SLOTTED POLYIMIDE-AEROGEL-FILLED-WAVEGUIDE ARRAYS

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OUTLINE

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• Millimeter-wave waveguides
• Slotted arrays
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• 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
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
• \( \varepsilon_r = 1.16 \), \( \tan\delta_X = 0.0015 \), \( \tan\delta_{Ka} = 0.0008 \)
**MILLIMETER-WAVE WAVEGUIDES**

- Reference: WR28, 1.016 mm thick Al 6061 walls.
- Aerogel ($\varepsilon_r=1.16$, $\tan\delta=0.001$) filled: same $f_{cmn}$ as WR28, 2 $\mu$m thick Au walls.
- Duroid 5880 SIW: same $f_{c_{10}}$ as WR28, 17 $\mu$m thick Cu walls.
- Aerogel SIW: same $f_{c_{10}}$ as WR28, 2 $\mu$m thick Au walls.

<table>
<thead>
<tr>
<th>Waveguide type</th>
<th>mass (g) for 20 mm long section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerogel filled WG</td>
<td>0.081</td>
</tr>
<tr>
<td>Commercial WG</td>
<td>1.394</td>
</tr>
<tr>
<td>Aerogel SIW</td>
<td>0.025</td>
</tr>
<tr>
<td>Duroid 5880 SIW</td>
<td>0.140</td>
</tr>
</tbody>
</table>

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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 $\lambda_g$ as WR28.
- All arrays provide about the same gain (9.4 dBi).
## SLOTTED WAVEGUIDE ARRAY

<table>
<thead>
<tr>
<th>Dimension</th>
<th>WR28</th>
<th>Aerogel Slot</th>
<th>Aerogel Folded Slot</th>
</tr>
</thead>
<tbody>
<tr>
<td>l₁, l₄ (mm)</td>
<td>3.870</td>
<td>3.599</td>
<td>3.560</td>
</tr>
<tr>
<td>l₂, l₃ (mm)</td>
<td>3.863</td>
<td>3.592</td>
<td>3.554</td>
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<tr>
<td>θ₁, -θ₄ (deg)</td>
<td>19.67</td>
<td>19.67</td>
<td>19.67</td>
</tr>
<tr>
<td>θ₂, -θ₄ (deg)</td>
<td>-23.74</td>
<td>-23.74</td>
<td>-23.74</td>
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<tr>
<td>wₛ (mm)</td>
<td>0.375</td>
<td>0.349</td>
<td>0.169</td>
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<tr>
<td>Sₙ (mm)</td>
<td>N/A</td>
<td>N/A</td>
<td>0.143</td>
</tr>
</tbody>
</table>
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 $\theta$
SLOTTED WAVEGUIDE ARRAYS: $S_{21}$, VARYING $\theta$
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