SLOTTED POLYIMIDE-AEROGEL-FILLED-WAVEGUIDE ARRAYS

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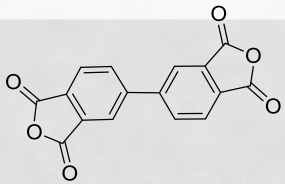
- Introduction
- Aerogel Measurements
- Millimeter-wave waveguides
- Slotted arrays
- Conclusions
- Questions

INTRODUCTION

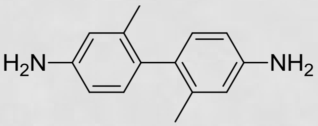
- Polyimide aerogels offer great promise as an enabling technology for lightweight aerospace antenna systems.
- They are highly porous solids possessing low density and low dielectric permittivity combined with good mechanical properties.
- Aggressively explored for thermal insulation
- Little effort has been made to use them for microwave and millimeter-wave antenna applications

POLYIMIDE AEROGELS

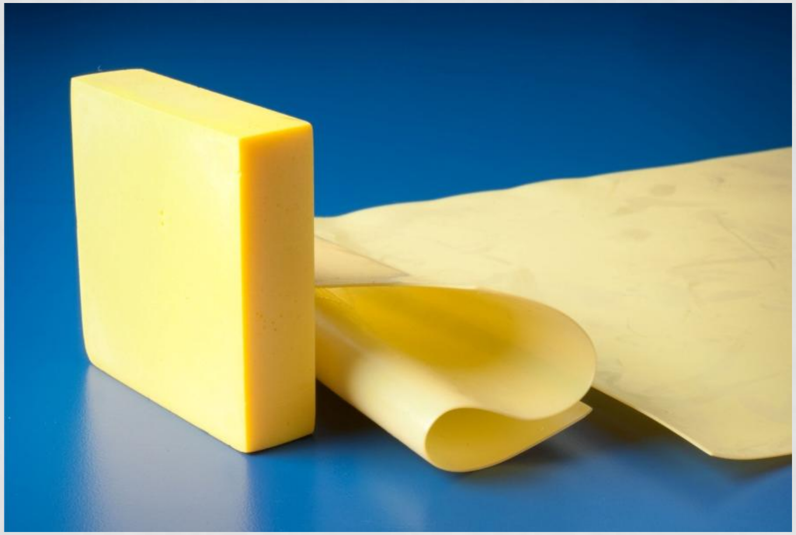
- Formulation made using DMBZ, BPDA and TAB cross-link
  - Lowest density ($0.14\ g/cm^3$)
  - Lowest dielectric measured (1.16)
  - Lowest loss tangent
  - Great mechanical properties
- Fabricated suitable sizes to make antennas



BPDA



DMBZ

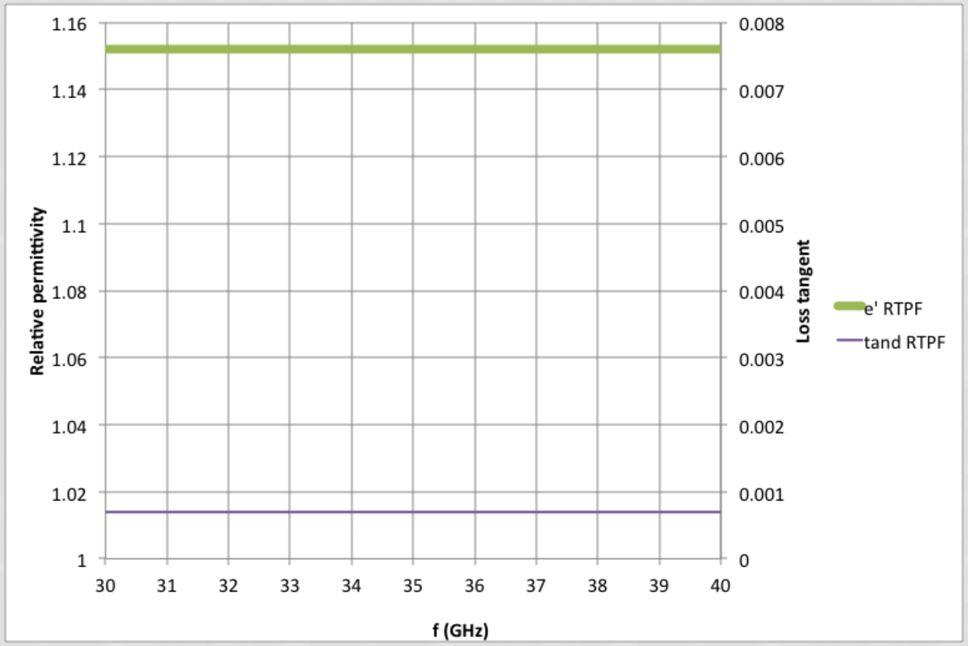


AEROGEL MEASUREMENTS

- Measured 12 different aerogel formulations with Agilent PNA E8364C/85071E (X-band and Ka-band), and with Agilent 4291B (1 MHz – 1.2 GHz).

