Compact Polarization Diversity Dielectric Resonator Antenna Array for WLAN Application

Yuan Gao [1 2], # Ban-Leong Ooi [1], Alexandre P. Popov [1]
[1] *Department of Electrical and Computer Engineering, National University of Singapore*
10 Kent Ridge Crescent, Singapore, 119620, eleooibl@nus.edu.sg
[2] *Institute of Microelectronics, 11 Science Park Rd., Science Park II, Singapore, 117685*
gao.yuan@ieee.org

Abstract

This paper presents the study on a compact polarization diversity antenna array consisting of two orthogonally placed hybrid dielectric resonator antenna (DRA) elements. A prototype antenna array for IEEE802.11a WLAN application is designed and measured. Over 20 dB isolation and 18% input impedance bandwidth is achieved while symmetrical and unidirectional radiation patterns are maintained over all the IEEE802.11a WLAN bands ($5150-5350$ *MHz/5725-5875 MHz).*

1. INTRODUCTION

Multi-path fading is an important issue in wireless communication, especially in the indoor environments. In order to reduce the signal fading caused by the multi-path effects, antenna diversity techniques are therefore applied to both the transmitter and receiver sides. Although extensive research efforts have been put into the diversity antennas development [1-3], the design of a compact diversity antenna system suitable for mobile application is still a significant challenge due to the stringent requirements on the antenna size, bandwidth, efficiency, and isolation.

Dielectric resonator antenna (DRA) is an efficient radiator with inherent merits such as small size, high efficiency and ease of excitation. However, the relative bandwidth of a single DRA is typically below 10%, which can not meet the increasing demand for wideband operation. Recently, the multiple resonances technique that was formerly employed in designing wideband microstrip antennas [4] has been successfully applied in DRA design to enhance the bandwidth of a single dielectric resonator (DR). By combining the resonance of the feeding structure with that of the DR, a compact wideband or multi-band hybrid DRA can be designed [5].

In this paper, a 2-element polarization diversity hybrid DRA array for IEEE802.11a WLAN is implemented on a small ground plane compatible with PCMCIA card. The single hybrid DRA element which is first reported in [6] comprises a rectangular dielectric resonator and a conductor-backed coplanar waveguide (CB-CPW) slot. The backing conductor and the lateral metal sidewalls around the substrate form a back-cavity to block the backward radiation from the slot. This structure has the advantage of working on a very small ground plane, while retaining symmetrical and unidirectional linear polarized radiation patterns. By putting two hybrid DRA elements orthogonally on a common ground plane, a compact polarization diversity array is achieved. This array occupies a small space of 53 mm $\times$ 25 mm while offers wide bandwidth (>18%) and high isolation (>22 dB) over all the IEEE802.11a WLAN bands ($5150-5350$ MHz/5725-5875 MHz).

2. ANTENNA STRUCTURE

The proposed single hybrid DRA element is depicted in Fig. 1. This antenna consists of a rectangular DR and a probe-fed CB-CPW inductive slot etched on an RT/Duriod substrate ($\varepsilon_r = 2.33$, $\mathrm{T} = 1.25$ mm), which has the same size as the dielectric resonator.

