

DESIGN AND OPTIMIZATION OF INTEGRATED DIELECTRIC RESONATOR ANTENNA FOR BLUETOOTH APPLICATIONS

Chee-Parng Chua¹, Alexander Popov² and Mook-Seng Leong¹

¹National University of Singapore
10 Kent Ridge Crescent, Singapore 119260
E-mail: g0202216@nus.edu.sg

²Institute of Microelectronics
11 Science Park Road, Singapore Science Park II, Singapore 117685
E-mail: popovp@ime.a-star.edu.sg

1. Abstract

By making use of a complementary pair of magnetic dipole and magnetic loop, a cylindrical dielectric resonator antenna has achieved wide impedance bandwidth of approximately 10%. Circular polarization can also be achieved by making use of a meandering magnetic dipole. The antenna is subsequently optimized using Ansoft High Frequency Structure Simulator (HFSS). Simulation results have shown the antenna having wide bandwidth, symmetrical radiation pattern and good polarization selectivity. Experimental results are currently in progress and will be presented at the conference.

2. Introduction

Dielectric resonator antennas (DRAs) are gaining popularity because of their various merits, which include high radiation efficiency, ease of implementing the feed and compactness. The motivation of this investigation is to propose an integrated dielectric resonator antenna for Bluetooth applications. Design of compact and fully integrated antennas is a major challenge in development of modern RF front end products for wireless communications. The conventional integrated patch antennas suffer from low efficiency, high sensitive fabrication tolerances, and narrow bandwidth. Another problem is that the antenna must operate with a finite “ground plane”, which has a great impact on the return loss and may have a low forward-backward ratio. To overcome these problems, a cylindrical dielectric resonator antenna is suggested in this paper. An approximate analysis of the fields inside the cylindrical dielectric resonator and its resonant frequency is carried out using the perfect magnetic wall model [1].

3. Proposed Antenna structure

A three-dimensional view of the proposed antenna is shown in Figure 1. Using feed design shown in Figure 2, a linearly polarized antenna is obtained. To achieve circular polarization, a meandering magnetic dipole is implemented (Figure 3). The potential advantages of using a DRA as compared to a conventional microstrip antenna, include its significantly higher radiation efficiency and broader impedance bandwidth. Moreover, small physical dimensions of the antenna can be achieved by using high permittivity ($\epsilon_r > 20$) ceramic material for the dielectric resonator whose physical dimension is proportional to λ_0/ϵ_r . To overcome the finite “ground plane” problem a feed structure comprising of a complementary pair of magnetic dipole and magnetic loop as suggested in [2], modified to exclude the ground plane and optimized for a wider bandwidth. The design parameters of the feed are chosen to allow a unidirectional radiation pattern away from the ground plane. So, the ground plane impact on the antenna parameters is significantly reduced allowing a compact design of the antenna system. The feed structure is etched on a 1mm thick FR4 substrate with metallizations on all sides. The purpose of having full metallizations is to prevent possible electromagnetic interference

from the antenna on the RF circuitry. A probe is then used to excite the feed structure beneath the dielectric resonator made of low loss ceramic material with permittivity of 20. The optimized dimensions of the resonator operating in the range of 2.5-2.7 GHz are: the height of 9mm and the radius of 11.8mm.

