A Polarization Diverse Antenna for Dual-Band WLAN Applications

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***Abstract*— A dual-band dual-polarized (DBDP) array antenna is proposed for wireless local area network (WLAN) applications. A four-element array is used to facilitate operation in both the standard WLAN frequency bands, while also incorporating the capacity to send/receive arbitrary orthogonal polarizations. The presented compact structure is characterized by wide bandwidths, average gains of 5.5 dBi and 7.0 dBi over the 2.4 and 5.2 GHz bands respectively, high F-to-B ratios, stable radiation patterns, as well as cross-polarization levels below 30 dB relative to the boresight.**

***Index Terms*—Dual-band, dual-polarized, dual-band dual-polarized (DBDP), wireless local area network (WLAN).**

I. INTRODUCTION

The recent growth in new applications for modern wireless communication systems has increased the demand for multi-band antennas that can satisfy the requirements pertaining to WLANs (Wireless Local Area Networks). The development of dual-band antennas that can cover the 2.4 GHz (2.4 – 2.484 GHz) band and the 5.2 GHz (5.15 – 5.85 GHz) band for the IEEE 802.11b and IEEE 802.11a WLAN standards respectively, are thus highly desirable. A second possible requirement for WLAN applications is polarization diversity, which can be achieved by making use of dual-polarized arrays. This allows communication systems to be able to send and receive signals with more than one polarization [1]. The need for data rates higher than 54 Mbps and thus higher bandwidth efficiency [2] for WLAN systems have increased MIMO (Multiple-Input-Multiple-Output) related research [3]. MIMO systems not only use multipath propagation in a constructive way, but increase the robustness and capacity of the whole system. Polarization diversity or dual-polarized configurations can assist in realizing bandwidth efficient schemes such as the MIMO-OFDM (Multiple-Input-Multiple-Output – Orthogonal Frequency Division Multiplexing) scheme, by increasing the system capacity without adding additional antennas at the receiver and transmitter. Various adaptive modulation and demodulation methods have been proposed in conjunction with the OFDM scheme [2] to provide a potentially more efficient solution.

It is relatively easy to realize a dual-polarized structure by making use of two ports in conjunction with a circular, square or annular microstrip antenna [4], but it is more challenging to design a structure that has the capacity to support dual-band and dual-polarized operations. A lot of research has thus been done to develop suitable antenna elements with the capacity to support orthogonal polarizations with dual frequency bands. Most of the dual-frequency dual-polarized designs make use of multiple-dielectric-layered configurations [4] or are realized by means of multiple antenna arrays, where each array is responsible for a certain frequency band or polarization. The disadvantages associated with the multi-dielectric-layered structures are fabrication difficulties, high costs and high back lobes [5]. The development of appropriate structures that comply with all the specifications for dual-band dual-polarized arrays, while aiming for single-dielectric-layered elements to reduce fabrication costs, will be an advantage for the implementation of WLAN communication systems.

Dual-frequency elements such as stacked-, notched- and dichroic patches have also been considered to be modified to facilitate dual-polarized operation. The size of the elements, the high cross-polarization levels associated with dichroic- and stacked patches and the complex routing of feeding networks needed to implement some of the antenna patch designs [4], disqualified these options in general to be used in dual-polarized arrays. Other printed dipoles and slot antennas, which occupy less space, have also been investigated and the feasibility of these options was ascertained in [6].

Another attractive printed planar design that has the potential capacity to support dual-frequency band operations, is the double Rhombus antenna presented in [7]. This antenna exhibits favourable characteristics such as easy adaptability to different frequency bands, light weight, small dimensions and low manufacturing costs.

In this paper a new DBDP design is presented. The basic radiating element consists of a rhombus shaped dipole above a planar ground plane for operation in the lower WLAN frequency band and a rectangular dipole with added director for operation in the higher WLAN frequency band. Dual polarization is achieved by orthogonally combining two, two element arrays. Each polarization is fed by a single port.

II. ANTENNA CONFIGURATION

The single-element design seen in Fig. 1, proliferated out of a parameter study pertaining to the various dimensions, where the double Rhombus design presented in [7] was used as inspiration. The final DBDP array was constructed out of an assembly of four of the single-elements. The single dual-band element was developed with two parallel dipoles of different shapes to facilitate operations in the 2.4/5.2 GHz WLAN bands and was designed to be implemented on a Rogers RO4003C substrate with a dielectric constant of 3.38, a height of 0.813 mm and a loss tangent (tan δ) of 0.0027 at 10 GHz. The lower band dipole is rhombus shaped and radiates above a planar ground plane, while radiation from the rectangular higher band dipole is directed through the use of a passive director. The upper and lower copper tracks pertaining to the single-element are shown in Fig. 1, where the two dipole halves of each element are printed on different sides of the substrate to ensure that the structure is balanced and thus eliminates the need to implement a balun. The lengths (L3 and L5) of the two dipoles control the two primary resonances and the rhombus shape are effectively defined by W2 and W3 as can be seen from Fig. 2. The combined length L1 + L2 is the spacing between the planar ground and the lower band dipole. The length L4 is the spacing between the lower band and the higher band dipole and the position, width and length of the passive director are defined by d, Wd and Ld respectively. The dimensions pertaining to the single-element can be seen in Tables 1 and 2.

