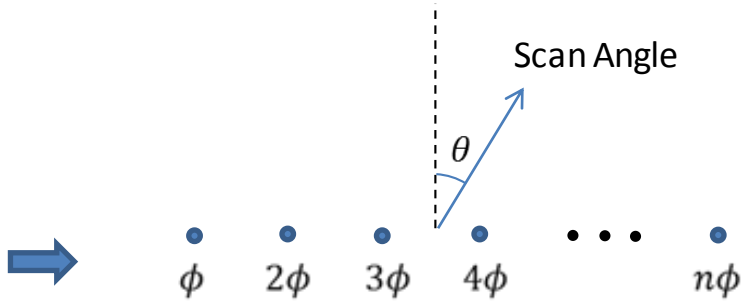
Field mostly in air, so low ε_{eff}

Field mostly in dielectric, so high ε_{eff}

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

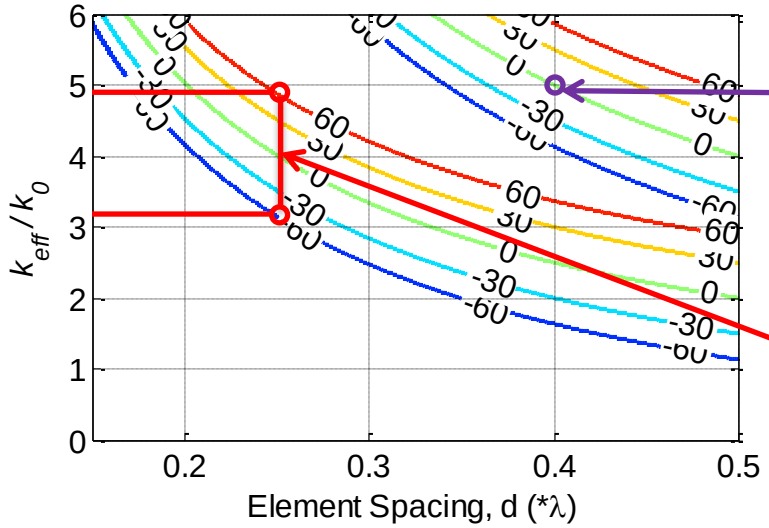
Needed Transmission Line Agility





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

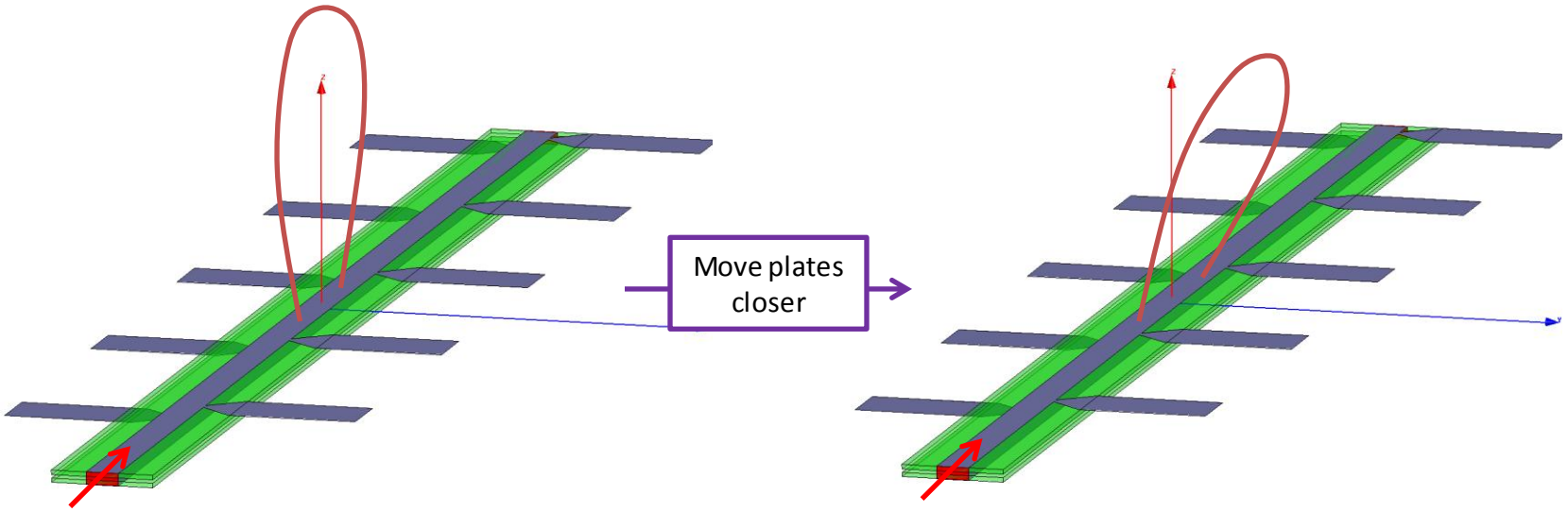
Scan Angle vs. k_{eff} and Element Spacing



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 $3.1 \le \frac{k_{eff}}{k_0} \le 4.9$

