Double Exponentially Tapered Slot Antenna (DETSA) on Liquid Crystal Polymer (LCP) for UWB Applications

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I. Introduction

The rapid developments in broadband wireless communications and the great number of commercial and military applications necessitate new types of antennas which can support higher bit rates. The Ultra Wide Band (UWB) [1] protocol using the spectrum from 3.1 GHz to 10.6 GHz is a new promising technology suitable for high rate communications in small distances. In this paper, a double exponentially tapered slot antenna (DETSA) on LCP organic material suitable for packaging and integration with other components is introduced and proposed for the UWB range with gain above 7 dBi and return loss below -10 dB for the whole frequency range. The DETSA is a variation of the Vivaldi antenna, with the outer edge exponentially tapered, and it was introduced for the first time in [2]. The design and performance characteristics of the DETSA are investigated in [3] and [4]. A coplanar waveguide – fed version of DETSA is explored in [5] for a UWB sub-band, while in [6] a Vivaldi antenna is proposed for the ultra wide band.

II. Antenna Design and Fabrication

The proposed antenna was fabricated on a 200 μm thick Liquid Crystal Polymer (LCP) substrate. The copper layer is 18 μm thick. The DETSA design is presented in fig. 1. The length of the board is L=13.62 cm and the width is D=6.64 cm. The slot gap at the feeding point is 100 μm wide. LCP was preferred because of a number of desirable features. The dielectric constant ε_r=3.1 is low enough to be used for an end-fire antenna, it has low loss (tanδ=0.002) it is conformal and easy to fabricate with an engineered CTE [7]. Standard photolithography was used for the fabrication. The design dimensions have been optimized in order for the antenna to be matched in a frequency range starting at 3 GHz up to 11 GHz.

III. Discussion of Measurements and Simulated Results

For return loss and radiation pattern measurements an SMA connector was soldered directly on the slot in order for no tuning part to be necessary and an HP 8530A network analyzer was used. The simulated and measured results are presented in fig. 2, where it can be seen that good agreement is achieved. The return loss remains below -10 dB in the whole UWB range. The observed "saw" pattern is expected because DETSA is a traveling wave antenna, not a resonance radiation element. For the frequencies in the 8 GHz to 10.6 GHz range the return loss is below -15 dB. In those frequencies relatively higher gain is measured.

The radiation pattern measurements were performed at the far field E and H planes defined in fig. 1. The directivity direction is the intersection of the two planes. To characterize experimentally the DETSA antenna, it is sandwiched between two ½ inch thick styrofoam pieces to give it enough mechanical stability for the measurements. The antenna is tested in a far-field range with the DETSA as the receive antenna, and a 2 to 18 GHz, ridged-rectangular horn antenna with a gain of 6 dB at 2 GHz and 12 dB at 18 GHz is used for the transmitting antenna. After experimentally determining the transmitted power to maximize the detector sensitivity without saturating it, the system is calibrated. The rotary stage and the detector voltage recording from the lock-in amplifier are automated.

The main problem with wideband antennas is the electrical length variation because that causes significant distortion in the radiation patterns. Generally the increase in frequency in end-fire antennas causes the main beam to become more narrow (reduced beamwidth) and the directivity to increase. The y axis in fig.1 corresponds to $\varphi=90^{o}$ for the E plane cuts and to $\theta=90^{o}$ for the H plane cuts. x axis corresponds to $\varphi=0^{o}$ and z axis to $\theta=0^{o}$.

Radiation patterns in two frequencies, one in the low range and one in the center design frequency range of the ultra wide band are presented in figs. 3-6. Figs 3-4 are simulated and measured results at 4 GHz while figs. 5-6 are simulated and measured results at 8 GHz. The E plane beam is slightly wider and with fewer side lobes compare to the H plane beam for the same frequency. In addition to that, both E and H plane beams are wider for the lower frequency at 4 GHz compared to the higher frequency at 8 GHz. Generally though, the shape of the beam does not present great variations which is a major advantage of this antenna, with respect to competitive UWB designs [8]-[9] for which the shape of the beam changes significantly while the frequency increases. For 4 GHz the gain is 7.8 dB and for 8 GHz gain is 11.9 dB. The plots presented are normalized independently.

IV. Conclusion

A DETSA on organic material (LCP), suitable for packaging and integration with other components, is introduced and proposed for the UWB range. The measurements agree fairly well with the simulation and this antenna is proved to perform well in the whole UWB range. Return loss below -10 dB is measured for the whole frequency range of operation. The antenna performs with high gain starting from 7 dB for low frequencies and up to 12 dB for the higher frequencies. The antenna on LCP is conformal, can be easily fabricated with relatively low cost and is a good candidate for a number of UWB applications.

References:

[1] Win M. Z. and Scholtz R. A., “Ultra-wide bandwidth (UWB) time –hopping spread-spectrum impulse radio for wireless multiple access communications”, IEEE Trans. Commun., vol. 48, no. 4, pp.679-689, April 2000.

[2] Lee J. J. and Livingston S., “Wide band bunny-ear radiating element”, IEEE Antennas Propagation Society International . Symposium. pp. 1604-1607., July 1993, Ann Arbor, MI.

[3] Greenberg, M.C., Virga, K.L., “Characterization and design methodology for the dual exponentially tapered slot antenna” IEEE Antennas and Propagation Society International Symposium, Volume: 1 , pp:88 - 91, July 1999, Atlanta, GA.

[4] Greenberg, M.C., Virga, K.L., Hammond, C.L., “Performance characteristics of the dual exponentially tapered slot antenna (DETSA) for wireless communications applications” IEEE Transactions on Vehicular Technology, vol.52 , no.2 , pp.305 – 312, March 2003.

