Dual-Polarized Array Antenna with Quasi-End-Fire Radiation for 28 GHz 5G Mobile Terminals

Naser Ojaroudi Parchin[1], Atta Ullah[1], Haleh Jahanbakhsh Basherlou[2], Raed A. Abd-Alhameed[1], Embarak M Ibrahim Elfoghi[3] and Majid Salim Ali Alkhambashi[4]

{N.OjaroudiParchin, A.Ullah5, R.A.A.Abd}@Bradford.ac.uk

[1] Faculty of Engineering and Informatics, University of Bradford, Bradford BD7 1DP, UK
[2] Bradford College, Bradford, BD7 1AY
[3]College of Electronic Technology, Bani walid, Libya
[4]Sultanat of Oman, Muscat, PO Box 308, Oman

Abstract. In this palimpsest, an uncomplicated design technique of dual-polarized antenna array is suggested for the fifth-generation (5G) mobile terminal. Its structure contains a pair of conventional slot antenna arrays arranged with a 90° difference on the top portion of the smartphone printed circuit board (PCB). The employed substrate is Rogers 5880 laminate with an overall size of 75×150×1.2 mm^3. The proposed design is designed to work at 28 GHz. The essential characteristics of the design in terms of S-parameters, radiation patterns, efficiency, and antenna gain are investigated. The obtained results show good features of the antenna array for non-identical polarizations.

Keywords: 5G, dual-polarized antenna, slot antenna, Smartphone applications.

1 Introduction

5G wireless mobile networks will avail mm-Wave frequency bandwidths, Compared to the cellular networks used today (operating at the frequencies less than 4 GHz) [1-2]. 28 GHz is the most promising candidate band for 5G mobile wireless communications [3-6]. Increasing the operation frequency of the future wireless systems requires new techniques and attentive analysis in the design of antennas for upcoming wireless devices [7-10]. Compact antennas can be arranged in linear or planar array form to be used in phased array structures with high-gain characteristics for 5G wireless communications [11-15].

One of the main ultimata in the antenna designing for 5G smartphones is the execution of antenna arrays with dual-polarization function to support both vertical and horizontal polarization with broadband impedance bandwidth which could cover multiple 5G candidate bands. Consequently, a number of dual-polarized arrays with different geometries and radiation modes have been demonstrated [16-17]. However, all these antennas either occupy a huge three-dimensional space or have a complex feeding structure. In addition, it is preferred to use antenna arrays providing end-fire radiation mode. In this study, we propose a simple design technique for dual-polarized array antenna with quasi end-fire radiation beams for 5G smartphone applications.

The configuration of the suggested design is composed of slot array sets arranged on the top portion of smartphone PCB. Conventional slot antenna elements with a 90° difference in shape are used for the employed antenna arrays of the dual-polarized 5G smartphone antenna. The suggested design is working at 28 GHz, a 5G candidate band, and covering 2 GHz impedance bandwidth. Its characteristics in terms of S-parameter, radiation beams, efficiency, and beam steering are investigated. The following sections present the radiation characteristics of the conventional slot radiator, horizontally-polarized array, horizontally-polarized array, and the accomplishment of the proposed dual-polarized smartphone antenna design.

2 Conventional 28 GHz Slot Antenna

Conventionally, the microstrip slot antenna is a radiation element formed by cutting a narrow slot in a metal ground plane. The extent of the antenna is half-wavelength ($\lambda/2$) at operating frequency [18-20]. Based on different placement of the rectangular of slot antenna, it can provide different types of polarization such as vertical and horizontal polarization. Figure 1 (a) shows the layout of the rectangular antenna element. It has been cut on a Rogers RT5880 substrate with details of 1.2 mm thickness, 2.2 dielectric constant, and 0.0009 loss tangent. The discrete feeding technique is employed for the designed antenna. Its design parameters in mm are as below: W=

