A Dual-Polarized Sakura-Shaped Base Station Antenna for 5G Communications

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Abstract – In this paper, a dual-polarized sakura-shaped base station antenna for the fifth generation (5G) communication is designed and optimized. The antenna is mainly composed of four parts: main radiator, feed structures, bedframe and reflector. By fabricating and testing of the prototype of the antenna, the results show that the bandwidth (return loss >10dB) of antenna port 1 and port 2 are 9.2% (3.3-3.62GHz) and 16.5% (3.12-3.68GHz), respectively. In the entire working frequency band, the isolation is greater than 23.5dB. Moreover, the proposed antenna has a stable radiation pattern, and the horizontal half-power beam width (HPBW) and gain of the antenna vary within 65±4° and 5.25-6.31dBi, respectively. The antenna adopts PCB printed structure and has a compact structure $70\times70\times28mm^3$. The designed antenna has the advantages of low cost, light weight and good consistency of direction pattern.

Index Terms – 5G, Base station antenna, dual-polarized, low cost, printed-dipole.

I. INTRODUCTION

With the rapid development of modern communication technologies, the channel will be contaminated by various noises that has been suppressed using channel estimations [1-4], which is realized on algorithms. For the antenna design, the MIMO antenna and dual-polarized antenna has been widely concerned by scholars [5-10] to combat multipath fading and improve the capacity of mobile communication system in complex environment. Considering the actual wireless communications [11-12], the 45° oblique polarization omnidirectional antenna [11-21] has been widely studied for base station applications. Not only does the 45° oblique polarization antenna receive electromagnetic waves from more directions, but also have higher diversity gain. Thus, the design of base station antenna has gradually adopts the form of dual-polarized. For example, in [12], a wideband dual-polarized antenna with anti-interference capability has been studied. The antenna obtained 52.6% (VSWR<1.5) bandwidth at the operating frequency band of 2.27-2.53 GHz and peak notch bandwidth from 1.68 to 2.68GHz. In literature [11-12], dual-polarized antennas with simple structure and wide bandwidth are also developed. From the processing technology of base station antenna, metal [11-12] and PCB [12, 18, 21] are commonly used in the design procedure. Printed antenna has been widely used in base station because it is simpler and cheaper than metal fabrication. For example, in [15], two orthogonal placed dipoles and ±45° dual-polarized feeding structures are adopted to realize broadband operation. The bandwidth reaches 38% in the working band ranging from 3.3 GHz to 4.2GHz, and its bandwidth is better than that in the literature [18, 20]. In [14], the ME dipole antenna not only embeds the metamaterials of the broadside coupled E-shaped unit cells into the magnetic dipole, but also adds two U-shaped patch together with a rectangular patch to the E-dipole, which can reduce the height of magnetic dipole and improve the anti-interference effect, respectively. In the range of 3.32-3.64GHz, the bandwidth is only 9.2%, which is far less than the literature [16-17,19]. Thus, the bandwidth is too narrow to cover the entire sub-6GHz band for 5G applications. In literature [17,19], the working frequency band of 5G base station antenna designed can well cover the entire sub-6GHz frequency band, which are 3.3-3.8GHz, 4.8-5.0GHz and 3.14-5.04GHz, respectively.

In this paper, a dual-polarized sakura-shaped base station antenna is developed, principally covering the frequency band required for 5G (3.3-3.6GHz). The measurement results of the prototype are consistent with the simulated results. The designed antenna achieves a bandwidth of 16.5% over 3.12-3.64GHz, which is wider than that of the antennas in the literatures [19,21]. The size of antenna is $0.91\lambda_0\times0.91\lambda_0\times0.33\lambda_0$ (λ_0 being the wavelength in free space at center operating frequency). Compared with literatures [15, 20], the designed antenna is smaller and cheaper. Herein, the antenna is well simulated, optimized, fabricated and measured to verify the performance for the practical application of 5G communication systems.

