Design of Broadband Dual-Polarized Oval-Shaped Base Station Antennas for Mobile Systems

Ahmed Alieldin
Department of Electrical Engineering and Electronic,
University of Liverpool,
Liverpool, United Kingdom
e-mail: ahmed.alieldin@liverpool.ac.uk

Yi Huang
Department of Electrical Engineering and Electronic,
University of Liverpool,
Liverpool, United Kingdom
e- mail: yi.huang@liverpool.ac.uk

***Abstract*—This paper proposes a new design of wideband oval-shaped antenna with ±45° dipoles suitable for the base station of mobile communication systems. The designed antennas cover bands of 700-960 MHz (the lower band antenna) and 1700-2700 MHz (the upper band antenna) for cellular 2G/3G/LTE technologies. The design enjoys the advantages of stable directivity and beamwidth within frequency bands and a simple feeding structure with a compact size and low profile. The oval-shaped structure makes the antenna smaller in size than other polygon shapes. The antenna in the lower band has a beamwidth of 85.4°± 1.3° and directivity of 7.2±0.13 dBi with the reflection coefficient ≤ -17 dB and the isolation between the ports ≥ 19 dB while the antenna in the upper band has a beamwidth of 84.15°±3.9° and directivity of 6.94±0.38 dBi with the reflection coefficient ≤ -10.5 dB and the isolation between the ports ≥ 20.5dB. High cross polarization discrimination ratios were also achieved within the desired frequency bands.**

Keywords—dual-polarized antenna; base station antenna; wideband antenna;

I. INTRODUCTION

Dual-polarized antennas with a broad bandwidth have become necessary requirements for cellular mobile communication systems because of the rapid development in communication technologies [1]. The simplest and most common way to radiate a dual-polarized wave is to use two orthogonal dipoles with two separate feeding structures and a metallic reflector [2], [3]. Base station antennas should enjoy three main characteristics: a) good impedance matching within its band, b) stable beamwidth and directivity within its band and, c) high cross polarization discrimination ratio (XPD) within the beamwidth [4]. Many designs have been introduced in the literature. In [5], despite the achievement of a high XPD, the limited bandwidth (1920- 2200 MHz) of the designed antenna limits its usage for mobile systems. In [6], [7], the antennas have a wider bandwidth (1700- 2700 MHz). Unfortunately, its large dimensions in comparison to the wavelength in addition to its beamwidth (which is up to 70°) limit the ability to construct a known 3-sided mobile base station structure. In [8], [9], a multiband array design with a compact structure was introduced using optimal array scheme. Later on, in [10], the XPD was improved by adding parasitic elements on the expense of the antenna size. In this paper, a dual-polarized antenna with a compact size and a simple feeding structure is introduced for both the lower band (LB) and upper band (UB). Oval-shaped geometry enhances the size reduction with a wider beamwidth suitable for mobile base station applications.

The paper is organized as follows; section II describes the proposed antenna design, section III illustrates the simulated results. Finally, the paper is concluded in section IV

II. DUAL-POLARIZED ANTENNA ELEMENT

Fig. 1 illustrates the geometry of both the LB and UB antennas while Table I gives the dimension parameters related to each one. Generally, we can describe the geometry as two orthogonal dipoles placed on X-axis and Y-axis respectively on an FR4 substrate with a relative dielectric constant ε_r =4.3, loss tangent of 0.025 and, thickness H_d = 0.8 mm. The substrate lies in the XY plane. Each dipole consists of two oval shapes linked to a feeding strip and a connector. The substrate lies above a square metallic ground reflector at high H with four sidewalls of height H_w. The square reflector is positioned such that its diagonals lie in parallel to X-axis and Y-axis and its sides make angle of ±45 with X-axis and Y-axis.

