# *A high gain dual-polarized planar slot array for WLAN applications*

J. Joubert, J.W. Odendaal and J. Prinsloo

In this paper we present a high gain dual-polarized planar etched slot array for use in wireless local area networks (WLAN). Two sets of four collinear slots are used as radiators for each polarization. Each set of four collinear slots is constructed as a centre-fed long slotline, with etched crossovers to split the slotline in four resonant and in-phase half-wavelength slots. A reflector etched on a separate substrate spaced a quarter-wavelength away from the slot array ensures uni-directional radiation. The final antenna achieved a gain of 14.5 dBi, a return loss better than 10 dB, and port isolation in excess of 30 dB over the 2.4 – 2.484 GHz WLAN frequency band.

***Introduction:*** Dual-polarized antennas are attractive in wireless communication systems since polarization diversity is effective in mitigating the detrimental fading loss caused by multipath effects [1]. Polarization diversity can also be utilized to realize frequency reuse and thus increase the system capacity [2]. A common way to achieve dual-polarized operation is to excite orthogonal modes of patch radiators. To achieve high antenna gain an array of such radiators has to be used, eg. the 2×4 electromagnetically coupled patch array described in [3], for which the measured gain was 12.7 dBi and the isolation between diversity ports better than 20 dB. It is also possible to use orthogonal [4] or crossed electric dipoles as radiating elements, but compared to patch arrays it is somewhat more difficult to combine arrays of dipoles to achieve dual-polarized high gain radiation properties. A non-planar array (which results in a large volume) of four interleaved etched dipole radiators with end-fire radiation patterns was presented in [5], with relatively low gain of 5.2 dBi in the 2.4 GHz band, and port isolation also around 20 dB.

In this paper we present a high gain dual-polarized magnetic dipole array for use as an antenna suitable for WLAN base stations or access points for indoor WLAN in the 2.4 – 2.484 GHz frequency band. Two sets of four collinear slots are used as radiators for each polarization. A reflector etched on a separate substrate spaced a quarter-wavelength away from the slot array ensures uni-directional radiation. The feed network to achieve the dual-polarized operation is split between the two substrates, with four coaxial transmission line sections to connect the two parts of the feed network. The antenna is shown in Fig. 1.

The new antenna presented in this paper is a novel extension of the high gain linear slot arrays presented in [6], where a long slotline is split with non-radiating open circuit slots and crossovers. The extension in this paper is to replace the non-radiating open circuit slots with radiating slots for a second linear polarization, and to demonstrate the concept (as a planar array with separate feeds for each polarization) as a dual-polarized high gain WLAN antenna.

***Antenna geometry and design*:** Fig. 1(a) shows four long crossed slotlines etched on one side of a substrate. An etched crossover (one side of the crossover has to be through-connected with vias) at each slotline crossing switches the field polarity in order to divide each long slotline in a series of in-phase half-wavelength slot dipoles. Each of the four long slotlines is centre-fed with a microstrip-to-slotline transition. A reflector etched on a separate substrate (see Fig. 1(b)) spaced a quarter-wavelength away from the slot array ensures uni-directional radiation. The feed network to achieve the dual-polarized operation is partly etched on the reflector substrate, and partly on the slot array substrate, with four coaxial transmission line sections to connect the two parts of the feed network. A side view of the complete assembled antenna is shown in Fig. 1(c).

The design of the antenna was performed with the assistance of IE3D [7], a moment-method based full-wave simulator. The design process was as follows: (a) the dimensions for the slot width W and resonant slot length L were determined (using the IE3D optimizer function) for optimum gain and a 50 Ω input impedance as seen from the microstrip-to-slotline transition (a quarter-wave matching section forms part of the microstrip-to-slotline transition); (b) a microstrip feed network using 50 Ω microstrip lines and 35 Ω quarter-wave transformers were designed for each polarization; (c) the distance between the slotline edges and the ground plane edge (parameter $\ell$ in Fig. 1(a)) was optimized to minimize the first sidelobe level in the E-plane of the antenna.