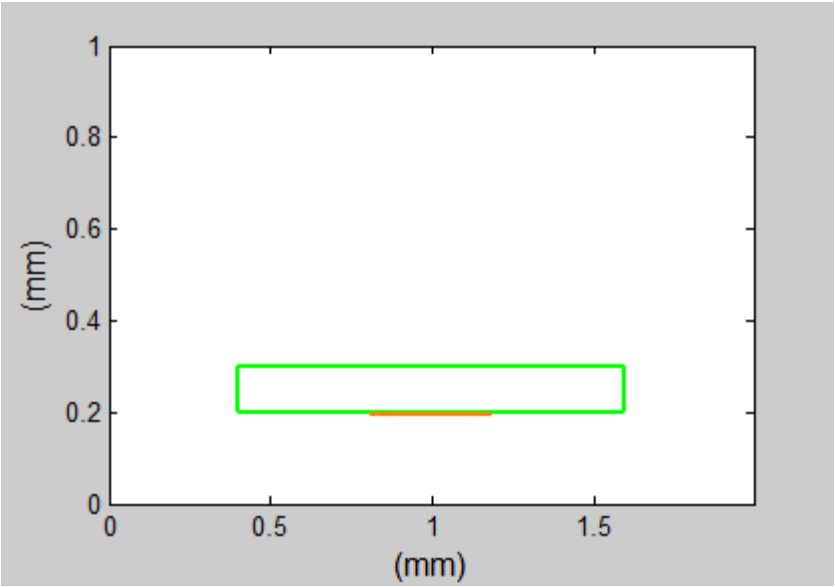
Achieving Scanning

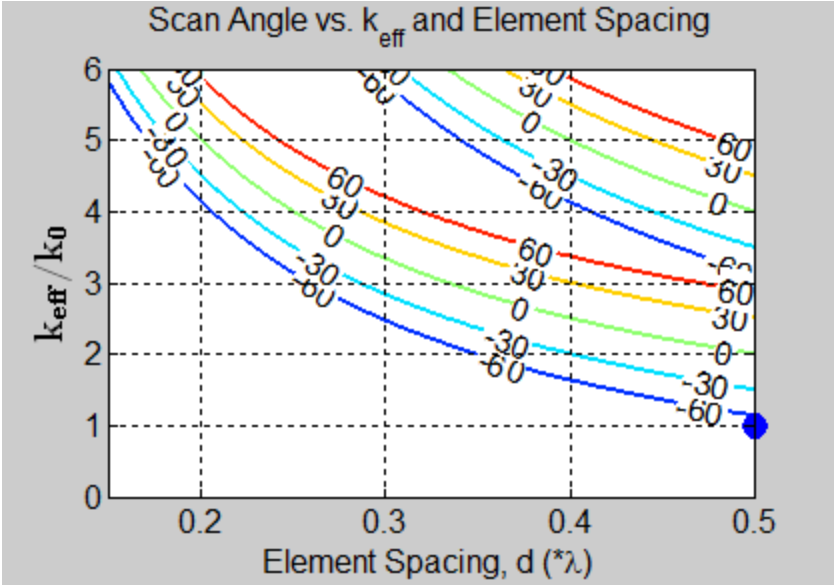


Scanning is achieved with one mechanical motion and no phase shifters

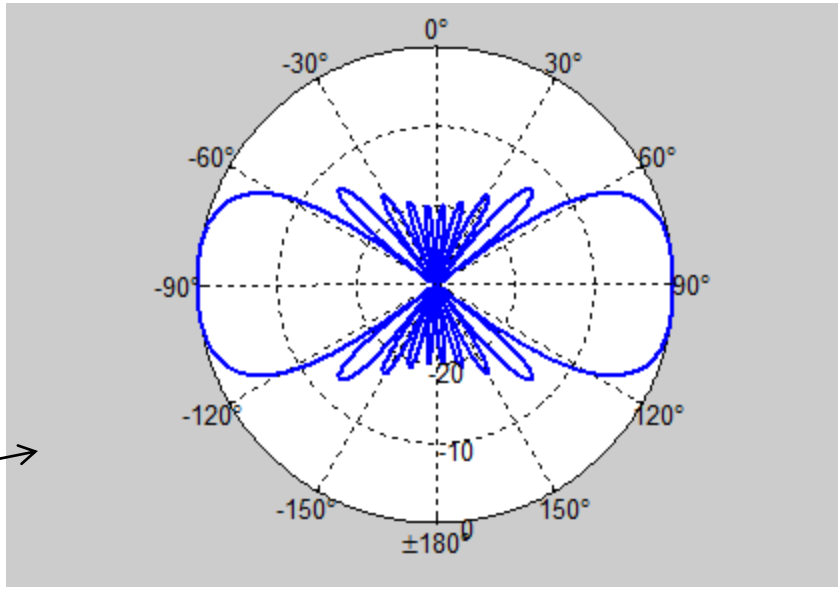
Process to Scan

As the parallel plates close (left)
- k_{eff} ↑ (right top)
- For given $d = \lambda/2$
  - Scan angle (right top)
  - Pattern (right bottom)

