Broadband Dielectric Loaded Trapezoidal Planar Antenna

Z. Wang[(1)], *Student Member, IEEE*, C. C. Chiau[(1)], *Student Member, IEEE*, X. Chen[(1)], *Member, IEEE*, B. S. Collins[(2)], *Member, IEEE*, S. P. Kingsley[(2)], *Member, IEEE* and S.C. Puckey[(2)]

[(1)] Dept. of Electronic Engineering, Queen Mary, University of London, Mile End Road, London, E1 4NS, UK
[(2)] Antenova Ltd., Far Field House, Albert Road, Stow-cum-Quy, Cambridge, CB5 9AR, UK

***Abstract*— This paper presents an optimised design of a broadband dielectric loaded planar monopole developed by Antenova Ltd. UK. With knowledge of its operating principle, the design is optimised to achieve a smaller dielectric size and an even wider impedance bandwidth. The bandwidth of the optimized antenna is up to 63%, covering four frequency bands, DCS 1800, PCS 1900, WCDMA 2100 and IEEE802.11 2400, using a smaller dielectric (ceramic) pellet, which is only 70% of the original one.**

***Index Terms*— Dielectric Resonator Antenna, Dielectric Loaded Antenna, Broadband Antenna, microstrip line feeding**

I. Introduction

The Dielectric Resonator Antenna (DRA) has attracted considerable interest as a novel antenna, having the features of high efficiency and resistance to proximity detuning [1] [2]. Their radiation arises from a displacement current circulating through a dielectric medium, which is usually a high-permittivity, low-loss ceramic. However, the narrow impedance bandwidth, due to them naturally being resonators with high values of both loaded and unloaded Q, and the high cost of the high-permittivity ceramic material, are two obstacles hindering the application of this advanced antenna.

The Dielectric Loaded Antenna (DLA), another subcategory of dielectric antennas, has been studied for small mobile and personal communication terminals for a long time [3] [4]. Compared with the traditional DRA, DLAs are known for their intrinsic lower Q-factor and expanded bandwidth whilst maintaining the advantages of dielectric antennas, such as high efficiency and resistance to proximity detuning. In the new era of small user terminals for mobile communications, it is advantageous to improve the performance of antennas within a small fixed volume by using dielectric loading.

Recently, significant efforts have been put into expanding the bandwidth of DLAs by research groups worldwide, including that at Antenova Ltd. U.K. They developed a broadband dielectric antenna by removing the conducting ground plane underneath the dielectric resonator, making it into a dielectric loaded antenna; this has a reduced loaded Q which results in a considerable increase in its bandwidth [5]. The operating principle of the prototype antenna was analysed in our previous work, through numerical simulation and experimental verification [6].

In this paper, the original antenna was optimised to overcome the two obstacles which formerly hindered the application of dielectric antennas: the bandwidth has been broadened, and a smaller ceramic pellet has substituted for the original pellet. The bandwidth of the optimized antenna is from 1.59GHz to 3.053GHz, up to 63%, with a smaller dielectric (ceramic) pellet, which is only 70% of the original one. Simulations were performed using the CST Microwave Studio™ software package which utilizes a Finite Integration Technique for electromagnetic computation [5]. The antenna was tested in the Antenna Measurement Laboratory of Queen Mary, University of London. The return loss was measured using an HP8720ES Network Analyser and the radiation patterns were measured in an anechoic chamber.

II. Prototype Antenna Design and Characteristics

A. *Antenna structure*

The prototype broadband dielectric antenna, designed and fabricated by Antenova Ltd., consists of four layers: the ground plane (GP), substrate (PCB board), the microstrip feeding line and the metal coating, and the ceramic pellet. The substrate, 80mm (L_s) by 35mm (W), has a metal ground plane (GP) 63mm (L_g) by 35mm (W) printed on its reverse side. The permittivity and thickness of the substrate are 4.7 and 1.6mm, respectively. A microstrip line having a width of 2.6mm (to achieve a characteristic impedance of 50Ω) is connected to the coaxial cable through an SMA connector. The distance between the microstrip line and the edge of PCB (x_{min}) is 2mm. There is a top-flattened ceramic half-cylinder of permittivity around 90 with a metal coating on its bottom, whose length (DR_l), width (DR_w), and height (DR_h) are 15.2mm, 7mm and 3.5mm, respectively. The gap between the ceramic pellet and the ground plane is 10mm. The structure of the prototype antenna is shown in Fig.1.