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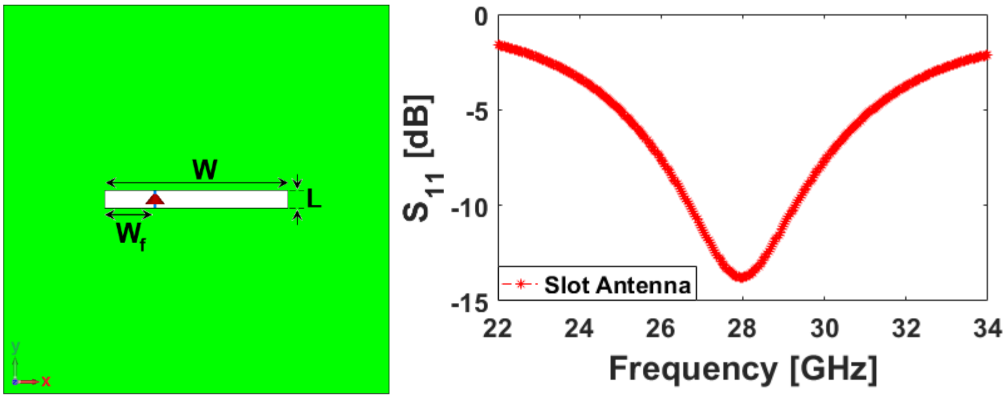
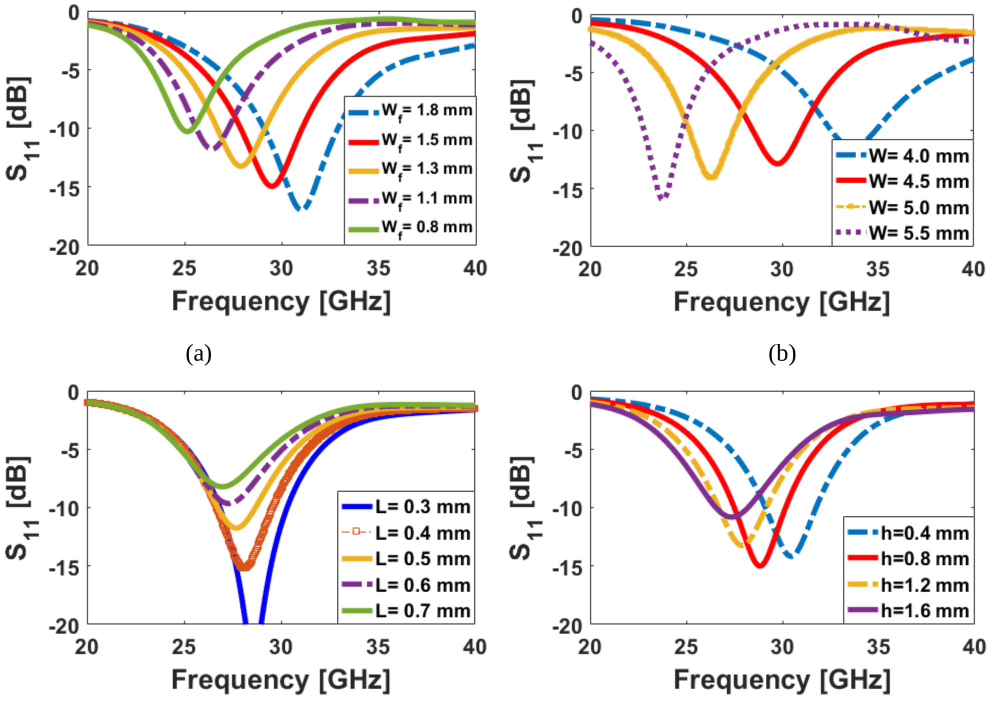
4.75, L= 0.45, and W_f= 1.3. The S_{11} result of the antenna is plotted in Fig. 1 (b). As shown, the antenna provides good performance with 2 GHz impedance bandwidth at 28 GHz.



(a) (b)

Fig. 1. (a) Configuration and (b) S_{11} result of the conventional slot antenna.