The four-element configuration as seen in Fig. 3 was constructed via the orthogonal interleaving of the two two-element arrays, where the distance between the centres pertaining to the two elements was chosen to be equal to 58 mm. The distance is approximately equal to 0.44 λ_0 at 2.3 GHz, the lower limit of the first frequency band and equal to 1.13 λ_0 at 5.85 GHz, the upper frequency limit of the 5.2 GHz WLAN frequency band. The overall structure imbue an area equal to 148 mm x 148 mm x 101.3 mm (L x W x H).

TABLE I
THE LENGTHS OF THE SINGLE-ELEMENT CONFIGURATION [UNITS: MM]

L1	L2	L3	L4	L5	Lf	Ld	d
19.0	4.3	25.0	3.0	9.5	39.0	17.0	3.5

TABLE II
THE WIDTHS OF THE SINGLE-ELEMENT CONFIGURATION [UNITS: MM]

W1	W11	W2	W3	W4	W5	Wf	Wd
1.4	0.7	4.2	2.5	0.6	2.5	1.4	1.0

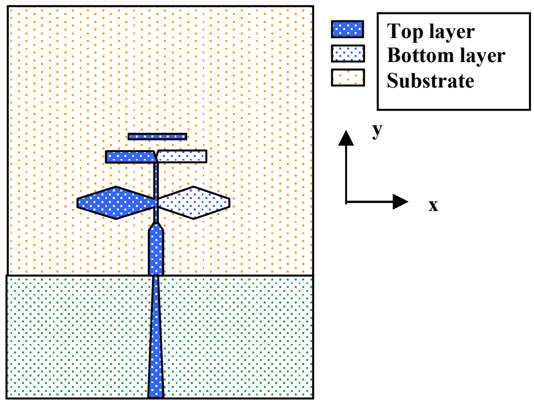


Fig. 1 The upper level of the single-element

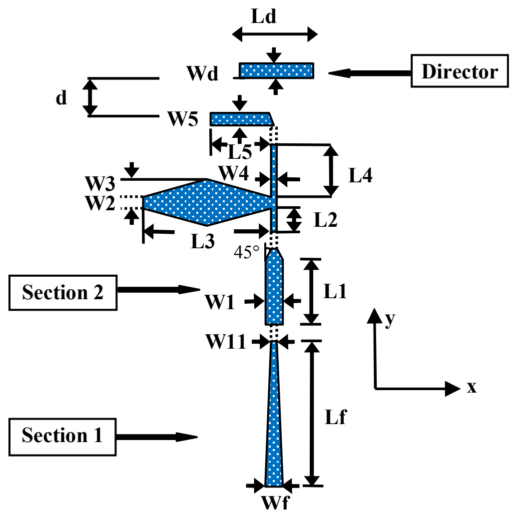


Fig. 2 The upper layer of the antenna showing the design parameters

III. MEASURED AND SIMULATED RESULTS

All the simulations were conducted with the aid of CST Microwave Studio® and the measurements were performed at the Compact Range of the University of Pretoria.

A. Reflection coefficients and gain

The simulated and measured reflection coefficients and gain pertaining to the single-element are discussed, as well as the simulated reflection coefficients and gain pertaining to the DBDP configuration.

1) *Single-element:* The simulated results pertaining to the single-element indicated that the antenna operates from 2.30 GHz to 2.75 GHz in the lower band (17.9% bandwidth) and

from 4.56 GHz to 5.95 GHz in the upper band (26.4% bandwidth), assuming 2:1 as acceptable VSWR. The measured results correlated very well with the simulated results, with a matched lower band of 17.8% (2.32 – 2.77 GHz) and an upper band of 34.8% (4.25 – 6.03 GHz), shown in Fig. 4. The average measured gain in both frequency bands were better than 4.0 dBi, and corresponds reasonably well with the simulated gain as seen in Figs. 5 and 6.