***Results:*** To validate the theory the slot array geometry as discussed in the previous section was designed and simulated, and also manufactured and measured. The antenna was designed for and etched on Rogers RO4003 substrate with $\varepsilon_r$ = 3.38, tan δ = 0.0027 and h = 0.813 mm, with dimensions $L$ = 45.0 mm, $W$ = 4.0 mm, $\ell$ = 20.0 mm, $L_1$ = 21.0 mm, $W_1$ = 3.0 mm, $L_2$ = 21.0 mm, $W_2$ = 3.5.0 mm, and $H$ = 31.0 mm. The etched crossovers were all 1 mm wide. Both substrates were cut to a finite size of 220 mm x 220 mm. A comparison between the simulated and measured reflection coefficient at the ports, and the isolation (s21) between the ports are shown in Fig. 2. The two sets of data correspond well, with suitable impedance bandwidth and good isolation to operate satisfactorily as a dual-polarized antenna in the 2.4 GHz WLAN frequency band. The E- and H-plane radiation patterns for both ports were measured at 2.45 GHz. The data for port#1 is shown in Fig. 3 (the results for port#2 were very similar). The cross-polarization was found to be very low, and the side-lobe levels and front-to-back ratio acceptable. A comparison of the simulated and measured gain as function of frequency is shown in Fig. 4 – more than 14.5 dBi over the WLAN bandwidth. The simulated radiation efficiency of the antenna array was around 85%.

***Conclusions:*** A novel design topology consisting of crossed long intersecting slotlines and etched crossovers (to create a 2D array of half-wavelength slot dipoles), in conjunction with a suitable feed network and reflector, is used to realize a high gain dual-polarized WLAN antenna. The final antenna achieved a gain of 14.5 dBi, a return loss better than 10 dB, a front-to-back ratio better than 15 dB, and port isolation in excess of 30 dB.

## ***References***

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***Figure captions:***

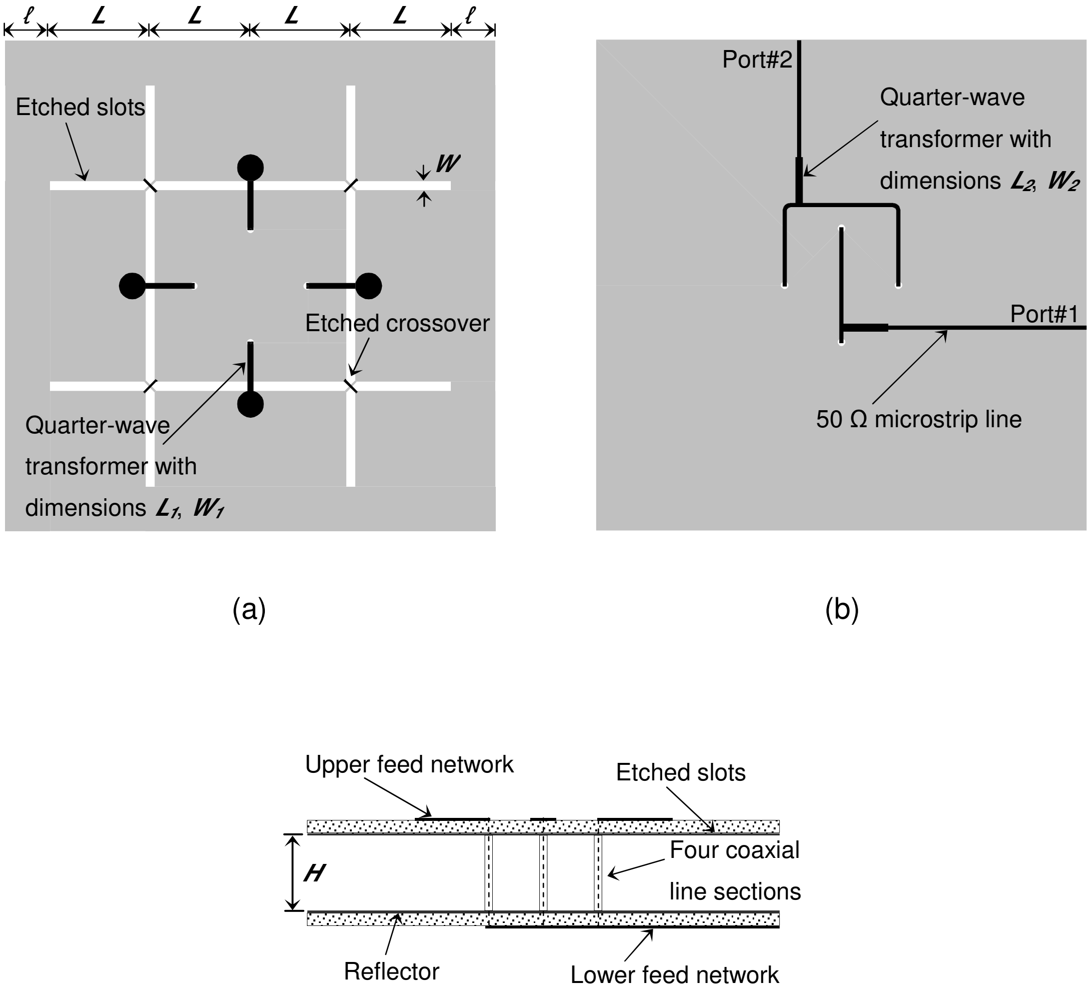
***Fig. 1*** (a) The top substrate with four microstrip line feed lines exciting the long slotline radiators with etched crossovers; (b) The bottom substrate with the two-port microstrip line feed network; (c) A side view of the assembled antenna.

