SAND2007-3661C

Dual-Polarization Large Scan Angle Broadband Thick-Metal FSS

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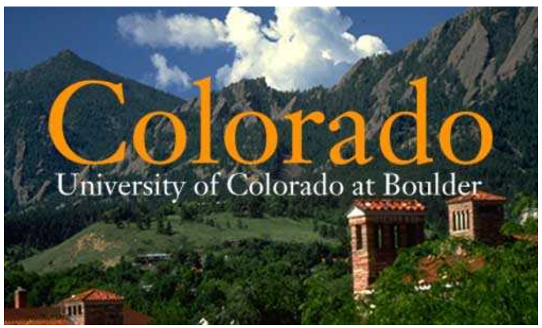

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Introduction

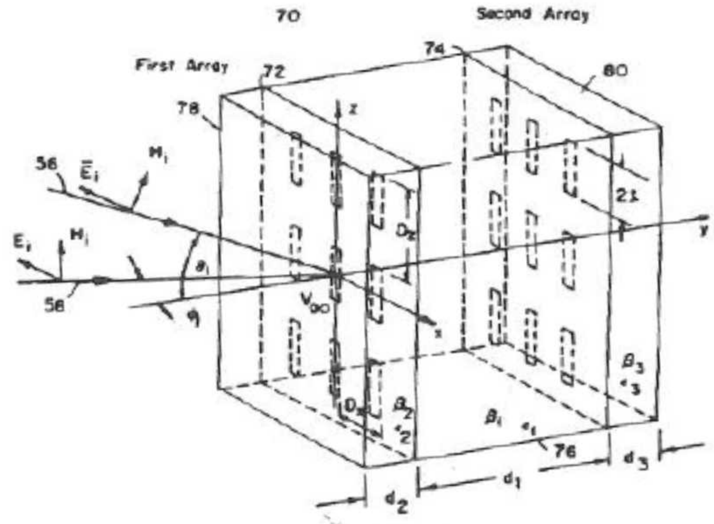
- Frequency selective surfaces (FSSs) can be (1) thin metal (printed on dielectrics) or (2) thick metal with or without dielectrics

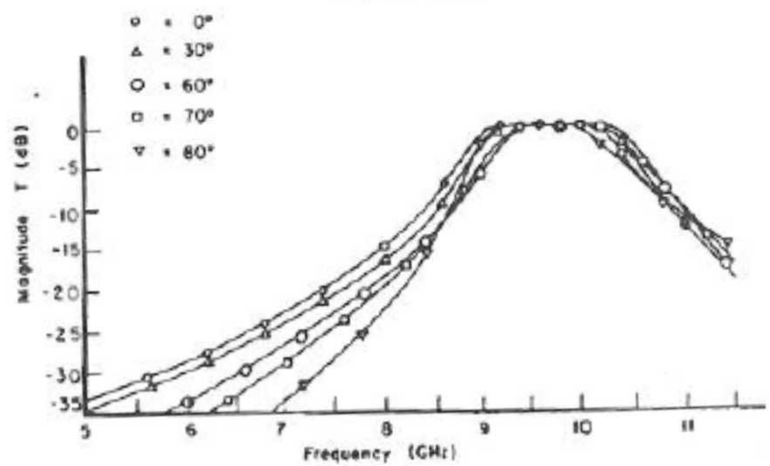
- It is difficult to design a thin printed FSS that has equal TE and TM performance over a large range of incidence angles, for a large bandwidth

- With thick metal FSSs, the third dimension can be exploited as an additional design parameter

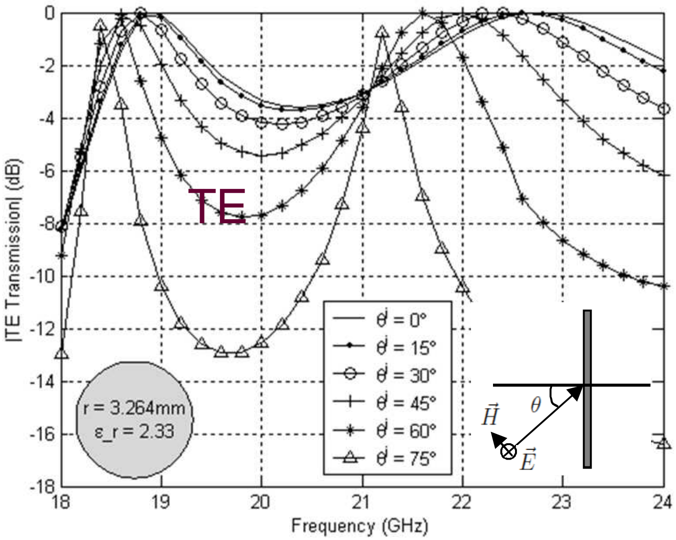
- We show that a thick FSS can have improved dual-polarization performance over large scan angles and bandwidth