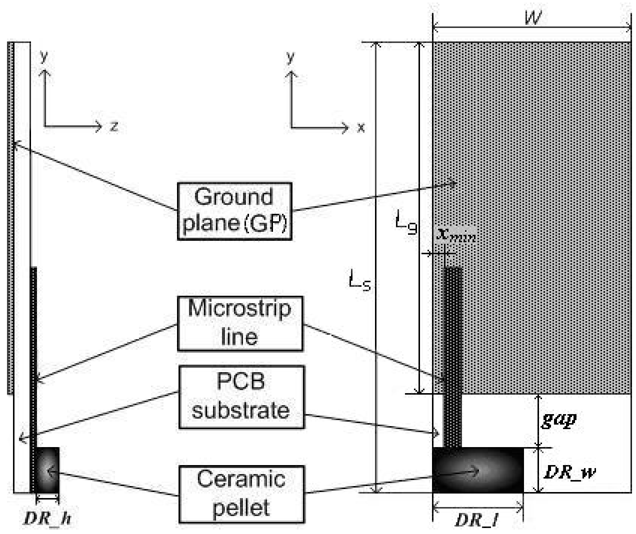


Fig. 1. Geometry of the prototype antenna

B. *Simulation and Measurement Results*

Fig.2 shows a good agreement between the simulated and measured return losses. It indicates that the main resonant frequency of the prototype antenna is 2.11GHz, and there is also another resonance around 1.55GHz (called the secondary resonance of this antenna). The measured bandwidth at 6dB return loss is 44.4% (i.e. from 1.433GHz to 2.25GHz).

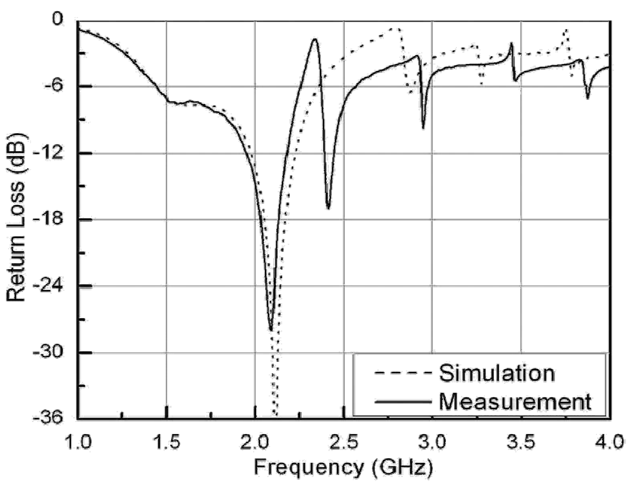
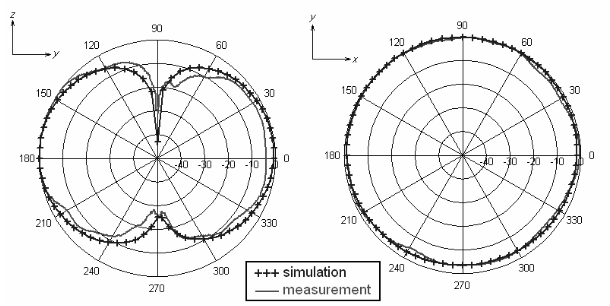
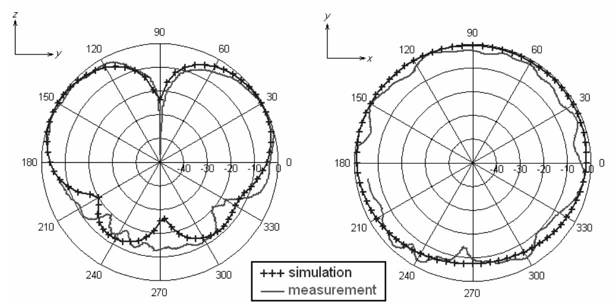


Fig. 2. Simulated and measured return losses of the prototype antenna

The measured and simulated radiation patterns at the two resonant frequencies of 1.55 GHz and 2.11 GHz are plotted in Fig.3. It is shown that the measured radiation patterns are very close to those obtained in the simulation. The *H*-plane patterns are omni-directional, similar to those of the traditional monopole.



(a) Radiation patterns at 1.55GHz



(b) Radiation patterns at 2.11GHz

Fig. 3. Simulated and measured radiation patterns of the prototype antenna

C. *Principle of Operation*

According to the previous study [6], this antenna is a dielectric loaded antenna. The primary resonance can be attributed to the metal coating under the dielectric pellet, which works as a planar monopole and is coupled with the front edge of the ground plane; so the resonant frequency is determined by the planar monopole length and the width of the ground plane. The secondary resonance at the lower frequency band is due to radiation from currents flowing in the ground plane. The broadband property of this antenna results from the overlap of the two resonances, and can be influenced by many parameters. The ceramic pellet acts as a load to the planar monopole, lowering its resonant frequency.

III. DESIGN OPTIMISATION

The dielectric pellet in the prototype antenna was a top-flatted half cylinder, whose section was rectangular in the x-y plane. According to the aim of this study, the dielectric pellet was modified to provide a wider bandwidth with a smaller volume. With the knowledge of the operating principle, removing two corners of the pellet and maintaining its length of can be one way to achieve the goal, and the section of the modified dielectric pellet is trapezoidal, as shown in Fig. 4.

