PROCEEDINGS OF ISAP2000, FUKUOKA, JAPAN

A 1.6 GHz SLOT ANTENNA ON A CYLINDRICAL ALUMINA SUBSTRATE

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1. INTRODUCTION

This paper describes the fabrication and performance of a 0.5 wavelength slot antenna that is patterned on a cylindrical alumina substrate, similar to the antennas described in [1,2]. The antenna is fed using cylindrical coupled slotline (essentially a "cylindrical coplanar waveguide") that runs along one edge of the alumina cylinder (see Figure 1). The radiation pattern is similar to that of a simple dipole, with the exception of a partial null that exists along one side of the cylinder and a resulting increase in the maximum gain (2.6 dBi). In this work, the antenna and its feedline are deposited using a direct-write method that is capable of depositing materials on non-planar surfaces.

The use of the alumina substrate for designing a cylindrical slot antenna proves to offer the advantages gained by a high-ε_r material without the problems often encountered with microstrip patch or planar slot antennas. In this example, the $\varepsilon_r = 9.8$ material provides a relatively small (1.27 cm-diameter) antenna with a resonant frequency at 1.6 GHz. Unlike a microstrip patch, the radiation efficiency is not adversely affected by surface mode propagation in the high-ε_r material. Unlike a planar slot, the problems associated with reflections at dielectric boundaries (often leading to the use of a dielectric lens) are not encountered since the cylindrical slot radiates into free-space, rather than into the substrate. One precaution with the cylindrical geometries is to operate below the cutoff frequency of the dominant waveguide mode, which in this case is at 4.4 GHz.

In the following sections the fabrication of the antenna is discussed along with the measured input impedance and radiation characteristics. The measurements of S_{11} (and Z_{in}) were performed using thru-reflect-line (TRL) standards deposited on 1.27 cm-diameter alumina cylinders. It is demonstrated that proper placement of a shorting strip across the slot antenna [3] provides a simple means of matching the antenna to the feedline. The resulting 10-dB return loss bandwidth is 2%.

2. ANTENNA FABRICATION ON NON-PLANAR SURFACES

The cylindrical slot antenna was fabricated using a prototype direct write tool capable of depositing metals and dielectrics directly onto conformal surfaces. This tool is known as the MesoTool and is comprised of deposition techniques for both thick and thin film applications. The existing tool comprises two separate instruments: 1) MicroPen for thick film paste dispensing and 2) Laser Chemical Vapor Deposition (LCVD) for thin film deposition. The development of this tool is currently being funded by U.S. DARPA (contract number DABT63-99-C-0008).

The MicroPen is a tool capable of dispensing pastes with a vast range of viscosities (0.001 to 900

Pascal/seconds). The line width resolution of the pen varies from 50 um to several millimeters. The MesoTool process for pastes that are deposited using this method is to dispense and then sinter the paste with laser heat. To date silver pastes are available that can be processed with a laser at 200°C. In this work, the MicroPen was used to deposit 37 micron-thick silver lines on the alumina substrate.

LCVD can be used to deposit thin films with higher resolution than the MesoTool; line widths in the submicron range are possible. This deposition method can lay down patterns in both two and three dimensions. While it is common to grow lines on a flat or curved surface, LCVD also allows growth of vertical lines, thus enabling new possibilities in the area of antenna design. In addition, LCVD permits the deposition of several metals (e.g., gold, copper, and tin) and dielectric materials.

3. ANTENNA CHARACTERISTICS

As illustrated in Figure 1, the slot antenna (1.5 mm-width) extends partially around the circumference of the 1.27 cm-diameter cylinder where it is terminated by a shorting strip with a 4.8 mm-arc length. The coupled slot-line (CCS) feed has 1.14 mm-wide slots separated by 2.5 mm. The characteristic impedance of the feedline is 50 Ω. One precaution that should be followed with this configuration is to maintain an operating frequency below the cutoff frequency for the TE_{11} circular waveguide mode [4], which in this case is 4.4 GHz.

By varying the position of the shorting strip relative to the feedline, it is possible to change the input impedance of the antenna. In this design, the optimum location for the center of the shorting strip was found to be approximately 110 degrees from the center of the feedline. At the resonant frequency of 1.6 GHz, the resulting configuration is a slot length of 0.44 guide wavelengths around the cylinder with a feedpoint at 0.125 guide wavelengths from one end. With respect to this offset feed arrangement, an advantage of the cylindrical ground plane is that the parasitic even-mode on the CCS feedline is naturally suppressed. For a comparable uniplanar coplanar waveguide, air-bridges would be required at the feedpoint in order to equalize the ground planes. The measured input reflection coefficient (S11) and input impedance are given in Figures 2 and 3, respectively. The 10-dB return loss bandwidth is approximately 2%.

The measured H- and E-plane gain patterns of the antenna are given in Figures 4 and 5, respectively. The H-plane pattern, measured around the cylinder, shows a variation between 0 and 2.6 dBi with the minimum gain occuring approximately opposite the shorting strip. The E-plane pattern resembles that of a linear dipole, with the null occurring along the central axis of the cylinder. Some distortion in the E-plane pattern can be attributed to the coaxial connector used to connect to the alumina rod.

