Low Cost High Gain 8×8 Planar Array Antenna for 5G Applications at 28GHz

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Abstract- In next-generation mobile networks, hundreds of diverse devices aim to be interconnected, posing huge challenges in capacity, coverage, efficiency, reliability, and connectivity. These and other challenges are addressed at Radio Frequency (RF) parts such as several radiating unit antennas, with very fine beamforming capabilities along with the requirements of high gains and minimized size. This work presents an 8×8 Aperture Coupled Microstrip Patch Antenna (AC-MPA) in the form of a planar array modeled for the 28GHz frequency band with high gain and compact size, making it suitable for 5G networks. The antenna is designed using a substrate with overall dimensions of 74.6×85.648×0.107mm^3 and relative permittivity of ε_0 = 4.3.

Keywords-5G; microstrip patch antenna; planar array

I. INTRODUCTION

Moving towards 5G means increased data rate needs in order to meet the requirements of high quality applications such as video streaming, endless connectivity, and maximum capacity and coverage with reduced cost [1-3]. Antenna arrays in next generation networks for mobile communication at higher frequency spectra, such as the mm-Wave band, have received attention to meet and support the growing higher data rates with greater throughput and improved performance [4-6]. Very precise and proper consideration is needed regarding the antenna design of future wireless devices due to increased operating frequency [7-10]. It is very challenging to put more antenna elements in a confined specific space. Apart from design issues in terms of physical geometry, designing 5G broadband antennas, operating at multiple frequencies as candidates for 5G bands is a challenging issue. A number of array designs for 5G broadband communication have been proposed [11-13]. Almost all these antennas occupy large space in mobile phone devices operating at very few 5G bands. In this work, a high gain, compact size, and wider band antenna has been proposed. The structure of the antenna contains 64 elements in an 8×8 array arrangement. At different scanning angles, it provides quite considerable radiation beams. The antenna has been modeled, simulated, and analyzed with the CST software [14]. Geometry and structure of the antenna are discussed in detail below.

The need of enhanced communication is essential due to the advancement and exponential growth of new technologies such as the massive Internet of Things (IoT), which are less power demanding and low-cost. These technologies consist of connections among hundreds of small size sensors, with specific application such as agriculture, smart cities, smart home, etc.. Services with specific purpose need very high throughput, lower latency, improved security, and reliability. Therefore, communication needs wide coverage and faster service [15]. The proposed spectrum for 5G by 3GPP (3rd Generation Partnership Project) consists of two bands, one below 6GHz (also known as the sub-six band) and one above 6GHz, typically from 26GHz to 40GHz (also known as millimeter wave) [15-16].

II. ANTENNA DESIGN

In order to fulfill the requirements of 5G networks in terms of flexibility, usefulness, proficiency, and integration, microstrip antennas are a considerable solution as they put together all the required characteristics. They are compacted and easy to develop on PCBs (Printed Circuit Boards) cost-effective solutions [17]. The primary structure of these antennas consists of a dielectric material both sides of which contain conducting sheets, one known as the radiating element (patch) and the other as the ground plane. An antenna array must be properly designed so that beam-forming and beam-steering abilities can be achieved. Each element in the array must be separately fed. The proposed antenna is a planar array with 64 elements formed with single elements of dimensions 9.4×10.75×0.107mm^3. Figure 1 depicts the diagram of the proposed 5G array antenna.

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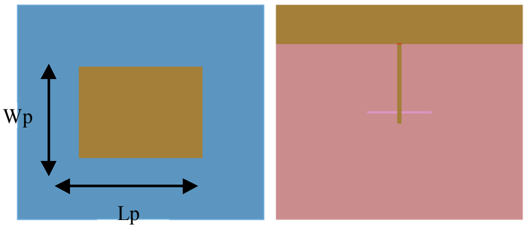

(a) (b)

Fig. 1. Single element patch antenna. (a) Top view, (b) side view.