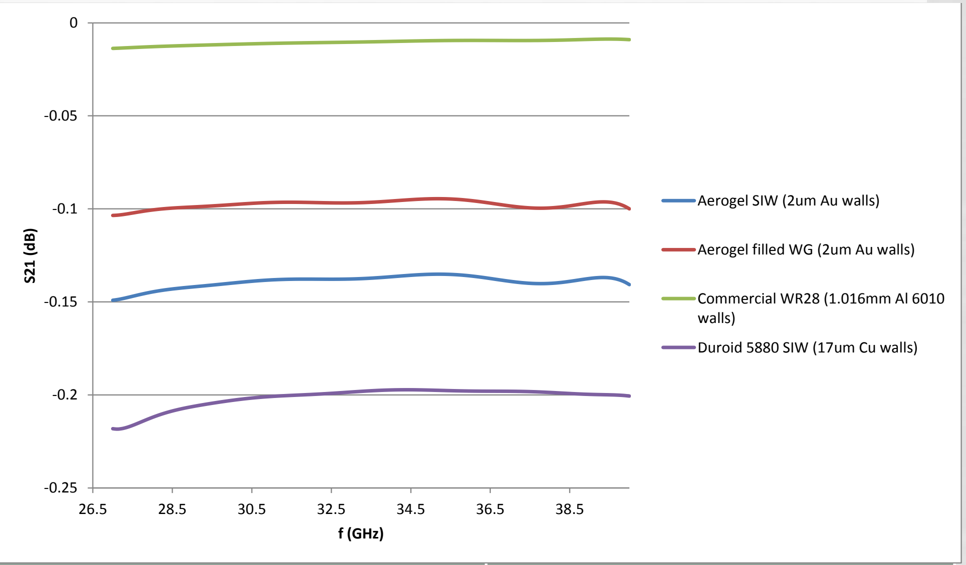
AEROGEL MEASUREMENTS

- First time the electrical properties of these aerogels are measured at Ka-band
- Best electrical performance for formulation 17.03
- ε_r=1.16, $\tan\delta_X$=0.0015 $\tan\delta_{Ka}$=0.0008



MILLIMETER-WAVE WAVEGUIDES

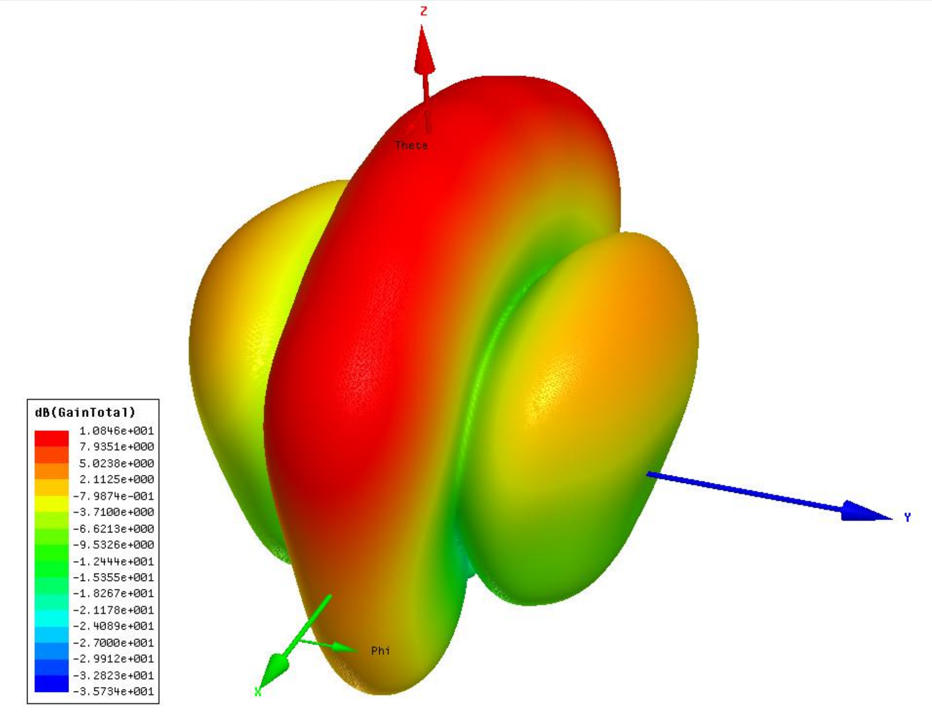
- Reference: WR28, 1.016 mm thick Al 6061 walls.
- Aerogel (ε_r=1.16, tanδ=0.001) filled: same fc_{mn} as WR28, 2 μm thick Au walls.
- Duroid 5880 SIW: same fc_{10} as WR28, 17 μm thick Cu walls.
- Aerogel SIW: same fc_{10} as WR28, 2 μm thick Au walls.



Waveguide type	mass (g) for 20 mm long section
Aerogel filled WG	0.081
Commercial WG	1.394
Aerogel SIW	0.025
Duroid 5880 SIW	0.140