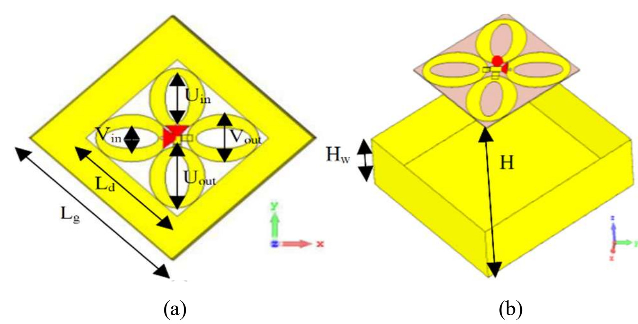

Fig. 1. Geometry of the proposed antenna. (a) Top view (b) Prospective view

TABLE I. DIMENSIONAL PARAMETERS OF THE DESIGNED ANTENNA

Parameter	Value (mm)	
	LB antenna (700-960 MHz)	***UB antenna (1700-2700 MHZ)***
U_{in}	58.91	22.23
U_{out}	77.47	29.23
V_{in}	26	7
V_{out}	60	21
L_d	140	52
L_g	220	80
H	120	37
H_w	47.7	14.5

III. SIMULATION AND RESULTS

The proposed antennas were designed and simulated using CST microwave studio. Fig. 2 illustrates the reflection coefficient and coupling between the ports for both antennas. For the LB antenna, very good impedance matching for band (700-960 MHz) to a 50Ω port was achieved with the reflection coefficient less than -17 dB and isolation between the ports more than 19 dB while for the UB antenna, the reflection coefficient of less than -10.5 dB was achieved within band of (1700-2700 MHz) while the isolation between ports was obtained more than 20.5 dB. Fig. 3 shows directivity in dBi for both antennas. It can be seen that the LB antenna has directivity of 7.2±0.13 dBi within the bandwidth while the UB antenna has directivity of 6.94±0.38 dBi within its assigned bandwidth. Fig. 3 also shows the half power beamwidth (HPBW) for both antennas against frequency. It is noticeable that LB antenna has an HPBW of 85.4º± 1.3º within its bandwidth while the UB antenna has HPBW of 84.15º±3.9º. Fig. 4 illustrates the radiation patterns of the proposed antennas; co- and cross-polarized; at frequencies 700 and 960 MHz for the LB antenna and 1700 and 2700 MHz for UB antenna. It worth noting that both V-plane and H-plane have the same radiation patterns as the antennas structure is symmetrical around the X-axis and Y-axis. XPD for each case are shown in Table II at boresight and HPBW.

Table III compares the proposed UB antenna to the octagonal-shaped dipole antennas in [6] and [10] that resonate within the same frequency band. The proposed UB antenna has a smaller size, higher XPD within the beamwidth, in addition to its wider beamwidth which makes it suitable for mobile base station applications

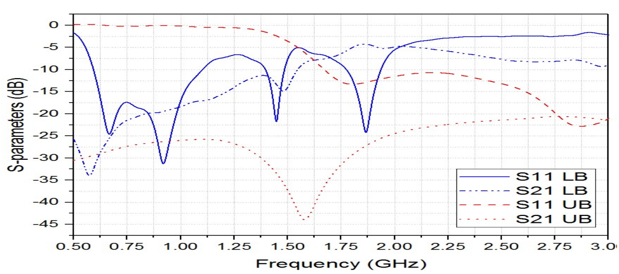

Fig. 2. Reflection coeffient and ports isolation for both LB and UB antennas

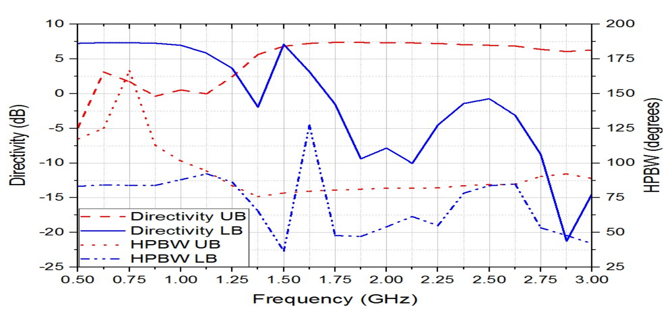

Fig. 3. Directivity and HPBW for both LB and UB antennas

TABLE II. XPD FOR SIMULATED RADIATION PATTERN

Position	XPD (dB)				
	LB antenna		*UB antenna*		
	700 MHz	*960 MHz*	*1700 MHz*	*2200 MHz*	*2700 MHz*
Boresight	24.5	19.4	30.9	25	22.3
HPBW	20	10.8	23	17.9	11