***Fig. 2*** Simulated and measured reflection coefficient (s11 and s22) for the two ports, and simulated and measured isolation between the ports (s21).

***Fig. 3*** Measured radiation patterns.

***Fig. 4*** Simulated and measured gain of the antenna.

Fig.1


ℓ
L
L
L
L
ℓ
Etched slots
W
Etched crossover
Quarter-wave transformer with dimensions $L_1$, $W_1$
Port#2
Quarter-wave transformer with dimensions $L_2$, $W_2$
Port#1
50 Ω microstrip line
Upper feed network
Etched slots
H
Four coaxial line sections
Reflector
Lower feed network

(a)

(b)

(c)

Fig. 2

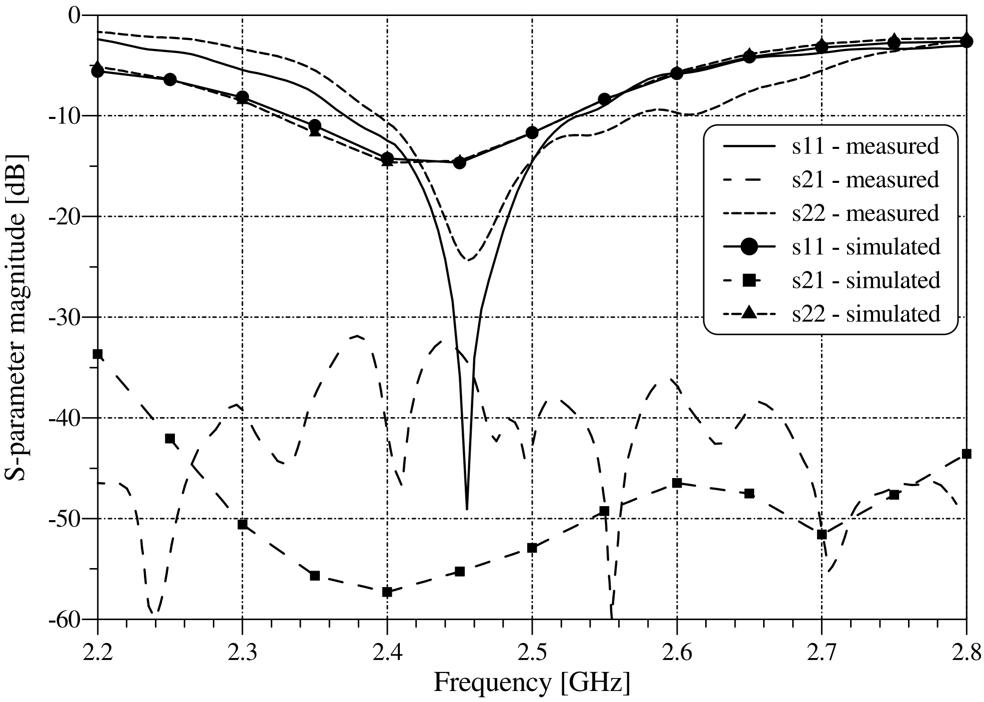

0
-10
-20
-30
-40
-50
-60
S-parameter magnitude [dB]
2.2
2.3
2.4
2.5
2.6
2.7
2.8
Frequency [GHz]
s11 - measured
s21 - measured
s22 - measured
s11 - simulated
s21 - simulated
s22 - simulated

