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DESIGN OF A LOW-PROFILE DUAL EXPONENTIALLY TAPERED SLOT ANTENNA

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Abstract—A planar Dual Exponentially Tapered Slot Antenna (DET SA) is presented. The DETSA is simulated and designed with the software Ansoft High frequency Structure Simulator (HFSS). The dimensions of the antenna and the exponential functions of tapered slot are also described. To verify the design, the DETSA is fabricated and measured, good impedance matching over a very wide bandwidth is achieved, measured radiation patterns of the proposed antenna are compared with the simulated one, good agreement is observed. Simulated group delay of the antenna is presented.

1. INTRODUCTION

In recent years, short range and high data rate wireless communication are widely applied. Ultra Wide Band (UWB) radio technology can meet these requests, thus design of UWB antennas becomes significant [1–18]. According to the Federal Communication Commission (FCC) UWB rulings the signal is recognized as UWB if the signal frequency band is from 3.1 GHz–10.6 GHz or the signal bandwidth is more than 500 MHz.

Dual Exponentially Tapered Slot Antenna (DETSA), also known as Bunny-Ear Antenna (BEA), is an end-fire traveling wave antenna used for UWB applications. This antenna is a special form of Tapered Slot Antenna (TSA). It is created by tapering the outside edge of the slotline conductor of a Vivaldi antenna. The outer slot taper of the DETSA is described by an exponential function. This adds additional antenna design degrees of freedom. The radiation mechanism of the DETSA is based on traveling wave propagation

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along the inner tapered slot line, which results in an end-fire antenna. The distance between inner slot line at the feed location is small and the waves are tightly bound. As the slot line widens, the bound becomes weaker gradually and the waves get radiated away from the antenna. The narrow slot line decides high frequency band, otherwise the wide slot line decides low frequency band. The electric lengths of different radiation parts at different frequencies remain constant. The radiated E-field is parallel to the substrate plane and linearly polarized. The H-field is perpendicular to the substrate plane. This antenna features low-profile, light weight, easy fabrication and compatibility with microwave integrated circuits (MIC). The DETSA also demonstrates good performance, such as wide band and symmetric E- and H-plane beam patterns. The antenna was first proposed by Lee in 1993 [1]. Since then some advances have been made. In designs, Full-wave numerical techniques and simulation tools are used to analyze the antenna. In applications, BEA arrays were built for radar applications [2], Wireless communications applications [3] and for dual polarization applications [4]. Those multi-function applications are the current trends.

In this paper, a low-profile DETSA is presented. The impedance bandwidth of the proposed antenna is very wide, but the dimensions $0.427\lambda_{\max} \times 0.24\lambda_{\max}$ (where $\lambda_{\max}$ is the wavelength at the lowest frequency over the entire frequency band) are smaller compared with $0.762\lambda_{\max} \times 0.677\lambda_{\max}$ in [5].

2. ANTENNA DESIGN

Figure 1 shows the presented sketch of the DETSA geometry. According to Lee in [6], the design parameters are dielectric constant and thickness of the substrate, conductor width and the gap width of the slot.

The antenna is located in the x-z plane, the E-plane of the antenna is in the x-z plane ($\varphi = 0°$), and H-plane is in the y-z plane ($\varphi = 90°$).

The DETSA is described by two exponential function, inner and outer tapered slotline. The inner and outer tapered slotline are described by the following exponential functions respectively.

$$x_i = \pm c_i \exp(k_i z) \tag{1}$$

$$x_o = \pm c_o \exp(k_o z^2) \tag{2}$$

where x_i (x_o) is the distance from the center line of the slot to the inner (outer) tapered slot line. c_i (c_o) determines the inner (outer) slot width

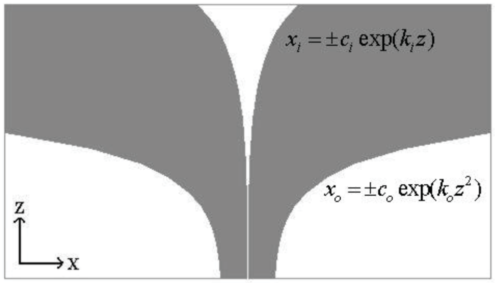


Figure 1. The DETSA geometry.

at the feed port, k_i (k_o) specifies how the slot widens. The feed port is located across the narrow slot, where a $50\,\Omega$ coaxial line is connected, the location of the feed point is also important for impedance matching.

