Mutual Coupling Reduction in a Multi-mode Multi-function Dielectric Resonator Antenna

Longfang Zou, Christophe Fumeaux
School of Electrical and Electronic Engineering, The University of Adelaide
Adelaide, South Australia, Australia
lfzou@eleceng.adelaide.edu.au, cfumeaux@eleceng.adelaide.edu.au

***Abstract*—In a rectangular dielectric resonator, the mutual coupling between TE_{111} and Quasi-TM_{111} mode is in theory zero due to the orthogonal field distributions. In practice, some coupling is observed in a two ports dielectric resonator antenna (DRA) design based on those two modes. The mutual coupling can be explained by the asymmetric field distribution resulting from asymmetric feeding methods. Through analysis of the field distribution, two different methods are proposed to reduce mutual coupling to less than -15 dB. The first method considers an asymmetric resonator, whereas the second one symmetrizes the feeding. Designs with both methods are presented and their advantages and weaknesses are discussed.**

I. Introduction

Dielectric resonator antennas (DRAs) are considered as an alternative choice to conventional metallic antenna due to their large radiation bandwidth, high radiation efficiency and flexibility in their shape and feeding mechanism [1]. Furthermore, various modes with diverse characteristics can be excited within a dielectric resonator (DR) volume, which creates the possibility of multiband, multifunction or diversity operation within one single antenna. For example, a dual band rectangular DRA has been designed by using fundamental and higher-order modes [2]. Hady et al. [3] proposed a dual-band antenna for GPS and WLAN applications by using a single cylindrical DR. In [4], we presented a cross-shaped DRA with broadside circularly polarized and omnidirectional vertically polarized radiation patterns operating at the same frequency. This design can act both as multifunction or diversity antenna.

This paper presents a detailed investigation of mutual coupling reduction between two modes excited in a rectangular DR. Ideally, the coupling between pure modes is zero due to the mode orthogonality in the DR. However, the orthogonal field distribution can be disturbed by an asymmetric feeding network, which can cause significant inter-port coupling. Through analysis of the field distribution, the issue can be solved by using either an asymmetric antenna geometry to compensate the effect, or by symmetrizing the feeding network.

II. Mutual Coupling Analysis

The antenna consists of a cross-shaped DR (ε_r = 50) mounted on a Rogers RO4000® substrate (with relative permittivity of 2.5, thickness of 1.524 mm) (Fig. 1, left-hand side). The cross-shaped DR is composed of two identical rectangular dielectric slabs and the interaction between these two slabs can be neglected. So, only the field distribution in one rectangular slab is considered in this paper. The modes to be excited for broadside and omnidirectional radiation pattern are the TE_{111} and Quasi-TM_{111} mode, respectively, as shown in Fig. 1. A microstrip line (Port 1) can be used to excite the TE_{111} mode from the DR side and the quasi-TM_{111} mode can be excited by a center probe (Port 2). The center of the DR is often notched to hold the probe, as visible in Fig. 2. The size of the DR is calculated based on the rectangular waveguide model [5]. The DR size, probe radius, notch height and length are optimized in Ansoft® HFSS to make these two modes resonant at the same frequency of 4.5 GHz. The final DR has height of 13 mm, length 20 mm, width 1 mm, notch length 8 mm, notch height 3 mm and probe radius 1.5 mm.

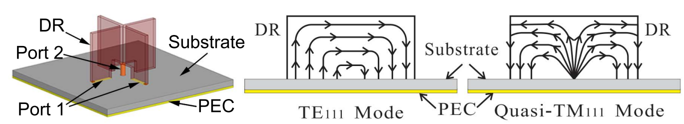

Fig. 1. TE_{111} and Quasi-TM_{111} mode in rectangular DR.

In theory, the mutual coupling between the orthogonal TE_{111} and Quasi-TM_{111} modes is zero. However, the symmetric field distribution is disturbed when a microstrip line is used to excite TE_{111} from one side. Fig. 2 (a) and (b) illustrate the simulated field distribution while exciting one port and terminating the other port with a matched load. It can be observed that the both TE_{111} and Quasi-TM_{111} mode are significantly disturbed due to the existence of the feeding microstrip line underneath the resonator. The asymmetric field distribution is the source of mutual coupling between the two ports. For the present case, as shown in Fig. 3, the simulated coupling coefficient is higher than -15 dB in the band of operation, which is not acceptable in diversity systems.

III. Mutual Coupling Reduction

Due to the effect of the microstrip feeding line, the magnitude of the E-field located in the left side is larger than that in the right side. Therefore, an asymmetric structure

978-1-4673-0462-7/12/$31.00 ©2012 IEEE

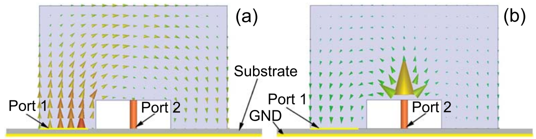

Fig. 2. Simulated TE_{111} and Quasi-TM_{111} mode in rectangular DR using one side feeding. (a). Excited from Port 1; (b) Excited from Port 2.