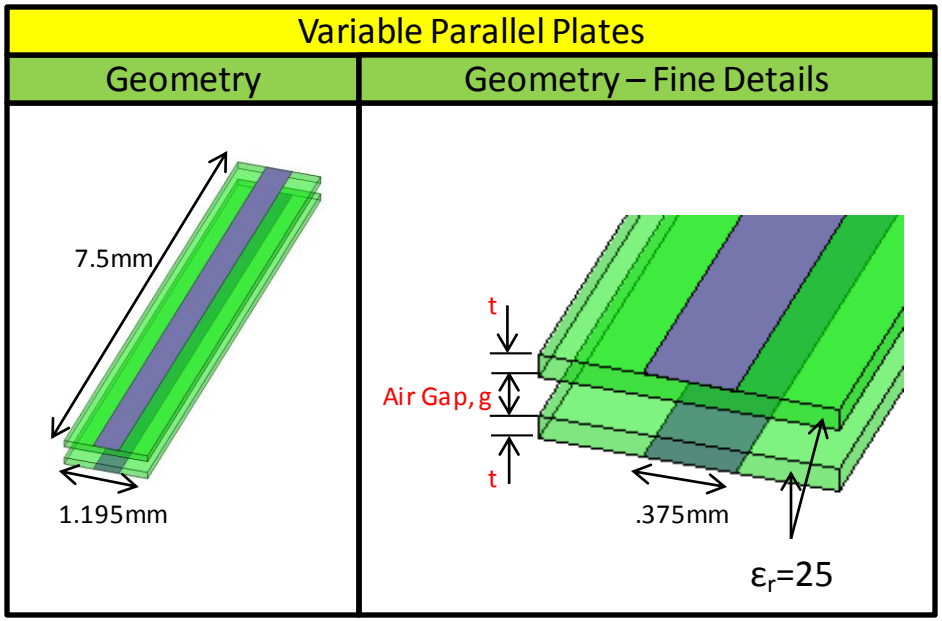


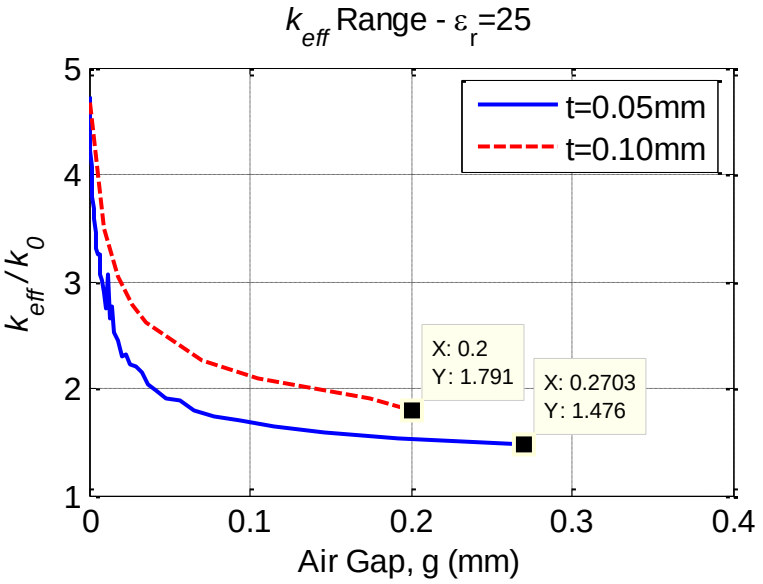


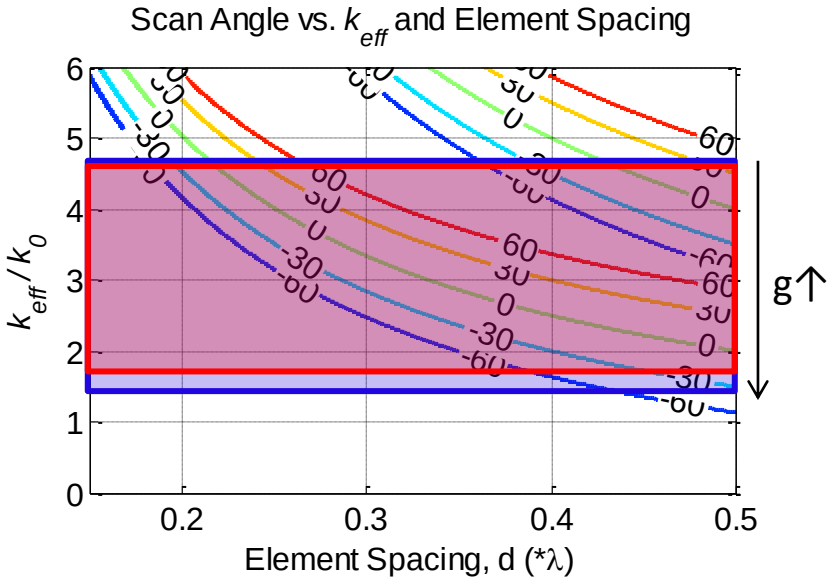
Theoretical 10 Element array with $\lambda/2$ element spacing



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

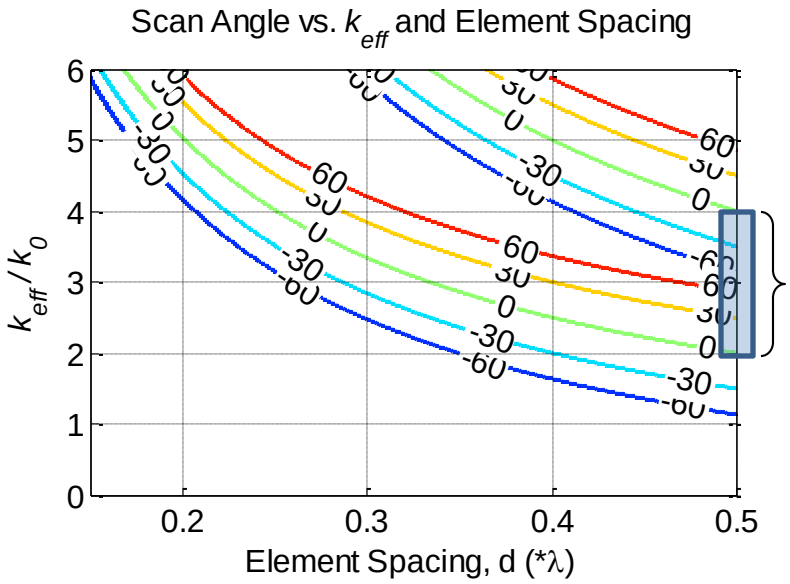






- Strip Spacing ≤ 0.40mm (λ/20 @ 40GHz)
  - t=0.1mm case → lower max g
- t=0.05mm
  - Larger $\varepsilon_{eff}\mu_{eff}$ range
  - More precision needed
- t=0.10mm
  - Smaller $\varepsilon_{eff}\mu_{eff}$ range
  - Less precision needed