Results of miscellaneous design specifications including W_f, W, L, and h are investigated in Figure 2. Figure 2 (a) illustrates the effects of feeding point (W_f) on the operation frequency and impedance matching. As seen, decreasing the feeding point of the design its operation frequency and matching can be decreased simultaneously. Another parameter which has a remarkable impact on tuning the antenna frequency band is the length of the slot radiator (L). It can be distinguished from Fig. 2 (b), when the slot size increases from 4 to 5.5 mm, the antenna operation band decreases from 34 to less than 24 GHz. In contrast, as shown in Fig. 2 (c), the matching utility of the antenna can be changed for different widths of the slot radiators. As seen, when the slot width changes from 0.3 to 0.7 mm, the impedance-matching of the antenna improves from -0.8 to less than -20 dB. Apart from the design parameters, the thickness of the employed substrate has an impact on the antenna performance, but not significantly. It is shown in Fig. 2 (d), various thicknesses of the substrate affect the antenna operation band and impedance matching around 28 GHz [21-24].



(c) (d)

Fig. 2. The S_{11} results for different values of (a) W_f, (b) L_3, (c) L, and (d) h.

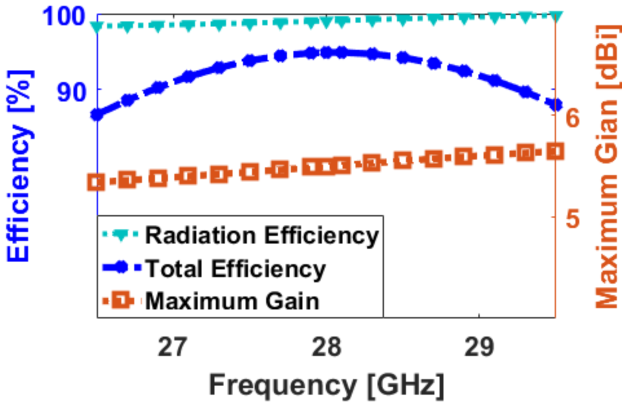
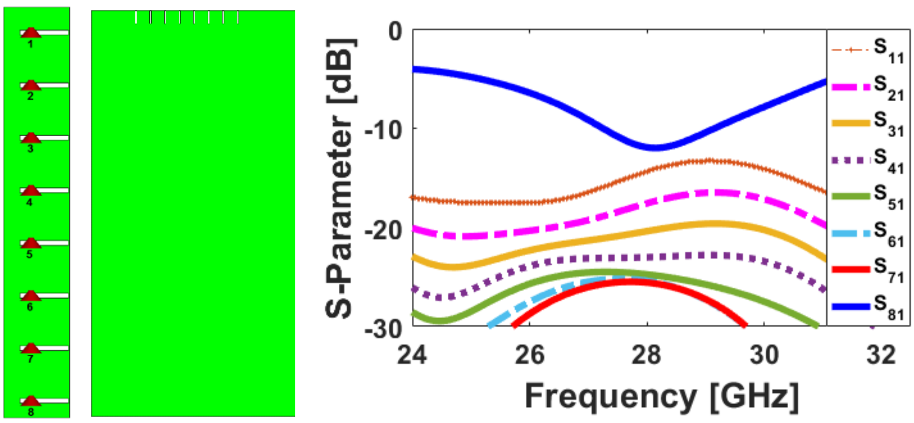


Fig. 3. Maximum gain and efficiencies of the designed slot antenna.

The slot antenna also delivers good radiation and total efficiencies over the operation band, as illustrated in Fig. 3: more than 97% radiation efficiency and 90% total efficiencies are obtained for the radiation elements at the frequency range of 27-29 GHz. It also exhibits high maximum gain with a value around 5.5 dBi.