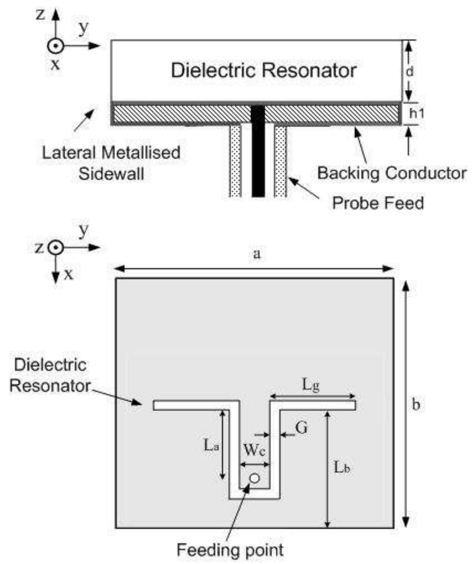


Fig. 1: Top view and side view of the single DRA element

As shown in Fig. 1, the CB-CPW is designed with a metal strip of width $\mathrm{W_c}$ and a gap of width G, whereas the inductive slot has two arms of equal length $\mathrm{L_g}$, and the distance from the slot to the probe feed point is $\mathrm{L_a}$. The rectangular DR with dielectric constant ε_{dr} has a hight of d and a rectangular cross section of $\mathrm{a} \times \mathrm{b}$. DR is placed above the slot with a distance of L_b from the slot to the lower edge of the DR. All the sidewalls of the substrate are metallized so as to connect the coplanar ground planes to the conductor backing. The lateral metal walls together with the conductor backing constitute a back-cavity to block the backward radiation from the slot. The resonance frequency of the rectangular DR can be roughly estimated with the modified dielectric waveguide model [7] and the inductive slot resonates at approximately one guided wavelength ($2(L_g + L_a) \approx \lambda_g$) where λ_g is the guided wavelength of the slot.

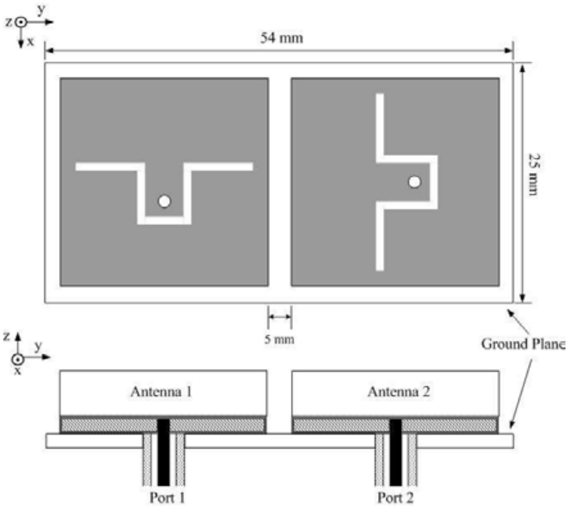


Fig. 2: Top view and side view of the DRA array structure

The 2-element polarization diversity antenna structure is shown in Fig. 2. Two identical hybrid DRA elements are mounted orthogonally to each other on a common ground plane. The ground plane has the dimension of 54 mm $\times$ 25 mm, which is close to the space for antenna on a standard PCMCIA card. The gap between the two DRA elements is 5 mm.

3. Measurement Results

The single DRA element geometry is simulated and optimized in the commercial software ANSOFT HFSS. The optimized antenna parameters for IEEE802.11a WLAN application are $a = b = 22$ mm, $d = 4.0$ mm, $\varepsilon_{dr} = 14$, $W_c = 2.6$ mm, $G = 0.5$ mm, $L_g = 6.6$ mm,$L_a = 6.2$ mm and $L_b = 9.2$ mm. Fig. 3 shows the measured antenna input impedance and return loss for the single hybrid DRA element. Two resonance frequencies around 5.3 GHz and 5.8 GHz can be observed. The frequency range of the measured bandwidth is from 5.05 GHz to 6.05 GHz, corresponding to a relative bandwidth of 18% ($S_{11} < -10$ dB).

The measured return loss of the 2-element array is shown in Fig. 4. There are some differences between the input return loss at the two ports (S_{11} and S_{22}) due to the antenna fabrication tolerance. However, both antennas have input return loss greater than 10 dB in the frequency range of