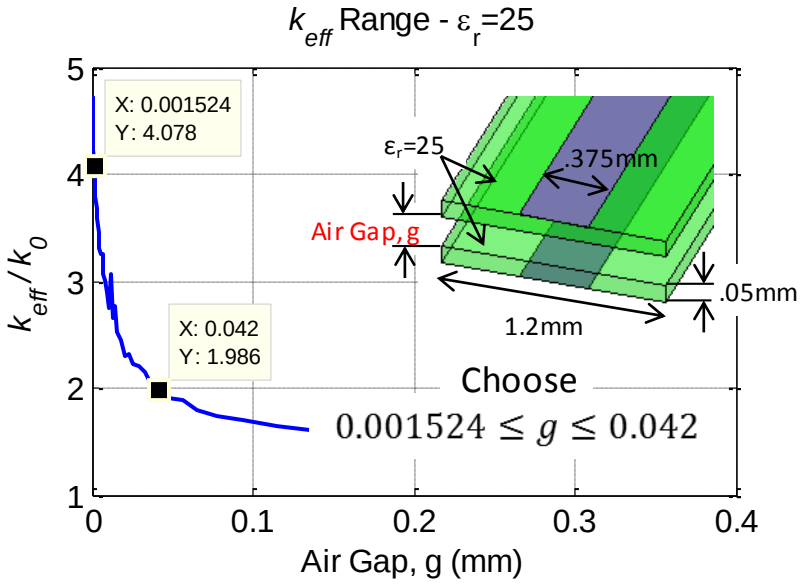
Transmission Line Attributes

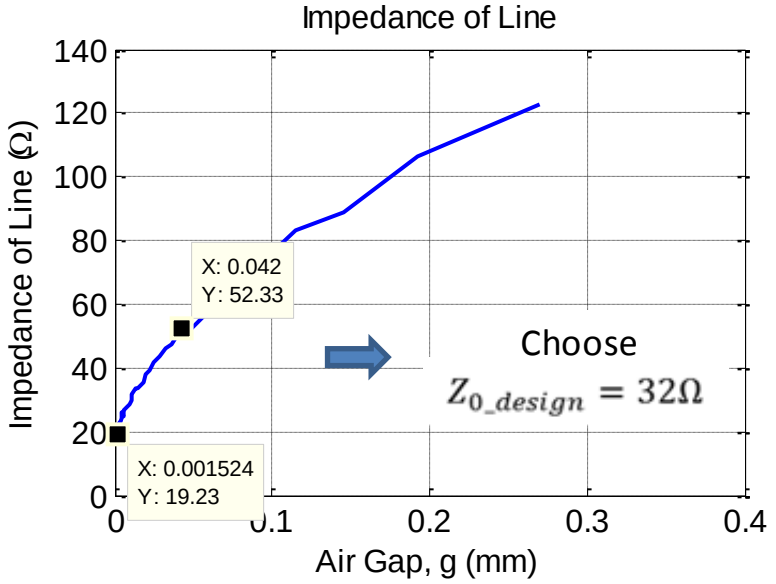


$$d = \frac{\lambda}{2}$$

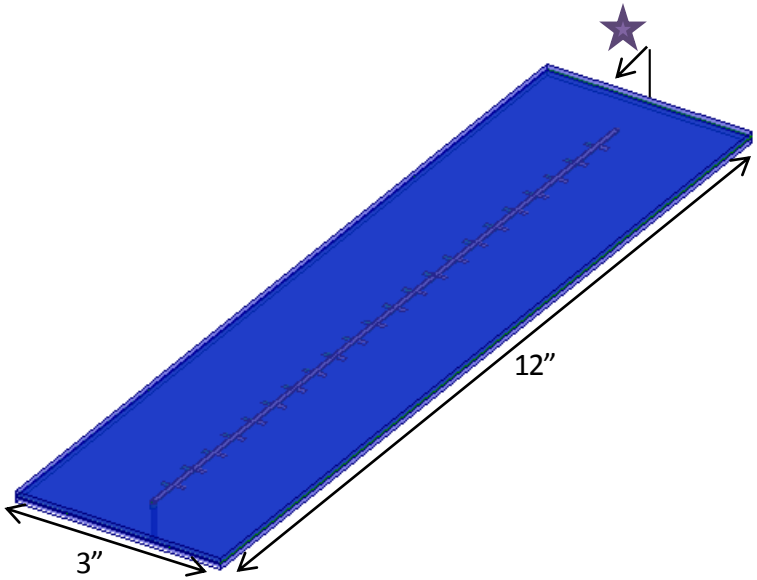
$$2 \leq \frac{k_{eff}}{k_0} \leq 4$$

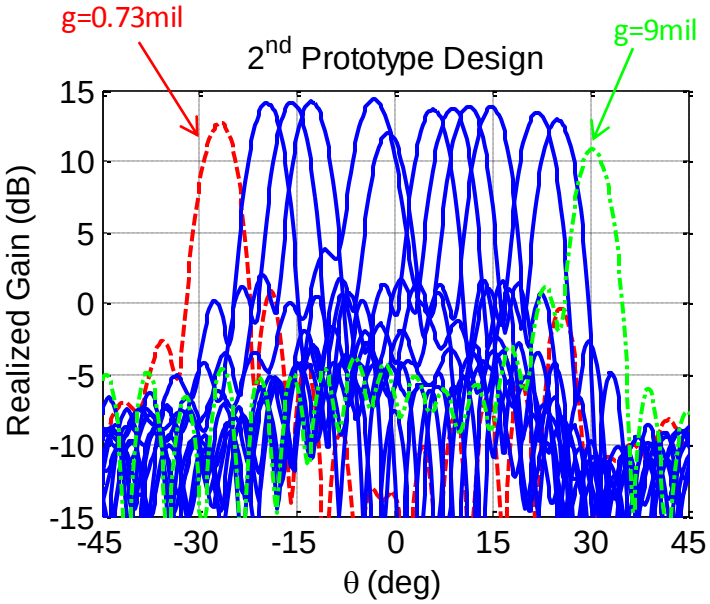
➡ Can scan to all angles

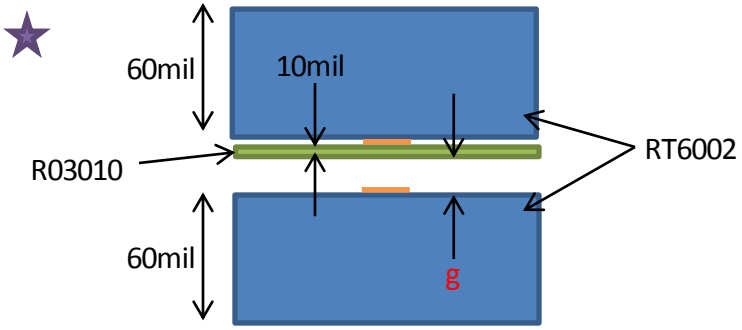




22 Element Prototype Design

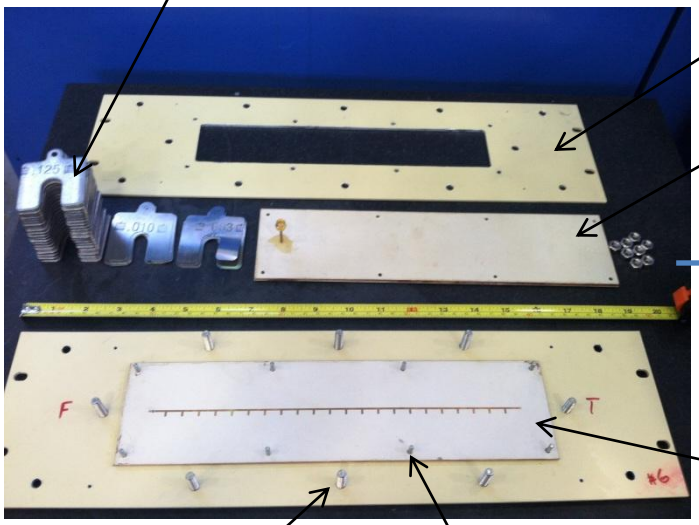