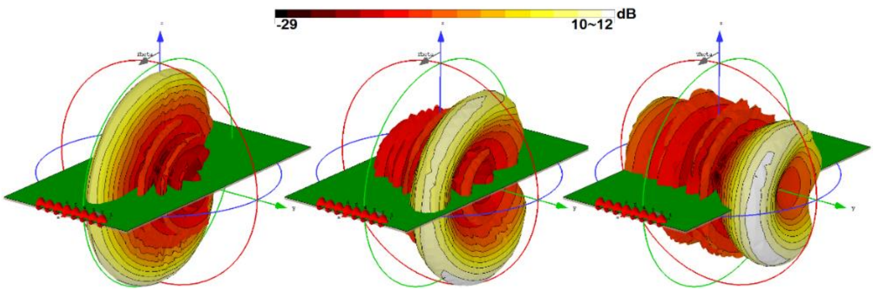
3 Horizontally-Polarized Antenna Array

The configuration of the antenna array with horizontal polarization is illustrated in Fig. 4 (a). As can be observed, eight slot antenna radiators with compact sizes organized in a linear form on the upper portion of mobile-phone PCB with Rogers RT5880 substrate and overall dimension of 75×150×0.8 mm^3. Due to the placement of the antenna, the array can provide end-fire radiation beams with horizontal polarization. Figure 4 (b) demonstrates the simulated S parameters (including S_{11}~S_{81}) of the design. As shown, the antenna elements provide sufficient S-parameter results with mutual coupling better than -15 dB. Figure 5 illustrates the 3D radiation beams of the designed array at diverse scanning angles. As shown, the design provides end-fire radiation beams at 0°,30°, and 60° which could cover half-space of the required radiation coverage for the smartphone [25-28].



(a) (b) (c)

Fig. 4. (a) Configuration, (b) placement, and (b) S-parameters of the horizontally-polarized antenna array.

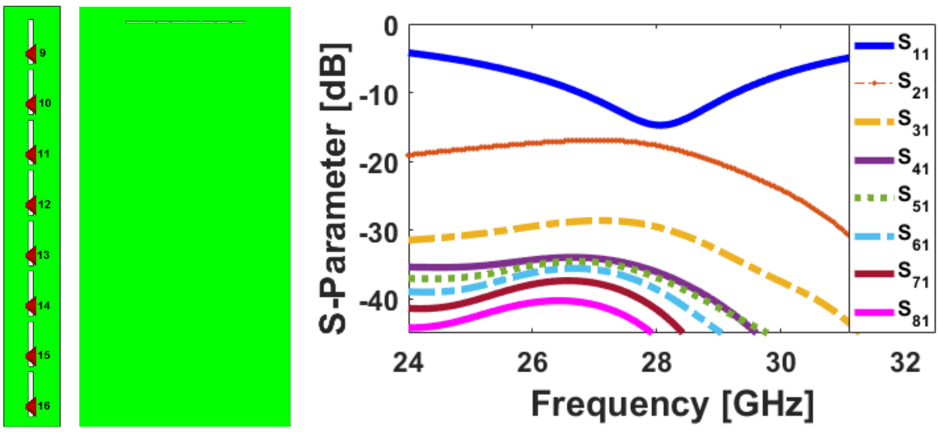


(a) (b) (c)

Fig. 5. 3D radiation beams at, (a) 0°, (b) 30°, and (c) 60°.

