Millimeter-Wave Microstrip Antenna Array for 5G Smartphone Applications

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Abstract: In this paper, a phased array antenna is designed for 5G smartphone applications. A Microstrip rectangular patch antenna is devised at millimeter-wave frequency bands. The antenna array operates at 28GHz. The antenna is printed on RTRogers 5880 substrate of thickness 0.787mm with 2.2 of dielectric constant. Ten elements of the microstrip patch antenna are designed with five power sources. The antenna is designed by using HFSS software, the simulated array antenna at 28GHz frequency shows good performance in terms of gain and S-parameters which makes it suitable for fifth-generation smartphone applications.

Keywords: Millimeter-wave, Microstrip patch antenna, 5G.

I. INTRODUCTION

There has been a rapid development in wireless communication starting from analog(1G) to digital(2G,3G&4G) systems, as all these generations operate below 6GHz frequency which leads to a shortage of frequency band [3]. The Quick and wide development of wireless communication leads to higher data rates, to achieve these higher data rates higher frequencies are required. The millimeter-wave(mmw) communication technique uses unlicensed bandwidth beyond the traditional licensed wireless microwave bands and this millimeter wave(mmw) is recognized as a key technology in fifth-generation mobile communication systems [2]. Millimeter-wave (mmw) is a new and less used band where higher frequency wave carries much more data than lower frequency wave. In the future small cells are expected to provide several services with high data rates nearly Gigabit per second, for this a small cell should cover up to hundreds of meters and the line of sight propagation can be achieved using the directional antennas with a high gain property which reduces the intrusion with other communication systems and make possible the outdoor implementation for millimeter-wave communication [1].

Microstrip patch antenna has several advantages like low cost, lightweight, simpleand conformable to planar and nonplanar surfaces [4]. Due to its planar configuration, it is easy to integrate into arrays and produces the best results for mobile radio and wireless communication [4, 10].

Microstrip antenna array operating at 28GHz is proposed in this paper which is suitable for 5G smartphone applications.

II. PROPOSED MICROSTRIP PATCH ANTENNA

a. Single patch antenna:

The rectangular patch antenna printed on RTRogers 5880 substrate with a thickness of 0.787mm, the dielectric constant of 2.2, loss tangent of 0.0009, better performance is observed in this type of substrate. The ground plane of the substrate uses copper, as it has high conductivity. The single patch antenna operating at 28GHz for 5G has shown in Figure 1. With all dimensions specified in table 1.

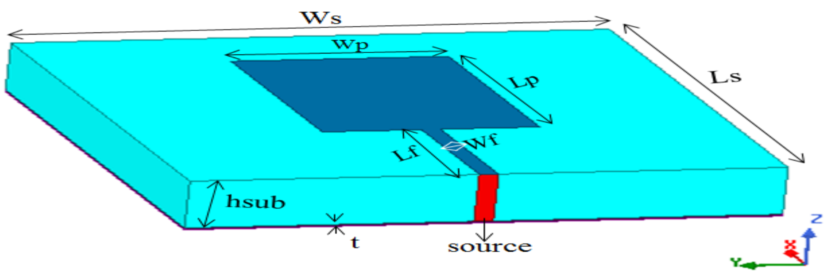


Fig. 1. Design of Single patch antenna

The Basic calculations used in designing the proposed antenna involve the following formulas:

$$(1)\ \boldsymbol{w} = \frac{\boldsymbol{c}}{\boldsymbol{2f}}\sqrt{\frac{\boldsymbol{2}}{\boldsymbol{\epsilon_r + 1}}}$$

$$(2)\ \epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \left(\frac{\epsilon_r - 1}{2}\right) \Big/ \left(\sqrt{1 + \frac{12h}{w}}\right)$$

$$(3)\ L_{eff} = \frac{c}{2f\sqrt{\epsilon_{reff}}}$$

$$(4)\ \Delta L = 0.412h\left(\frac{(\epsilon_r + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\epsilon_r - 0.258)\left(\frac{w}{h} + 0.8\right)}\right.$$

$$(5)\ L = L_{eff} - 2\Delta L$$

Where w = Width of the patch

L = Length of the patch

ϵ_r = Dielectric constant value of the substrate h = Height of the Substrate

ΔL = Effective Dielectric constant value

ϵ_{reff} = Extension in Length due to fringing effect

L_{eff} = Effective Length

TABLE 1. Dimensions of the 5G microstrip patch antenna

Parameter	Value(mm)
Ws	5.5
Ls	6
hsub	0.787
Wp	2
Lp	3.062
Wf	0.176
Lf	1.95
t	0.035
d	5.5

The values of Wp and Lf are modified to get resonance frequency at 28GHz. Here Wp decreases from 4 to 2 and Lf increased to 1.95 for the operation band of the antenna.
Figure 2 shows the S-parameters of the patch antenna. S_{11} of the antenna is simulated by using HFSS Software, the antenna covers the frequency bands from 27.46 to 28.64 GHz (~1200MHz of bandwidth).