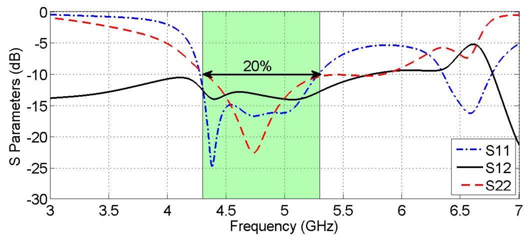

Fig. 3. Simulated S parameters of rectangular DR using one side feeding.

is introduced to compensate this imbalance by increasing the DR volume on the left side and conversely decrease it on the right side. A parallelogrammatic DR is used to validate this concept. Fig. 4 sketches the simulated TE_{111} and Quasi-TM_{111} field distribution in the parallelogrammatic DR. Through the optimization of the angular parameter α, mutual coupling between the two ports is reduced to below -15 dB, which is generally accepted for practical applications. This is achieved at the cost of slight decrease in the common impedance bandwidth of port 1 and 2, as shown in Fig. 5.

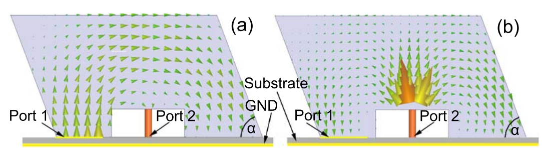

Fig. 4. Simulated TE_{111} and Quasi-TM_{111} mode in parallelogrammatic DR using one side feeding. (a). Excited from Port 1; (b) Excited from Port 2.

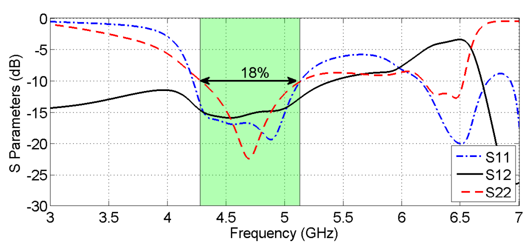

Fig. 5. Simulated S parameters of parallelogrammatic DR using one side feeding.

Since the asymmetric field distribution results from the asymmetric feeding, a symmetric feeding method is proposed next to reduce its impact on the ideal field distribution, as shown in Fig. 6. The rectangular DR is excited by two microstrip lines located on each side and driven with 180 degree phase difference. With these symmetric feeding lines, both TE_{111} and Quasi-TM_{111} field are symmetrically distributed and mutual coupling is reduced to less than -25 dB in the operation band, as shown in Fig. 7. The negative effect is the reduction of overlapping impedance bandwidth of port 1 and 2. This symmetric feeding method has been successively applied in a dual function DRA design and validated experimentally in [4].

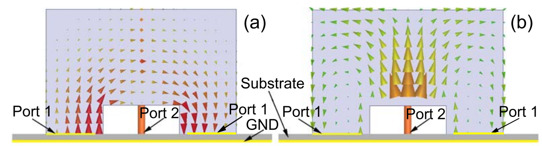

Fig. 6. Simulated TE_{111} and Quasi-TM_{111} mode in rectangular DR using two-side feeding. (a). Excited from Port 1; (b) Excited from Port 2.

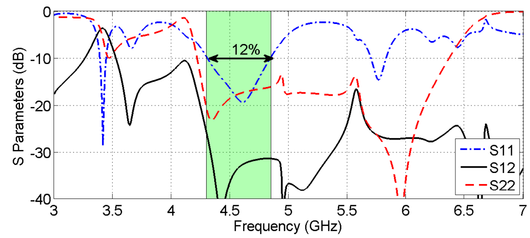

Fig. 7. Simulated S parameters of rectangular DR using two side feeding.

IV. Conclusion

An asymmetric feeding disturbs both TE_{111} and Quasi-TM_{111} field distribution in a DR. The asymmetric field distribution increases mutual coupling between modes and consequently decrease antenna performance. The asymmetric field distribution can be corrected by using either an asymmetric DR structure or a symmetric feeding method. Using either of these two methods, the coupling coefficient can be reduced to less than -15 dB.

Acknowledgement

C. Fumeaux acknowledges the support of the Australian Research Council (ARC) Future Fellowship funding scheme (under FT100100585).

References

[1] A. Petosa and A. Ittipiboon, "Dielectric resonator antennas: A historical review and the current state of the art," *IEEE Antennas Propag. Mag.*, vol. 52, no. 5, pp. 91–116, Oct. 2010.

[2] X. S. Fang and K. W. Leung, "Designs of single-, dual-, wide-band rectangular dielectric resonator antennas," *IEEE Trans. Antennas Propag.*, vol. 59, no. 6, pp. 2409 –2414, Jun. 2011.

[3] L. K. Hady, A. A. Kishk, and D. Kajfez, "Dual-band compact DRA with circular and monopole-like linear polarizations as a concept for GPS and WLAN applications," *IEEE Trans. Antennas Propag.*, vol. 57, no. 9, pp. 2591–2598, 2009.

[4] L. Zou and C. Fumeaux, "A cross-shaped dielectric resonator antenna for multifunction and polarization diversity applications," *IEEE Antennas Wireless Propag. Lett.*, vol. 10, pp. 742 –745, Jul. 2011.

[5] 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 Millimeter-wave Computer-aided Engineering*, vol. 4, no. 3, pp. 230–247, 1994.