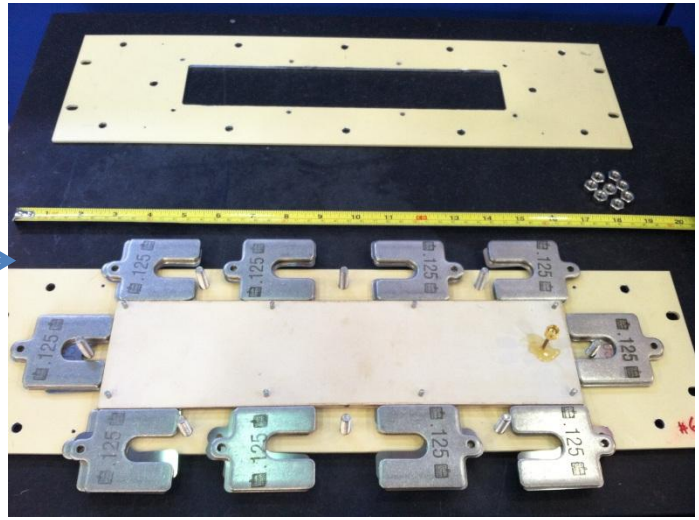


Practical Transmission Line Design
- Circuit printed on two 60mil thick RT6002 boards
  - RO3010 becomes ripply when unsupported
- RO3010 material bonded to inside of one of boards

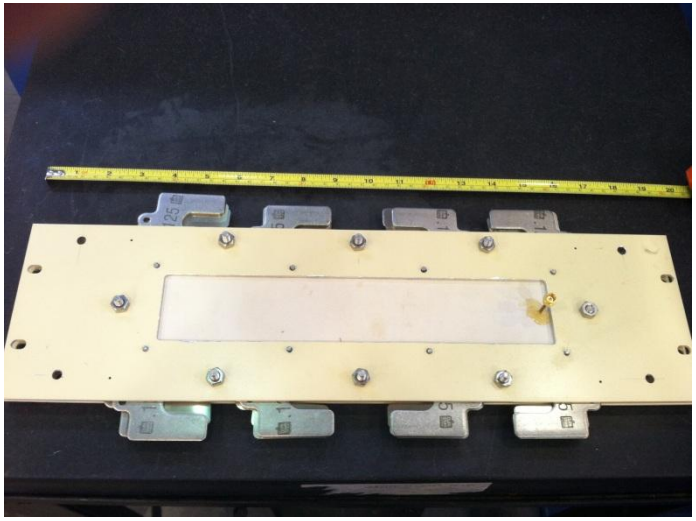
Assembly of Prototype



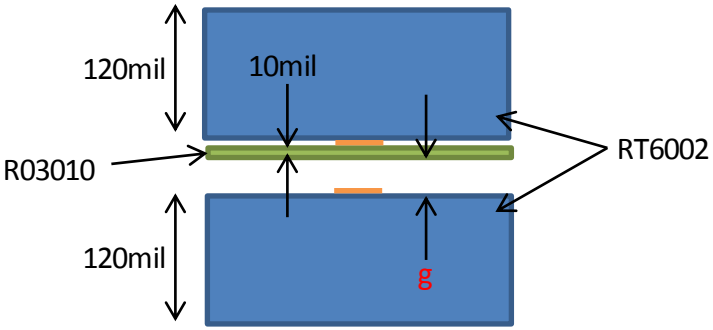
Fit top dielectric on with shims as spacers

