STUDY AND OPTIMISATION OF A BROADBAND DIELECTRIC ANTENNA

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ABSTRACT – This paper presents a study of a Broadband Dielectric Antenna performed through numerical modelling and experimental verification. Upon understanding of the operating principle of the prototype antenna, an optimised design has been demonstrated to provide an even wider impedance bandwidth.

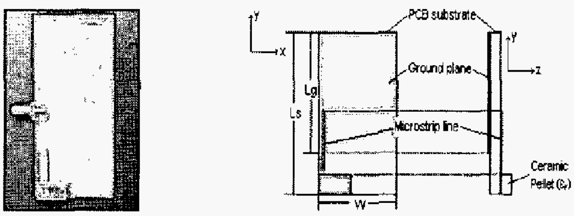
I. INTRODUCTION

Dielectric Resonator Antennas (DRAs) have been around since the 1980's; their radiation arises from a displacement current circulating through a dielectric medium [1][2]. DRAs utilising high-permittivity and low-loss ceramics offer advantages of high efficiency and resistance to proximity detuning. However, the impedance bandwidth of DRAs is usually narrow due to them naturally being resonators with high values of both loaded and unloaded Q.

Recently, significant research efforts have been put into expanding the bandwidth of DRAs by the research groups worldwide, including that at Antenova Ltd, UK. The company has noticed that removing the conducting ground plane underneath a dielectric resonator results in a considerable increase in its bandwidth, and they have developed from this a wideband antenna, which is known as the Broadband Dielectric Antenna [3] [4]. One design of the Broadband Dielectric Antenna has already been used in a commercial wireless modem. In this paper, the operating principle of this antenna was analysed through numerical simulation and experimental measurement. Subsequently, the design of the original antenna was optimised to cover an even wider frequency range, including the 2.4GHz WLAN band (the operating bandwidth of, the original antenna = 1.433 ~ 2.25GHz; the optimised antenna = 1.413 ~ 2.53GHz).

II. PROTOTYPE ANTENNA DESIGN AND SPECIFICATIONS

The prototype antenna designed and fabricated by Antenova Ltd consists of four layers: the ground plane, the substrate (PCB board), the microstrip feeding line and the ceramic pellet as shown in Fig. 1.



(a) (b)

Fig. 1 Prototype of the Broadband Dielectric Antenna. (a) Photo of the embodiment; (b) 3-D model for simulation.

The substrate size is 80mm(L_s) x 35mm(W), with permittivity 4.7 and thickness of 1.5mm, and the ground plane size is 62.7mm(L_g) x 35mm(W), leaving a blank beneath the ceramic pellet. The ceramic pellet is a top-flattened ceramic half-cylinder of permittivity around 90 with a metal coating on the bottom face. The ceramic pellet's length (DR_l), width

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(DR_w), and height (DR_h) are 15.6mm, 7.3mm and 3.5mm, respectively. A 50Ω-microstrip line having a width of 2.7mm is connected to the coaxial cable through an SMA connector. In the simulation, all components are modelled as being their true size, except the SMA connector, which is approximated by a discrete port, defined as a voltage gap.

III. STUDY OF THE PROTOTYPE ANTENNA

The prototype antenna was simulated using the CST Microwave Studio™ package which utilises the Finite Integration Technique (FIT). The prototype antenna was tested at both Antenova Ltd, UK and the Antenna Measurement Laboratory of Queen Mary, University of London (QMUL). The return loss was measured using an HP8720ES Network Analyser and the radiation patterns were measured in an anechoic chamber.

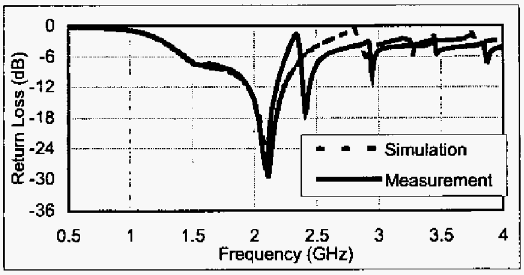
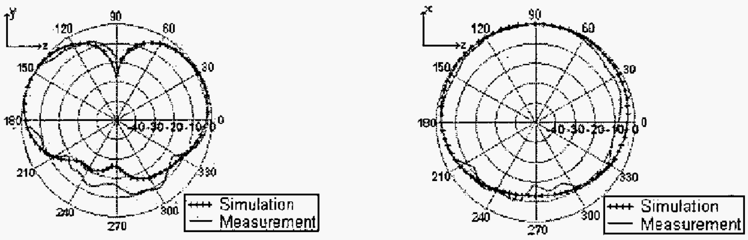


Fig. 2 Simulated and measured return losses for the prototype antenna.



(a) (b)

Fig. 3 Radiation patterns of the prototype antenna at 2.11 GHz. (a) E-plane; (b) H-plane.

Fig. 2 shows a very good agreement between the simulated and measured return losses and indicates that the main resonant frequency of the prototype antenna is 2.11GHz. The measured –6dB return-loss-bandwidth is 38.8% (i.e. from 1.433GHz to 2.25GHz). The slight discrepancies between the simulated and measured results at higher frequencies can be attributed to the discrete port used in the simulation model.

