Characteristics of Corrugated Double Exponentially Tapered Slot Antenna

Jennifer L. Jordan*[(1)], Christine Chevalier[(2)], and George E. Ponchak[(1)]
(1) NASA Glenn Research Center, 21000 Brookpark Rd, Cleveland., OH, 44135
(2) Analex Corp. at NASA Glenn Research Center, 21000 Brookpark Rd, Cleveland, OH 44135

Introduction

There is a demand for ultra wide band antennas for both commercial and military systems. The family of Tapered Slot Antennas (TSAs) has been under investigation for many years because it is easy to fabricate, has a good radiation pattern, is easily combined into arrays, and has a wide 10 dB return loss bandwidth [1]. One disadvantage of TSA's is their large size; they are traveling wave antennas that are typically 2 to 12 λ_0 long. A Double Exponentially Tapered Slot Antenna (DETSA) on Liquid Crystal Polymer (LCP) substrate with a wide bandwidth of 2 octaves (9 GHz) has been demonstrated [2], and in the same paper, a slightly curved DETSA was demonstrated where it was shown that the main beam was skewed towards the direction that the DETSA was curved. In this paper, a DETSA is bent into a corrugated shape to physically shorten the DETSA while keeping the electrical length the same. Measured and simulated radiation patterns and measured return loss are presented.

Design and Fabrication

A DETSA was fabricated with 18 μm thick copper on a 200 μm thick LCP substrate, which has a dielectric constant of $\varepsilon_r = 3.1$ and a loss tangent of 0.003 [2]. The physical properties of LCP provide flexibility to corrugate the antenna. The geometry of the DETSA was optimized for the antenna to operate over the frequency range of 4 to 10 GHz when held in a perfectly flat shape. Figure 1 shows an artist drawing of the DETSA with all dimensions and the equations for the exponential tapers.

The form of the DETSA was held by placing the antenna between two pieces of Styrofoam, which also provided structural support. For the corrugated DETSA, the Styrofoam was cut in a saw-tooth pattern to shorten the antenna length to 90%, 80%, and 70% of its original linear length of 10.5 cm. The first bend occurs where the antenna begins to taper. Three-half wavelengths are cut in each piece of Styrofoam, creating angles of $\Theta_{90\%} = 25.8°$, $\Theta_{80\%} = 36.87°$, and $\Theta_{70\%} = 45.46°$ defined in Figure 2. Figure 2 shows an artist rendition of the corrugated DETSA. An SMA connector was soldered directly to the slot of the antenna for all measurements; one side of the slotline is excited by the center conductor pin and the opposite side of the slotline is excited by a tab extending from the outer conductor of the coax.

Simulation

The DETSA was simulated with the commercial software CST Microwave Studio (MWS) [3]. The antenna outline was drawn using the 2D polygon function with depth added using the Extrude function. The metal was defined as a perfect electrical conductor (PEC). The antenna is excited with a coaxial cable with the same SMA launcher already

described. The coaxial cable is excited with a Waveguide Port using the Transient Solver. An automatic meshing of eight lines per wavelength is used in conjunction with MWS's Perfect Boundary Approximation (PBA) method. The PBA method allows mesh cells to be partially filled for more accurate representation of shapes compared to software packages where only rectangular or triangular mesh cells are available. Farfield monitors were defined at various frequencies throughout the bandwidth to capture the E-fields for comparison with experimental results.