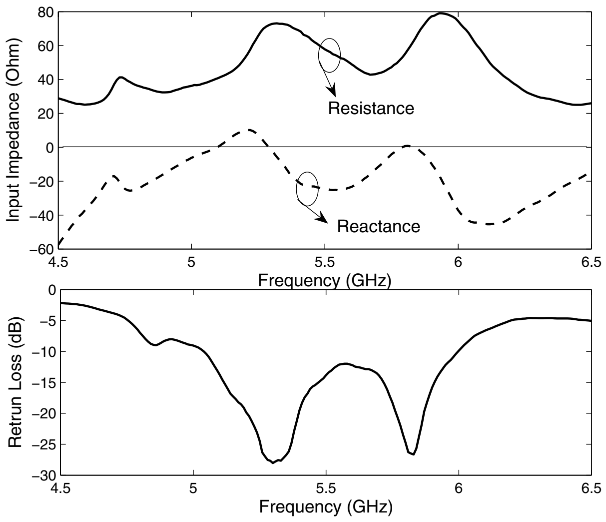


Fig. 3: Measured input impedance and return loss of the antenna element.

$5.125 - 5.875$ GHz, which covers all the 5 GHz WLAN frequency bands. Furthermore, the measured mutual coupling (S_{12}) is less than -22 dB over the matched frequency band.

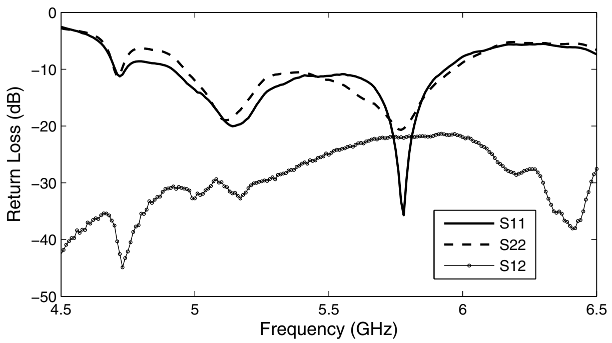
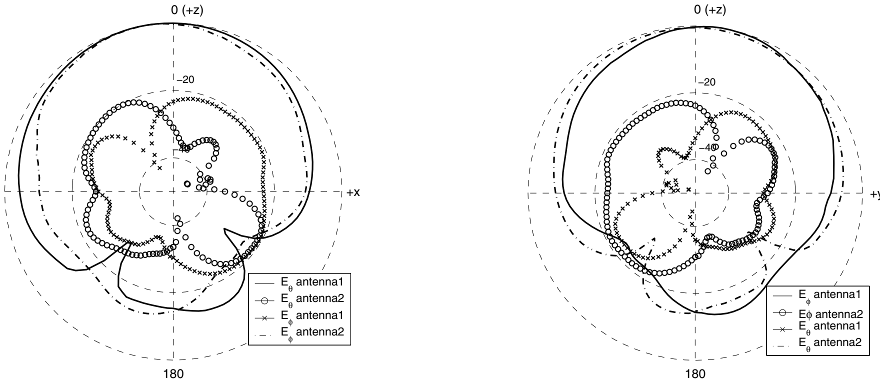


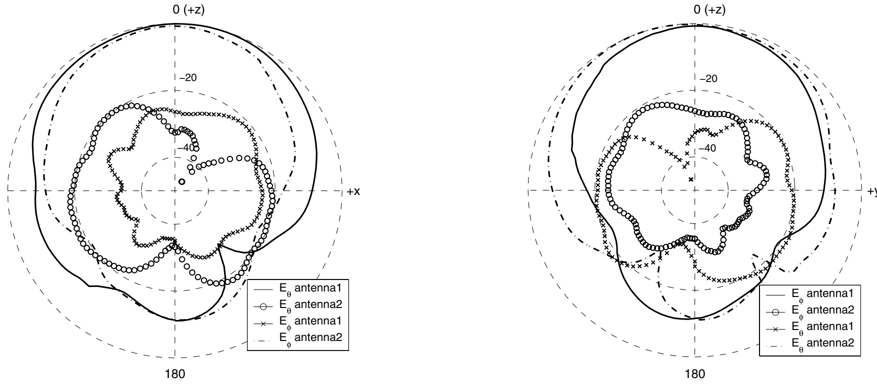
Fig. 4: Measured S-parameter of the antenna array