III. SINGLE ELEMENT ANTENNA

Figure 2 shows the schematic diagram of the single element of antenna and Figure 3 shows its S11 result. These elements are further combined to form an antenna array. From the results it can be observed that return loss below -26dB is achieved at 28GHz and a bandwidth around 4GHz is obtained. The values of the parameters affect the performance of the antenna in terms of its matching and band. The optimized antenna parameters are shown in Table I.

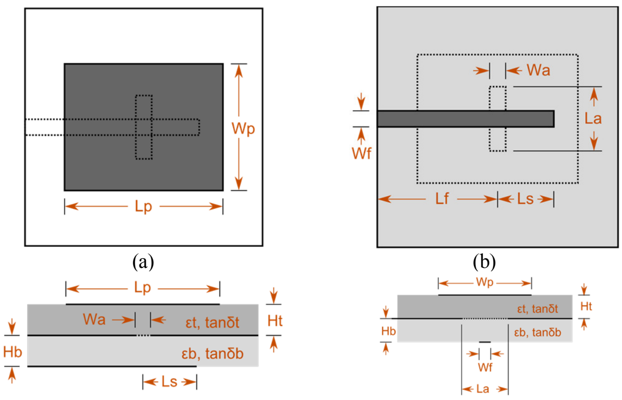

Fig. 2. Array antenna single element multiple views: (a) top, (b) bottom, (c) side, and (d) end.

TABLE I. ANTENNA ELEMENT PARAMETER DESCRIPTION

Name	Parameter Value (mm)
Frequency	27.89
Port_width	2.305
Port_height	0.967
Wavelength center	10.749
Groundplane_width	10.749
Groundplane_length	9.352
Groundplane_feed_extension	-1.702
La	2.799
Wa	0.107
Lf	2.973
Wf	0.209
Lp	3.978
Wp	5.374
Eb	4.3
Et	1
Ls	0.478
Hb	0.107
Ht	0.859
Tanδb	0
Tanδt	0

IV. THE PROPOSED 5G ANTENNA ARRAY

The proposed design of the 5G antenna array with 64 elements formed using the discussed above single element is illustrated in Figure 4. The design has overall dimensions of 74.6×85.648×0.107mm^3. As can be seen, 64 compact antenna components with distance d are used to make an array in the top segment of the PCB. The antenna is constructed on the FR-4 as bottom substrate and vacuum as the top part.

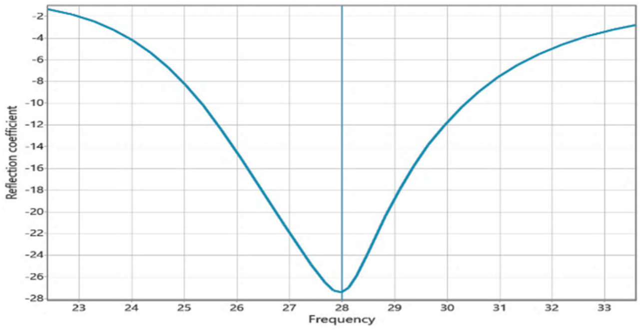

Fig. 3. S11 of the single element antenna.

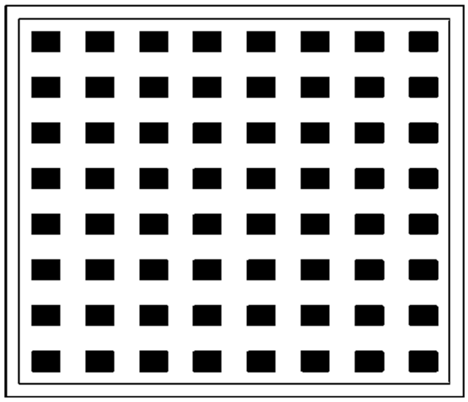

Fig. 4. Array arrangement of the 8×8 (64 elements) antenna.

