INVESTIGATION OF RECTANGULAR DIELECTRIC RESONATOR ANTENNAS FOR SWITCHING POLARISATION DIVERSITY COMMUNICATION SYSTEMS

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ABSTRACT

In this paper a new application of a Rectangular Dielectric Resonator Antenna (RDRA) is presented. The experimental and simulation results of the RDRA show that the difference between the co- and cross-polar radiation is at least 15dB. Using a single RDRA exciting by two probes at two modes TE^{x}_{111} and TE^{y}_{111}, an antenna to receive two orthogonal polarisation waves is made. A communication system including a transmitter with two orthogonal dipoles and correspondence switching polarisation diversity receiver at 2.36 GHz was designed and implemented to demonstrate polarisation diversity using RDRA as the receiver antenna.

INTRODUCTION

Dielectric Resonators (DRs) made of low-loss and high relative dielectric constant have been extensively studied in the past decades for designing miniaturised microwave components and devices, which have been well used in microwave circuits such as filters and oscillators. On the other hand, the use of DRs for antenna application received less attention even though the first study of dielectric resonator antennas (DRAs) was made in 1983 [1]. However, in recent years DRAs have received increased interest and a significant amount of research activities have been reported [2-6].

DRAs can be in a few geometries including cylindrical, rectangular, spherical, half-split cylindrical and hemispherical shaped. Among them, rectangular DRA are attractive for easier fabrication. Their radiation characteristics such as resonance frequency, patterns and bandwidth could also be more conveniently adjusted by tuning the two aspect ratios. Simulations and experimental studies of RDRAs have been reported in the literature [7,9].

In this paper, the study of the use of a RDRA for switching polarisation diversity is presented, which includes the design and implementation of a dual polarised RDRA, a transmitter with two dipole antennas for transmitting waves of orthogonal polarisation and a receiver for diversity reception at 2.36 GHz.

Probe-fed Rectangular Dielectric Resonator Antenna

Figure 1 shows the structure of a single probe-fed RDRA. The DR with dimensions a=b=18mm, h=9mm and ε_r=37 is placed at the centre of a circular ground plane of a diameter d=10cm with an operation frequency of 2.36GHz. The rectangular DR is excited by a small probe located at x=a/2, ϕ=0° at the fundamental mode of the DR TE^{y}_{111} [8].

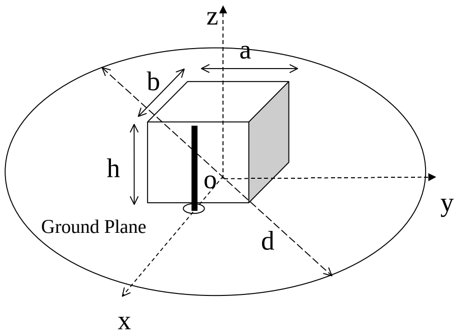

Figure 1: Single probe-fed rectangular dielectric resonator antenna excited by a probe located along x-axis.

The simulated co- and cross-polarised radiation patterns of the RDRA for the E- and H-plane using HP-HFSS [10] are shown in Figure 3 and the measured radiation patterns are shown in Figure 4. It can be seen that the RDRA antenna excited by a probe on *x*-axis radiates as predominantly a x-polarised wave in *xy*-plane, but with an orthogonal or cross polarisation which is along *y*-direction, with a cross polarisation level [11] at least 15 dB.

Hence, when two probes are used to feed the RDRA as shown in Figure 2 with probes located at x=a/2, ϕ=0° and y=a/2, ϕ=90°, a dual polarised RDRA is obtained, with polarisation in x- and y-direction. When this RDRA is used as a receiver antenna, each polarisation can be selected using a switching circuit, thus provided polarisation diversity. The return loss at each selected probe including the effect of the switch is shown in Figure 5 against frequency. The antenna is well matched at 2.36 GHz for both polarisations.

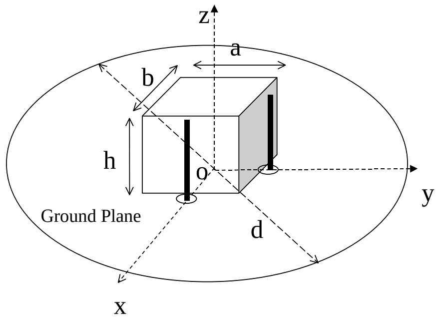

Figure 2: Rectangular dielectric resonator antenna fed using two probes along x and y-axis for polarisation diversity.