3. SIMULATED RESULTS AND MEASUREMENTS

For simulation, we calculate the antenna in Ansoft HFSS environment. The design dimensions have been optimized to get a low profile. By carefully tuning, optimized design parameters are obtained. The values of c_i, k_i, c_o, and k_o are 0.3, 0.015, 36 and 0.00006 respectively. As shown in Fig. 2, the antenna, which has compact dimensions of $0.427\lambda_{\max} \times 0.24\lambda_{\max}$, is printed on the front of substrate FR-4 of thickness 1.6 mm and relative permittivity 4.4. FR-4 is preferred because of a number of desirable features. FR4 resists higher heat and chemical. Especially FR4 is with excellent mechanical strength. For this antenna, radiation from very high-dielectric substrates is low, therefore FR4 is chosen.

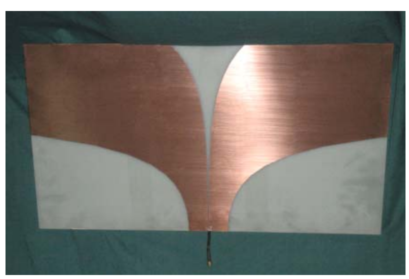


Figure 2. Photograph of the manufactured DETSA.

For VSWR measurements, a WILTRON37269A network analyzer is used. The measured VSWR as well as the simulated results are shown in Fig. 3.

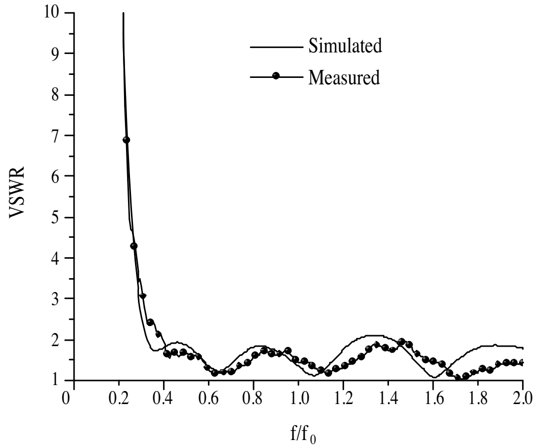
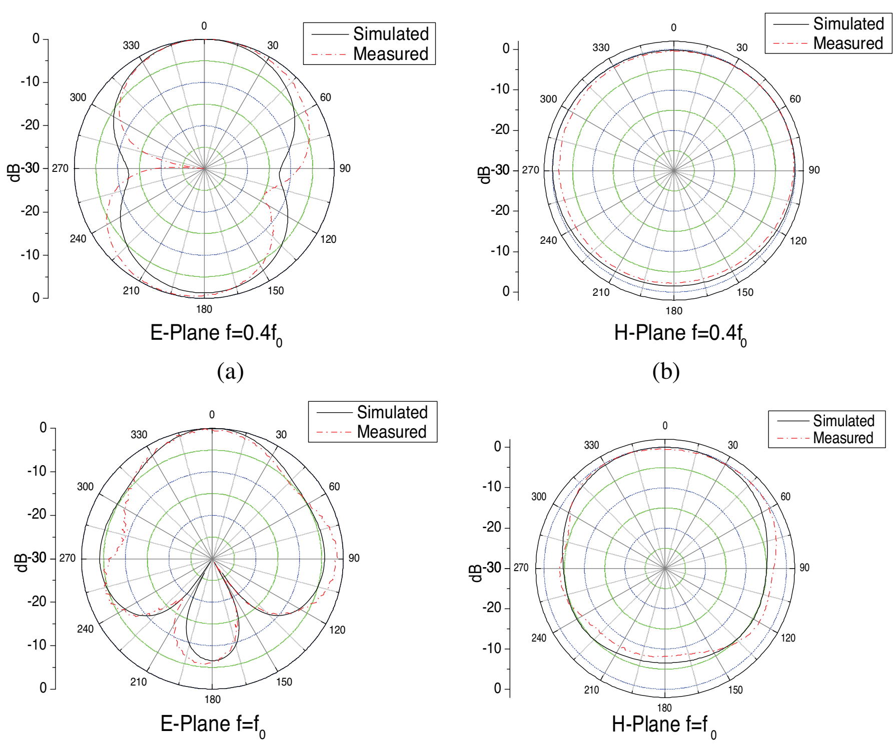