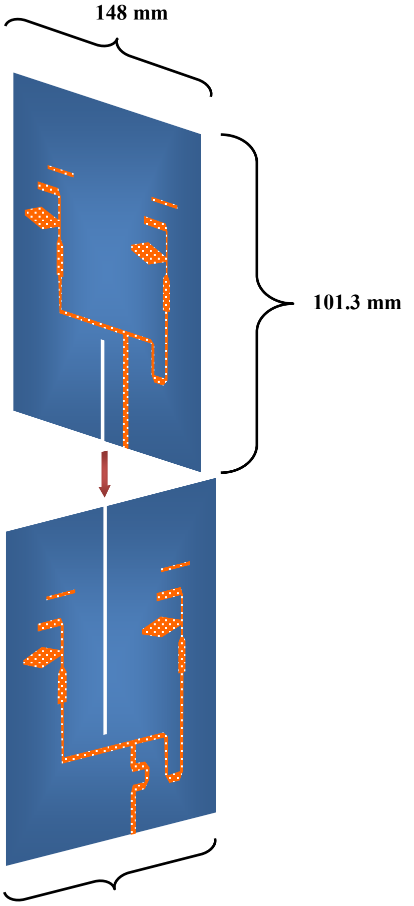


Fig. 3 The assembly of the four-element configuration

2) *DBDP array:* The horizontally polarized array produced simulated bandwidths of 24.3% and 18.6% over the 2.4 and 5.2 GHz bands respectively. The vertically polarized array produced similar results with bandwidths equal to 22.9% and 25.2% over the L- and C-bands respectively. The measured bandwidths of both polarizations proved to be slightly wider than the simulated bandwidths. The simulated and measured reflection coefficients can be seen in Fig. 7. The achieved bandwidth surpasses the minimum standard WLAN bandwidths of 3.4% and 14.4% pertaining to the 2.4 and 5.2 GHz bands respectively. The average simulated gain is 5.5 dBi over the first band and 7.0 dBi over the second band. The average measured gain is slightly lower with values equal to 5.1 dBi and 6 dBi over the first and second frequency bands respectively.

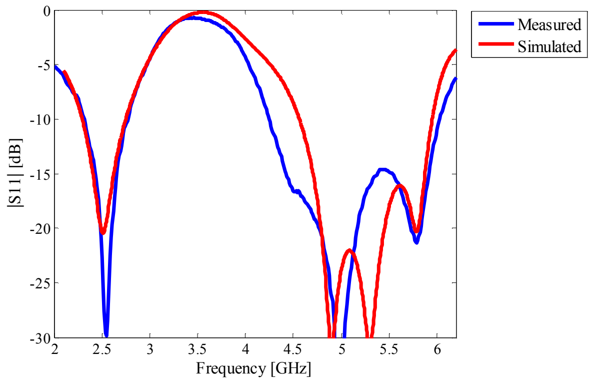


Fig. 4 The reflection coefficient of the single-element

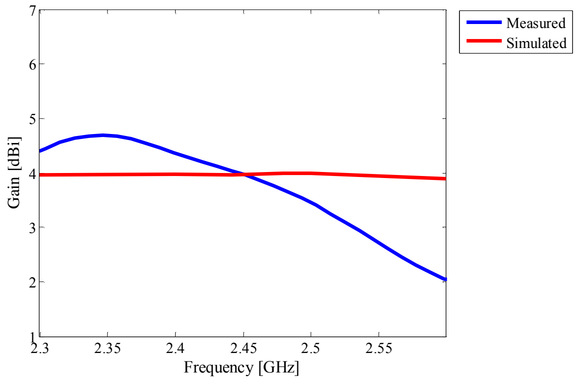


Fig. 5 The gain of the single element over the 2.4 GHz band

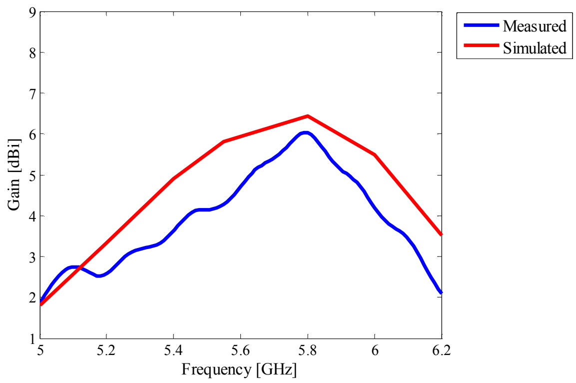


Fig. 6 The gain of the single element over the 5.2 GHz band

B. *Radiation patterns*

1) *Single-element:* Stable directional radiation patterns were achieved with low cross-polarization levels. The maximum front-to-back ratio in the lower band is close to 10 dB and even better in the higher band. The simulated and measured E- and H-plane normalized radiation patterns are shown in Figs. 8 and 9 respectively.

2) *DBDP array:* The H-plane patterns of the two 1×2 element arrays are very similar to the H-plane pattern of the single element. The simulated E-plane patterns of the two 1×2 element arrays are shown in Figure 10.

