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Design of a microstrip antenna array for 5G applications

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Abstract **–** For 5G applications, a millimeter wave microstrip patch antenna and associated array are suggested. The Rogers RT Duroid 5880 substrate, which has a standard thickness of 1.575 mm, a relative dielectric constant (εr) of 2.2, and a tan of 0.0013, is used to build the 5G Microstrip patch. The antenna has a bandwidth of 1.863 GHz, a return loss of -25.84 dB, and a resonance frequency of 27.95 GHz. The suggested antenna has a 1x2 array architecture with tapered line feeding. The 28 GHz frequency is where the antenna array resonates. There is a discernible increase in gain with the array of antennas. The antenna and its array can be utilized for 5G mobile communication due to their tiny size.

Keywords – Millimeter Wave, Array Antenna, Mobile Communication, 5G Applications

I. Introduction

After 2020, mobile communications are anticipated to be 5th Generation. These guidelines were developed to satisfy both the present and foreseeable needs of mobile users. However, mobile traffic is expected to continue to expand significantly in the near future as it does so internationally every year. Numerous research organizations and industry partners have recently conducted in-depth study on the concept of a fifth generation (5G) mobile network with improvements in capacity, latency, and mobility [1], [8]. Due to the paucity of spectrum in the conventional microwave frequencies, millimeter wave (mmWave) bands have attracted a lot of attention as an additional frequency band for 5G cellular networks. When 5G mobile stations switch to the mm-Wave frequency, new techniques in antenna design for mobile-station (MS) and base-station (BS) systems are required. One of the essential elements of 5G cellular networks is an efficient beam-steerable phased array antenna, which may be made by combining the smaller antennas into an array. Due to several new uses outside of personal communications, the number of devices by the time 5G is completely completed might reach the tens or perhaps hundreds of billions. The corporate feeding approach for microstrip array antennas is discussed in this study while taking into account the aforementioned considerations. Each of these antennas is made to function in the 28 GHz frequency range and provide an end-fire radiation pattern for 5G communication. [9],[10]

There are numerous distinct forms of microstrip patch antennas, such as round, square, elliptical, and rectangular. The rectangle typeface was picked for this because of how common and straightforward it is. There are four different techniques to feed single patch element antennas: inset feed, probe feed with a gap, aperture linked feed, edge feed with gap, and two layer feed.

II. DESIGN METHODOLOGY

A microstrip antenna element can be used individually or in an array with other similar components. In both situations, the designer has to have a step-by-step element design approach. The primary goal of a design is frequently to achieve a specific performance at a given operating frequency. Choosing an acceptable antenna geometry should be the first option if a microstrip antenna design can accomplish these basic goals.

Two U-shaped slots are etched on a rectangular patch of the antenna configuration that has been suggested and is seen in Figure 25. PEC material makes up the ground plane and the bottom plane. The Rogers RT/Duroid5880 antenna substrate has a dielectric loss tangent of tan s = 0.0009 and a relative permittivity Er = 2.2. We adopted the antenna concept that we looked at in [11].

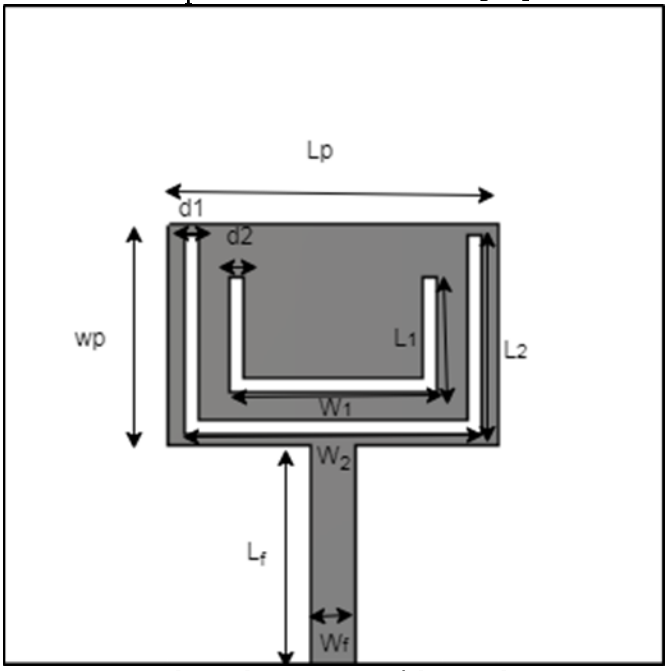


Fig.1 Shows the geometry of the simulation.