Figure 3. Simulated and measured VSWR of the DETSA.



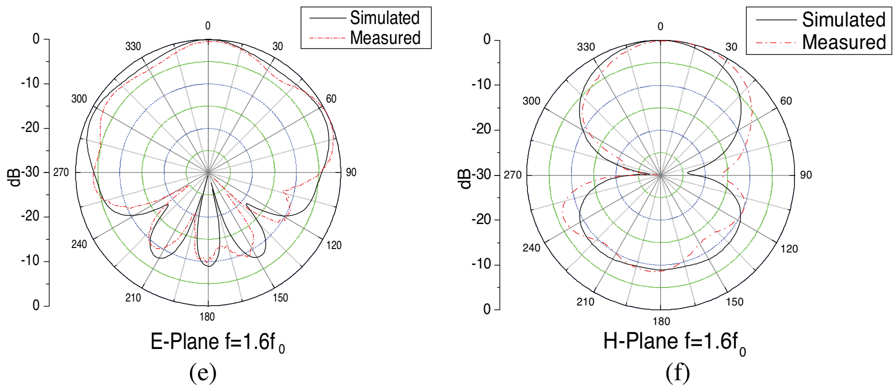


Figure 4. Simulated and measured patterns at different frequencies.

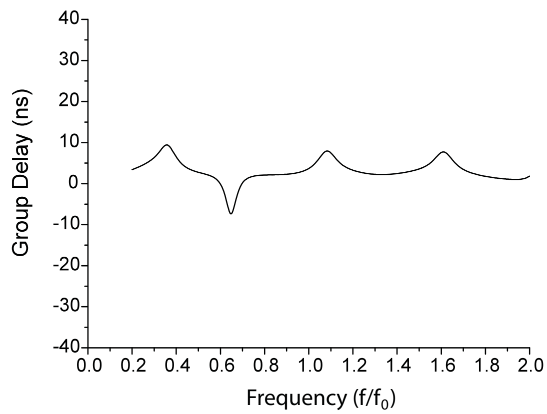


Figure 5. Simulated group delay.

As one can see, very wide-band impedance matching is achieved. Also good agreement between the simulated results and the measured data is observed.

The far-field (FF) patterns are measured, the normalized patterns of $|E_\vartheta|$ at high frequency band are shown in Fig. 4.

Measured patterns achieve good agreement with simulated ones. It can be found that at low frequency band, the patterns are much similar to that of a dipole. Because the effective region is located at the top of the antenna, the bottom part has little effects on the radiation. At medium and high frequency bands, the patterns behave more directivity. Because the effective region is moved to the middle part, the bottom part acts as a reflector.

Group delay describes a signal transition time through a device.

It is defined as the negative derivative of phase versus frequency. For the UWB applications, group delay should be discussed [7, 8]. Figure 5 shows the Simulated group delay.

4. CONCLUSION

A DETSA for UWB applications has been presented in this paper. The antenna is fabricated and measured. Measured results achieve great agreement with the simulated ones. The antenna has low profile, electrical small size, very wideband and symmetric E-plane and H-plane patterns. The variation of group delay is in the acceptable range across most frequency band. It is shown that this antenna is suitable for UWB applications.