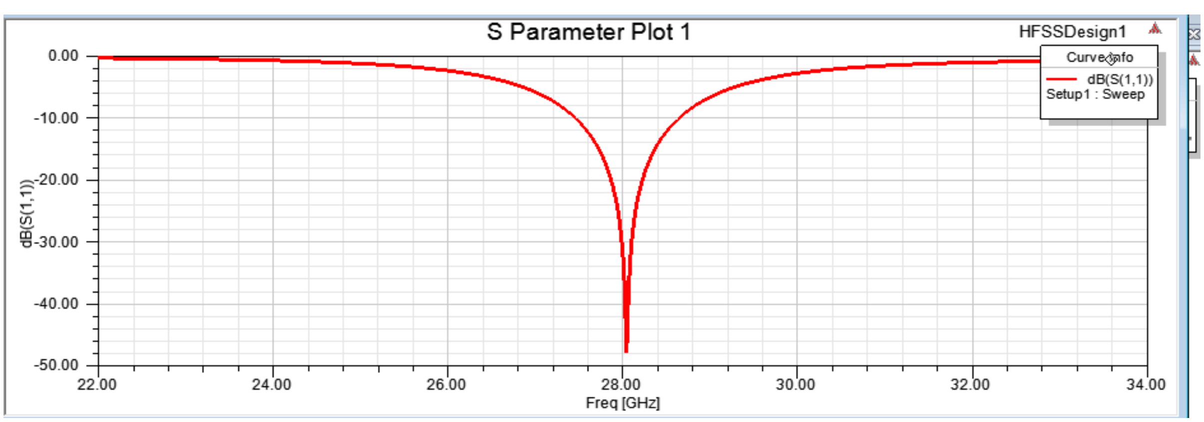
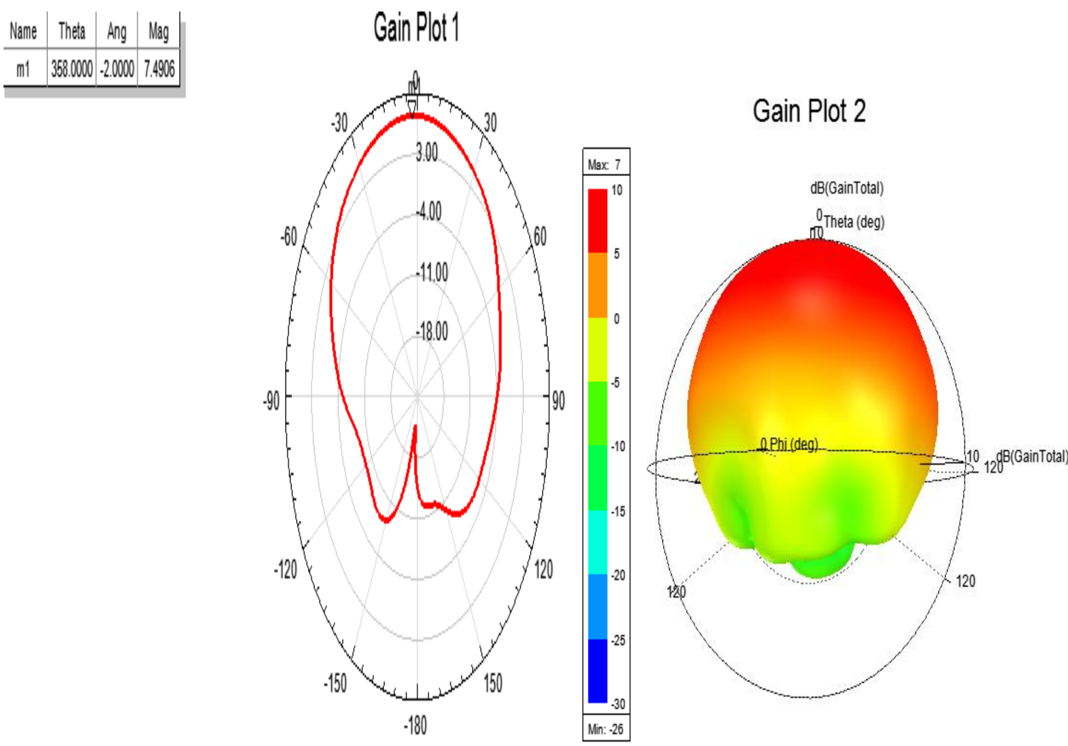


