A Half-Split Cylindrical Dielectric Resonator Antenna Using Slot-Coupling

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Abstract—**A half-split cylindrical dielectric resonator placed on a metallic plane and excited in its "magnetic dipole" mode is a potentially useful antenna element. The use of a microstrip line-slot feed scheme for exciting this antenna is reported. Experimental results show that the antenna displays the anticipated radiation pattern and it has a high operating frequency bandwidth (about 10%). Further, the overall antenna configuration can be easily integrated with MIC's.**

I. Introduction

A DIELECTRIC resonator placed in an open environment can exhibit low values of radiation Q-factor, and is therefore useful as a resonant antenna. Dielectric resonator antennas offer advantages such as small size, no conductor loss and mechanical simplicity. An important property of open dielectric resonators is that their radiation Q-factor depends strongly on the permittivity of the resonator and it decreases with a decrease in the permittivity. Since the operating frequency bandwidth of a resonant antenna is inversely proportional to the value of radiation Q-factor, a relatively large value of operating frequency bandwidth can be obtained by fabricating the resonator out of a suitably low dielectric constant material.

The lowest order modes of a cylindrical resonator are $TE_{01\delta}$, $HE_{11\delta}$, $EH_{11\delta}$, $TM_{01\delta}$, $TE_{011+\delta}$ etc. [1]. The $TE_{01\delta}$, $TM_{01\delta}$, $TE_{011+\delta}$ modes of an isolated cylindrical resonator radiate like a magnetic dipole, electric dipole and a magnetic quadrupole respectively. The $HE_{11\delta}$ and $EH_{11\delta}$ modes are hybrid modes and do not radiate like single pole terms. All the modes referred to above have different radiation patterns. Therefore, different modes may be suitable for different applications. A probe fed cylindrical DR antenna placed on a metallic plane and excited in its $HE_{11\delta}$ mode was the first DR antenna configuration reported in the literature [2]. A microstrip line-slot feed for exciting the same antenna structure was later reported [3]. A different antenna configuration in which a half-split DR is placed on a metallic plane and is excited in its magnetic dipole $TE_{01\delta}$ mode using a probe has also been reported [4]. In this latter configuration, the half-split dielectric resonator and its image in the metal plane combine to radiate like an isolated resonator of double the size. The radiation Q-factor for this configuration is the same as that of an isolated dielectric resonator and is considerably low if the resonator material used has a relatively small value of the dielectric constant. This antenna configuration provides some interesting features. It has a high operating frequency bandwidth. Further, in this configuration, the structure radiates strongly along the surface of the metallic plane on which it is kept. This may be of interest in some applications, for example where a low elevation angle radiation is required.

In this letter, we describe a new antenna configuration that uses a microstrip line-slot feed scheme for exciting the half-split DR antenna structure. The feed scheme readily allows for the excitation of the "magnetic dipole" mode of the resonator. The antenna is very easy to construct and the feed scheme employed makes the antenna structure compatible with MIC's and enhances its practical usefulness.

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II. Antenna Structure

Fig. 1 shows the DR antenna configuration along with the feed scheme employed. The DR is placed on the top side of a dielectric substrate. The top side of the substrate is metal coated. This metal surface also acts as the ground plane for the microstrip line which is etched on the other side of the substrate. The transverse slot in the metallic ground plane provides the coupling between the microstrip line and the "magnetic dipole" ($TE_{01\delta}$) mode of the dielectric resonator. In this mode, the nonzero field components inside the resonator are H_z, H_r, and E_ϕ and the resonator radiates like a horizontal magnetic dipole oriented along the z-direction. The microstripline is terminated in an "open circuit." The incident field in the microstrip line excites a magnetic dipole in the slot directed along the longer side of the slot. The DR is placed above the slot and is located symmetrically with respect to the slot. The length L of the slot and the distance S between the microstrip line end and the slot were experimentally adjusted to obtain optimum coupling.

The resonator material chosen had a dielectric constant of 10.8. The dimensions of the resonator were chosen as: diameter (2a) = 15 mm and thickness d = 3 mm. For these parameters, the resonant frequency of the $TE_{01\delta}$ mode was found to be 8.04 GHz which is based on calculations using closed form expressions given in [5].

III. Results

In Fig. 2, the return loss at the input of the microstrip

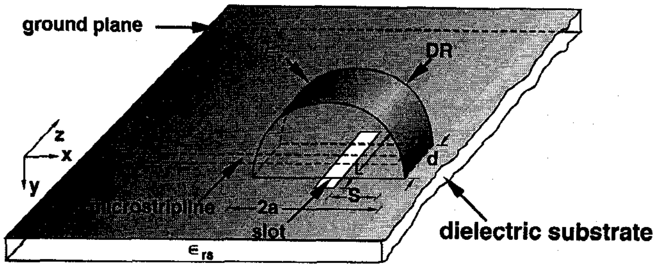

Fig. 1. Half-split dielectric resonator antenna with the slot coupling feed mechanism. $\varepsilon_r = 10.8$, $\varepsilon_{rs} = 10.2, d = 3$ mm, resonator radius $a = 7.5$ mm, slot length, $L = 6.12$ mm, slot width = 1.22 mm, and $S = 2.2$ mm.