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REFERENCES

1. Lee, J. J. and S. Livingston, "Wide band bunny-ear radiating element," *IEEE Society International Symposium on Antennas and Propagation*, Vol. 3, 1604–1607, 1993.
2. Lee, J. J., S. Livingston, V. I. Jones, J. B. Lewis, H.-W. Yen, G. L. Tangonan, and M. Wechsberg, "Photonic wideband arrav antennas," *IEEE Transactions on Antennas and Propagation*, Vol. 43, No. 9, 967–981, Sept. 1995.
3. Greenberg, M. C., K. L. Virga, and C. L. Hammond, "Performance characteristics of the dual exponentially taperd slot antenna (DETSA) for wireless communications applications," *IEEE Transactions on Vehicular Technology*, Vol. 52, No. 2, 305–312, Mar. 2003.
4. Lee, J. J., S. Livingston, and R. Koenig, "Performance of a wideband (3–14 GHz) dual-pol array," *IEEE International Symposium on Antennas and Propagation*, Vol. 1, 551–554, June 2004.
5. Greenberg, M. C. and L. L. Virga, "Characterization and design methodology for the dual exponentially tapered slot antenna," *IEEE Society International Symposium on Antennas and Propagation*, Vol. 1, 88–91, Atlanta, GA, July 1999.

6. Lee, J. J., "Slotline impedance," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 39, No. 4, 666–672, Apr. 1991.
7. Mohammadian, A. H., A. Rajkotia, and S. S. Soliman, "Characterization of UWB transmit-receive antenna system," *Proc. of Ultra Wideband Systems and Technologies*, 157–161, 2003.
8. Licul, S., J. A. N. Noronha, W. A. Davis, D. G. Sweeney, C. R. Anderson, and T. M. Bielawa, "A parametric study of time-domain characteristics of possible UWB antenna architectures," *Proc. of IEEE Vehicular Technology Conference (VTC 2003)*, Vol. 5, 3110–3114, 2003.
9. Lee, J. J., S. Livingston, R. Sauer, and G. Crandall, "A UHF wide-band SAR antenna," *IEEE International Conference in Phased Array Systems and Technology*, 437–440, May 21–25, 2000.
10. Symeon, N., G. E Ponchak, J. Papapolymerou, and M. M. Tentzeris, "Conformal double exponentially tapered slot antenna (DETSA) on LCP for UWB applications," *IEEE Trans. on Anten. and Propagat.*, Vol. 54, 1663–1669, Jun. 2006.
11. Jordan, J. L., C. Chevalier, and G. E. Ponchak, "Characteristics of corrugated double exponentially tapered slot antenna," *IEEE Antennas and Propagation Society International Symposium*, 2575–2578, July 9–14, 2006.
12. Thompson, D. C., 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 Tech.*, Vol. 52, No. 4, 1343–1352, April 2004.
13. Ren, W., J. Y. Deng, and K. S. Chen, "Compact PCB monopole antenna for UWB applications," *Journal of Electromagnetic Waves and Applications*, Vol. 21, No. 10, 1411–1420, 2007.
14. Kanj, H. and M. Popovic, "A novel ultra-compact broadband antenna for microwave breast tumor detection," *Progress In Electromagnetics Research*, PIER 86, 169–198, 2008.
15. Yang, Y., Y. Wang, and A. E. Fathy, "Design of compact VIVALDI antenna arrays for UWB see through wall applications," *Progress In Electromagnetics Research*, PIER 82, 401–418, 2008.
16. Kharakhili, F. G., M. Fardis, G. Dadashzadeh, and A. Ahmadi, "Circular slot with a novel circular microstrip open ended microstrip feed for UWB applications," *Progress In Electromagnetics Research*, PIER 68, 161–167, 2007.
17. Marrocco, G., M. Migliorelli, and M. Ciattaglia, "Simultaneous time-frequency modeling of ultra-wideband antennas by two-

dimensional hermite processing," *Progress In Electromagnetics Research*, PIER 68, 317–337, 2007.

18. Mehdipour, A., K. Mohammadpour-Aghdam, and R. Faraji-Dana, "Complete dispersion analysis of VIVALDI antenna for ultra wideband applications," *Progress In Electromagnetics Research*, PIER 77, 85–96, 2007.