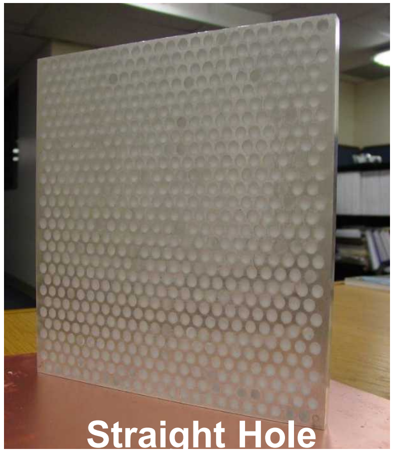
United States Patent, B. A. Munk, 1978

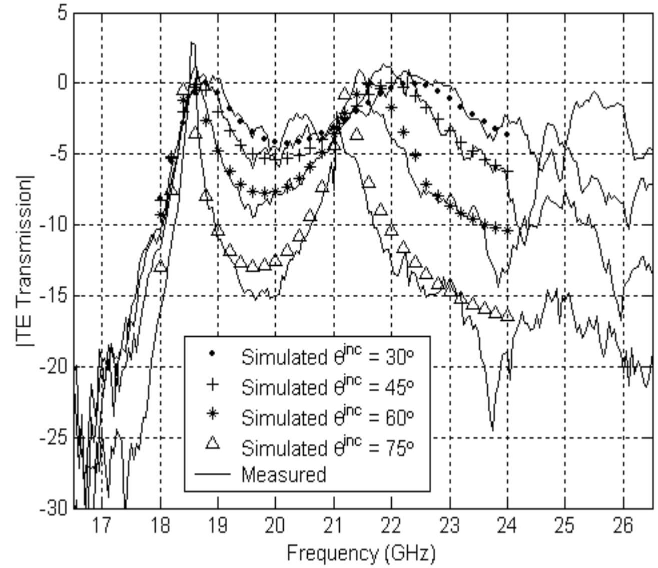


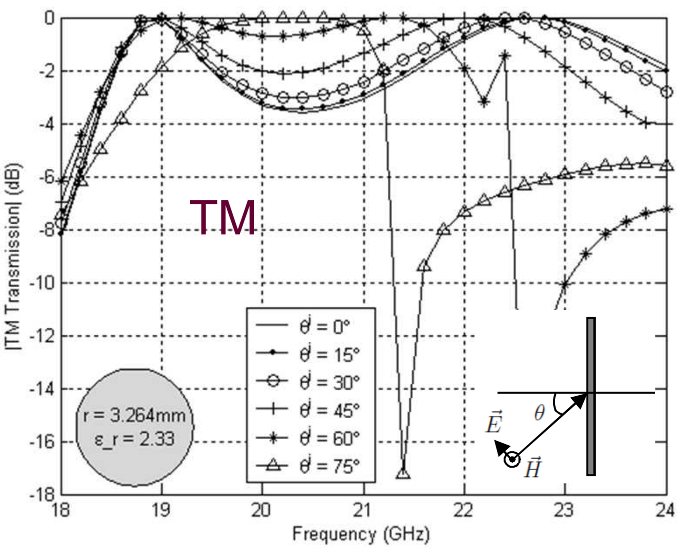


Previous results
(presented at APS in 2004)



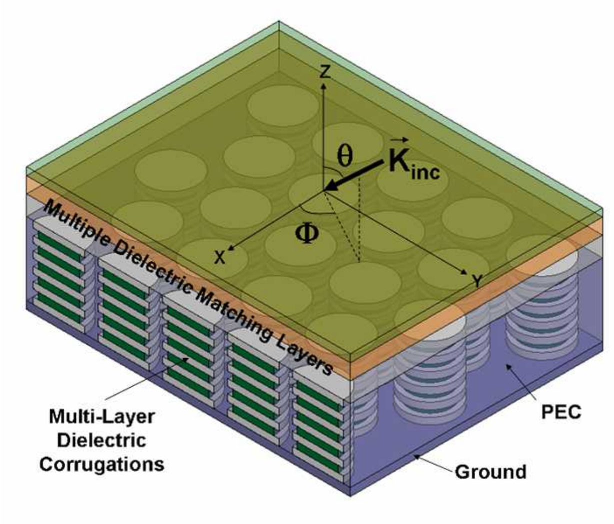


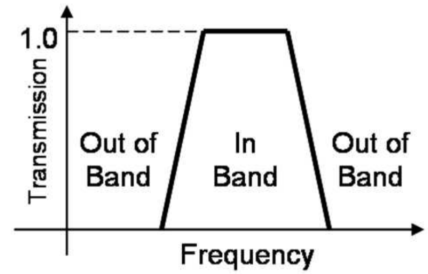




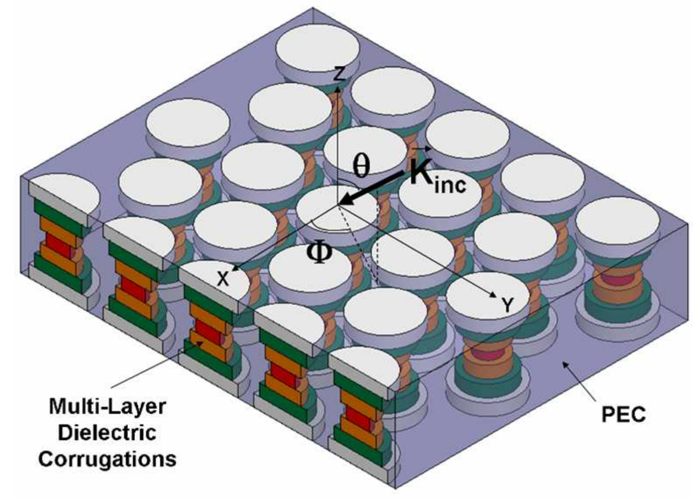
- A thick FSS at K-band implemented with straight cylindrical hole profile
- The FSS is half-wavelength thick at center frequency, machined in Al with paraffin filling
- Simulations are performed using an in-house modeling technique which combines waveguide and Floquet mode matching
- The simulated results show a narrow band frequency response
- The TE and TM polarization transmission is drastically different for larger scan angles
- Measurements confirm model

Thick FSS Bandpass Examples





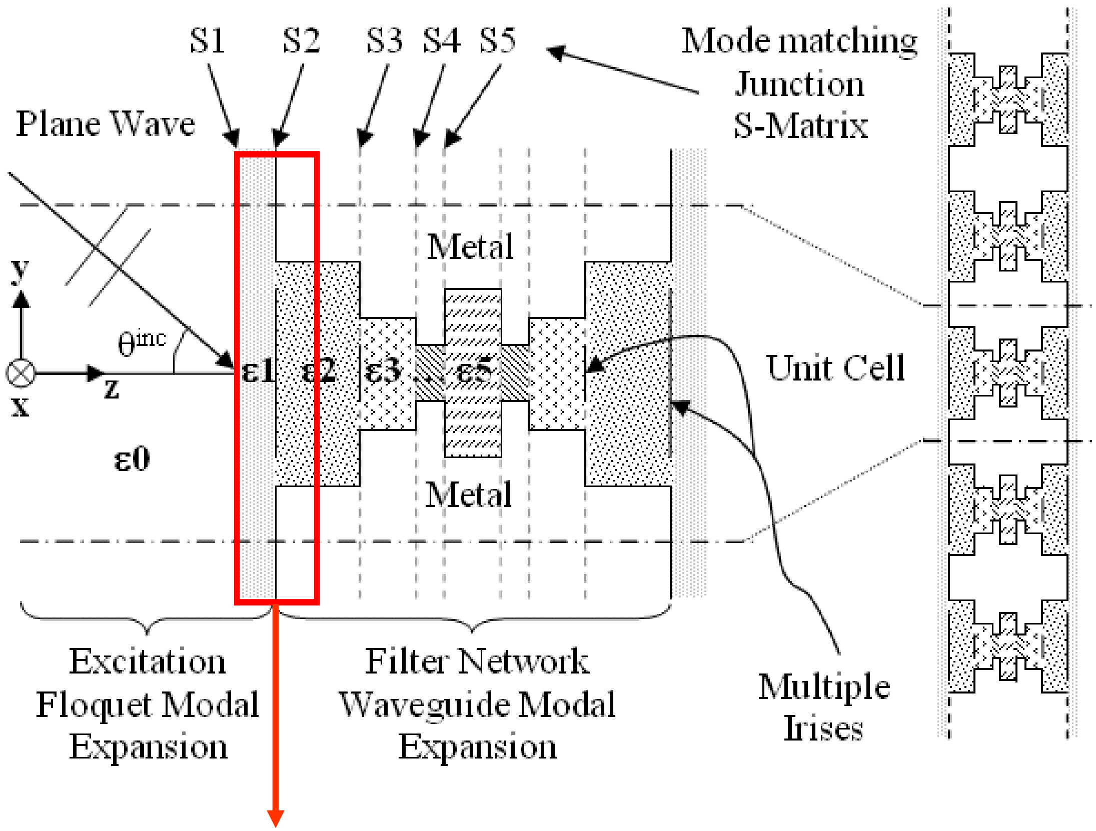
It is desired that both TE and TM transmission have this characteristic over large scan angles