Fig. 3

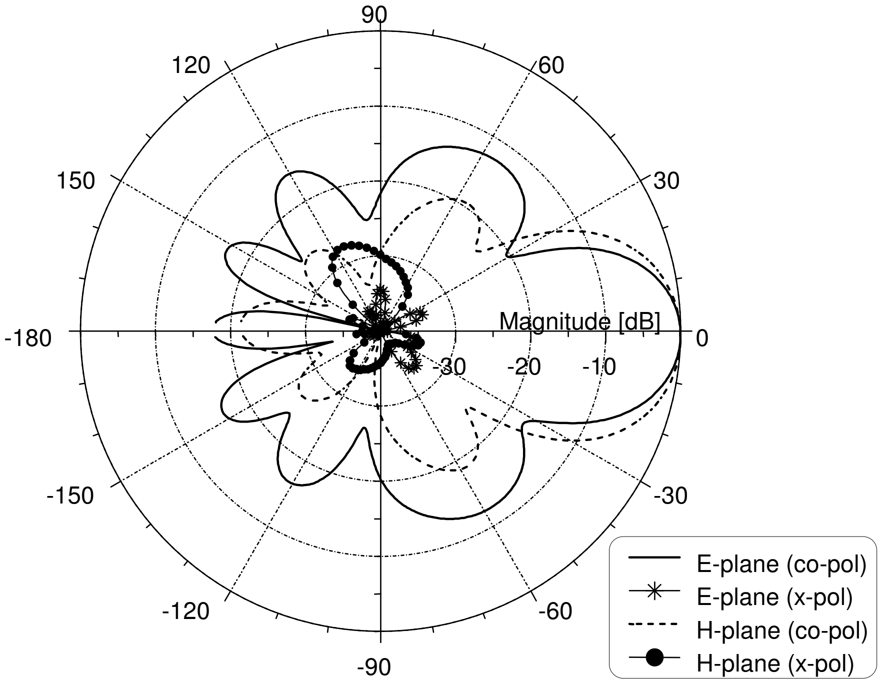
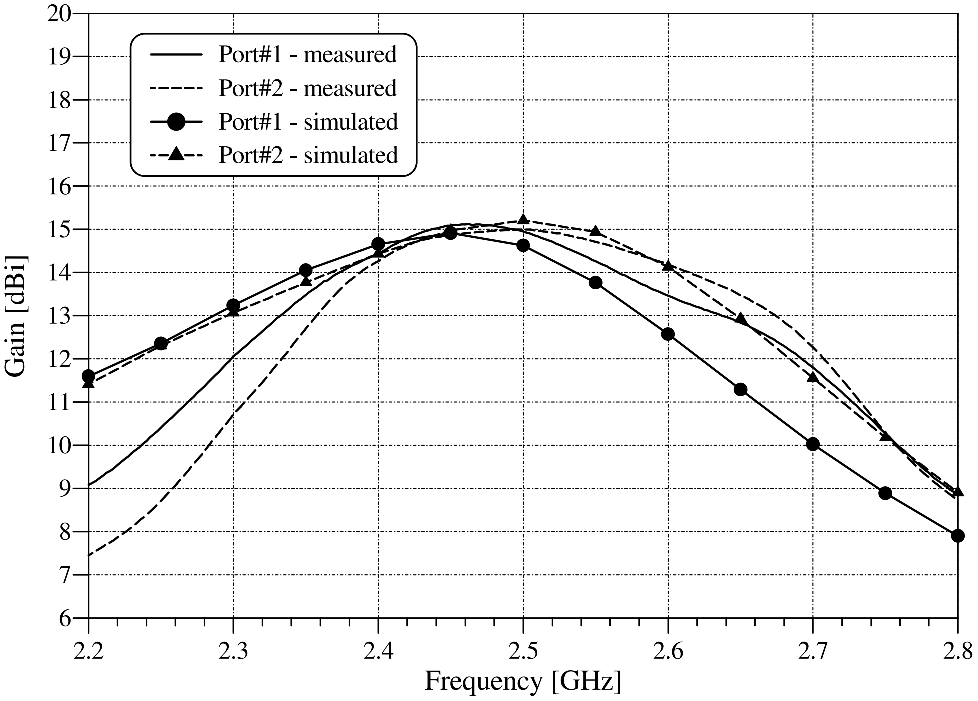

90
60
30
0
-30
-60
-90
-120
-150
-180
150
120
Magnitude [dB]
-30
-20
-10
E-plane (co-pol)
E-plane (x-pol)
H-plane (co-pol)
H-plane (x-pol)

Fig. 4


Port#1 - measured
Port#2 - measured
Port#1 - simulated
Port#2 - simulated
Gain [dBi]
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
2.2
2.3
2.4
2.5
2.6
2.7
2.8
Frequency [GHz]