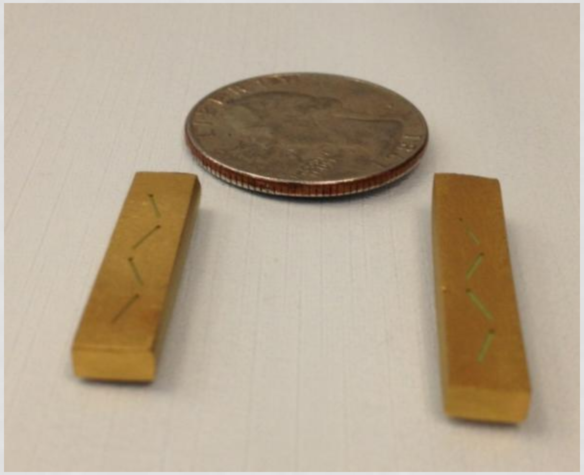
SLOTTED WAVEGUIDE ARRAY

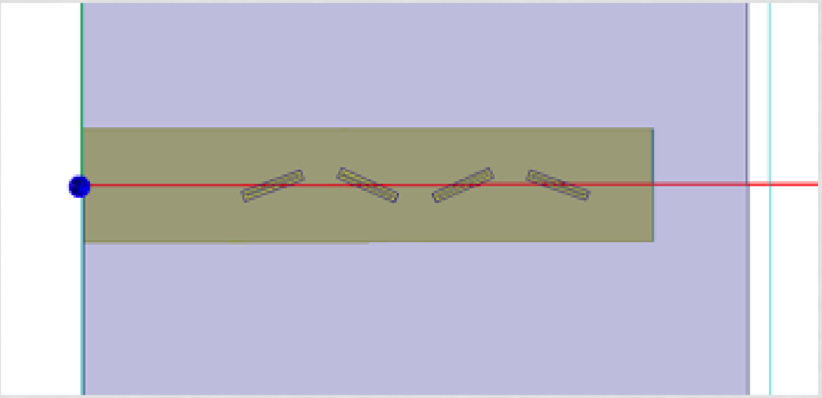
- Scaled from X-band to Ka-band a slotted waveguide array reported by Orefice and Elliott.
- Used one of the columns of the planar array on a WR28 waveguide.
- Aerogel filled waveguide designed to have the same λ_g as WR28.
- All arrays provide about the same gain (9.4 dBi).



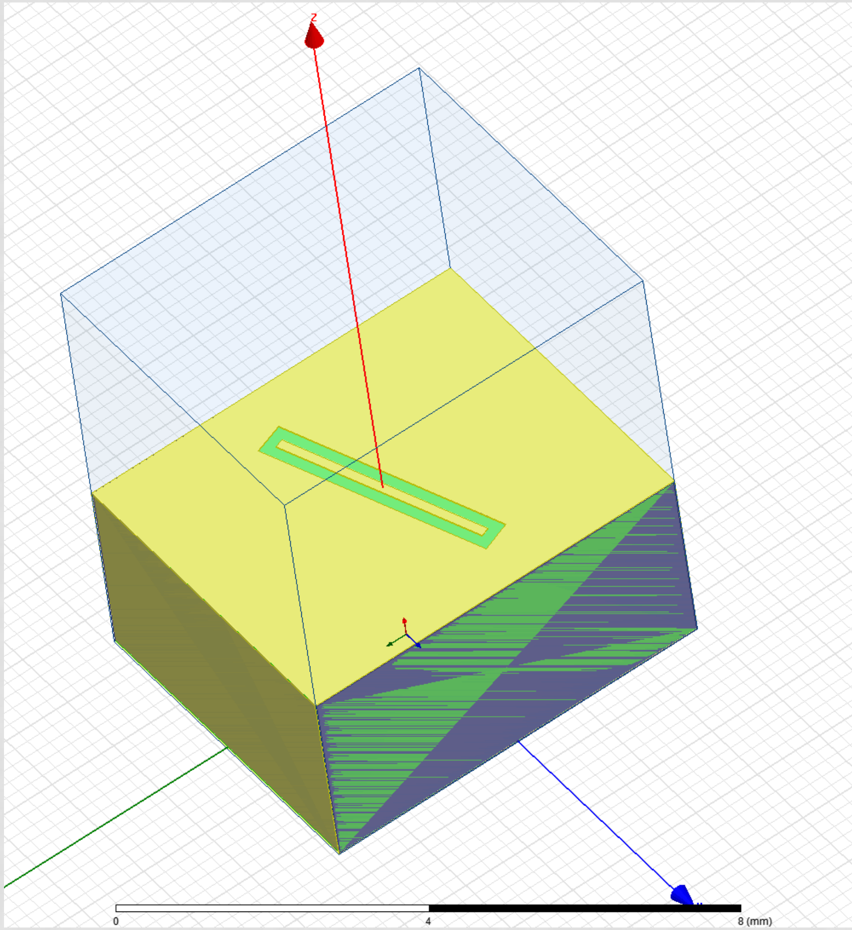
SLOTTED WAVEGUIDE ARRAY

Dimension	WR28	Aerogel Slot	Aerogel Folded Slot
l_1, l_4 (mm)	3.870	3.599	3.560
l_2, l_3 (mm)	3.863	3.592	3.554
θ_1, $-\theta_4$ (deg)	19.67	19.67	19.67
θ_2, $-\theta_4$ (deg)	-23.74	-23.74	-23.74
w_s (mm)	0.375	0.349	0.169
S_a (mm)	N/A	N/A	0.143