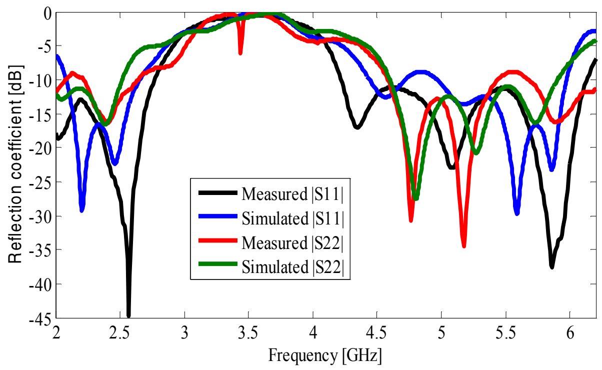
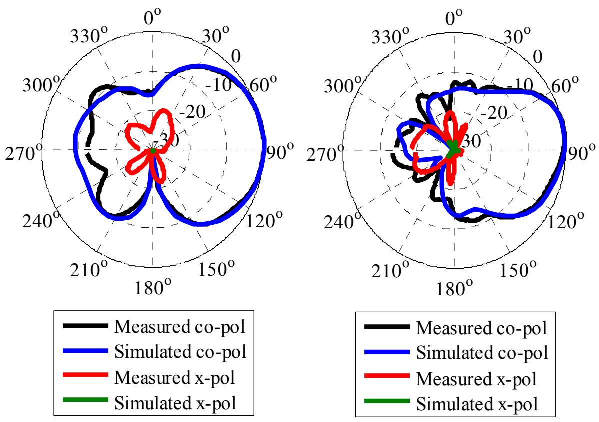
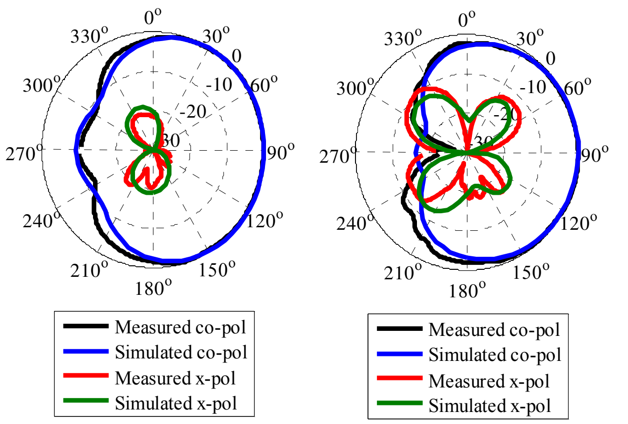


Fig. 7 The reflection coefficients versus frequency pertaining to the horizontal (Port 1) and the vertical (Port 2) polarization



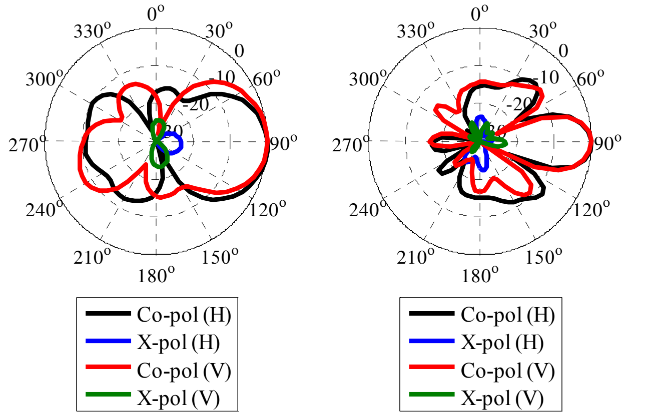
(a) (b)

Fig. 8 Normalized radiation patterns of the single-element in the E-plane at (a) 2.44 GHz (b) 5.55 GHz



(a) (b)

Fig. 9 Normalized radiation patterns of the single-element in the H-plane at (a) 2.44 GHz (b) 5.55 GHz



(a) (b)

Fig. 10 Normalized radiation patterns of the DBDP array in the E-plane at (a) 2.44 GHz (b) 5.55 GHz

IV. CONCLUSIONS

An alternative dual-band dual-polarized antenna for dual band WLAN applications is presented. The antenna consists of two orthogonal two element arrays that are light in weight, small in dimension and low in manufacturing costs. The design presents a dual-band dual-polarized configuration with two ports, and delivers stable directional radiation patterns, low cross-polarization levels, relatively high gain and good F-to-B ratios. Both frequency bands specified by the IEEE 802.11b and IEEE 802.11a WLAN standards are more than adequately covered, assuming an operating VSWR of 2:1.

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