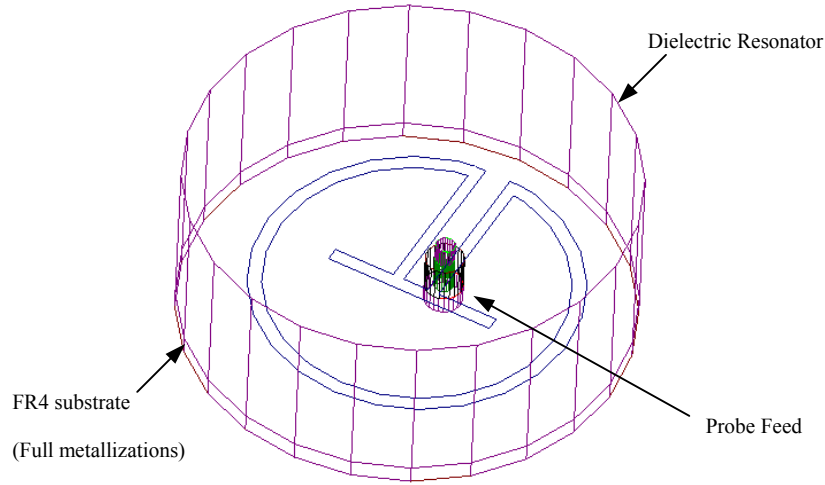


Fig.1: Three dimensional view of the proposed structure

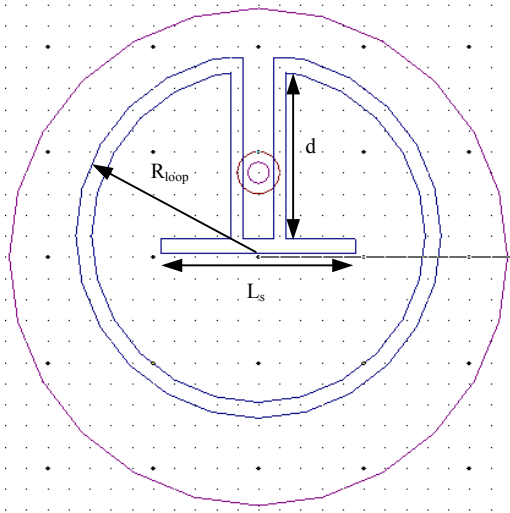


Fig. 2: Feed design for linear polarized (LP) antenna

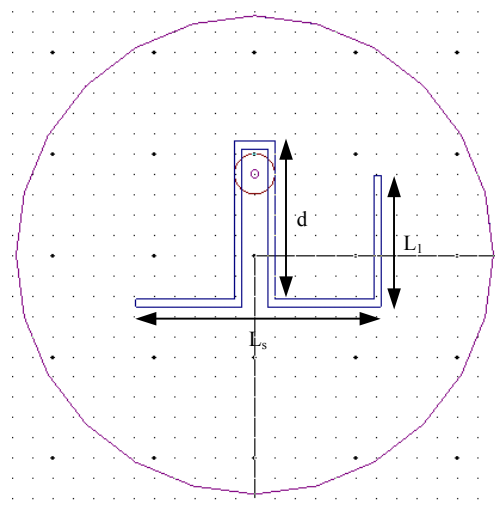


Fig. 3: Feed design for circular polarized (CP) antenna

4. Mode of excitation

Various modes can be excited depending on the type of feeding configurations employed. The lowest order modes [3] of a cylindrical resonator are $TE_{01\delta}$, $HE_{11\delta}$, $EH_{11\delta}$, $TM_{01\delta}$ and so on. Each of these modes corresponds to different radiation patterns and depending on applications, the modes can be excited. As it is desirable to design an antenna with the smallest dimension and having its main beam in the broadside direction, $HE_{11\delta}$ mode is the most suitable. The resonant frequency [1] of $HE_{11\delta}$ mode can be calculated using

$$f_o = \frac{3 \times 10^8}{2\pi\sqrt{\epsilon_r}} \sqrt{\left(\frac{1.841}{a}\right)^2 + \left(\frac{\pi}{h}\right)^2} \quad (1)$$

From equation (1), it can be seen that the resonant frequency of an isolated dielectric resonator is dependent on the resonator's relative permittivity ϵ_r , radius a and height h . A more accurate equation [3] to be used in this paper is given by

$$f_o = \frac{18.972 \times 10^8}{2\pi a \sqrt{\epsilon_r + 2}} \left(0.27 + 0.36 \frac{a}{h} + 0.02 \left(\frac{a}{h} \right)^2 \right) \quad (2)$$