Fig. 2. Simulated S-parameter of the microstrip patch antenna

The gain plot of the antenna is shown in Figure 3, the antenna shows good radiation performance with a maximum gain value of 7.5.

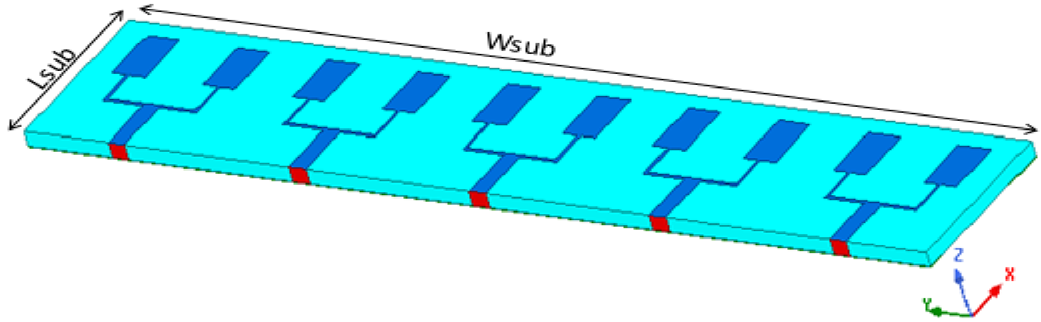


(a) (b)

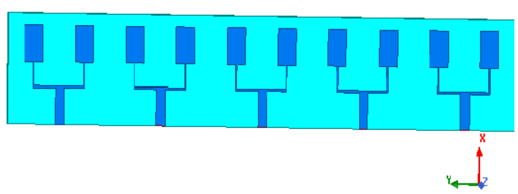
Fig. 3. 2D and 3D gain representation of the microstrip patch antenna

b. Proposed 5G antenna array:

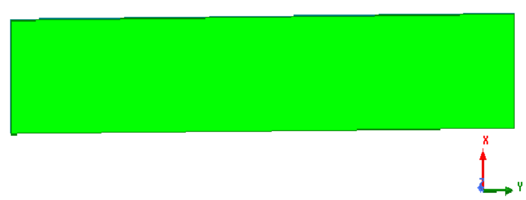
The proposed 5G antenna array design uses ten units of single patch antennas. The distance between the patch elements is taken as "d", where d is half of the wavelength ($\lambda/2$). The Proposed 5G antenna array design printed on substrate RTRogers 5880 substrate uses five power sources. The dimensions of the substrate will be Wsub=55, Lsub=9.176, and hsub=0.787. In the proposed antenna, two patch elements are combined by using a strip of dimension 5.676x0.176. The feed joining strip and source is of dimension1x3. Figure 4 shows the layout of the proposed ten element antenna array with five power sources.



(a)



(b)



(c)

Fig. 4.Design of proposed 5G antenna array with five sources (a) Side (b) Top and (c) Bottom views

The results of the simulated 5G antenna array are shown in Figure 5. The smartphone antenna array covers from 25.76 to 27.36(1600MHz of bandwidth) and upper mutual coupling is less than -16 dB which allows good isolation between antenna elements. Figure 6 shows the gain of the antenna array. The gain obtained by the proposed 5G smartphone antenna is 16.76dB.