How can complex periodic structure like these be analyzed?

	CEA	EMF	MoM	FEM	TLM	FDTD	MM
Speed	Fast	Fast	Slow	Slow	Medium	Medium	Fast
Oblique Incidence	No	No	Yes	Yes	No	Yes Recently	Yes
Thin Metal	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Thick Metal	No	No	Tedious	Yes	No	Yes	Yes
General	No	No	Yes	Yes	Yes	Yes	Semi

Network Representation of a Thick Unit-Cell



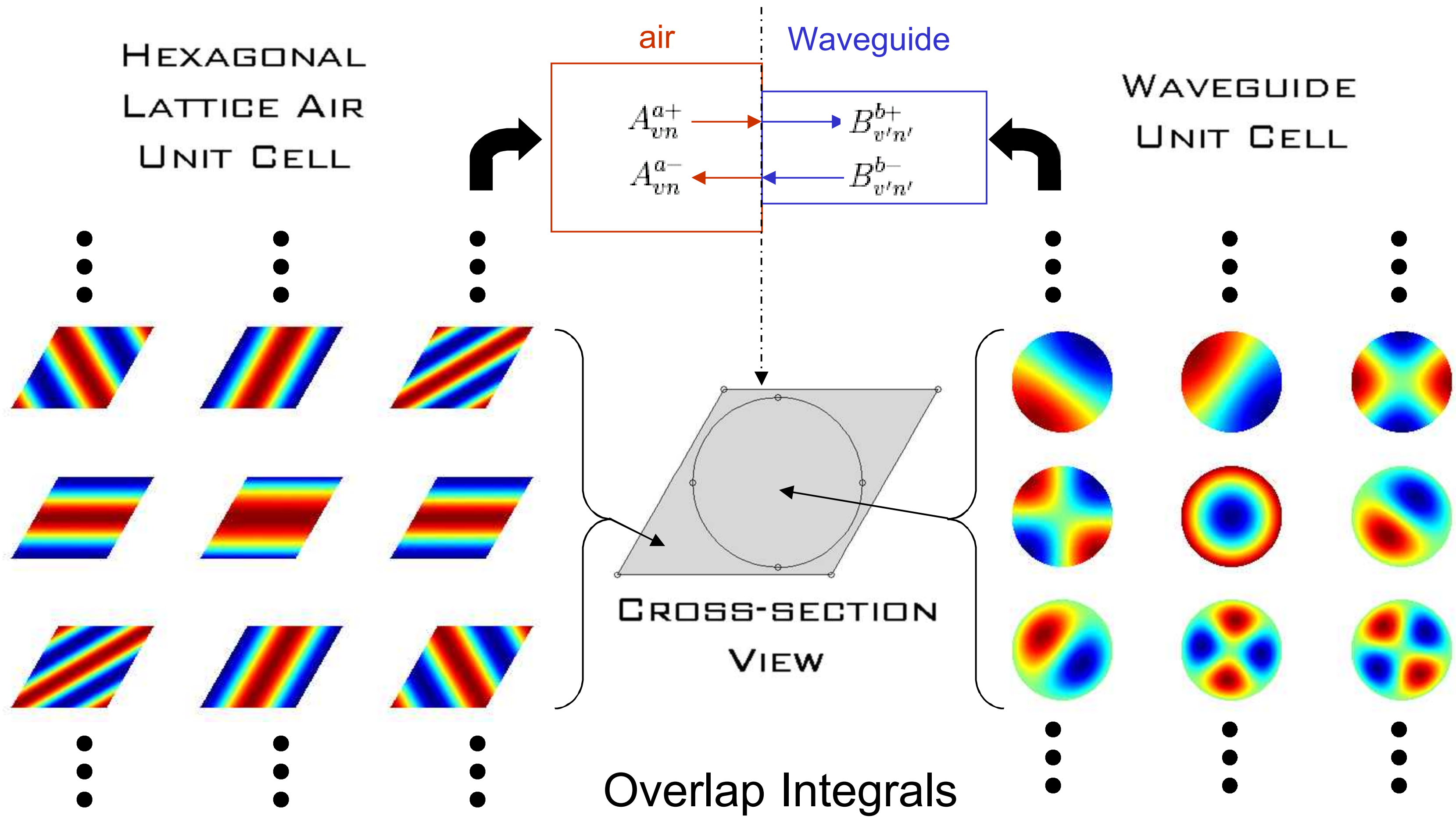
1. Divide the thick perforation into junctions and sections