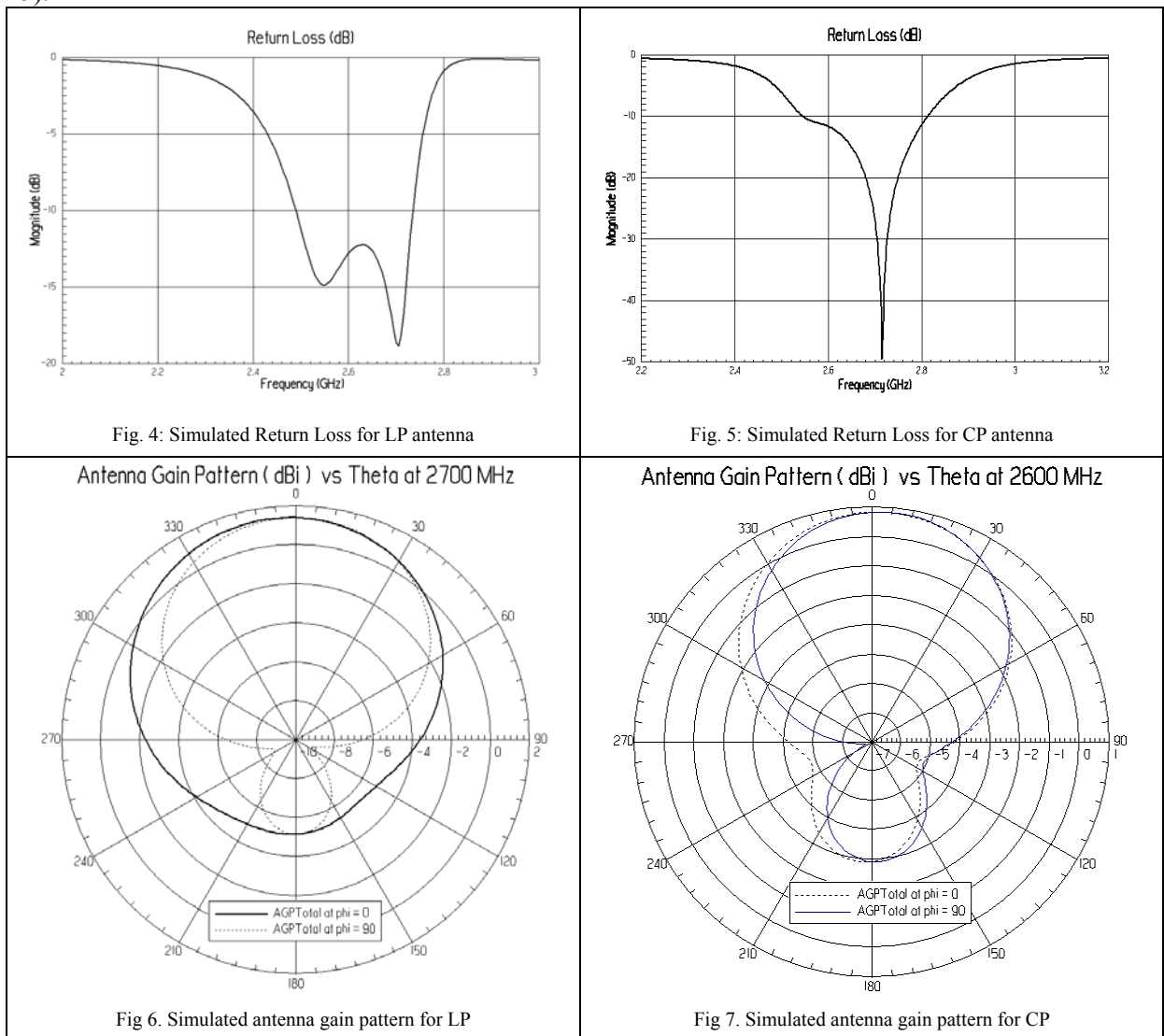
Using equations (1) and (2), resonant frequency of an isolated DR is calculated and tabulated in Table 1. It is desirable to tune the antenna to the natural frequency of an isolated dielectric resonator so that the DRA can function as an efficient radiator.