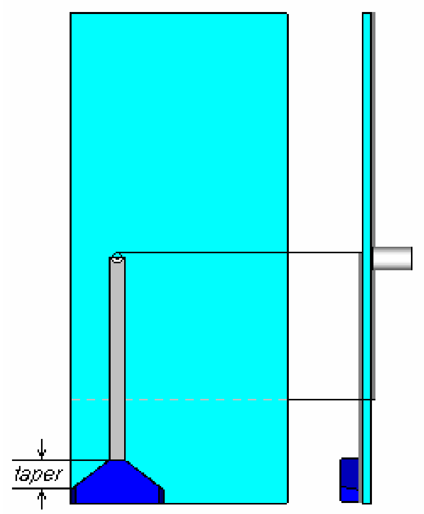


Fig. 4. Geometry of the trapezoidal pellet antenna

The parameter "*taper*" was swept from 1 to 7mm to find the best performance for the antenna. The return losses are plotted in Fig. 5.

Fig. 5. Return losses of the trapezoidal pellet antenna with different taper values

Fig. 5 shows that the resonance at 2.11GHz has been up-shifted to 2.4GHz at the expense of the loss of the bandwidth under 2GHz. However, the previous analysis of the operating principle illustrates that the secondary resonance at lower frequency band can be enhanced by reducing the ground plane length. Therefore, the structure was chosen with the ground plane length L_s 70mm, and *taper*=5mm.

As the load to the planar monopole, the permittivity of the dielectric affects the primary resonance depth without changing the resonant frequency. The return losses for different permittivity are summarised in Fig. 6.

Fig. 6. Return losses of the trapezoidal pellet antenna with different permittivity

Fig. 6 shows the return loss for permittivites of 20 and 50, and it may be seen that the antenna performs quite well at both high and low frequency bands. A permittivity of 20 is chosen as the final design. The return loss of the final design is compared with the prototype antenna in Fig. 7.

Fig. 7. Return losses of the optimisation and prototype designs

The bandwidth of the optimised antenna is 1.463GHz (from 1.59GHz to 3.053GHz), about 63%; and the volume of the ceramic pellet is 70.4% of that used for the prototype antenna.

Simulated radiation patterns of the optimised antenna are plotted in Fig. 8. They are similar to the prototype antenna, omni-directional in the H-plane.

(a) Radiation patterns at 1.8GHz

(b) Radiation patterns at 2.4GHz

Fig. 8. Simulated radiation patterns of the Optimised antenna

IV. CONCLUSIONS

A tri-band dielectric antenna operating at 1500 ~ 2200MHz for wireless application have been studied and optimised in this paper. Based on the knowledge of the effects of each design parameter, an optimised design has been obtained to provide an even wider bandwidth from 1.59 GHz to 3.053 GHz, with a ceramic pellet 70% of the size of the original. This size reduction lowers the cost as well as the weight of the antenna, both of which are important in commercial applications.

ACKNOWLEDGMENT

The authors would like to thank Mr. Scott Tyler of Antenova Ltd. and John Dupuy of the Department of Electronic Engineering, Queen Mary, University of London, for their help in the fabrication and measurement of the antennas. The authors would like to acknowledge Computer Simulation Technology (CST), Germany, for the complimentary license of the Microwave Studio^{TM} package.

REFERENCES

[1] R.K. MONGIA and P. BHARTIA, “Dielectric Resonator Antennas – A Review and General Design Relations for Resonant Frequency and Bandwidth”, *International Journal of Microwave and Millimetre- Wave Computer-Aided Engineering*, 1994, 4, (3), pp 230-247.

[2] K.M. Luk and K.W. Leung, “Dielectric resonator Antennas”, *Research Studies Press Ltd.*, 2003.

[3] J. Galejs, Dielectric loading of electric dipole antennas, J. Res. Nat. Bur. Standards, vol. 66D, pp. 557–562, Sept.–Oct. 1962.

[4] M. S. Smith, Properties of dielectrically loaded antennas, Proc. Inst. Elect. Eng., vol. 124, no. 10, pp. 837–839, Oct. 1977.

[5] T.J. Palmer, S. Wilson, S. Williams, S. Tyler and S.P. Kingsley, “An Electrically Small Dielectric Antenna with Wide Bandwidth”, *WO 2004/017461 A1, PCT/GB2003/003546*, 2004.

[6] Z.Wang, C.C.Chiau and X.Chen, “Study and Optimisation of a Broadband Dielectric Antenna”, *International Workshop on Antenna Technology: Small Antennas and Novel Metamaterials*, March 7-9, 2005.

[7] Computer Simulation Technology (CST), “User’s Manual 5”, in *CST-Microwave Studio*, 2003.