2. Compute generalized scattering matrices (GSM) for each junction and section

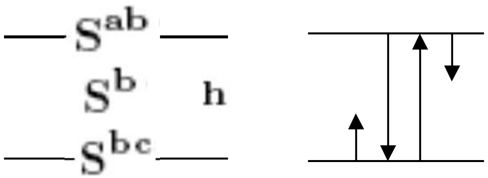
3. Cascade results

Apply Mode Matching to obtain GSM

Air-Waveguide Interface & Mode Matching



A clue showing what's inside matters



$$S^{ac} = S^{ab} \star S^{b} \star S^{bc}$$

$$S^{b}_{11} = S^{b}_{22} = 0$$

$$S^{b}_{12} = S^{b}_{21} = \mathrm{diag}\{e^{-\gamma_1^{b} h}, \ldots e^{-\gamma_n^{b} h}\}.$$

$$S^{ac}_{11} = S^{ab}_{11} + S^{ab}_{12} S^{b}_{12} \left[I - \Delta_R\right]^{-1} S^{bc}_{11} S^{b}_{21} S^{ab}_{21},$$

$$S^{ac}_{12} = S^{ab}_{12} S^{b}_{12} \left[I - \Delta_R\right]^{-1} S^{bc}_{12},$$

$$S^{ac}_{21} = S^{bc}_{21} \left[I - \Delta_F\right]^{-1} S^{b}_{21} S^{ab}_{21},$$

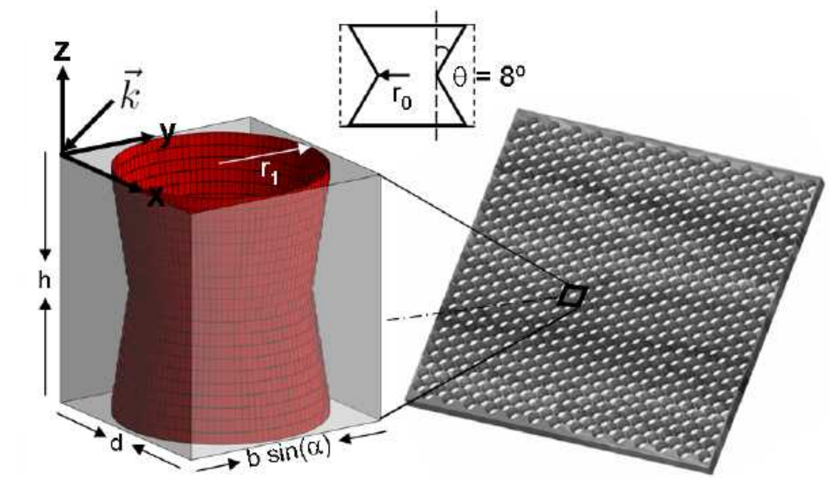
$$S^{ac}_{22} = S^{bc}_{22} + S^{bc}_{21} \left[I - \Delta_F\right]^{-1} S^{b}_{21} S^{ab}_{22} S^{b}_{12} S^{bc}_{12},$$

$$\Delta_R = S^{bc}_{11} S^{b}_{21} S^{ab}_{22} S^{b}_{12},$$

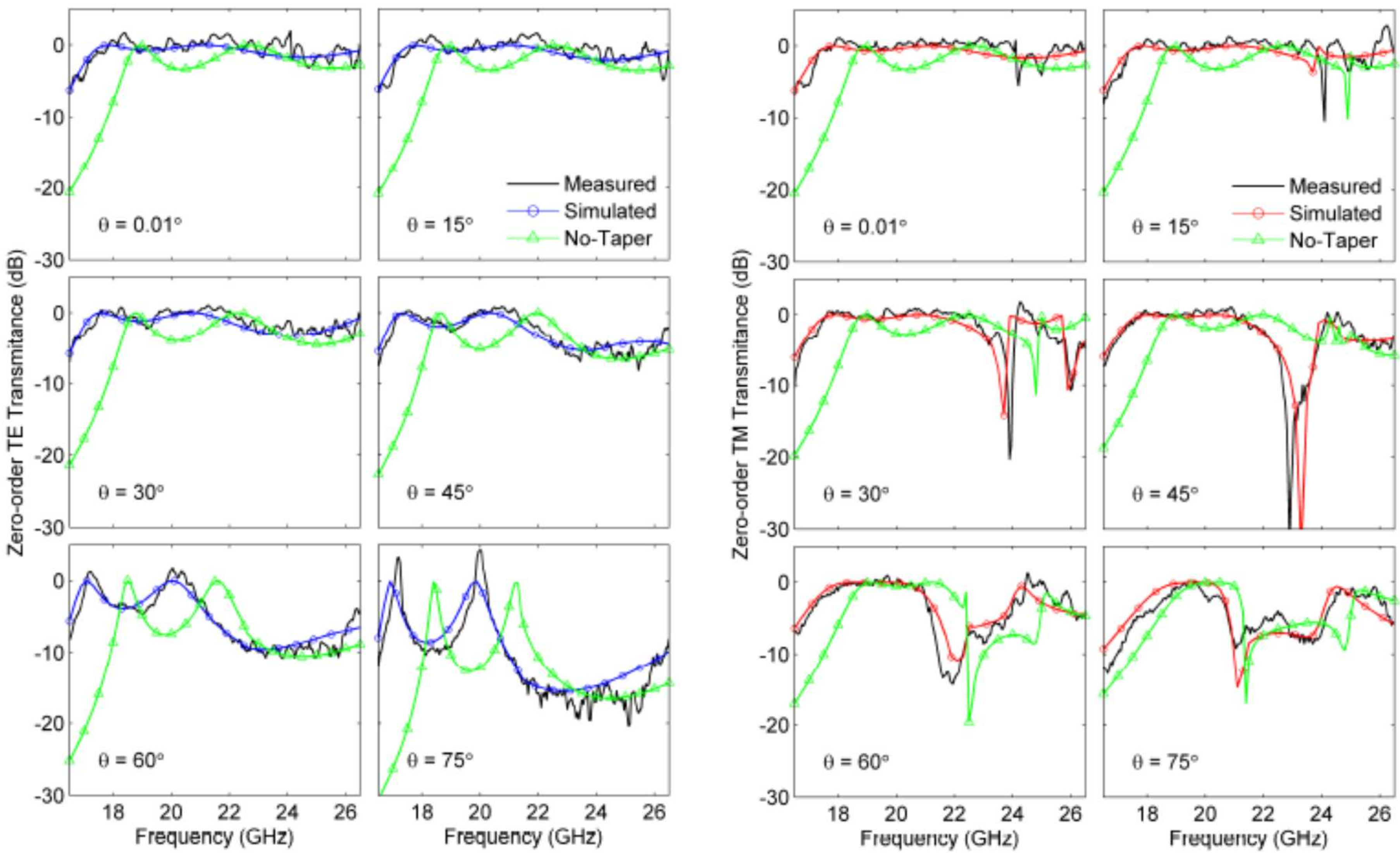
$$\Delta_F = S^{b}_{21} S^{ab}_{22} S^{b}_{12} S^{bc}_{11},$$