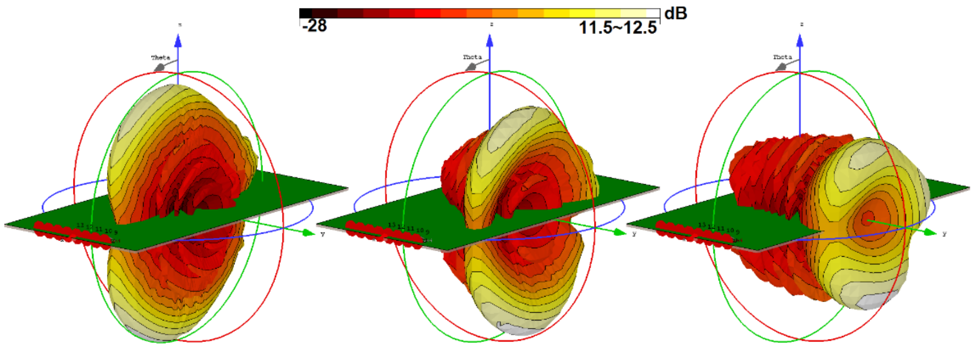
4 Vertically-Polarized Antenna Array

Figure 6 (a) shows the configuration of the antenna array with vertical polarization. Achieving the vertical polarization for phased array antennas with a simple design technique is a big challenge. As can be observed from Fig. 6 (b), we employed the eight slot antenna radiators with 0° difference arranged in a linear form on the top portion of mobile-phone PCB [29-31]. The array can provide quasi-end-fire radiation beams with vertical polarization. Figure 6 (b) depicts the simulated S parameters of the design. As can be observed, the slot array design exhibits good S-parameter results with mutual coupling better than -18 dB. The 3D radiation beams of the slot array at the scanning angles of 0°,30°, and 60°. As shown, the design provides quasi-end-fire radiation beams with a wide radiation coverage.



(a) (b) (c)

Fig. 6. (a) Configuration, (b) Placement, and (b) S-parameters of the horizontally-polarized antenna array.

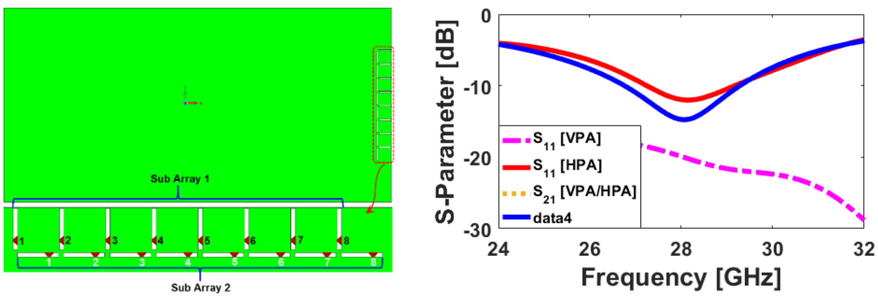


(a) (b) (c)

Fig. 7. 3D radiation beams at (a) 0°, (b) 30°, and (c) 60°.

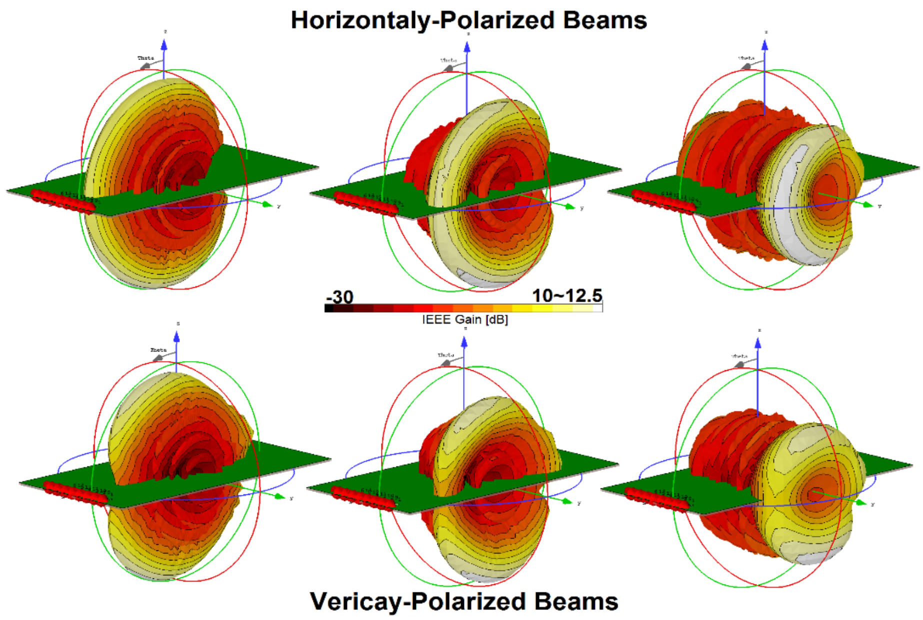
5 The Proposed Dual-Polarized Antenna Array

The configuration of the proposed design with dual polarization is represented in Fig. 8. As can be observed, the structure of the design is composed of two slot arrays arranged on the top portion of the smartphone PCB.