The antenna array was simulated in CST and the obtained values of S11 are shown in Figure 5. It can be observed that the designed antenna provides wide bandwidth more than 4.5GHz with an acceptable value of return loss at 28GHz, i.e. -28.5dB. Similarly, after the simulation of the antenna, a gain of 10.34dBi is achieved. Figure 6 gives the graphical representation of the 3D radiation pattern plot.

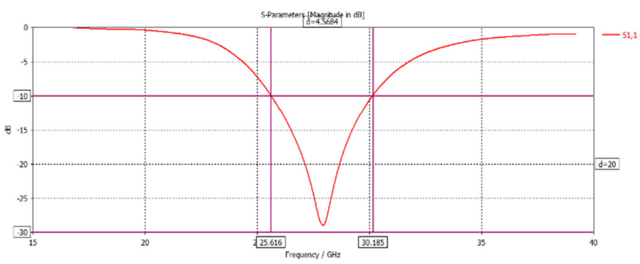

Fig. 5. S11 graph of the antenna array.

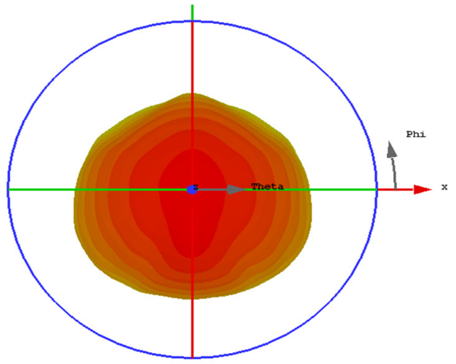

Fig. 6. 3D Radiation pattern (gain) at 28GHz.

The results obtained for the s-parameter of the 64-element antenna, simulated and analyzed in this work are shown in Figure 7. It can be observed that a very consistent and directional response is obtained and radiation with a very acceptable s-parameter is attained. Figures 8-9 show the E-plane and H-plane patterns in polar and Cartesian coordinates at 28GHz.

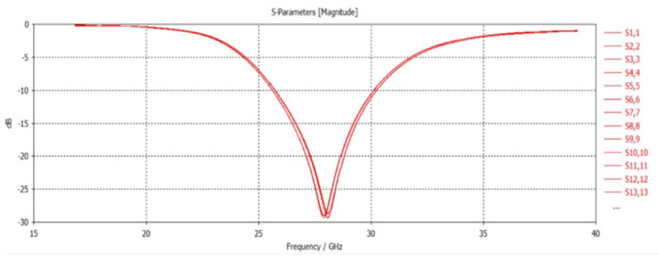

Fig. 7. S-parameter of the array arrangement in an 8×8 manner.

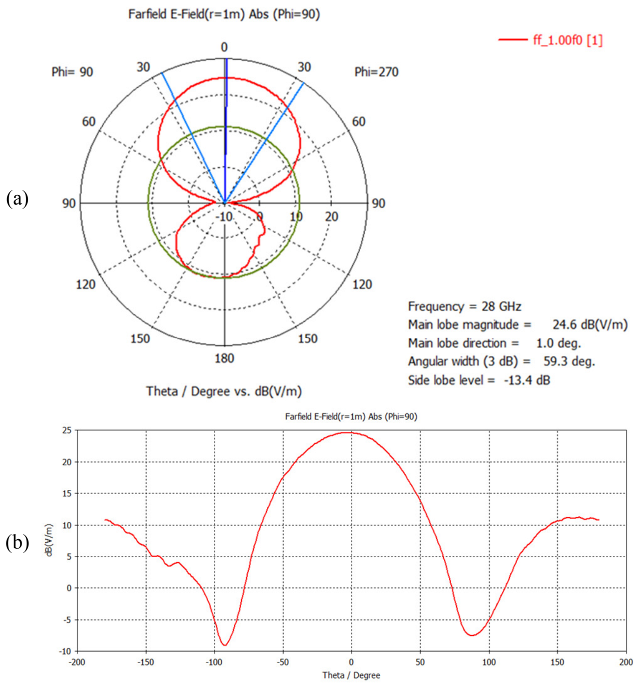

Fig. 8. E-plane pattern in (a) polar and (b) Cartesian coordinates.