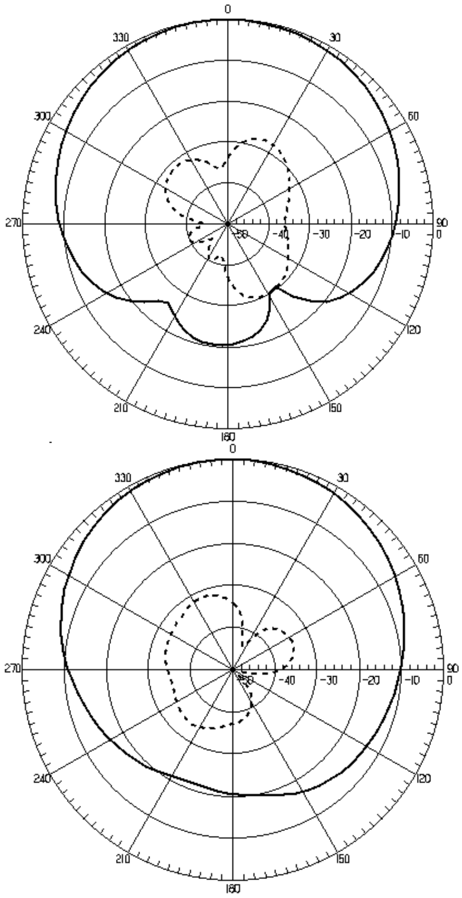

Figure 3: The simulated co- and cross-polarised radiation patterns of the RDRA at 2.36 GHz in dB scale. (——— co-polar patterns, - - - - - - cross-polar patterns).

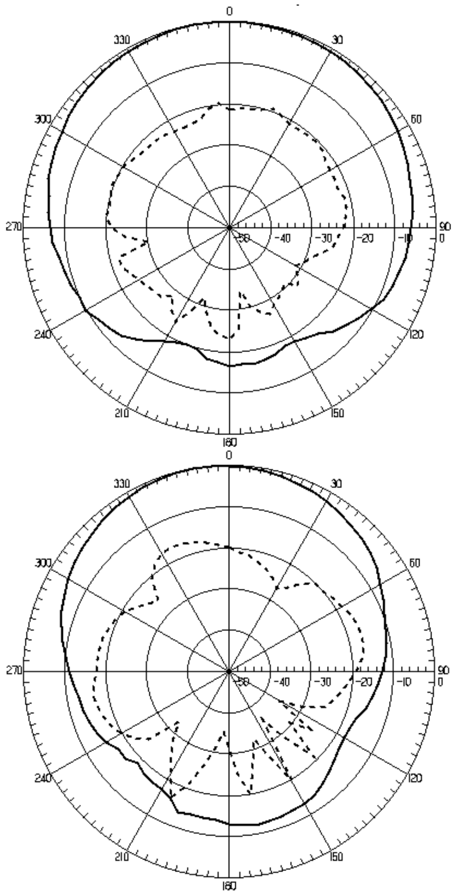

Figure 4: The measured co- and cross-polarised radiation patterns of the RDRA at 2.36GHz in dB scale. (——— co-polar patterns, - - - - - - cross-polar pattrns).

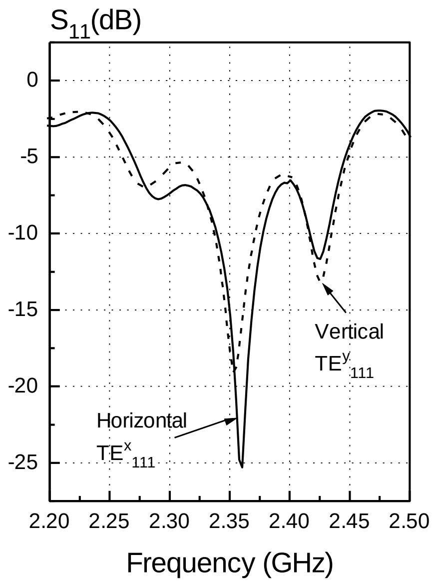

Figure 5. The measured reflection coefficient of the RDRA for two modes TE^{x}_{111} and TE^{y}_{111}.

The transmitter and Switching Polarisation Diversity Receiver

Figure 6(a) and (b) show the schematic diagram of the transmitter and switching polarisation diversity receiver operating at 2.36GHz. The frequency of the signal source in the transmitter can be adjusted between 2.0 and 2.5GHz. The polarisation of the wave radiated by two orthogonal dipoles in the transmitter is controlled manually using a SPDT microwave switch.

At the receiver, the outputs of the dual polarised RDRA are connected to another SPDT microwave switch. The switch is further controlled by the level of the carrier detected at the output of the RF detector. A low noise amplifier is used to amplify the received signal of the selected polarisation. A mixer and a local oscillator are used to down-converted the signal with an IF frequency around 100 MHz. After amplification the level of the IF signal detected by a RF detector. The detected DC signal is proportional to the amplitude of the carrier. This is compared with a pre-set reference voltage. If the DC level is less than the reference value, the switch will then be activated through a digital controller. Hence, a reception with a satisfactory level takes place.