[5] Yo-Shen Lin, Tzyh-Ghuang Ma, Shyh-Kang Jeng, Chun Hsiung Chen, **“**Coplanar waveguide-fed dual exponentially tapered slot antennas for ultra-wideband applications**”,** Antennas and Propagation Society Symposium, Volume:3 , pp. 2951 – 2954, June 2004, Monterey, CA.

[6] Sang-Gyu Kim and Kai Chang “Ultra wideband exponentially-tapered antipodal Vivaldi antennas” IEEE Antennas and Propagation Society Symposium, Volume: 3, pp. 2273 – 2276, June 2004, Monterey, CA.

[7] Thompson, D.C., Tantot O., Jallageas H.., Ponchak G.E., Tentzeris M.M., Papapolymerou, J., “Characterization of liquid crystal polymer (LCP) material and transmission lines on LCP substrates from 30 to 110 GHz”, IEEE Transactions on Microwave Theory and Techniques, vol.52 , no.4 , pp. 1343-1352, April 2004.

[8] *Hyungkuk Yoon, Hyungrak Kim, Kihun Chang, Young Joong Yoon, Young-Hwan Kim,”* A study on the UWB antenna with band-rejection characteristic”, IEEE Antennas and Propagation Society Symposium, Volume: 2, pp. 1784 - 1787 June 2004, Monterey, CA.

[9] *Tzyh-Ghuang Ma and Shyh-Kang Jeng* **“**A compact tapered-slot-feed annular slot antenna for ultra-wideband applications**”,** IEEE Antennas and Propagation Society Symposium, Volume: 3, pp. 2943 – 2946, June 2004, Monterey, CA.

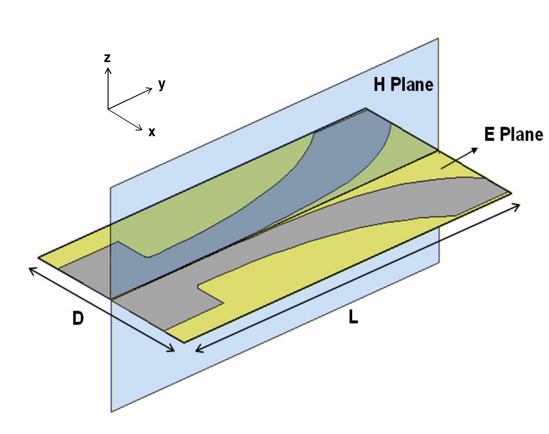

Fig. 1. DETSA Design

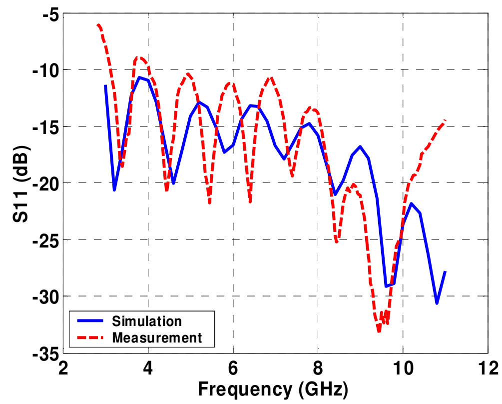

Fig. 2. Return Loss

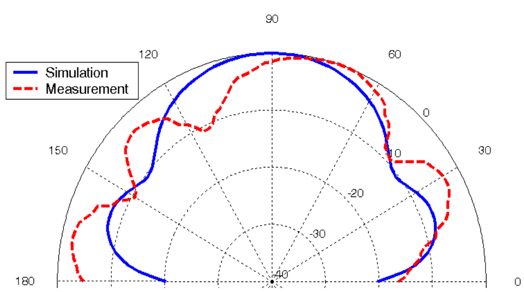

Fig. 3. E – Co. f=4 GHz

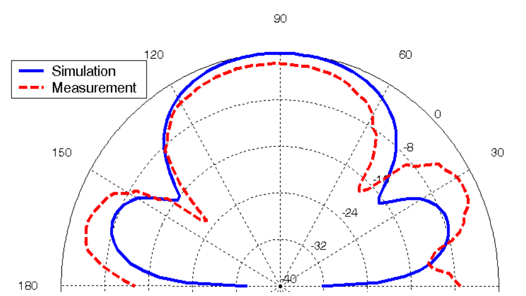

Fig. 4. H – Cross. f=4 GHz

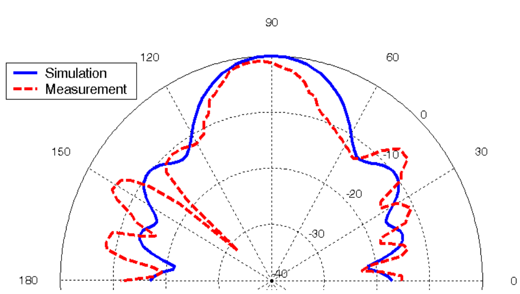

Fig. 5. E – Co. f=8GHz

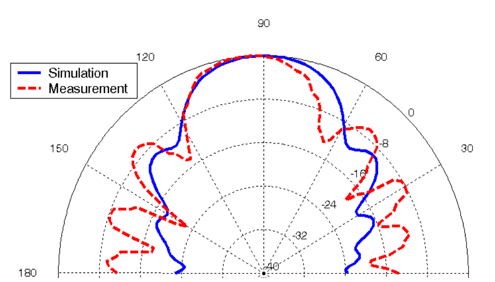

Fig. 6. H – Cross. f=8 GHz