(a) (b)

Fig. 8. Configuration and S-parameters of the proposed dual-polarized slot antenna array.

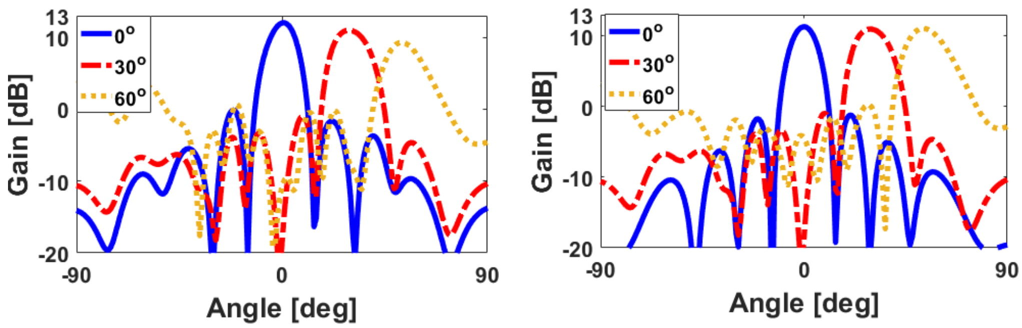


(a) (b) (c)

Fig. 10. Radiation beams of the proposed design at (a) 0°, (b) 30°, and (c) 60°.

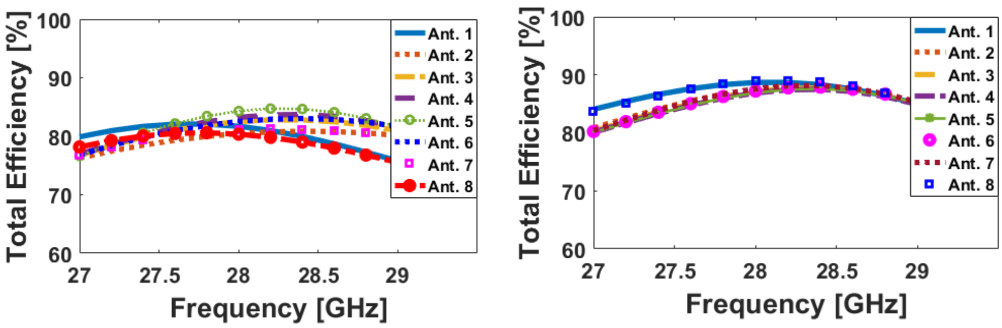
It can be observed that both employed arrays provide good radiation bemas with end-fire radiation mode. However, the second arrays bemas are quasi end-fire radiation. Both antenna arrays beam could cover half-space of the required radiation coverage for the smartphone. Another set of the employed slot array package can be employed at the bottom portion of smartphone PCB to achieve a full radiation coverage of mobile communications [32-35].

Figure 11 illustrates 2D-cartesian gain levels of the radiation beams at 28 GHz. It can be observed that the proposed design features sufficient radiation bemas with low side lobes. More than 10 dB IEEE gain levels are achieved for the scanning range of 0~60 degree. The total efficiency characteristics of the antenna elements for both horizontally and vertically polarized arrays are shown in Fig. 12: around 80% total efficiencies have been achieved for the element.



(a) (b)

Fig. 11. (a) S_{nn} and (b) S_{mn} results of the conventional PIFA array design.



(a) (b)

Fig. 12. Total efficiencies of the elements for (a) horizontally and vertically polarized arrays.

Conclusion

A simple design of the smartphone antenna with dual-polarization is proposed in this study. Its configuration is composed of two slot arrays with differently placed rectangular antenna elements. The design offers sufficient radiation characteristics at 28 GHz. The design is compact and can be easily integrated with the smartphone circuit planar form.

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