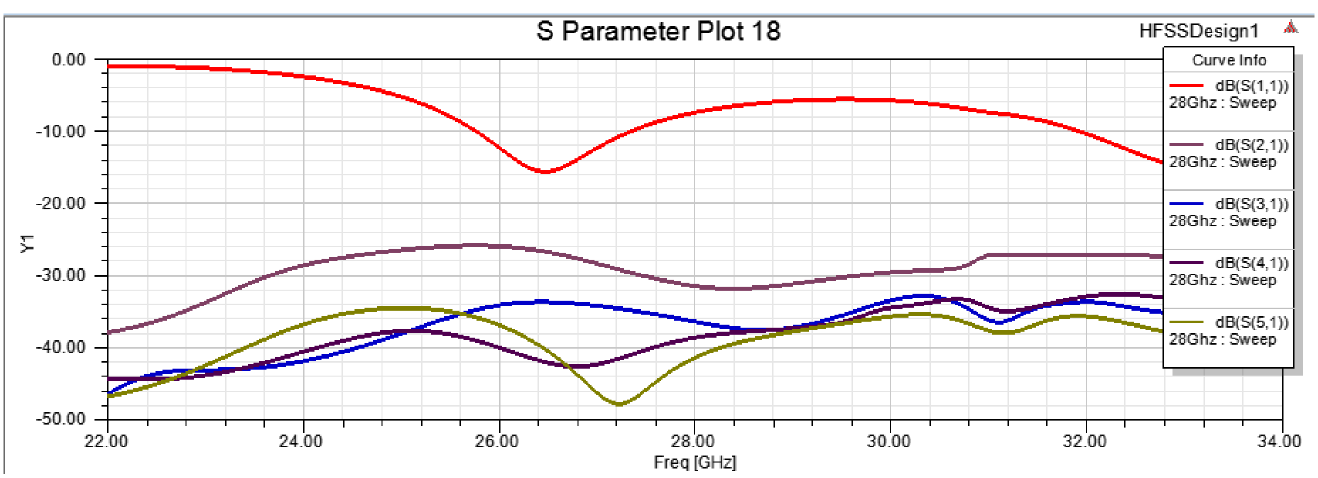
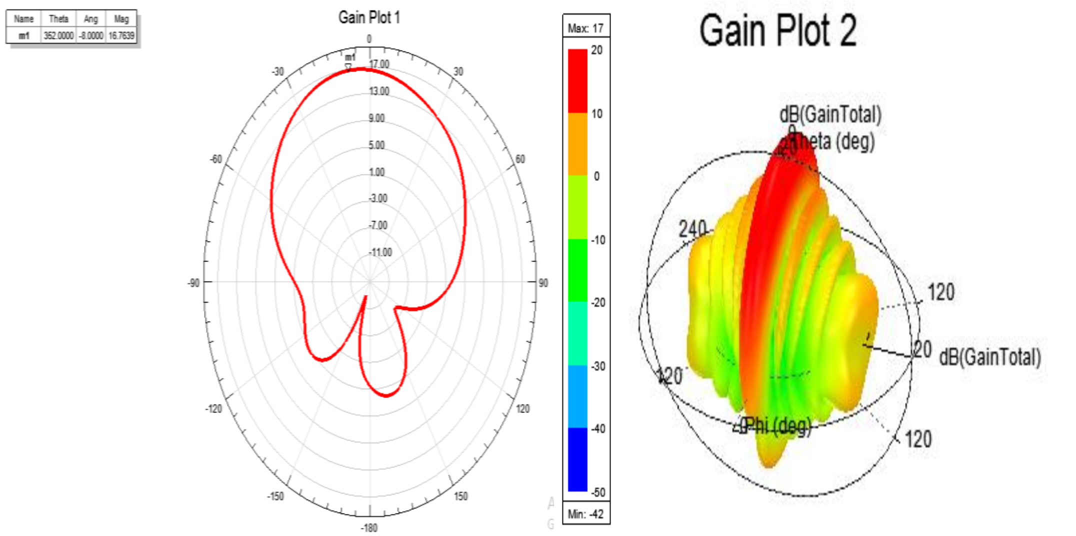


Fig. 5. S-parameters of the proposed antenna array



(a) (b)

Fig. 6. (a)2D, (b)3D gain plot of the proposed antenna array

Table 2: Comparison with the reference article

Source	Structure	Size	Bandwidth	Gain
Reference [1]	Phased array antenna with 10 sources	60x100mm	1200MHz	More than 15.5dB
Proposed antenna	Phased array antenna with 5 sources	55x9.176mm	1600MHz	16.76dB

III. CONCLUSION

In this paper, a microstrip antenna array is designed at millimeter-wave frequency. The Millimeter-wave band was a less used frequency band which is suitable for 5G mobile communication. Ten units of the single patch antenna are designed on RTRogers 5880 substrate using five sources. The simulated results of the proposed antenna show good performance in terms of S-parameters and gain. At 28GHz of frequency, the maximum gain obtained by the antenna is 16.76dB. The obtained results make the proposed phased antenna array suitable for 5G smartphones.

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