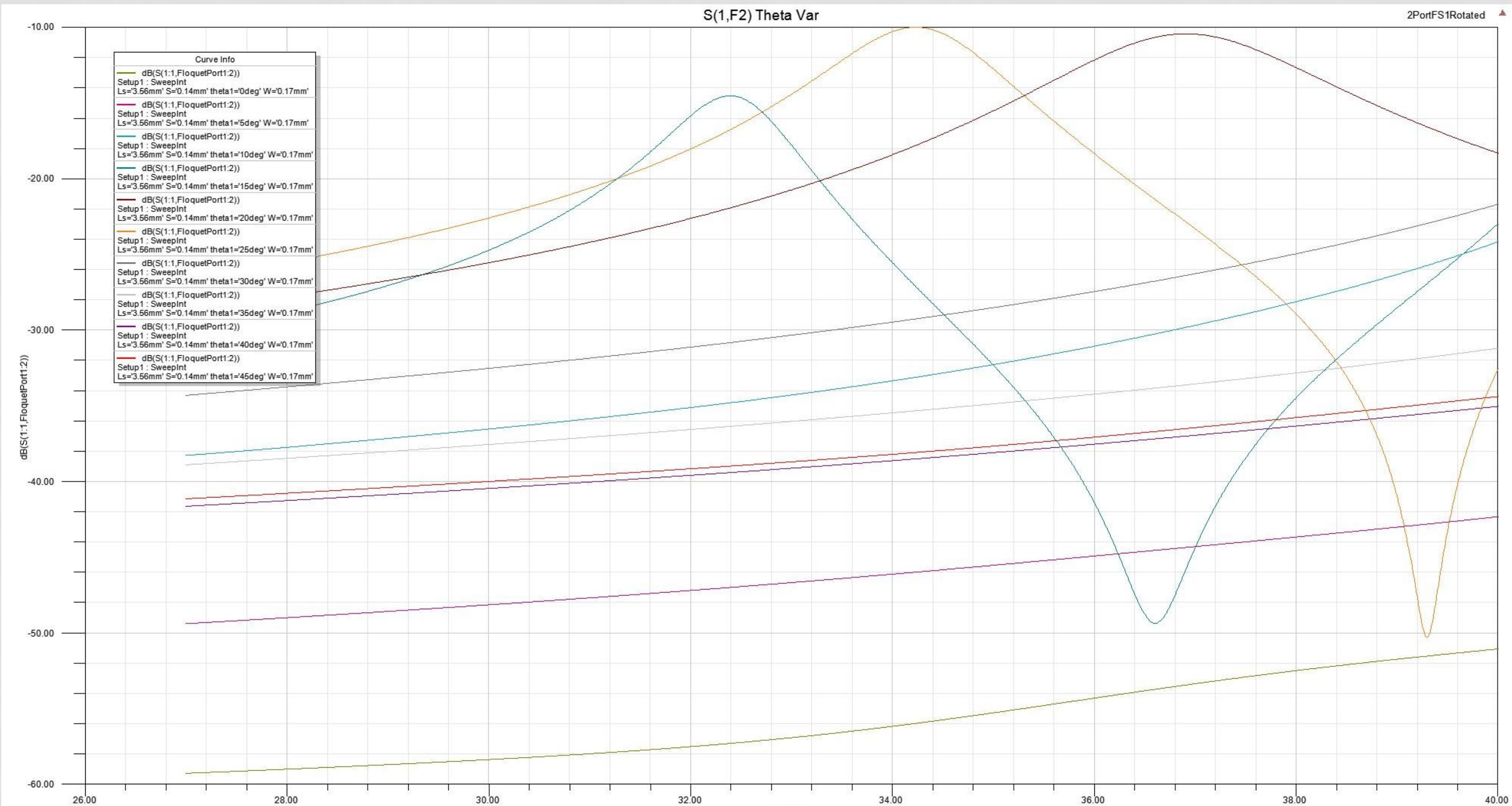


SLOTTED WAVEGUIDE ARRAYS

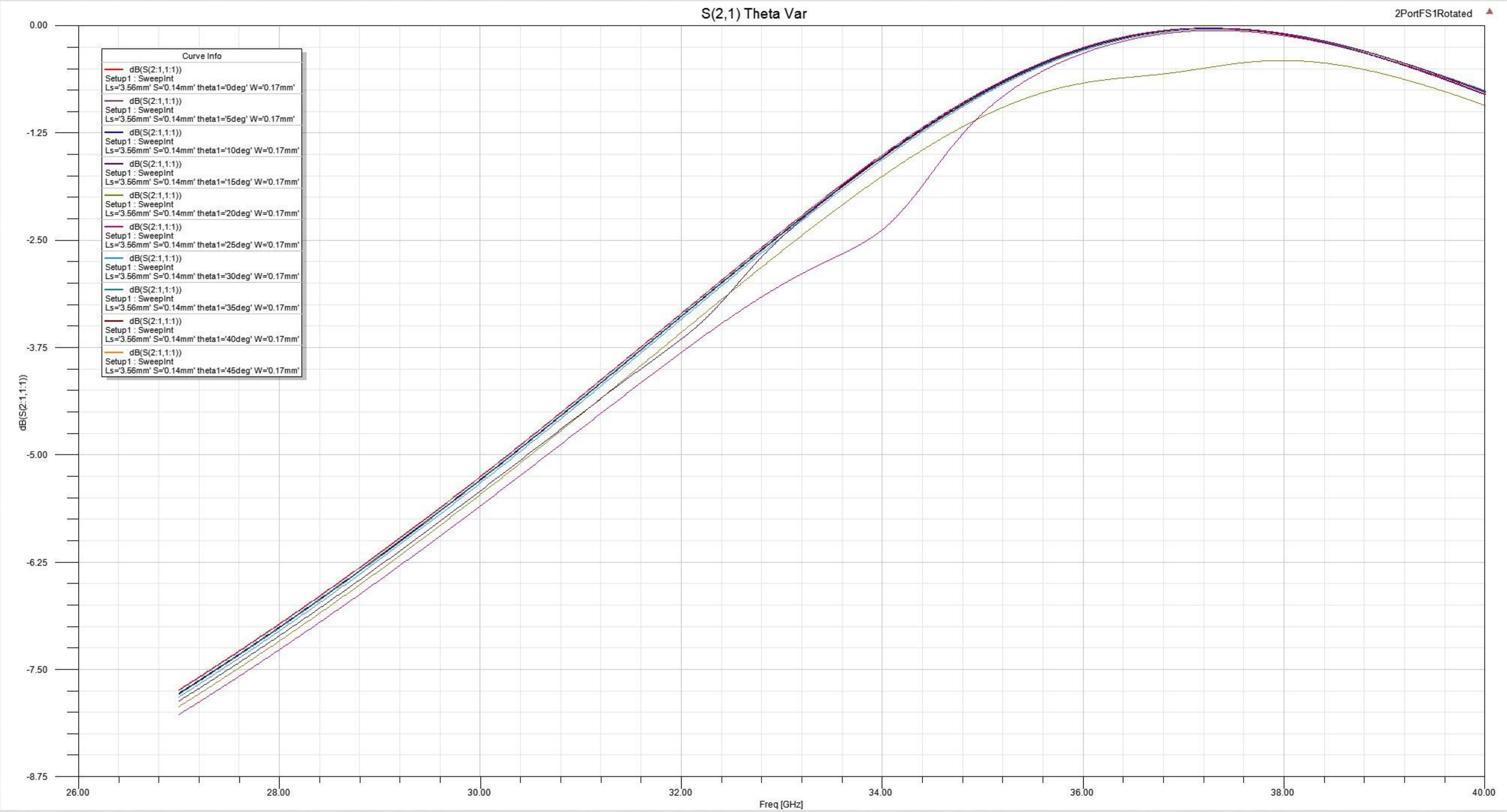


- Used fundamental Floquet modes in HFSS to determine S parameters