	S.A. Long [1]	R.K. Mongia [2]
Frequency (GHz)	2.499	2.807

Table 1: Comparison of resonant frequency calculated

5. Simulation Results

Subsequently, the above design is optimized using Ansoft HFSS. For the linearly polarized antenna, an impedance bandwidth of about 9% is achieved and it operates (return loss > 10dB) in the range of 2.49GHz – 2.74GHz (refer to Figure 4). As for the circularly polarized antenna, it has an impedance bandwidth of approximately 10%, operating in the range of 2.55GHz – 2.81GHz (Figure 5).



Using HFSS to further investigate the electric and magnetic fields within the dielectric resonator, it is observed to resemble the fields of a $HE_{11\delta}$ mode in an infinitely long dielectric waveguide. Far fields of the $HE_{11\delta}$ mode are identical to that of a magnetic dipole oriented along the transverse (horizontal) direction. This coincides well with the simulation results of the antenna's radiation pattern (E-Plane and H-Plane), which shows the main beam at bore-sight with gain of 1.4dB. Front-to-Back (F/B) ratio of the DRA is 6.5dB and has good polarization selectivity.

As for the circular polarized antenna, the antenna exhibits symmetrical radiation pattern (Figure 7) and has a gain of 0.8dB at broadside. The antenna has a F/B ratio of 4dB. A figure-of-merit for the CP antenna is to observe the antenna's axial ratio. From figure 8, it can be seen that the antenna's axial ratio is below 2 for the range of $-30^\circ \leq \theta \leq 30^\circ$.

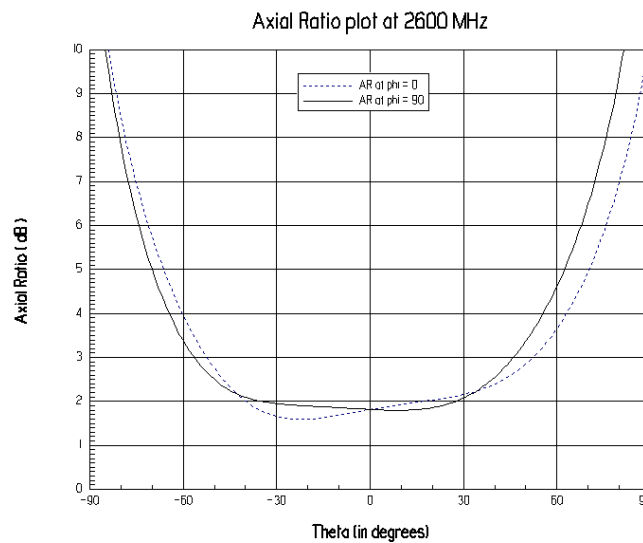


Fig.8 Axial ratio of the CP antenna

6. Conclusions

An integrated cylindrical dielectric resonator antenna has been studied using HFSS. Simulation results have shown the antenna exhibits wide impedance bandwidth of about 10% and has symmetrical radiation patterns for the E-Plane and H-Plane. Unlike conventional DRA [4] and microstrip antenna which required the presence of a ground plane, the antenna suggested in this paper makes use of a fully metallized substrate, resulting in a very compact “groundless” structure suitable for use as an integrated antenna.

7. References

- [1] S.A. Long, M.W. McAllister, and L.C. Shen, “The resonant cylindrical dielectric cavity antenna”, *IEEE Transactions on Antennas and Propagation*, vol. AP-31, no. 3, pp. 406-412, 1983.
- [2] A.P. Popov, and M.D. Rotaru, “A novel integrated dielectric resonator antenna for circular polarization”, *2003 Electronic Components and Technology Conference*, pp. 470-473.
- [3] R.K. Mongia, and P. Bhartia, “Dielectric resonator antennas – a review and general design relations for resonant and bandwidth”, *Intrenat'l Jour. Microwave and Millimeter-wave Computer-Aided Engineering*, vol. 4, no. 3, pp. 230-247, 1994.
- [4] M.T. Lee, K.M. Luk, K.W. Leung and M.K. Leung, “A small dielectric resonator antenna”, *IEEE Transactions on Antennas and Propagation*, vol.50, no. 10, pp. 1485-1487, Oct 2002.