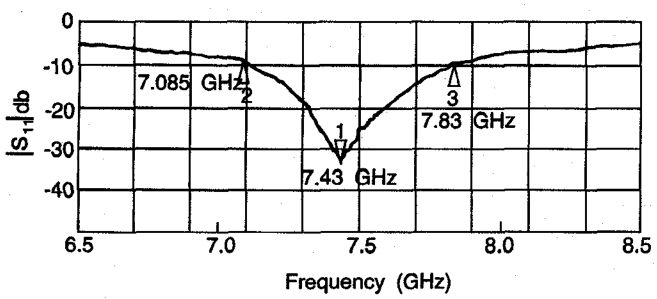

Fig. 2. Return loss with the same parameters as in Fig. 1.

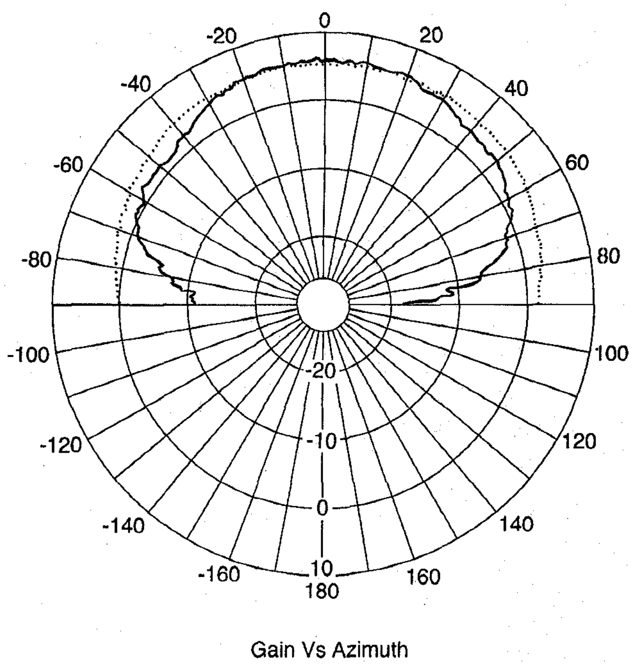

Fig. 3. Measured radiation pattern of the antenna with the same parameters as in Fig. 1 and at the resonance frequency, - - - - xy plane or vertical pattern, and ——— xz plane or horizontal pattern.

line is shown. It is seen that the resonant frequency (the frequency at which the return loss is minimum) is quite close to the theoretically predicted value. However, an important observation to make in Fig. 2 is to be the relatively large frequency bandwidth. The return loss is less than –10 dB over a frequency bandwidth of about 10% . This value is much higher than that possible using a basic microstrip patch antenna. It may be remarked that this frequency bandwidth can be further increased by choosing a lower value of dielectric constant. The radiation Q-factor of the $TE_{01\delta}$ mode varies approximately as $(\varepsilon_r)^{3/2}$ where ε_r denotes the dielectric constant of the resonator [1, ch. 5]. However, it has to be noticed that the value of ε_r cannot be chosen as very small, otherwise the radiation Q-factor may also become too small that will adversely affect the amplitude of fields for the resonant mode, and therefore the radiation characteristics. The bandwidth can also be increased by choosing a lower value of aspect ratio $(d/2a)$ of the resonator. No further attempts were tried in optimizing the bandwidth or other antenna parameters at this stage.

To confirm that the resonance observed was due to the dielectric resonator and not because of the slot, the return loss of the antenna was measured for three different values of slots with lengths (L) equal to 4.5 mm, 5.0 mm, and 6.12 mm, respectively. In all three cases, the resonance frequency observed was close to 7.4 GHz, which shows that the resonance was not due to the slot. The return loss was observed to be lowest when the slot length used was 6.12 mm.

The radiation patterns were measured both in the horizontal (xz) plane and in the vertical (xy) plane passing through the resonator. The measured results are shown in Fig. 3. As expected, the radiation patterns are similar to those due to a magnetic dipole oriented along the z-direction. It can be seen from the pattern that the antenna radiates along the surface of the ground plane with the radiation being maximum along the direction perpendicular to the direction of induced magnetic dipole moment. This feature represents the advantage of this antenna over other forms of antennas e.g., microstrip patch antennas and it could be useful in applications where low elevation angle radiation is required. Some ripples are also observed in the radiated fields. These are probably due to the finite size of the metallic plane on which the resonator is kept.

IV. Conclusion

The new antenna configuration described here, which comprises a microstrip line-slot feed scheme for exciting the "magnetic dipole" mode of a half-split DR antenna shows good performance. A 10%-frequency bandwidth has been obtained. The measured results for the radiated fields show the anticipated characteristics for this type of antenna and make the antenna attractive for certain applications. Furthermore, this antenna configuration is very easy to construct and is suitable for integration with MIC's.

References

[1] D. Kajfez and P. Guillon, Eds., *Dielectric Resonators*. Norwood, MA: Artech House, 1986.

[2] S. A. Long, M. Mc Allister, and L. C. Shen, " The resonant cylindrical dielectric cavity antenna," *IEEE Trans. Antenna Propagat.*, vol. AP-31, pp. 406–412, 1983.

[3] J. T. H. St-Martin, Y. M. M. Antar, A. A. Kishk, A. Ittipiboon, and M. Cuhaci, "Dielectric resonator antenna using aperture coupling," *Electron. Lett.*, vol. 26, pp. 2015–2016, Nov. 1990.

[4] R. K. Mongia, "Half-split dielectric resonator placed on metallic plane for antenna applications," *Electron. Lett.*, vol. 25, pp. 462–464, Mar. 1989.

[5] R. K. Mongia and B. Bhat, "Simple equations quickly design cylindrical DR's," *Microwaves & RF*, vol. 26, pp. 121–128, Sept. 1987.