# Characteristics of a Linearly Tapered Slot Antenna (LTSA) Conformed Longitudinally Around a Cylinder

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## Introduction

The family of tapered slot antennas (TSA's) is suitable for numerous applications. Their ease of fabrication, wide bandwidth, and high gain make them desirable for military and commercial systems. Fabrication on thin, flexible substrates allows the TSA to be conformed over a given body, such as an aircraft wing or a piece of clothing for wearable networks. Previously, a Double Exponentially Tapered Slot Antenna (DETSA) was conformed around an exponential curvature [1], which showed that the main beam skewed towards the direction of curvature. This paper presents a Linearly Tapered Slot Antenna (LTSA) conformed longitudinally around a cylinder. Measured and simulated radiation patterns and the direction of maximum H co-polarization (Hco) as a function of the cylinder radius are presented.

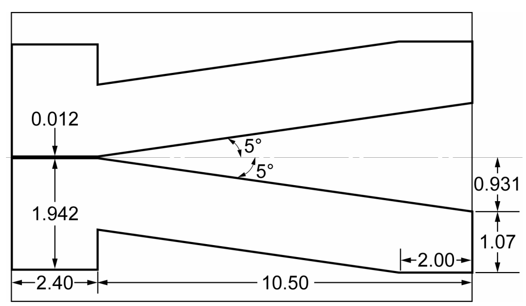


Fig. 1: Schematic of LTSA with dimensions in cm.

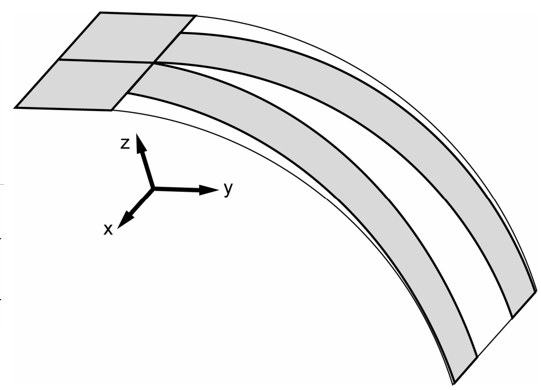


Fig. 2: LTSA wrapped around 90º curve.

## LTSA Design

A LTSA was fabricated with a 18 µm thick copper layer on 200 µm thick liquid crystal polymer (LCP), which has an effective dielectric constant, $\varepsilon_r$, of 3.1 and a loss tangent of 0.003 [2]. A schematic with dimensions of the LTSA is shown in Fig. 1. The LTSA was designed such that both tapers are parallel to one another. A 5˚ taper off the center was chosen for the design based on the recommendation in [3] that the slot taper angle to be between 2.5-12.5°. The LTSA length of 10.5 cm corresponds to 1.75 and 5.25 free space wavelengths, $\lambda_0$, at 5 and 15 GHz, respectively. Based on the criteria that the length should be at least $2\lambda_0$ for proper traveling wave radiation [3], the LTSA presented here operates at frequencies greater than 6 GHz. Table 1 shows the radii of curvature over which the LTSA was wrapped. Throughout this paper, the data presented will be as a function of the angle of curvature.

Table 1: Dimensions of LTSA radii of curvature

| Radius (cm) | Radius ($\lambda_0$ at 6 GHz) | Angle LTSA wraps around circle (degrees) |
|---|---|---|
| 13.37 | 2.68 | 45 |
| 26.74 | 5.35 | 22.5 |
| ∞ | ∞ | 0 (Flat) |

## Radiation Pattern Measurements

Styrofoam was cut using a band saw into the cylindrical shapes. The LTSA was secured between two pieces of Styrofoam. The beginning of the taper was placed where the Styrofoam starts to curve. To form a coaxial cable to slotline transition, the outer conductor of a semi-rigid coaxial waveguide was soldered perpendicular to one side of the slotline. The center conductor was extended across the slotline and soldered to the other side. This method of feeding has been shown through simulations to provide symmetric currents, which are critical for antenna radiation pattern measurements.

