Design and Analysis of a Novel Compact High Permittivity Dielectric Resonator Antenna

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Abstract — A very compact and efficient dielectric resonator antenna is proposed and investigated. The novel structure is analyzed using two numerical methods and design guidelines are established. Moreover, it is shown that – by using very high permittivity materials and appropriate design of the resonator and its feeding structure – a wide frequency coverage is possible even at cellular frequencies. Simulation results are reported showing the effectiveness of the proposed antenna structure.

I. INTRODUCTION

Dielectric Resonator Antennas (DRA) have been exploited in the past at high frequencies (gigahertz range) due to their particular advantages over their metal structure counterparts, such as high efficiency, small size and a simple feeding arrangement [1,2]. Because of these advantages, an implementation at cellular frequencies has been explored more recently. One of the main drawbacks of most of the reported designs, however, is the relatively large size of the resonator necessary to achieve an efficient antenna at these frequencies [3]. To obtain a reasonably sized antenna for such bands, a very high dielectric constant is required, which in turn may lead to an unacceptable reduction in bandwidth. The increase of the dielectric constant affects directly the quality factor (Q) of the resonator; in fact Q increases as $\varepsilon_r^{2/3}$ [4] which results in a very narrow band behavior. The Q of the antenna can be related to the unloaded Q of the resonant mode excited by the following expression:

$$Q = 4\pi f_0 \frac{StoredEnergy}{RadiatedPower} \propto 4\pi f_0 (\varepsilon_r)^p \left(\frac{Volume}{Surface}\right)^s . \quad (1)$$

where f_o is the resonant frequency and ε_r is the dielectric constant of the resonator, with $p>s\geq 1$. As can be seen from (1), increasing the dielectric constant improves the quality factor (which is a welcome result as far as the resonator is concerned) but reduces the bandwidth. It also follows from (1) that by minimizing the volume-to-surface ratio the quality factor can be decreased. This idea is exploited in this paper; it will be shown that by optimising the shape to minimise this ratio, combined with using a material with a high dielectric constant and designing appropriate feeding, a compact and wide-band DRA antenna for cellular frequencies is possible.

II. DESIGN AND MODELLING OF THE ANTENNA

As already mentioned, a high dielectric constant material has been used and in consistence with other studies the values between 80 and 100 have been tried. The minimization of the volume surface ration has been accomplished by using a resonator with one of its dimensions considerably smaller than the others. The starting point was a cylindrical resonator with a very small thickness (coin shape). The initial dimensions of the resonator were: diameter D=28mm and thickness t=2mm. The approximate resonant frequency for this resonator with ε_r=80 may be obtained from a model where the outer surfaces of the cavity are approximated by magnetic walls [1, 5] . For the lowest resonant mode, which is a $TE_{01\delta}$, the resonant frequency may be calculated using the following formula:

$$f_{approx} = \frac{78}{D\sqrt{\varepsilon_r}}\left(\frac{D}{2t} + 3.45\right). \quad (2)$$

Coupling the TE mode into this resonator using a simple and easy to implement feed (such as a microstrip line) is unfortunately not straightforward. The resonator has to be positioned in a transverse direction (relative to the microstrip feed) and even then the coupling is poor. A simpler and much more efficient solution has been found to solve this problem. The coin shape resonator is slightly modified into a “C” shape (see Figure 1) resulting in a flat face that can be easily mounted on top of a microstrip feed. The resultant structure has a very wide bandwidth (approximately 500Mhz) due to the two close resonant modes. Moreover, the bandwidth can be adjusted by choosing an appropriate length of the open stub at the end of the microstrip feed.

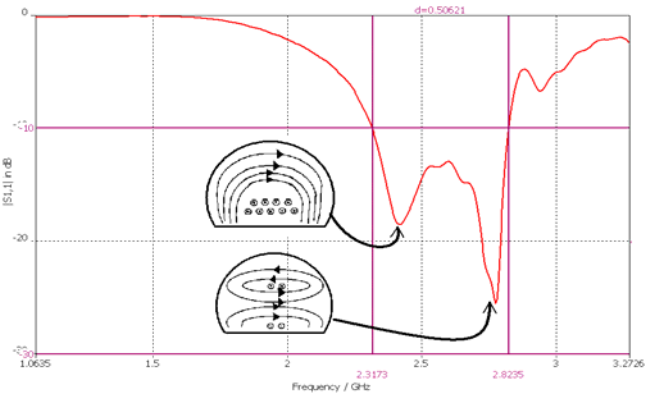

Fig. 1. Simulated S11 for the thin “C” resonator shaped antenna.

III. 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. 31, pp. 406-412, May 1983.

[2] K. W. Leung, K. Y. Chow, K. M. Luk and E. K. N. Yung, “Low-profile-circular disk DR antenna of very high permittivity excited by a micro-stripline,” *Electron. Lett.*, vol. 33, No. 12, pp. 1004-1005, June 1997.

[3] S. Brebels, J. Ryckaert, B. Come, S. Donnay, W. De Raedt, E. Beyne, and R. P. Mertens, “SOP integration and codesign of antennas,” *IEEE Trans. on Advanced Packaging,*,vol. 27, No. 2, pp. 341-351, May 2004.

[4] R. K. Mongia et al, “Theoretical and experimental investigation of rectangular dielectric resonator antennas,” *IEEE Transactions on Antennas and Propagation*, vol. 45, no. 9, pp. 1348-1356, 1997.

[5] R. K. Mongia, and P. H. Bhartia, “Dielectric resonator antennas – A review and general design relations for resonant frequency and bandwidth,” *Int. J. Microwave Millimetre-Wave Computed Aided Eng.*, vol. 4, no. 3, pp. 230-247, 1994.

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