$$\angle \Delta_{F,R} = 2\pi \, \mathrm{diag}\{n_1, \ldots, n_m\}$$

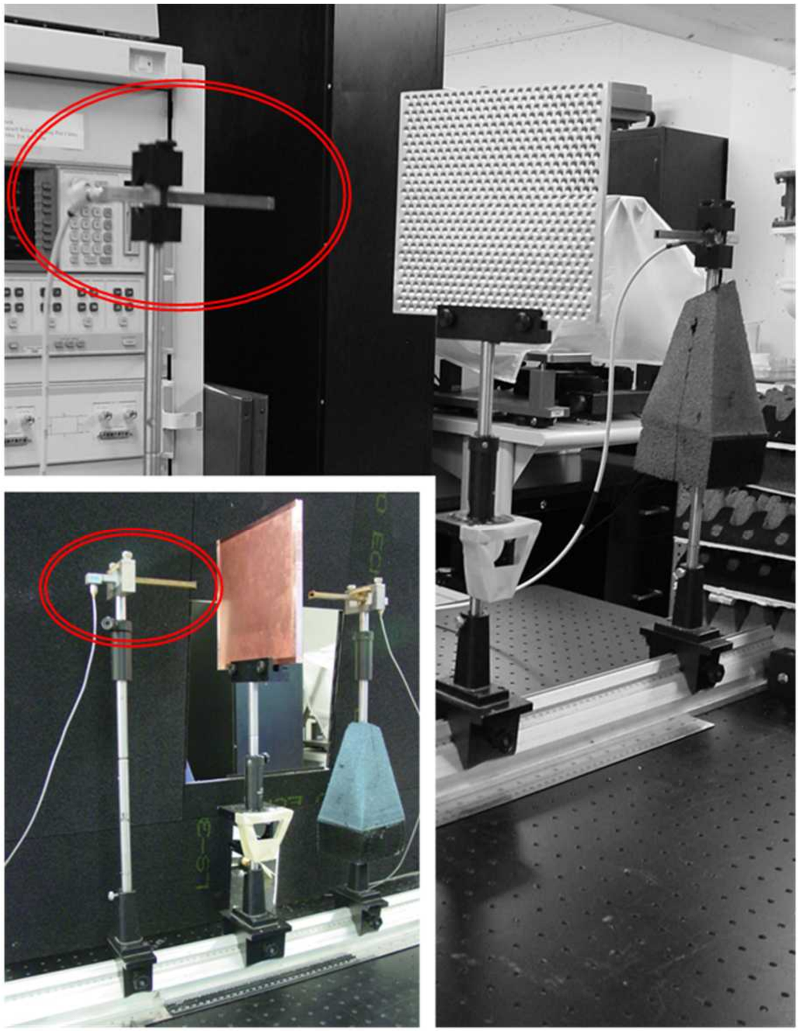
- Phase criterion determines resonance location
- $|\Delta_{F,R}|$ determines Q of the resonance and is dependent on the diameter/period ratio, larger d/p leads to broadband response