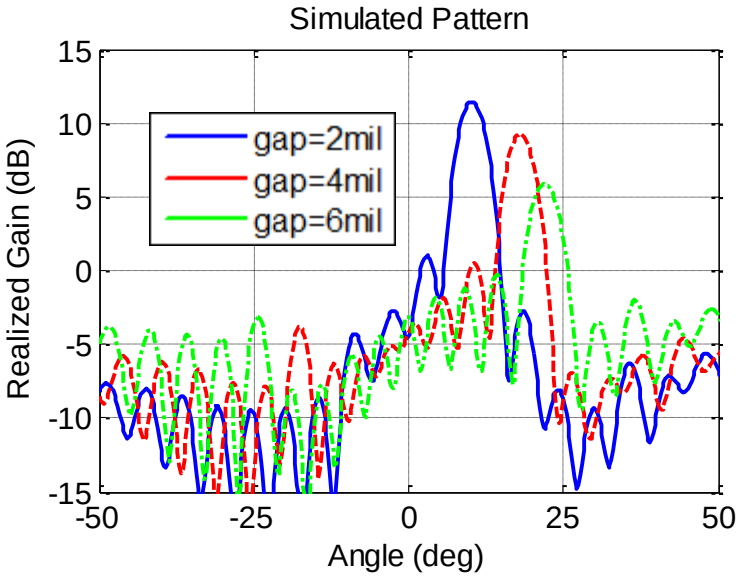


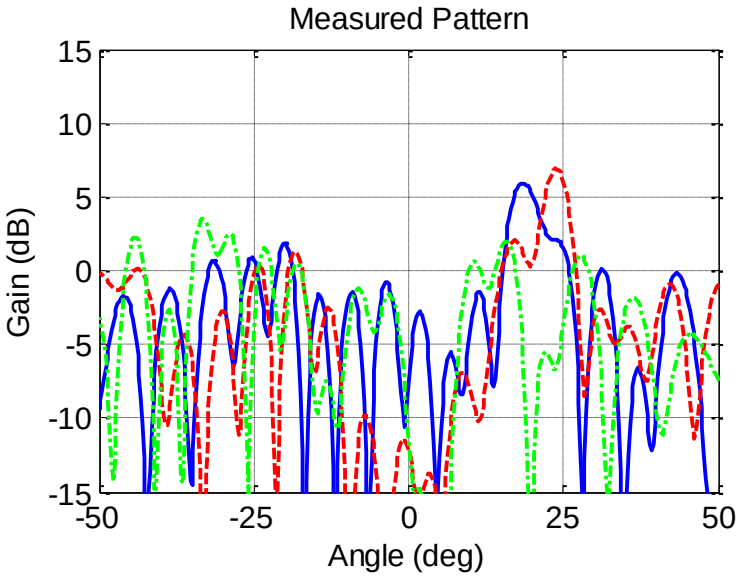
Pinch together two boards with metal frames



Validation



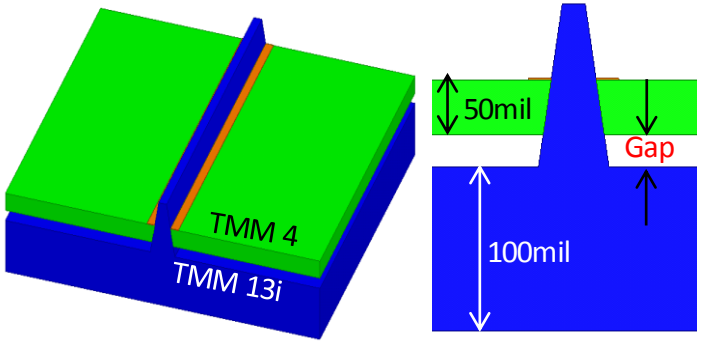


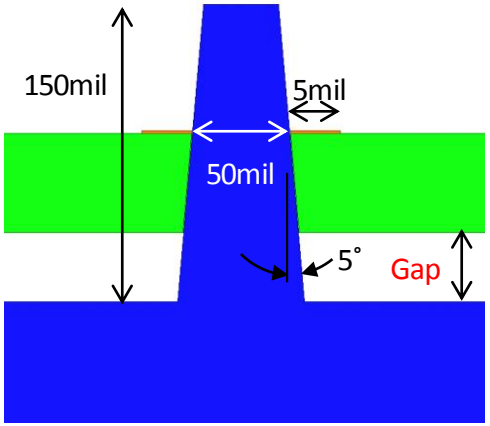


- Scanning Observed
- Achieving gap imprecise
  - Patterns shifted
  - Gain Lowered