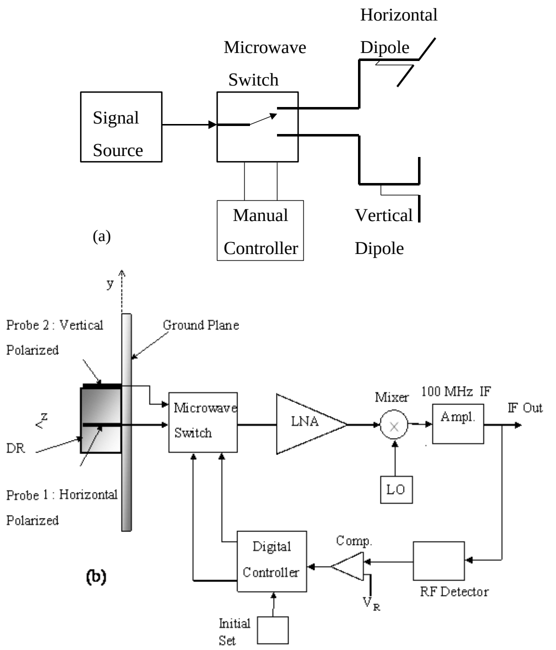

Figure 6. The diversity polarisation communication system a) transmitter, b) receiver

Table 1 shows the levels of the output of Mixer at IF and RF detector when the transmitting and receiving antennas are separated by a distance of 2m, and the dipoles are switched to produce either horizontally or vertically polarised waves, which corresponds to TE^{x}_{111} and TE^{y}_{111} modes of the RDRA respectively during testing. The co- and cross-polar outputs are significantly different. The polarisation diversity can be automatically realised when the reference V_R is set to 1V, which has been experimentally demonstrated.

Discussion and Conclusion

In this paper a new application of the RDRA has been described. A single RDRA has been shown to be able to receive orthogonal polarised waves for polarisation diversity. Simulation and experimental results show that the difference between co- and cross-polar radiation is at least 20dB. The polarisation diversity using the RDRA has been demonstrated with a transmitter capable of transmitting two orthogonally polarised waves and a receiver for signal amplification and switching control. For simplicity, the receiver has been designed to make use of a reference voltage for switching control. This would however can be improved by using two channels, one corresponding to each polarisation, and making an amplitude comparison of these two channels for switching control.

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References

1. M. W. McAllister, S. A. Long and G. L. Conway, " The Resonant Cylindrical Dielectric Cavity Antenna", IEEE Trans. Antenna & Propagation, Vol. AP-31, No.3 1983, pp- 406-412.

2. M. W. McAllister, S. A. Long And G. L. Conway, "Rectangular dielectric resonator antenna", Electronics Letters, Vol. 19, 1983, pp. 218-219.

3. G. Drossos, Z. Wu, and L.E. Davis, "Cylindrical dielectric resonator antennas: theoretical modelling and experiments", Microwave & Communication Technologies Conference (M&RF'97), Wembley Conference Centre, London, UK, pp. 34-39.

4. R. K.Mongia, and P. Bhartia "Dielectric resonator antenna - A Review and general design relations to resonant frequency and bandwidth", International Journal of Microwave and Millimetre-Wave Computer Aided Engineering, Vol. 4,1994, pp. 230-247.

5. R. K Mongia, "Theoretical and experimental resonance frequencies of rectangular dielectric resonators", IEE Proce.-H Vol. 139, 1992, pp. 98-104.

6. Petosa, A. Ittipiboon, Y. M. M. Antar, D. Roscoe and M. Cuhaci, " Recent advances in dielectric resonator antenna technology", IEEE Transaction on Antenna and Propagation Magazine, Vol. 40, 1998, pp. 35-48.

7. M. G. Keller, D.J Roscoe, M. B. Oliver, Mongia R. K., Y. M. M. Antar, and A. Ittipiboon, "Active Aperture-Coupled Rectangular Dielectric Resonator Antenna", IEEE Microwave & Guide Wave Letters, Vol. 5, 1995, pp. 376-378.

8. R. K. Mongia, and A. Ittipiboon, "Theoretical and experimental investigations on rectangular dielectric resonator Antennas", IEEE Transaction on Antenna and Propagation, Vol. AP-45, 1997, pp. 1348-1356.

9. M. H. Neshati and Z. Wu, "Theoretical and experimental investigation of probe-fed rectangular dielectric resonator antennas", Presented by poster at Millennium Conference on Antennas & Propagation, AP2000, Davos, Switzerland, 2000, published on CD-ROM, SP-444.

10. Hewlett-Packard, "HP85180A High Frequency Structure Simulator. User's Reference", 1994.

11. H. F. Lee and W. Chen, "Advances in Microstrip and Printed Antennas", John Wiley & Sons, 1997.

Table 1: The measured value of signals at the output of down converter and RF detector for different matched modes between transmitter and receiver.

Parameter	Horizontal Dipole Radiation		Vertical Dipole Radiation	
	TE^{x}_{111} mode	TE^{y}_{111} mode	TE^{x}_{111} mode	TE^{y}_{111} mode
Mixer out at IF (dBm)	-18.75	-26.5	-19.25	-5.45
RF Detector (V)	2.25	0.35	2.15	0.45