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II. ANTENNA STRUCTURE

The structure of the dual-polarized dipole-like base station antenna designed in this paper is shown in Fig. 1. The antenna is mainly composed of a pair of cross dipoles with ±45°, two microstrip Balun printed with coupling feedings of height H1, ground plane and a metal reflector. Two of them are placed vertically and a 164mm×164mm×8mm reflector with side wall is placed, mainly to enhance the stability and the directivity of the antenna.

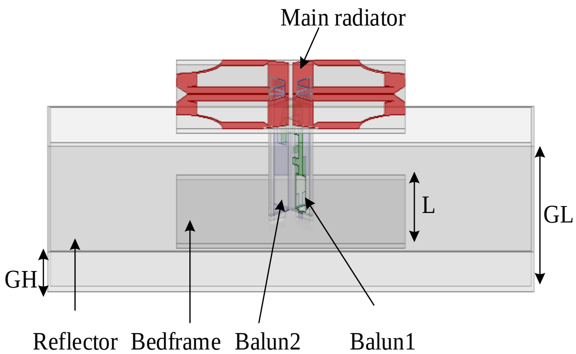

Fig. 1. Configuration of the proposed antenna.

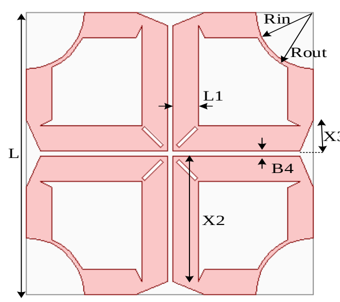

Fig. 2. Configuration of the main radiator.

As shown in Fig. 2, the main radiator of the antenna is sakura-shaped orthogonal dipoles printed on a 1mm thick FR-4 substrate with a relative dielectric constant of 4.4. Gaps in the dipole arm can be used as capacitive loads for good impedance matching. In Fig. 3, Two crossed substrates are distributed between the main radiator and reflector, which have Γ-shaped feeding lines on the front side and rectangle patches on the back side. Two slit orthogonal placement Baluns can not only make the coupling between the microstrip coupling feeder small, but also can make the structure stable and easy to process.

To get the good performance of the antenna, the antenna was simulated by electromagnetic (EM) simulation software Ansoft HFSS 15. By reasonably choosing the geometric parameters, the designed antenna is able to exhibit good performance. Geometric parameters of the antenna are displayed in Fig. 1-Fig. 3 and optimized values listed as follows (unit: mm): L=90, L1=6.9, X2=34, X3=8.5, B4=1.5, Rin=15.5, Rout=16.5, BW=3, H1=28, w7=1.8, d8=2.52, d4=d6=7, w4=4.6, d7=11, d3=7.7, w5=1.3, w2=w6=2.4, d2=5.9, d1=5.5, w1=4.3, GL=164, GH=8, w3=d5=2.8, L5=20.

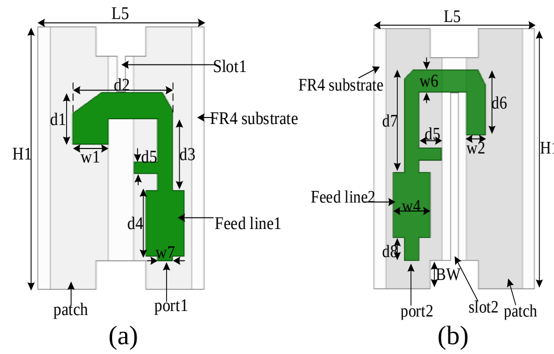

Fig. 3. Configuration of the Baluns: (a) Balun 1 and (b) Balun 2.

III. RESULTS AND DISCUSSION

In order to validate the designed antenna, a prototype of the antenna is fabricated in Fig. 4. The network analyzer and chamber are used to measure the developed antenna. The return losses with different shapes are studied in Fig. 5. Ants.1, 2 and the proposed antenna are the evolution of the main radiators. We can see from the figure, the impedance matching of Ant.1 and Ant.2 is not good. By using the slots on the dipole arms as capacitive loading, the impedance match of the proposed antenna is improved, and it can cover the entire frequency band.