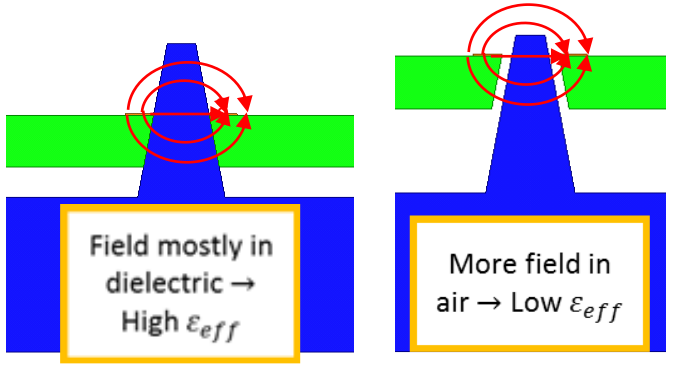
CPS Line

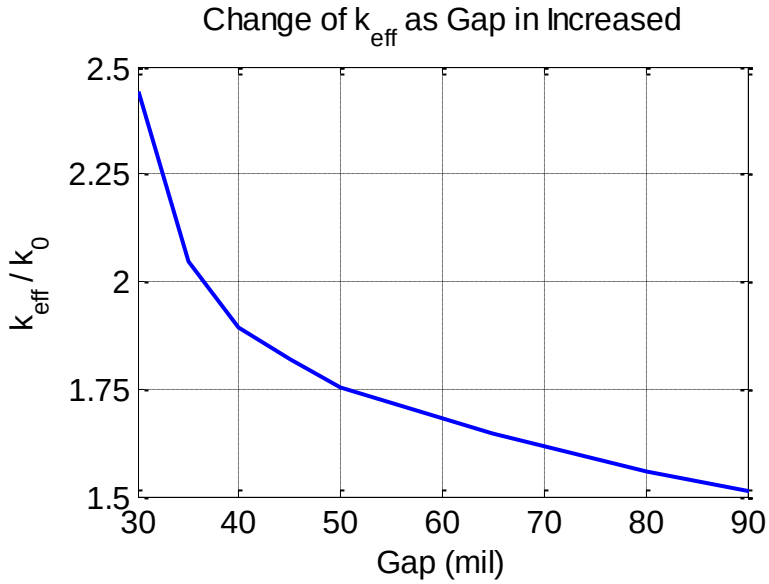
Design



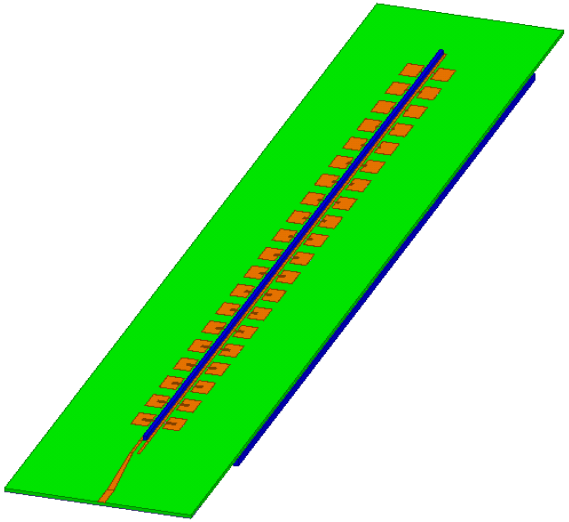


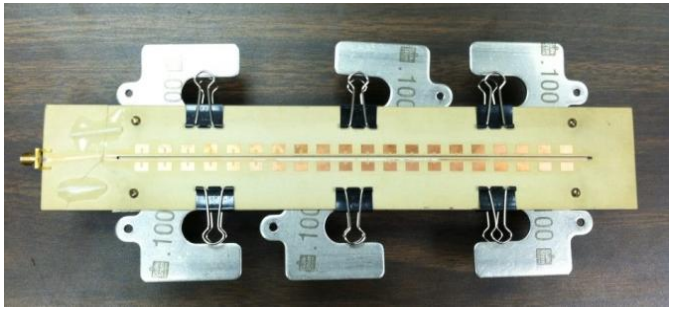
Operation

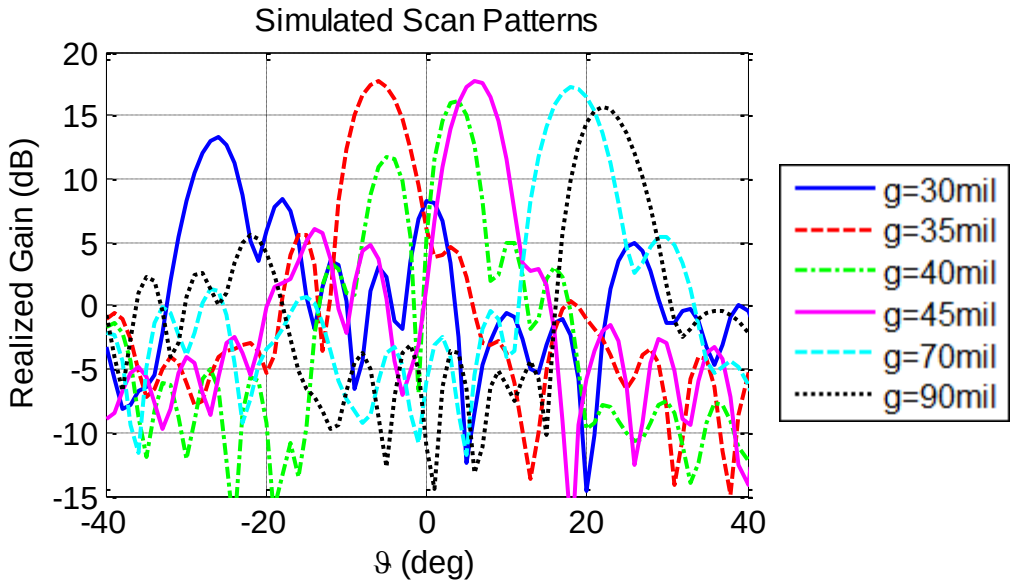


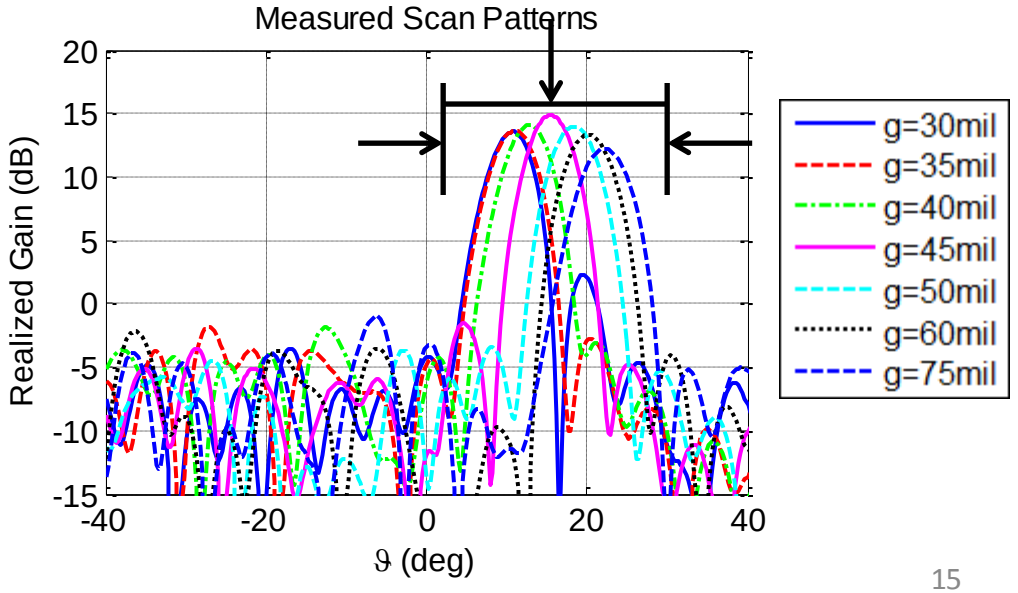


Simulated vs. Measured