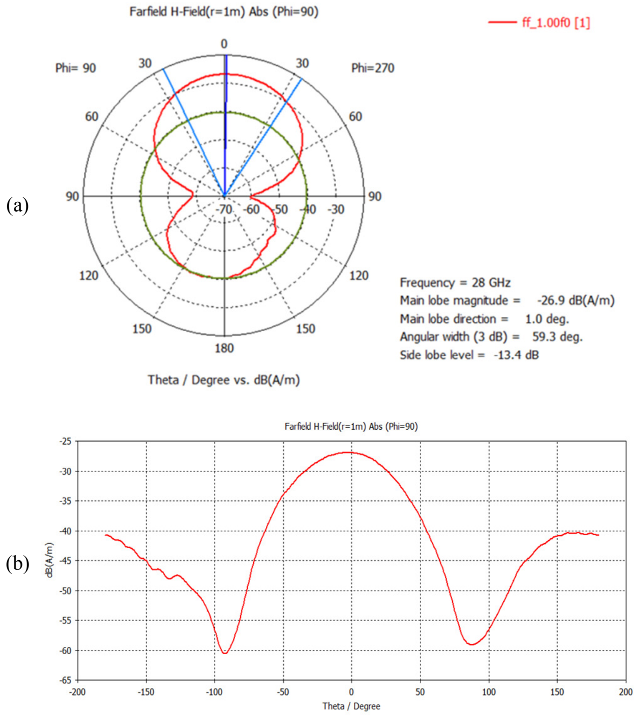

Fig. 9. H-plane pattern in (a) polar and (b) Cartesian coordinates.

The elements of the proposed array exhibit great performance. The efficiencies (radiation and total) of the proposed planar antenna array are exhibited in the related Figures. It can be observed that adequate efficiency outcomes are achieved at 25-30GHz. Higher than 97% radiation efficiency is gained. Likewise, more than 70% total efficiency has been attained for the introduced array elements [18-19]. It can also be observed that the proposed 5G antenna design offers steady radiation (patterns/beams) with enough gain [20].

V. COMPARISON WITH STATE OF THE ART ANTENNAS

A comparison with known related antennas is shown in Table II. It can be understood that the presented antenna is a low-cost antenna with much improved impedance bandwidth and acceptable peak gain in comparison with other known, state of the art antennas. The antenna has efficient planar structure, it is easy to implement and has a high directive gain. The presented antenna achieves an impedance bandwidth of 29% and a peak gain of 10.5dBi which outperforms the other antennas, and is adequate for millimeter-wave communication. It has a much wider bandwidth of 4.5GHz.

TABLE II. COMPARISON OF THE PROPOSED ANTENNA WITH PREVIOUS WORKS

Ref./Year	Freq. band (GHz)	Bandwidth (GHz)	Peakg gain (dBi)	Type
[21]/2021	24.25-29.5	6	0-5	Phased array
[22]/2018	39–49.3	2.0	5.5	Reflector, omni
[23]/2017	24–32	3.5	9	SIW/tapered slot
[24]/2016	57–67	-	2.2	Micro-strip
This work	25-30	4.5	10.5	Planar array

VI. CONCLUSION

The aim of this work was to present a new and compact array with WB function for 5G mobile communication. Its arrangement includes 64 compact antennas in an 8×8 planar form, positioned at the top edge of the FR4-material mainboard. The fundamental properties of the proposed antenna were examined. The introduced array shows satisfactory features over its operation band, which can be appropriate for multi-mode communications in 5G systems. This antenna has a considerable bandwidth over 4.5GHz, a gain of about 10.5dBi and is offered as a solution for beamforming application scenarios. Moreover, not only it has small dimensions but also it possesses a modular structure that can be simply scalable for a greater number of ports and elements.

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