for variations in folded slot dimensions
- Used these results in antenna design

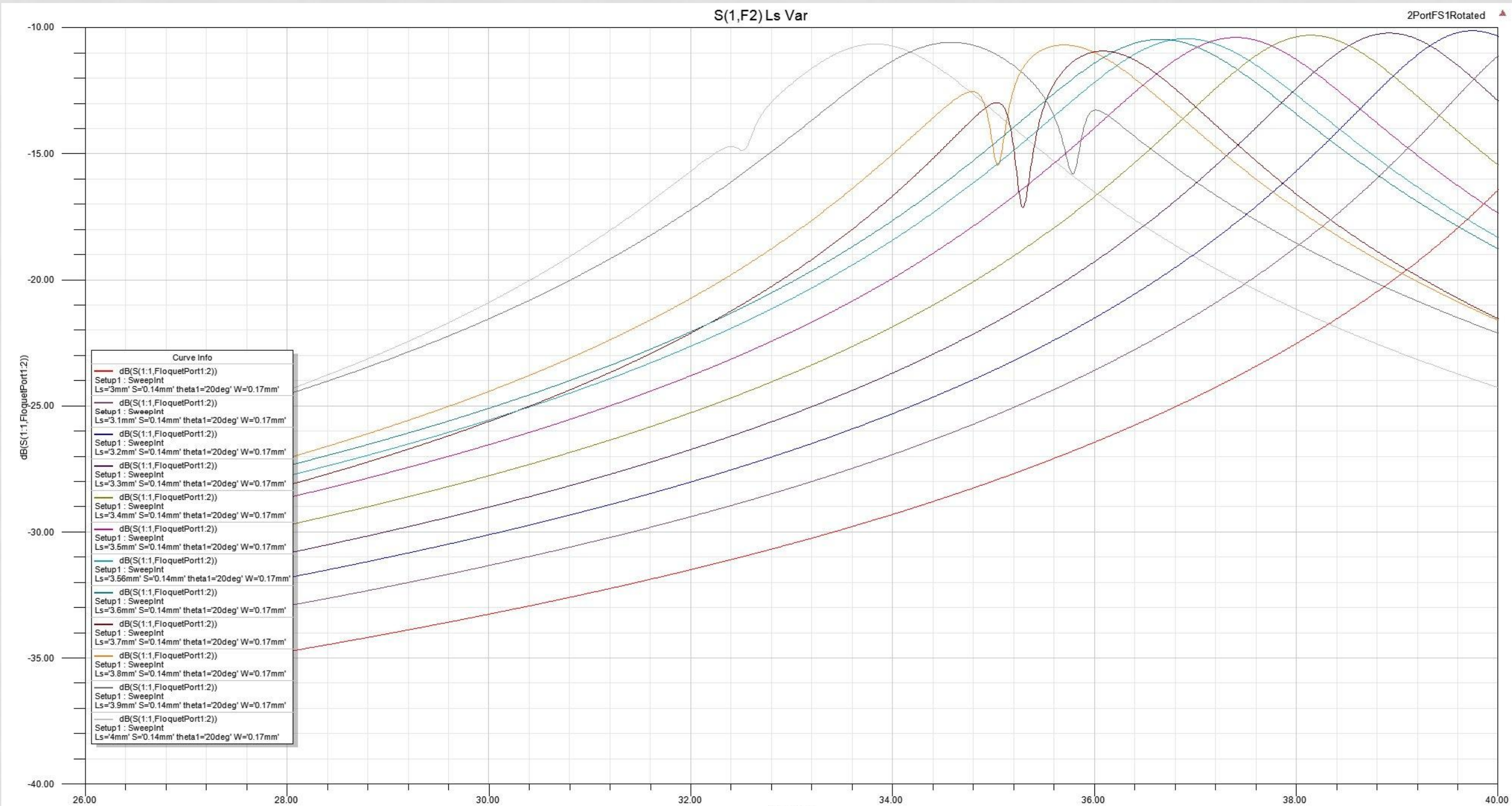
SLOTTED WAVEGUIDE ARRAYS: S_{F1}, VARYING Θ