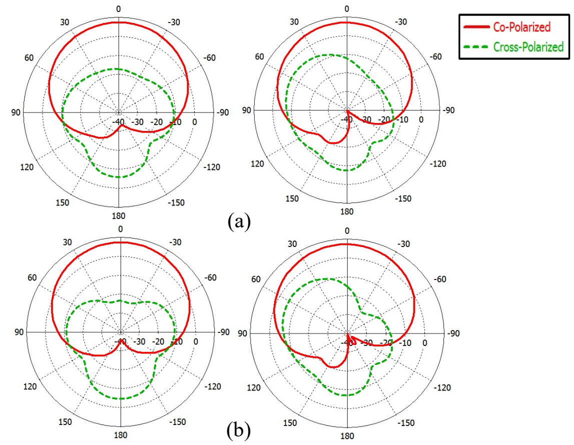

Fig. 4. Radiation pattern in dBi (a) LB 700 MHz (left-hand side) and 960 MHz (right-hand side) (b) UB 1700 MHz (left-hand side) and 2700 MHz (right-hand side)

TABLE III. COMPARISON OF PROPOSED UB ANTENNA PERFORMANCE WITH RECENT ANTENNA DESIGNS

Parameter		UB antenna	[6]	[10]
Dimensions (mm)		80×80×37	140×140×34	140×140×41
Minimum XPD (dB)	1700 MHz	23	Not mentioned	13.3
	2200 MHz	17.9	Not mentioned	12.3
	2700 MHz	11	Not mentioned	10.1
HPBW (º)		84.15	68	64.5

IV. CONCLUSION

Dual polarized antennas with oval-shaped orthogonal dipoles were designed with compact size and low profile suitable for mobile base station applications.

REFERENCES

[1] K. L. Wong, "Compact and broadband microstrip antenna," Hobken, NJ, USA: Wiely, 2002, p. 10.

[2] R. G. Vaughan, "Polarization diversity in mobile communications," IEEE Trans. Veh. Technol., vol. 39, no. 3, pp. 177-186, Aug. 1990.

[3] J. Lempiainen, and J. Laiho-Steffens, "The performance of polarization diversity schemes at a base station in small/micro cells at 1800MHz," IEEE Trans. Veh. Technol., vol. 47, no. 3, pp. 1087–1092, Aug. 1998.

[4] Qing-Xin Chu, Yu Luo, and Ding-Liang Wen, "Three principles of designing base-station antennas," International Symposium on Antennas and Propagation (ISAP 2015), 9-12th Nov. 2015, Tasmania, Australia.

[5] N. Fhafhiem, P. Krachodnok, and R. Wangsan, "Design of a dual polarized resonator antenna for mobile communication system," International Journal of Electrical, Computer, Energetic and Communication Engineering, vol. 8, no. 7, 2014

[6] Qing-Xin Chu, Ding-Liang Wen, and Yu Luo, "A broadband ±45º dual-polarized antenna with Y-shaped feeding lines," IEEE Trans. Antennas Propag., vol. 63, no. 2, pp. 483- 490, Feb. 2015.

[7] Yu Luo, and Qing-Xin Chu, "Oriental crown-shaped differentially fed dual-polarized multidipole antenna," IEEE Trans. Antennas Propag., vol. 63, no. 11, pp. 4678- 4685, Nov. 2015.

[8] Young-Bae Jung, and Soon-Young Eom, "A compact multiband and dual-polarized mobile base-station antenna using optimal array structure," International Journal of Antennas and Propagation, vol. 2015, p. 11.

[9] Yejun He, Zhengzheng Pan, Xudong Cheng, Yuan He, Jian Qiao, and Manos M. Tentzeris, " A novel dual-band, dual-polarized, miniaturized and low-profile base station antenna," IEEE Trans. Antennas Propag., vol. 63, no. 12, pp. 5399- 5408, Dec. 2015.

[10] Yu Luo, Qing-X Chu, and Ding-L Wen, " A ± 45 degree dual-polarized base-station antenna with enhanced cross-polarization discrimination via addition of 4 parasitic elements placed in a square contour," IEEE Trans. Antennas Propag., vol. 64, no. 4, pp. 1514-1519, Apri