Figure 6 shows the simulated and measured S−parameters results for port1and port2. Owing to the slight discrepancy in the two Balun structures, the operating frequency bands for port1and port2 are not exactly same. The working bandwidth for port1 and port2 are 9.2% (3.3-3.62GHz) and 16.5% (3.12-3.68GHz). Since the measurement of the S-parameters is not obtained in the chamber, the simulated S_{12} is quite different from measured. The simulation efficiency of the antenna is about 0.857. However, the measured and simulated isolations are greater than 23.5dB over the entire operating frequency band.

Figure 7 shows the peak realized gain of the fabricated antenna and simulated S_{11} for different Rin and Rout. Measured peak realized gain varies from 5.25dBi to 6.31dBi, and beam width of the radiation pattern is 65±4° over 3.3-3.6GHz. Since there is a slight difference between the simulated reflector and the actual reflector, the gain varies is about 0.6dBi. We can see from this figure, when the value of the Rin increases, the frequency moves towards the high frequency. When the value of Rout is 17.5mm, the return loss is best. The measured and simulated radiation patterns are shown for xoz-plane and yoz-plane at 3.3, 3.45 and 3.6GHz in Fig. 8. Owing to the symmetry of the antenna, only the simulated and measured radiation patterns for port1 are presented in the figure. The measured radiation patterns agree well with the simulated ones.

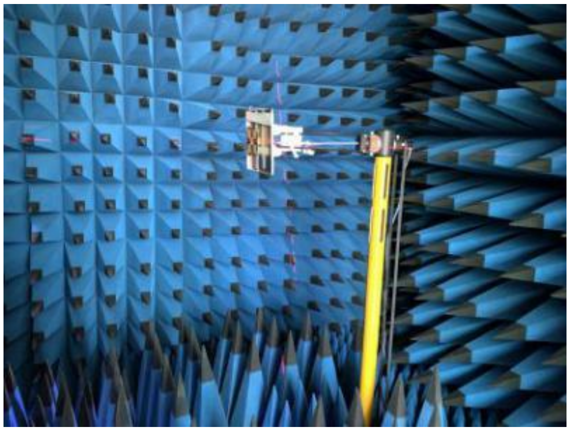

Fig. 4. Photograph of the designed antenna.

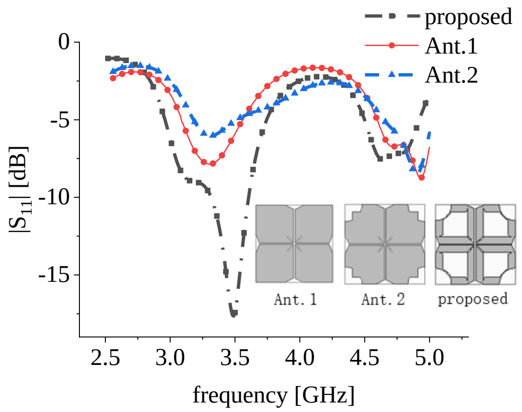

Fig. 5. Simulated S_{11} for Ant.1, Ant.2 and proposed antenna.

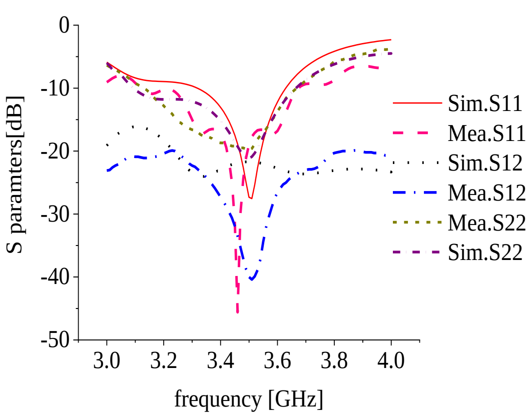

Fig. 6. Simulated and measured S-parameters of the proposed antenna.