Fig.3 shows the radiation patterns obtained from the simulation and measurement, which agree with each other quite well.

Once the computer model of the antenna had been verified, we were ready to do further modelling to gain insights into the operation of the antenna. For a conventional DRA, the resonant frequency should be inversely proportional to the square root of the permittivity of the ceramic pellet, so the effect of the permittivity ε_r was examined first.

Fig. 4 shows that the permittivity of the ceramic pellet does not affect the resonance of the antenna significantly as it would for a conventional DRA. Even when $\varepsilon_r = 1$ (i.e. the antenna does not have a ceramic pellet on the top), the antenna is still operating around 2.11GHz. Therefore, it is suggested that the primary radiating component of this antenna is not the ceramic pellet, but the planar monopole (i.e. metal coating under the ceramic pellet and the associated microstrip feed line). Fig. 4 also shows that there is always a secondary resonance around 1.6 GHz. This resonant frequency is also unaffected by the changes in the permittivity of the ceramic pellet. However, with a high permittivity ceramic pellet, both the primary and secondary resonances are getting deeper and the bandwidth is increased.

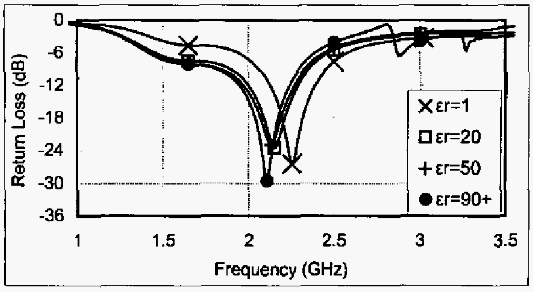


Fig. 4 Return losses for the antennas with different permittivity.

Next, the surface currents were examined (Fig. 5) in order to find the factors determining the two resonant frequencies.

(a) (b)

Fig. 5 Surface current distributions of the prototype antenna. (a) 2.11GHz; (b) 1.6GHz.

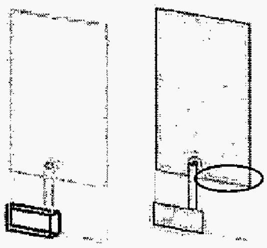
The surface current distributions of the prototype antenna show that the ground plane is also radiating, both from its length (L_g) and width (W). The ground plane width (W) is coupled to the planar monopole, contributing to the primary resonant frequency at 2.11GHz. The secondary resonance is attributed to the radiation from the length of the ground plane (L_g).

The simulation suggests that the prototype antenna is mainly radiating from the planar monopole that is coupled to the ground plane width (W). The ground plane length (L_g) radiates to provide the secondary resonant frequency, which overlaps with the primary resonant frequency to achieve a wider bandwidth. The ceramic pellet acts as a load to the planar monopole to lower the resonant frequency.

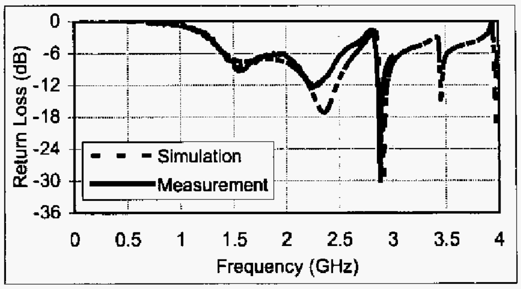
IV. OPTIMISATION OF THE DESIGN

Having had examined the operation of the prototype antenna, we were ready to improve the design to achieve even wider bandwidth. One optimised design to cover up to 2.4GHz (the WLAN frequency band) is shown in Fig. 6.

In this optimised antenna, the coaxial port feeding was modelled to reduce the discrepancies between the simulated and measured results, which were due to the discrete port feeding in the prototype antenna. As shown in Fig. 6 (a), the length of the ground plane (L_g) is kept the same as that of the prototype antenna, so the second resonant frequency remains at around 1.6GHz. By moving the microstrip line position from the side of the PCB board to the centre, the width of the radiating part of the ground plane (i.e. the part circled in Fig. 6(a)) is reduced, hence the upper frequency has been shifted upwards. This change results in an increase of the -6dB bandwidth from 38.8% to 49.8% (i.e. from 1.413GHz to 2.53GHz) as indicated by the measured return losses in Fig. 6(b). Moreover, in this design, the reduction of the volume of the ceramic pellet, i.e. *DR_w* being reduced from 7.3mm to 6.5mm, can reduce fabrication costs as well.



(a)



(b)

Fig. 6 (a) Optimised antenna structure (x_{min}=11mm, *DR_w*=6.5mm); (b) Return losses (S_{11}) for the optimised antenna.

V. CONCLUSION

The operation principle of the prototype Broadband Dielectric Antenna developed at Antenova Ltd, UK has been shown to be the overlap of two resonances; the primary resonance being determined by the planar monopole and the width of the ground plane, while the secondary resonance can be attributed to the length of the ground plane. It has also been shown that the design of the antenna can be further optimised by adjusting the position of feed line and reducing the ceramic pellet volume to achieve an even wider bandwidth extending upwards to cover the 2.4GHz WLAN frequency band.

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