Far field E and H plane radiation pattern measurements were taken in a calibrated far field antenna range from 5 to 15 GHz. The H plane measurements were taken in the *xz* plane, shown in Fig. 2. The E plane was measured in the plane of excitation (*xy* plane) rather than the location of the maximum in the H plane. To measure the true E plane would require cutting several pieces of Styrofoam at specific angles.

## Simulations

The LTSA was simulated using Ansoft HFSS [4], based on the finite element method. Frequencies in the range of 5-15 GHz were simulated. A wave-port is used for excitation, automatic meshing was used for discretization, and all materials were assumed to be lossless. The antenna was modeled with a PEC (perfect electric conductor) and the LCP had a dielectric constant of $\varepsilon_r = 3.1$ with a thickness of 200 μm. The curved structure is built using the sweep function in HFSS.

## Results

The normalized radiation patterns for a flat LTSA and a conformed LTSA over a 45° curvature in the longitudinal direction are shown in Figs. 3 and 4, respectively. The measured and simulated radiation patterns are in good agreement. The measured E co-polarization (Eco) of the flat antenna demonstrates unexpected skewing of the main beam, which may be attributed to asymmetric currents due to the soldering of the feed. As the LTSA is conformed over a cylinder, the Hco main beam rotates towards the curved end of the LTSA as shown in Fig. 4. Since the Eco is measured in the plane of excitation, and not the angle of the maximum Hco, the main beam of the Eco is narrowed. This is not an indication that the actual Eco beamwidth in the direction of maximum radiation has narrowed. Figure 5 shows the angle of the maximum H plane main beam for both measured and simulated data. Due to the skewed co-polarization, as mentioned above, the angle is determined by taking the two 3 dB points from the Hco maximum and finding the midpoint. The tighter the radius of curvature, the more the beam is directed towards the negative Θ direction.

## Conclusions

An LTSA fabricated with copper metallization on LCP was proven to effectively operate in a wide bandwidth while conformed longitudinally over cylindrical curvatures of 22.5° and 45˚. The H plane main beam generally had the same beamwidth when the LTSA was conformed into the cylinder, but displayed skewing in the direction of the curve. The presented narrowing of the beamwidth in the E plane is associated to the measurement method of aligning the LTSA with the plane of excitation rather than at the angle at which the maximum Hco beam is directed.

## References


[1] S. Nikolaou, L. Marcaccioli, G. E. Ponchak, J. Papapolymerou, and M. M. Tentzeris, "Confromal double exponentially tapered 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.

[2] D. C. Thompson, O. Tantot, H. Jallageas, G. E. Ponchak, M. M. Tentzeris, and J. Papapolymerou, "Characterization of liquid crystal polymer (LCP) material and transmission lines on LCP substrates from 30-110 GHz," IEEE Trans. Microwave Theory and Tech, Vol. 52 , No. 4, pp. 1343 - 1352, April 2004.

[3] 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. 450, 484.

[4] www.hfss.com


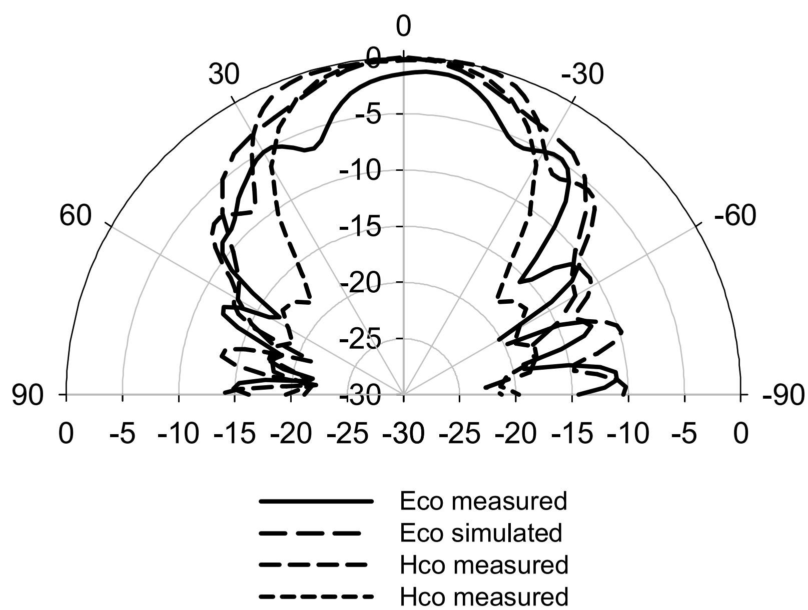


Fig. 3: Radiation pattern of flat LTSA at 9 GHz.