Fig. 5 and 6 show the measured antenna radiation pattern on the x-z and y-z planes at 5.2 GHz and 5.8 GHz respectively for individual excitation of antenna 1 or antenna 2. The radiation patterns of the single antenna element are broadside and symmetric at both planes. It can be observed that, antenna 1 radiates a strong E_θ component while antenna 2 radiates a strong E_ϕ component in the x-z plane. The cross-polarization field component is at least 20 dB below the co-polarization field component in the broadside direction. The reverse phenomena can be observed in the y-z plane, which reflects the polarization diversity property of the array. It is noted that the radiation front-to-back ratio is above 12 dB at both frequencies, confirming the consistent unidirectional radiation characteristics across the matching band. Fig. 7 presents the measured single antenna element radiation gain in the broadside ($\theta = 0^o$) throughout the matching band and



x-z plane   y-z plane

Fig. 5: Measured antenna radiation pattern at 5.2 GHz



x-z plane   y-z plane

Fig. 6: Measured antenna radiation pattern at 5.8 GHz

a peak gain of 5.4 dBi is achieved around 5.2 GHz.

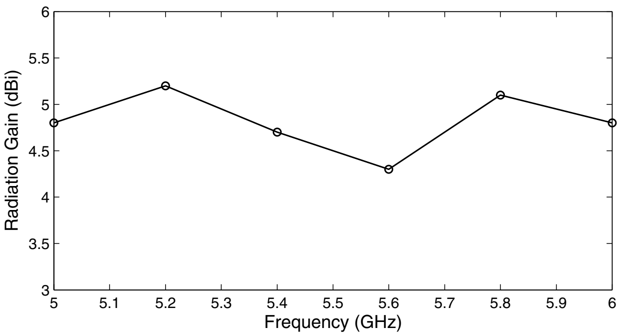


Fig. 7: Measured antenna radiation gain in the broadside

4. Conclusion

In this paper, a polarization diversity hybrid dielectric resonator antenna array structure is proposed. Two identical linear polarized hybrid DRA elements are placed orthogonally on a common ground plane with narrow spacing. A prototype antenna array for IEEE802.11a WLAN application demonstrated a 18% bandwidth, over 22 dB isolation and consistent unidirectional radiation patterns within the working frequency band. The size of the dielectric resonator can be further reduced with higher dielectric constant material to achieve more compact array size.

References

[1] Y. Gao, C.C. Chiau, X. Chen and C.G. Parini "Modified PIFA and its array for MIMO terminals", *IEE Proc., Microw. Antennas Propag*, vol. 152, pp. 255–259, Aug. 2005.

[2] R. R. Ramirez and F. D. Flaviis, "A mutual coupling study of linear and circular polarized microstrip antennas for diversity wireless systems", *IEEE Trans. Antennas propag.*, vol. 51, no. 2, pp. 238–248, Feb. 2003.

[3] S.B. Yeap, X. Chen, J.A. Dupuy, C.C. Chiau and C.G. Parini "Low profile diversity antenna for MIMO applications", *Electron. Lett.*, vol. 42, no.2, pp. 69–70, Jan. 2006.

[4] F. Croq and A. Papiernik, "Large bandwidth aperture-coupled microstrip antenna", *Electron. Lett.*, vol. 26, no.16, pp. 1293–1294, Aug. 1990.

[5] A. Buerkle, K. Sarabandi, and H. Mosallaei, "Compact slot and dielectric resonator antenna with dual-resonance, broadband characteristics", *IEEE Trans. Antennas propag.*, vol. 53, no. 3, pp. 1020–1027, Mar. 2005.

[6] Y. Gao, A.P. Popov, B.L. Ooi and M.S. Leong, "Experimental study of wideband hybrid dielectric resonator antenna on small ground plane", *Electron. Lett.*, vol. 42, no. 13, pp. 731–732, Jun. 2006.

[7] R. K. Mongia and A. Ittipiboon, "Theoretical and experimental investigations on rectangular dielectric resonator antennas", *IEEE Trans. Antennas propag.*, vol. 45, no. 9, pp. 1348–1356, Sep. 1997.