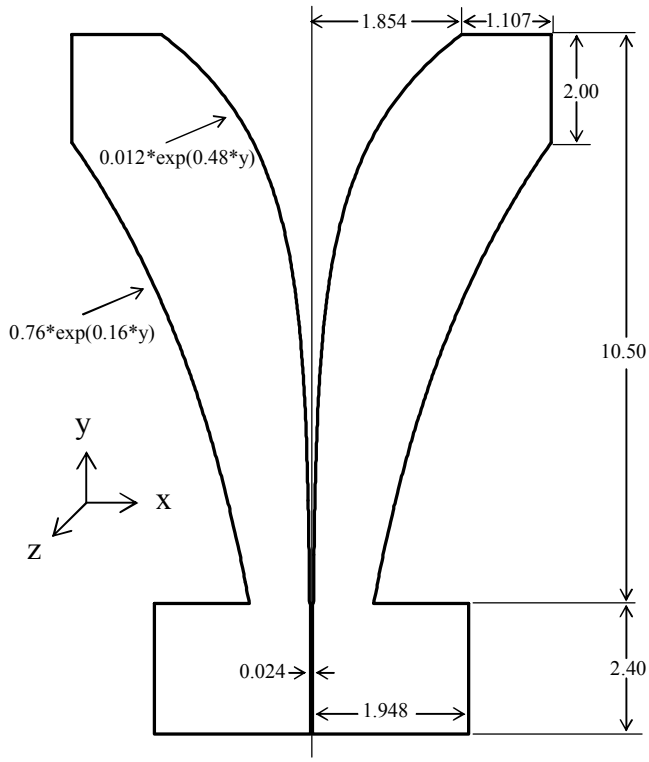

Figure 1: DETSA Diagram with Dimensions in Centimeters

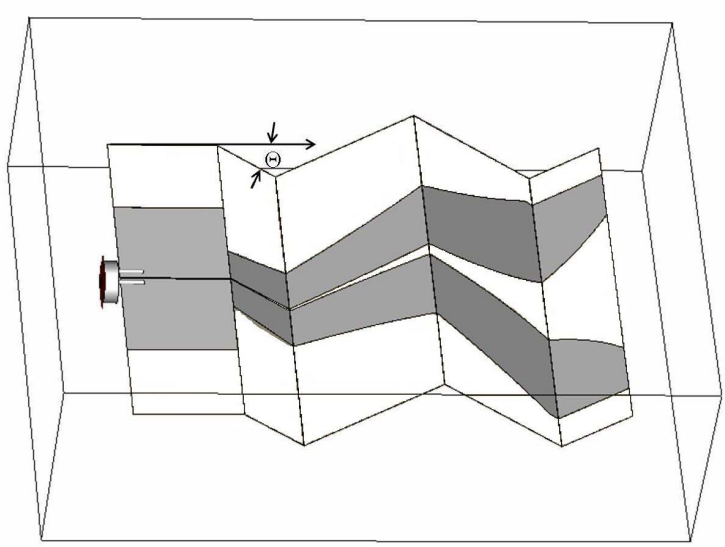

Figure 2: 80% Corrugated DETSA

Results

Using the HP 8510 network analyzer, S_{11} measurements were recorded for each antenna. Figure 3 shows the bandwidth and return loss is degraded as the amount of corrugation is increased, but there is still a wide bandwidth of better than -10 dB return loss for each case. Simulations verify that reflections occur at each fold of the corrugated antenna.

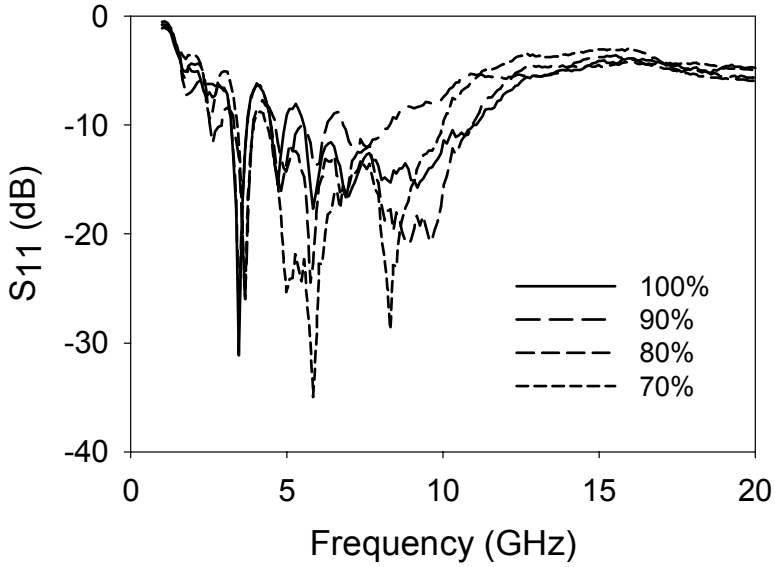

Figure 3: Return Loss Measurements

Far field E and H plane measurements were taken for the flat and corrugated DETSAs in a far field antenna range with a 2 to 18 GHz ridged rectangular horn transmitting antenna and the DETSA as the receiver antenna. The system is calibrated before use. With respect to the established coordinates shown in Figure 1, the E plane was measured in the xy plane and the H plane was measured in the yz plane. The SMA connector remained along y = 0. Measurements were taken over the operating frequency range 4 to 10 GHz, in 1 GHz increments.