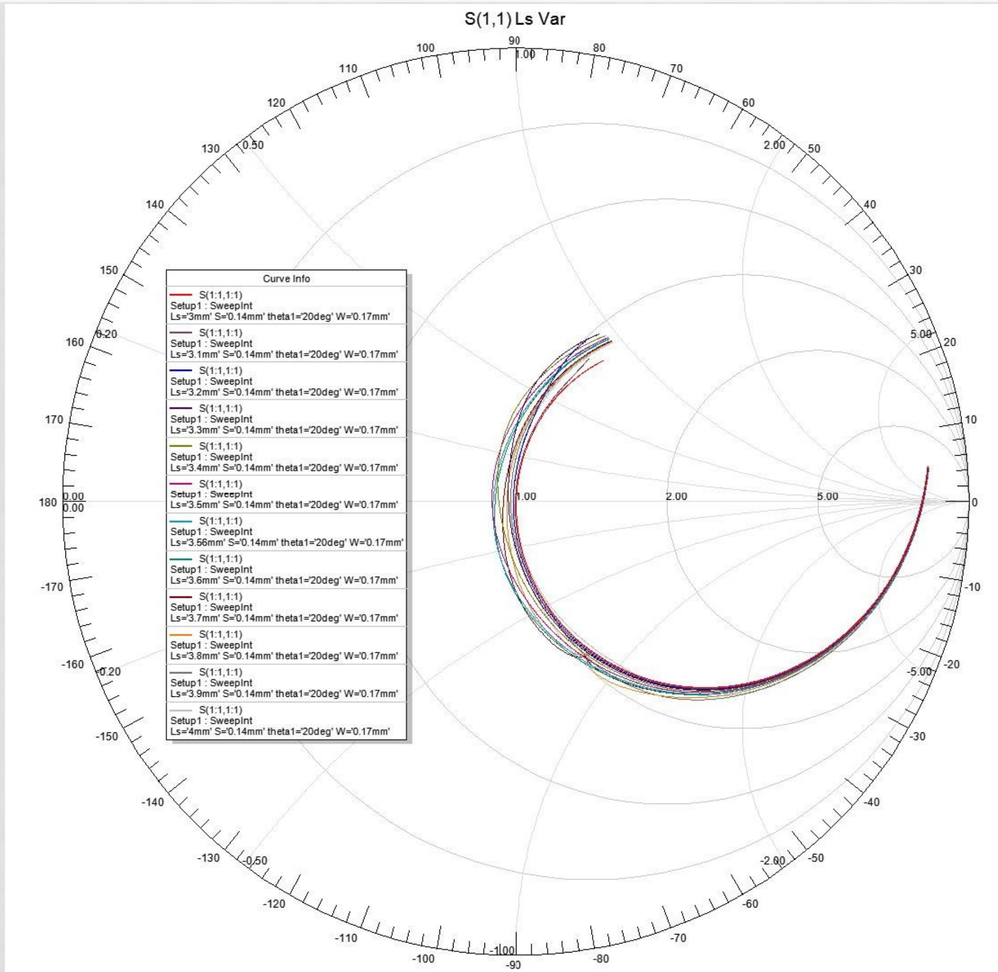
SLOTTED WAVEGUIDE ARRAYS: S_{21}, VARYING Θ