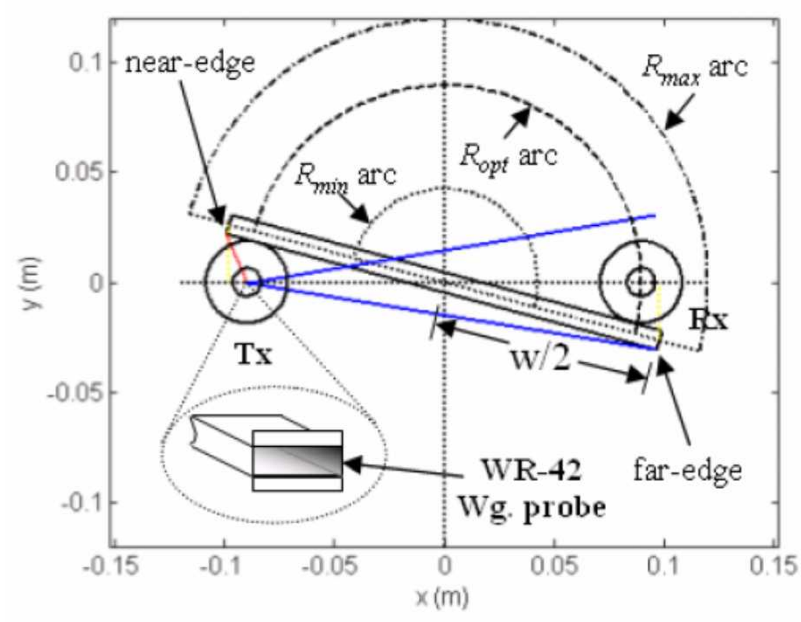


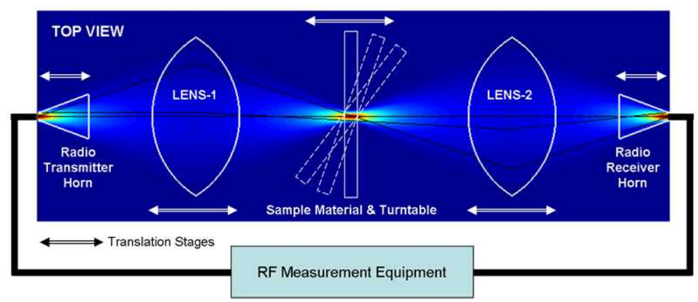
Linear Taper Results

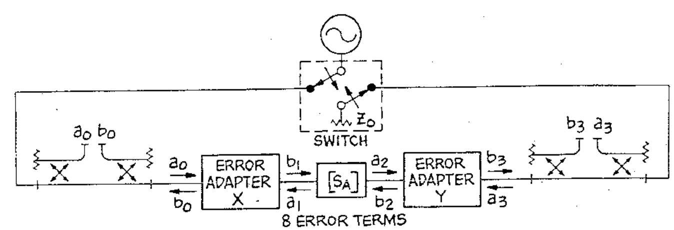


Measurement Setup

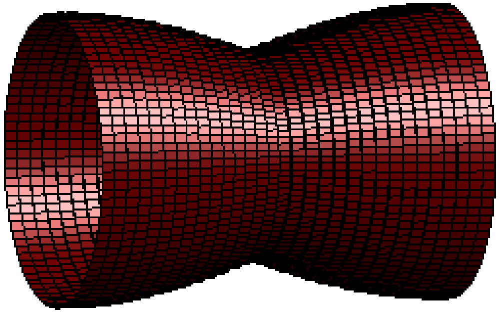


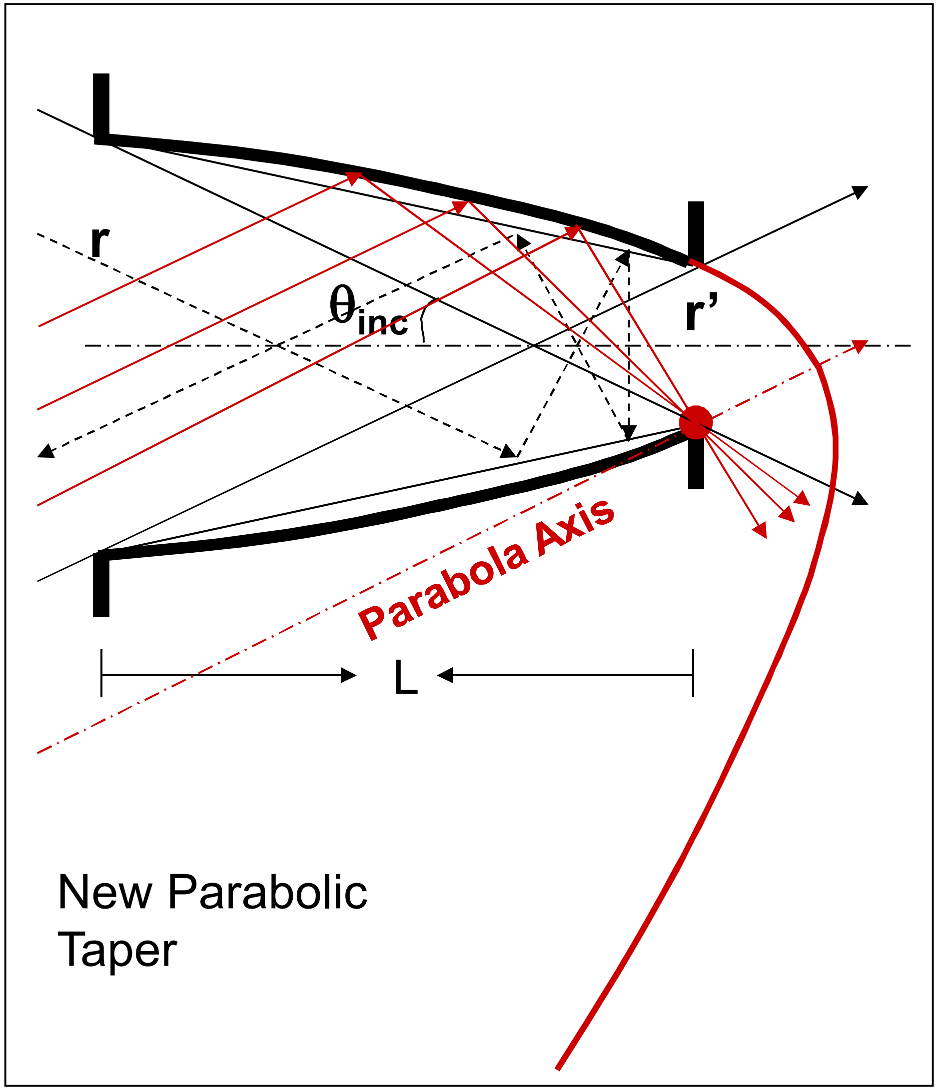