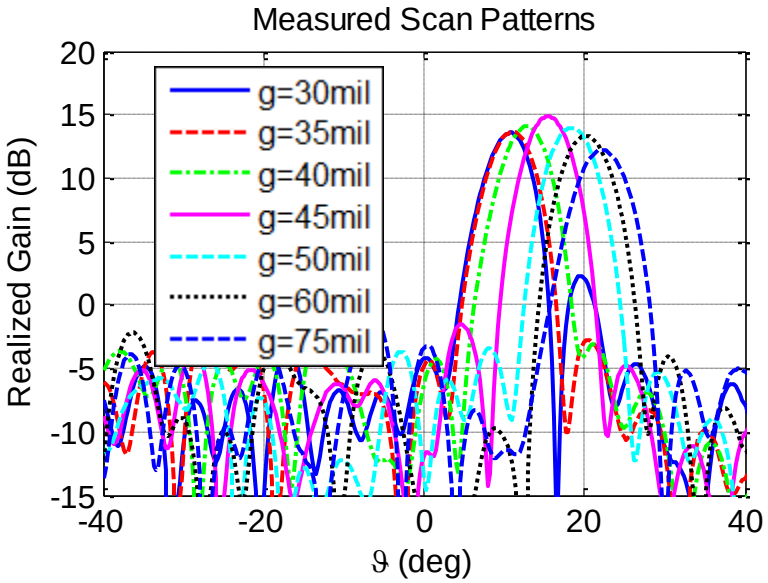


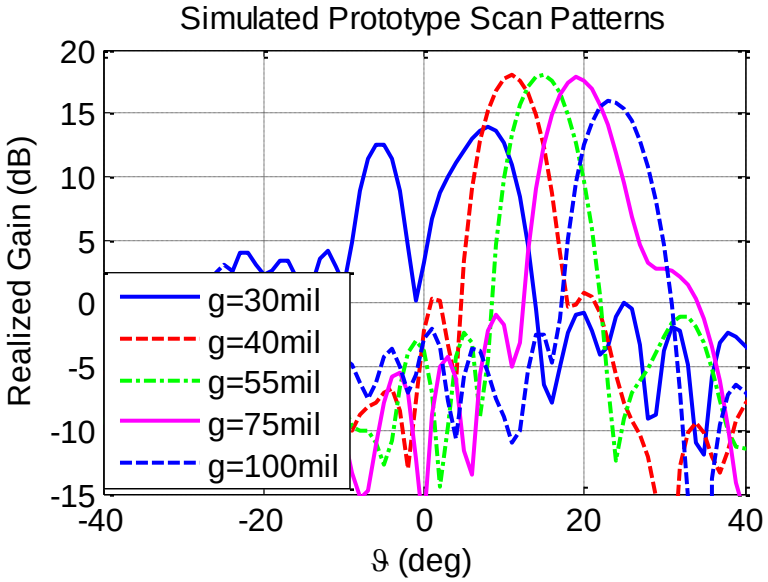






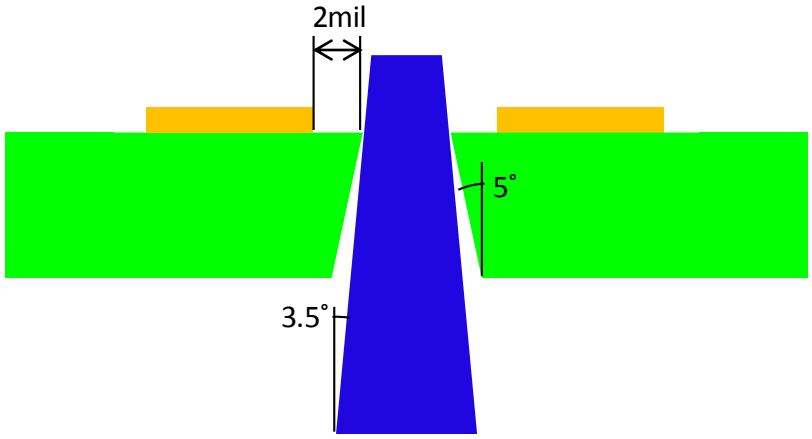
Simulating Known Differences





Simulated with known differences

- Ridge dimensions
- Overetch



Future Work

2-D Scanning

- *One feed*
- *Independent control of each scanning axis*

Ka Band

- *Smaller dimensions*