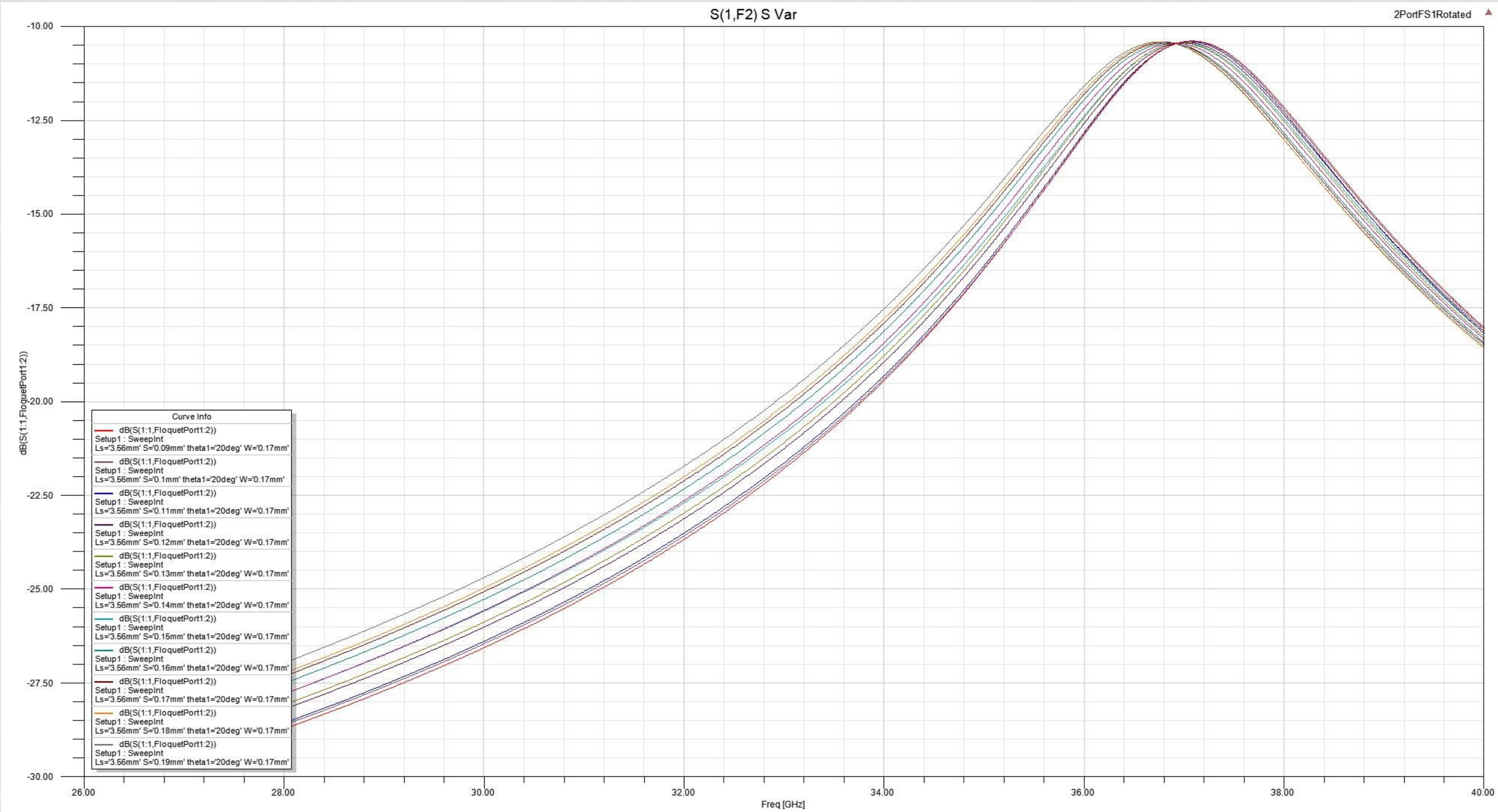
SLOTTED WAVEGUIDE ARRAYS: S_{F1}, VARYING L_S



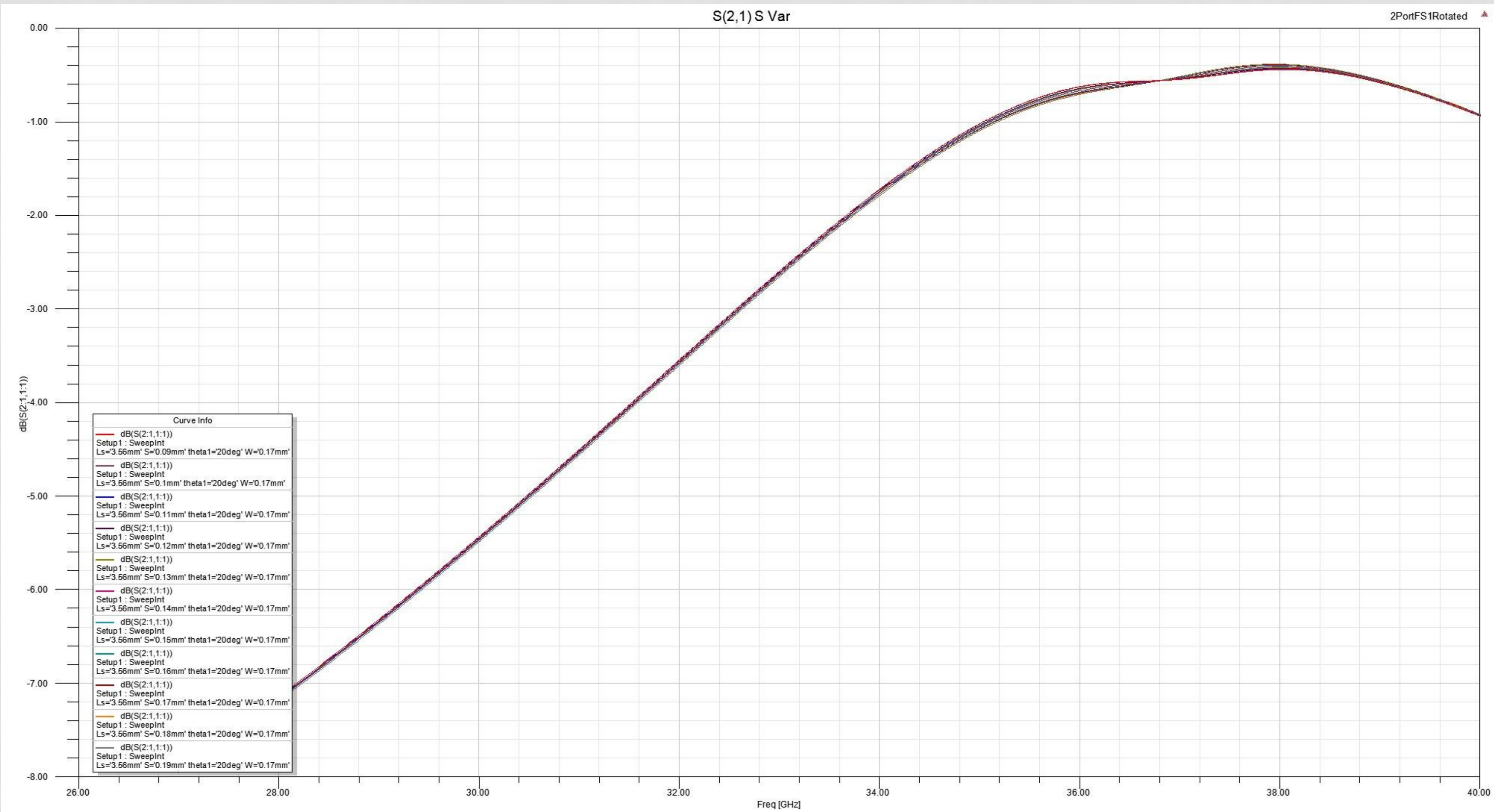
SLOTTED WAVEGUIDE ARRAYS: S11, VARYING L_S