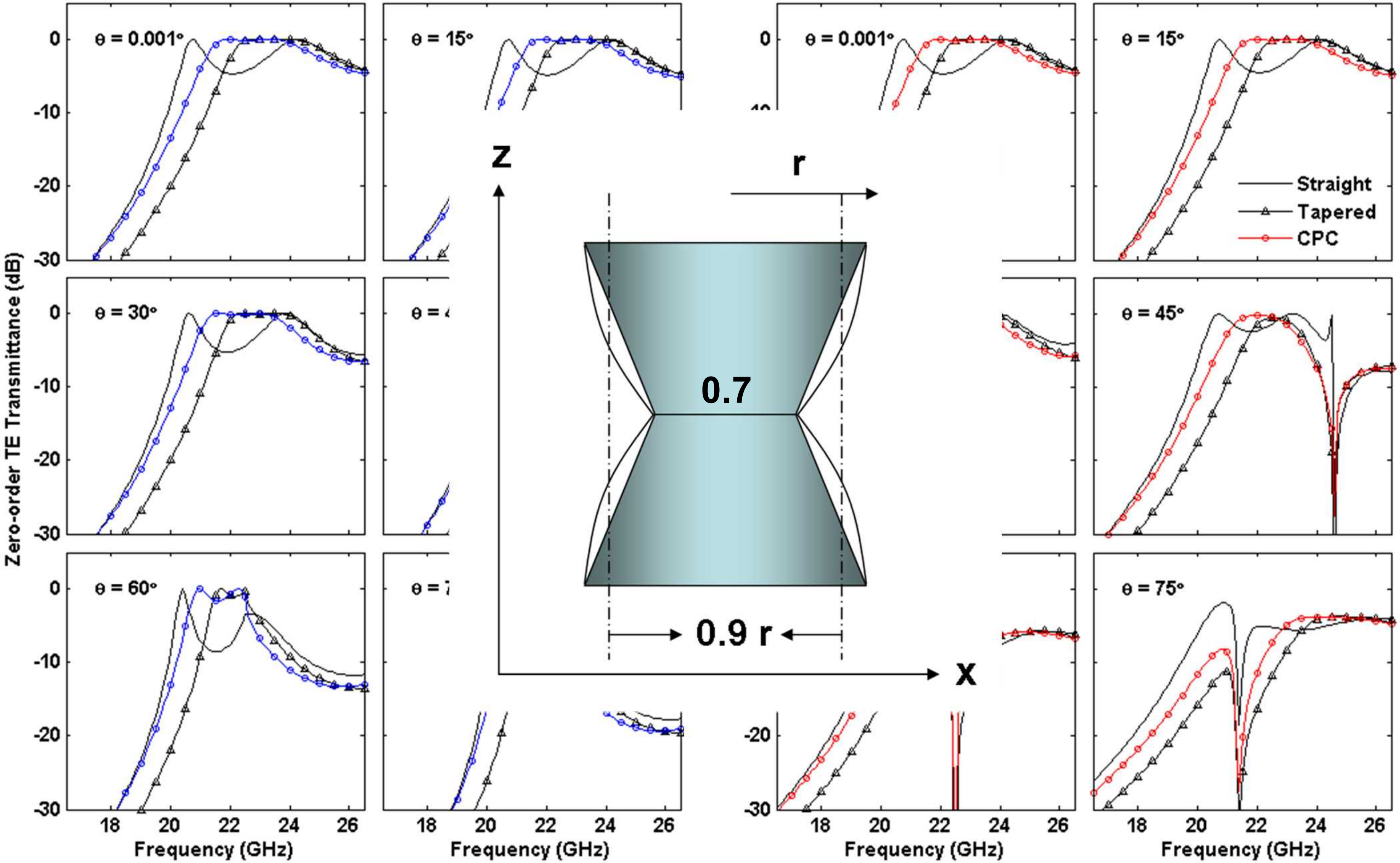
Parabolic Taper





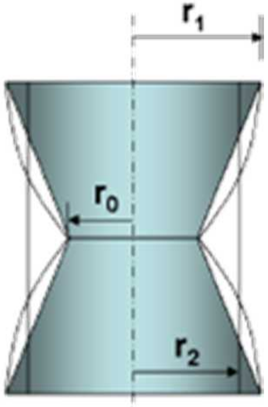
Simulated Results

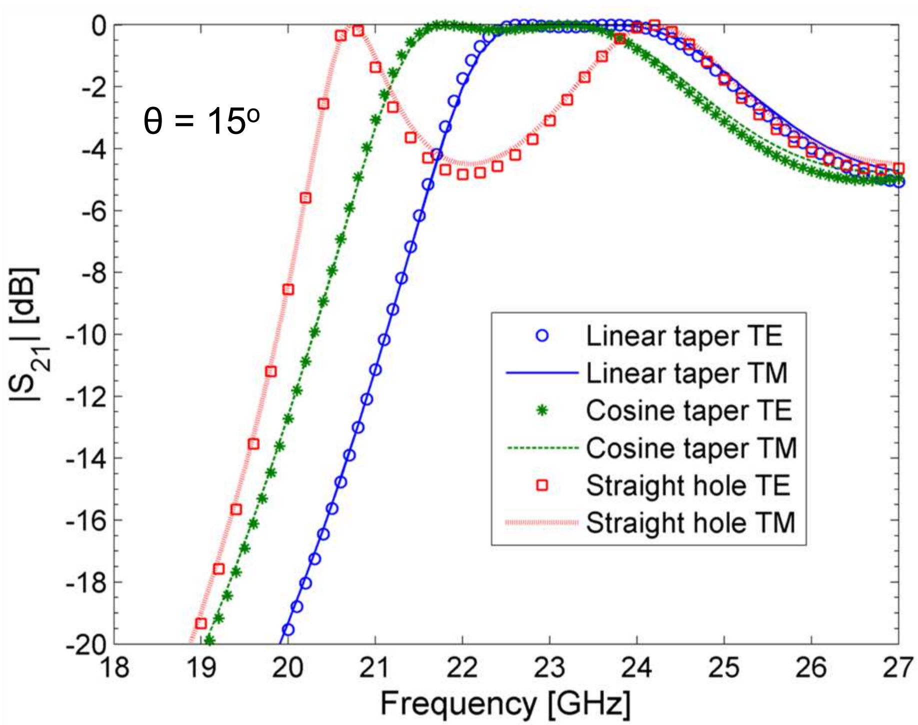
$$r(z) = r_1\left(0.7 + 0.3\left|\cos\left(\frac{\pi}{h}z\right)\right|\right) \qquad -h \le z \le 0$$