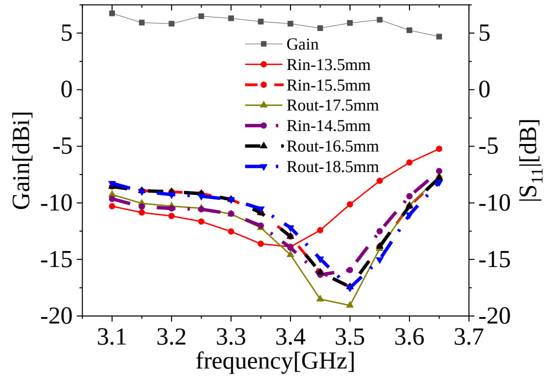

Fig. 7. Realized peak gain of the fabricated antenna and simulated S_{11} for different Rin and Rout.

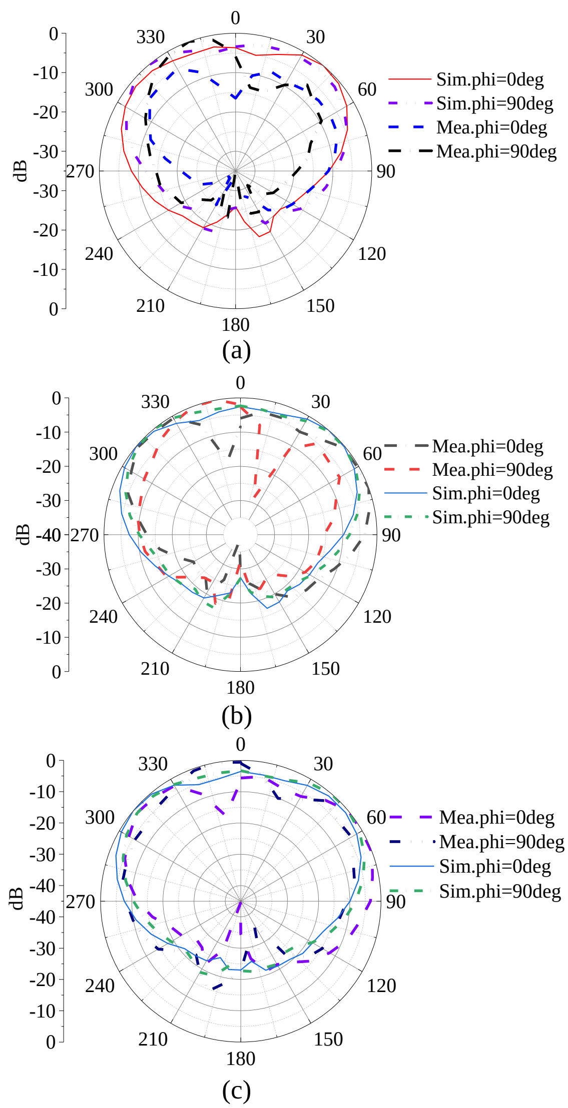

Fig. 8. Simulated and measured radiation patterns of the fabricated antenna at: (a) 3.3GHz, (b) 3.45GHz, and (c) 3.6 GHz.

The performance comparison between the designed antenna and the relevant 5G antenna are summarized in Table 1. To sum up, the antenna is an ideal choice for 5G base station antenna because of its advantages of strong structure, low cost, light weight and good consistency of direction pattern.

Table 1: Performance comparison of 5G base station antennas with the proposed antenna

Ref.	Bandwidth (GHz)	G (dBi)	Size (λ_0^3)	Isolation (dB)	Cost
[13]	3.3-4.2 (38%)	7	2×2×0.42	<-25	H
[16]	3.2-3.5 (8.9%)	5.61	0.91×0.63×0.58	–	L
[18]	3.25-3.81 (4.3%)	10.5	1×1×0.04	<-31	H
Proposed	3.12-3.68 (16.5%)	6.31	0.91×0.91×0.33	<-23.5	L

Note:"-" means not provided; λ_0 is the wavelength in free space at center operating frequency.

IV. CONCLUSION

A novel dual-polarized sukura-shaped antenna is designed, fabricated and measured. According to the measured results, the proposed antenna achieves a reflection coefficient lower than -10dB and a minimum port-to-port isolation higher than -23.5dB over 3.3-3.62GHz. Furthermore, the antenna shows very stable radiation patterns with HPBWs varying in 65±4°and average gain of around 5.84dBi. It has some advantages that low cost, light weight, strong structure and good consistency of direction pattern.

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