Figures 4 and 5 show the measured and simulated radiation patterns in the E and H planes for the 100% and 80% lengths, respectively, at 6 GHz. All data was normalized based on the highest received power for all frequencies. First, it is seen that there is excellent agreement between the measured and simulated antennas in the H plane. The center lobe for the E plane is consistently skewed to the side. Simulations show that the SMA connection results in a current asymmetry in the slotline and a skewing of the radiation pattern. It is seen in Figure 4 that the simulation and measured are both skewed approximately 15º. Because the simulations are lossless, the magnitudes of the simulated data are greater than those of the measured data. Even at 80% corrugation, there is a main bean along 0º, but the sidelobes are higher than the flat DETSA case.

Conclusions

DETSAs corrugated at 90%, 80%, and 70% total length were proven to operate within the bandwidth of the full length DETSA, but further work is required to improve the radiation patterns.

References:

[1] R. Q. Lee and R. N. Simons, *Tapered Slot Antenna* in Advances in Microstrip and Printed Antennas, Kai Fong Lee and Wei Chen Editors, John Wiley and Sons, Inc, 1997, pp. 443-514.

[2] S. Nikolaou, L. Marcaccioli, G. E. Ponchak, J. Papapolymerou, and M. M. Tentzeris, "Conformal double exponentially slot antennas (DETSA) for UWB communications systems' front-ends," *2005 IEEE Int. Conf. on Ultra-Wideband (ICU 2005) Dig.*, Zurich, Switzerland, Sept. 5-8, 2005.

[3] www.cst.de

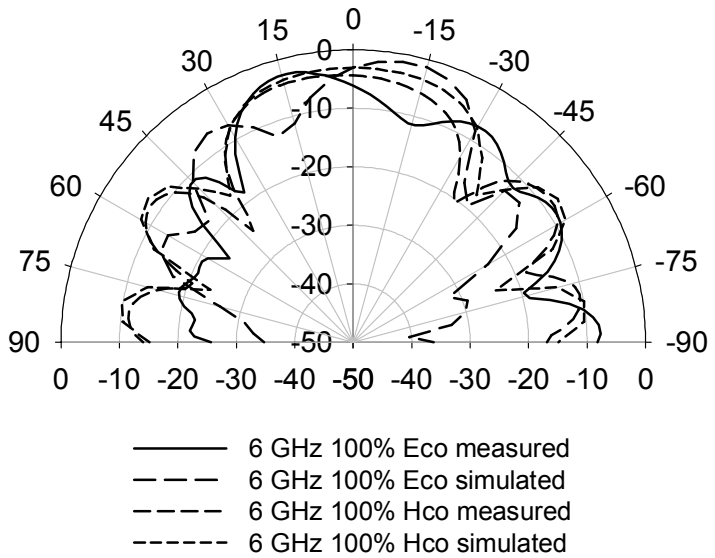

Figure 4: 100% DETSA Radiation Pattern

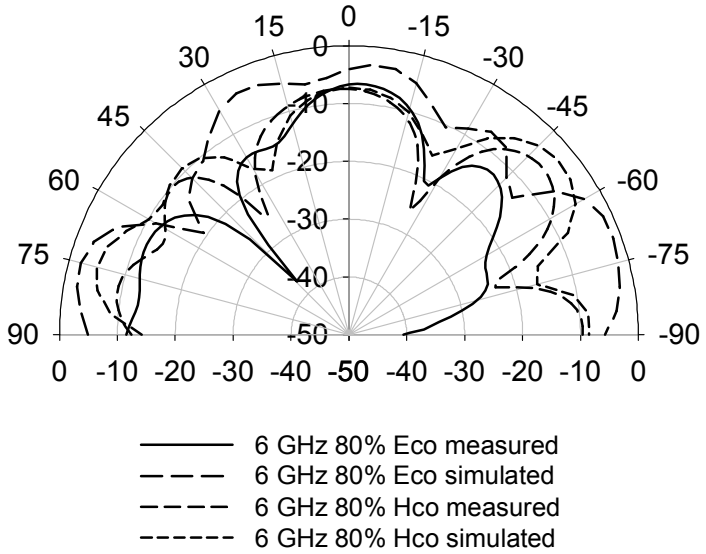

Figure 5: 80% DETSA Radiation Pattern