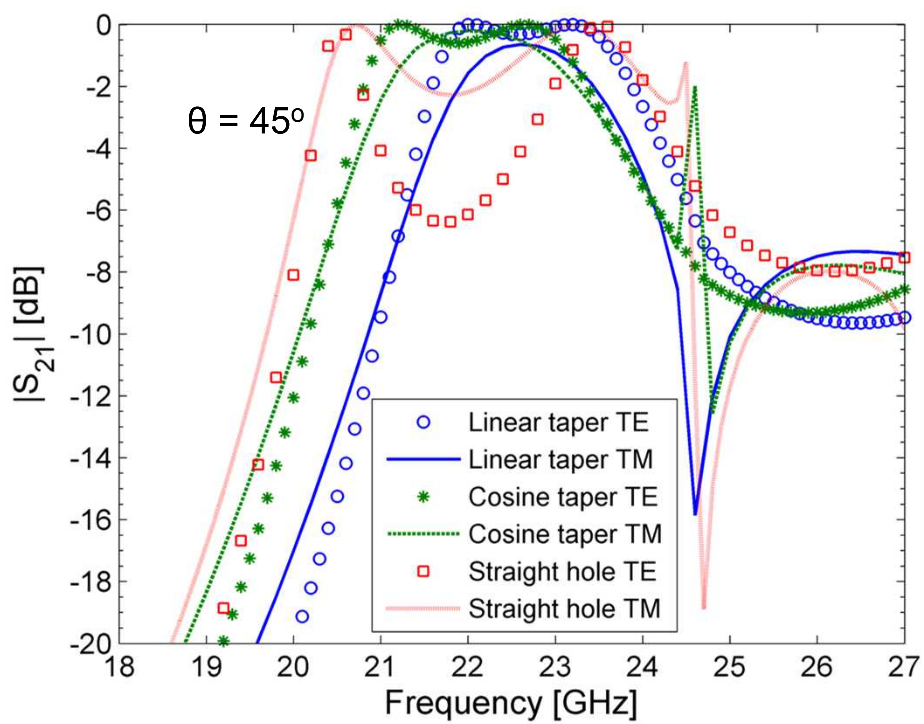


Comparison of Thick Metal FSSs with Different Tapers

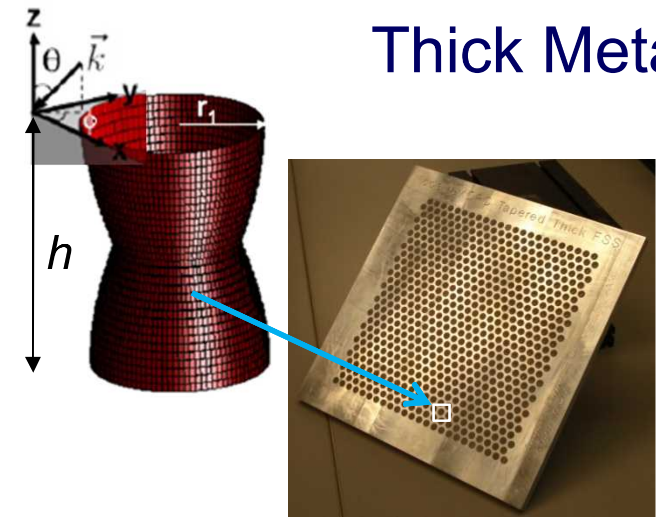
FSSs with straight, linearly tapered, and cosine tapered holes (right: cross-section geometry) show dramatically different TE and TM wide scan angle transmission responses between 18 and 27 GHz (simulated results are shown below).





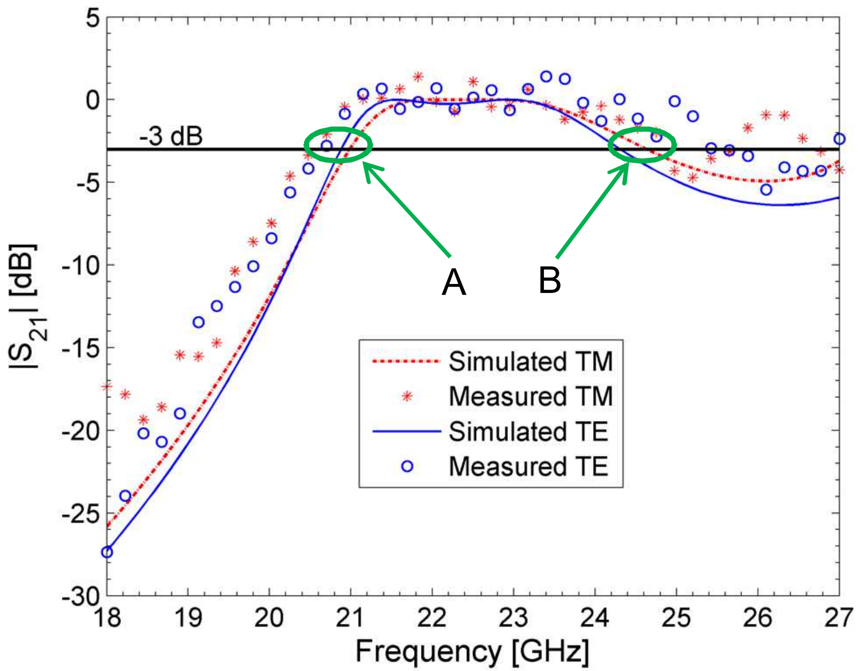


Thick Metal FSS with Cosine Tapered Holes

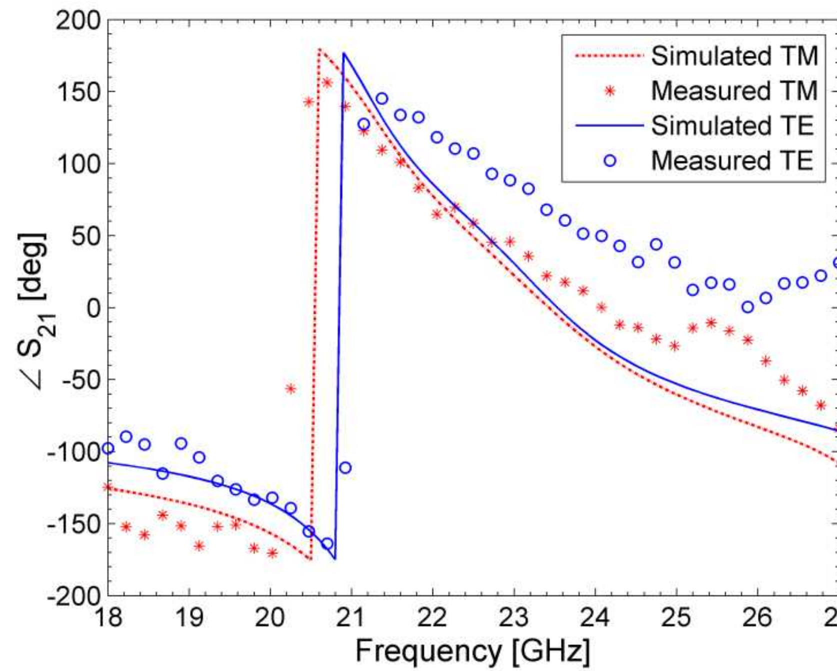


Cosine tapered K-band thick-metal FSS shows the widest bandwidth and largest scan angle for TE and TM transmission responses compared to straight and linearly tapered.

$$r(z) = r_1 \left(0.7 + 0.3 \left|\cos\left(\frac{\pi}{h} z\right)\right|\right) \qquad -h \le z \le 0$$



Simulated and measured results for the transmission response of TE and TM at θ = 30°.



Simulated and measured 3-dB points of the transmission coefficient amplitude for incidence angles up to 75° (indicated as A and B on the left).

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Contributions

- Based on network representation of the thick-metal FSS, we showed that modification of the propagation path inside of a thick-metal unit-cell affects transmission resonance.
- Designed, fabricated and measured thick-metal FSSs with straight, linear tapered and cosine tapered holes in K-band.
- Comparison of results showed that hole tapering reduces the pass-band ripple in the transmission response by as much as ~5dB which equalizes TE and TM responses up to 45 degrees from bore sight.
- A cosine taper similar in shape to the compound parabolic taper used for solar concentrators was found to produce a broader bandwidth.

Questions?