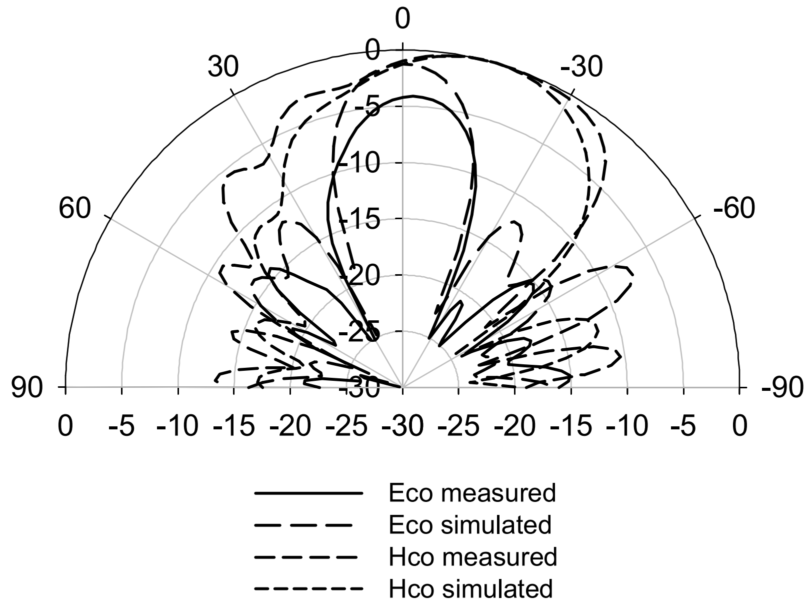


Fig. 4: Radiation pattern of longitudinally conformed LTSA over 45º cylinder at 9 GHz.

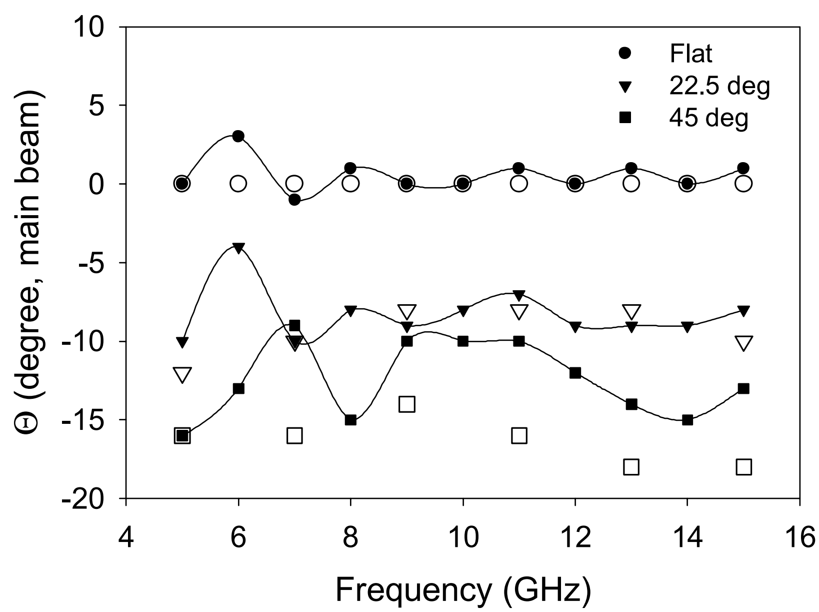


Fig. 5: Measured (solid symbols) and simulated (open symbols) angle of maximum H plane as a function of curvature.