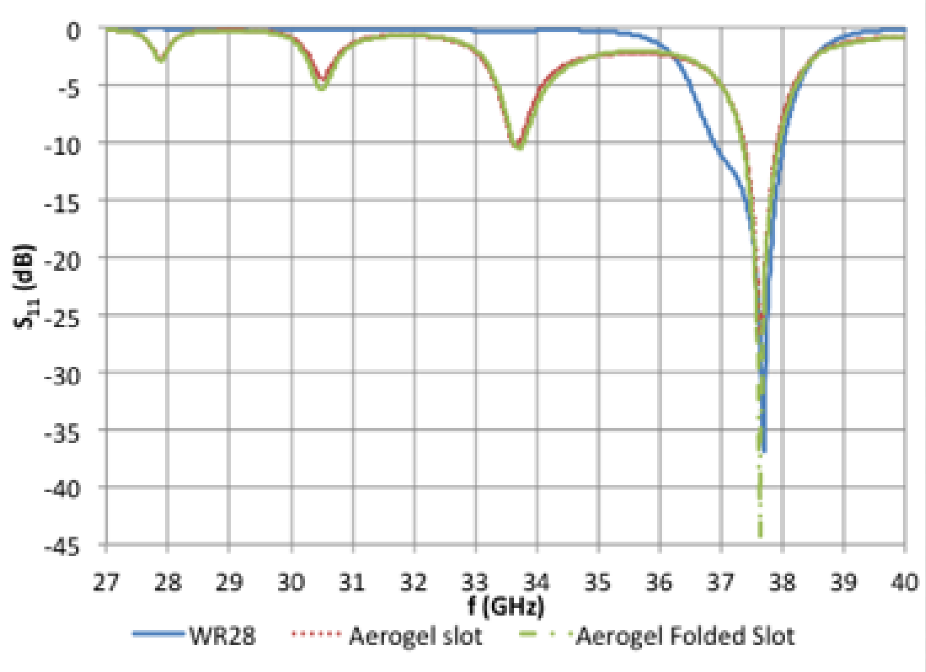
SLOTTED WAVEGUIDE ARRAYS: S_{F1}, VARYING *S*

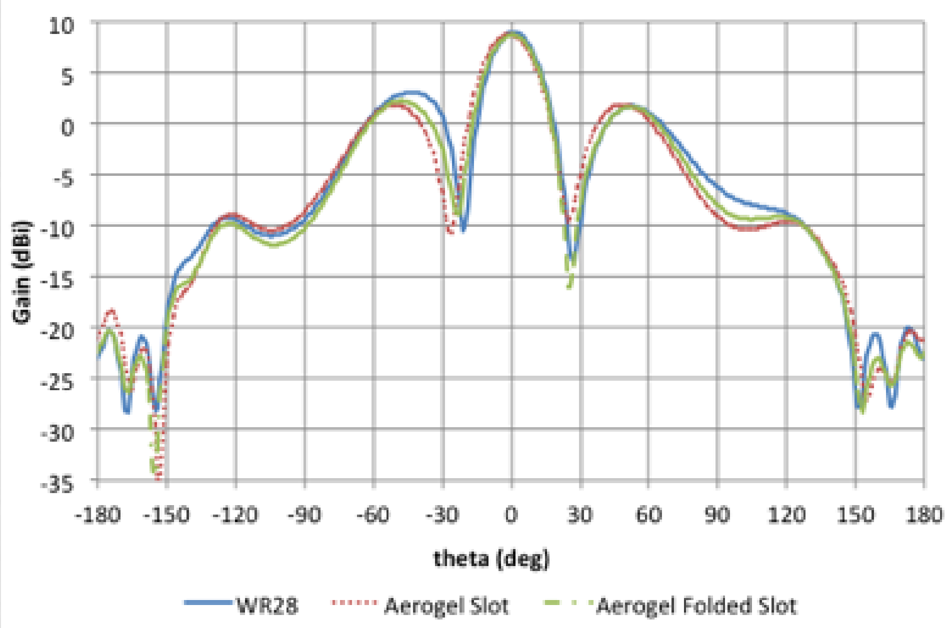


SLOTTED WAVEGUIDE ARRAYS: S21, VARYING *S*



SLOTTED WAVEGUIDE ARRAYS: S_{11} AND GAIN FOR WR28 SLOT, AEROGEL SLOT AND AEROGEL FOLDED-SLOT ARRAYS





CONCLUSIONS

- Polyimide aerogels could be used to substitute PTFE and ceramic loaded substrates (e.g., Duroid) in applications where mass is of great importance.
- The operating bandwidth and gain of antennas can be increased when compared to standard antenna substrates.
- Their low dielectric constant make coaxial probe and aperture-coupled feeding more attractive alternatives for microstip antennas.
- For waveguide applications, there are significant advantages in mass that more than compensate for the slightly higher loss of the aerogel filled waveguide, when compared to a commercial waveguide.

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QUESTIONS