REFERENCES

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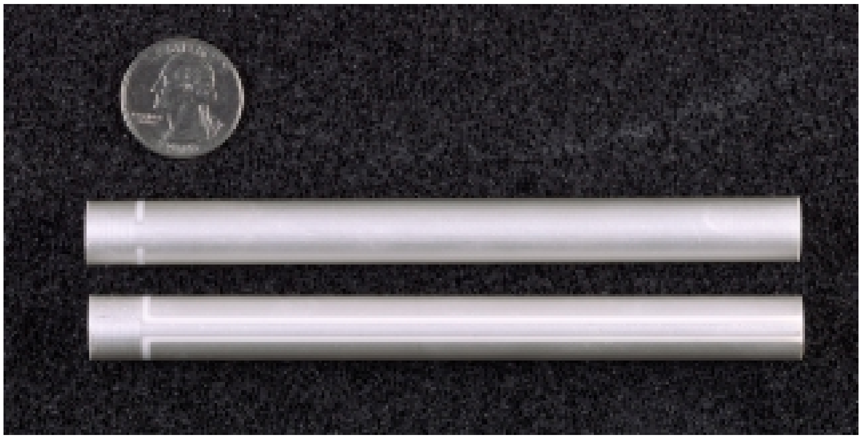

Figure 1. Photograph of the cylindrical slot antennas fabricated on 1.27 cm-diameter alumina rods. The upper photograph shows the shorted ends of the slot on the back side of the antenna. The lower photograph shows the cylindrical coplanar slot feedline.

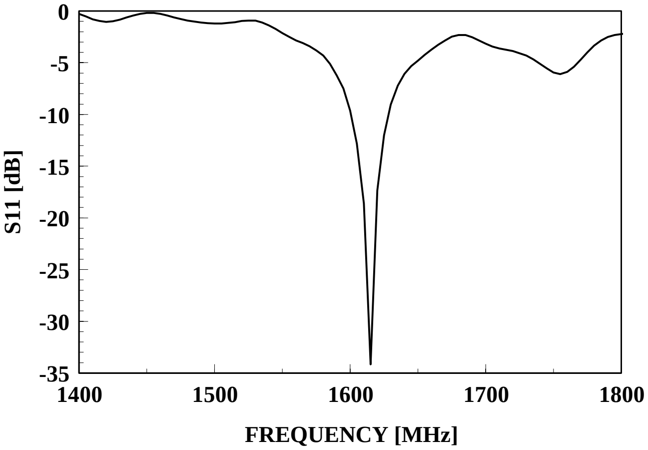

Figure 2. Measured input reflection coefficient (S11) for the cylindrical slot antenna.

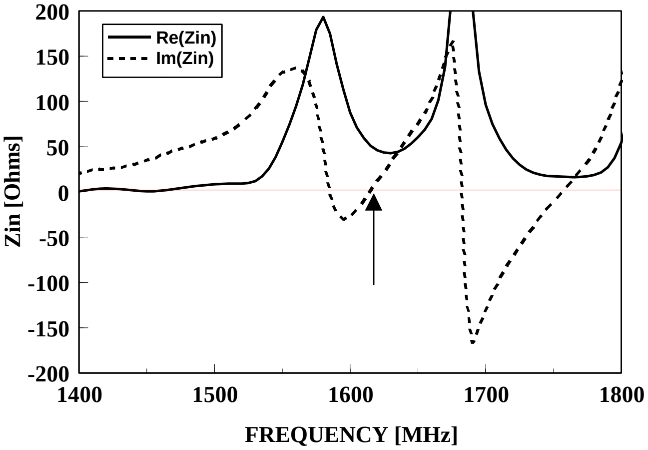

Figure 3. Measured input impedance for the cylindrical slot antenna.

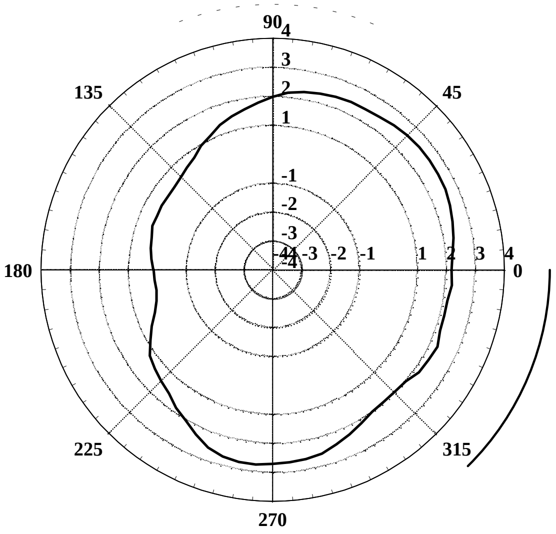

Figure 4. Measured H-plane gain pattern for the cylindrical slot antenna. The feedline location is indicated by the dashed line centered around 90 degrees, while the shorted slot section is indicated by the solid line centered around 348 degrees.

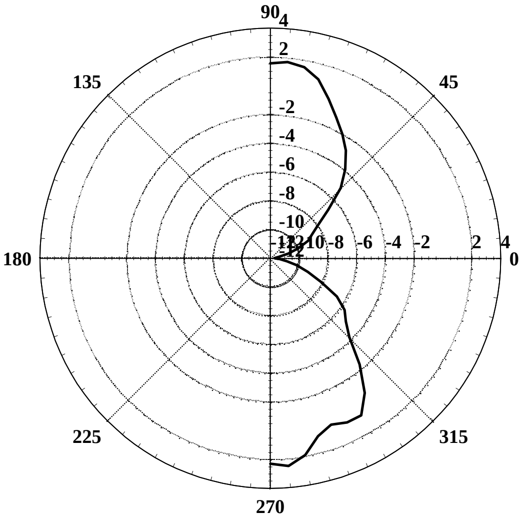

Figure 5. Measured E-plane gain pattern for the cylindrical slot antenna. The top of the cylindrical alumina rod corresponds to 0 degrees.