Table 1 lists the values of the key variables used to create our suggested antenna.

Table 1. Proposed antenna size.

Parameter	Dimensions (mm)	Parameter	Dimensions (mm)
Lp	**4**	**W1**	**3.8**
Wp	**6**	**W2**	**5.4**
Lf	**4**	**d1**	**0.25**
L1	**2.1**	**d2**	**0.25**
L2	**3.6**	**ht**	**0.035**
wf	**0.78**	**hs**	**0.508**
Wg=ws	**12**	**Lg=ls**	**12**

III. 2X1 ANTENNA ARRAY STRUCTURE

Figure 2 depicts a microstrip patch antenna with a 2x1 element array. With the introduction of this design, the performance of the single element antenna which is challenging to enhance in the single element case will be improved. The previously proposed antenna was recreated in this study using a 2x1 rectangle patch antenna array with the same substrate properties.

A 2×1 antenna array is created by placing microstrip patch components at equal intervals of 2λ, as illustrated in Figure 2. Each microstrip strip constituent is fed via enterprise networks.

Table 2 lists the values of the key variables used to create our suggested antenna arrangement.

Table 2. 1x2 array antenna size.

Parameter	Dimensions (mm)	Parameter	Dimensions (mm)
Length of substrate and ground plane	**22**	**W_f**	**0.78**
Width of substrate and ground plane	**16**	**$W_{f(100)}$**	**0.42**
2λ the space between the 2 patch	**12**	**$W_{f(75)}$**	**0.78**
ht	**0.035**	**hs**	**0.508**

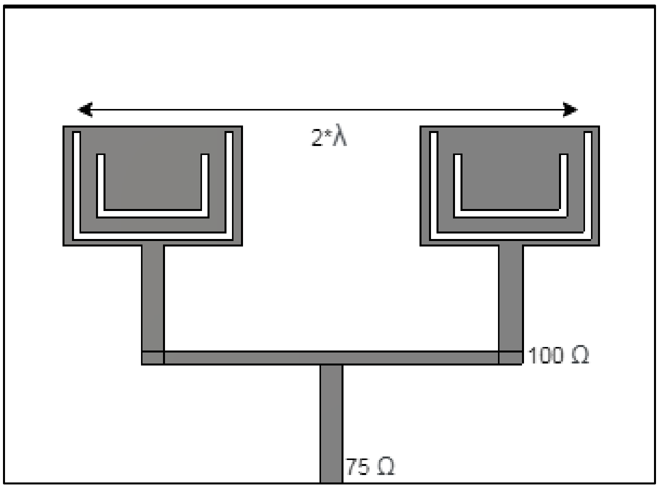


Fig. 2 Shows the geometry of 2x1antenna

IV. RESULTS AND DISCUSSIONS

Utilizing CST Microwave Studio Ver. 2014, antenna study was carried out to show simulated findings for the reflection coefficient (S11), the 2D radiation pattern, the 3D gain, and the directivity. This section provides the major simulation findings for the planned antenna.

A. *Return loss*

The simulation results of the Return loss (S11) of the basic antenna and antenna arrays as a function of frequency are displayed in Figures 3 and 4.

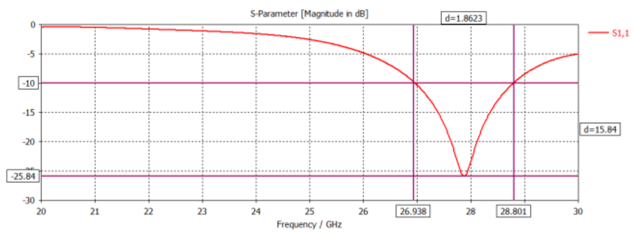


Fig.3 S11 Parameter for 28 GHz single element antenna.

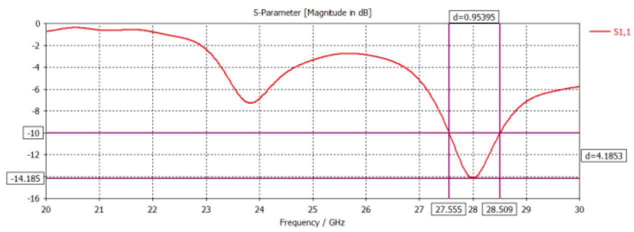


Fig.4 S11 Parameter for 28 GHz 2×1 antenna.

These findings demonstrate the antenna's suitability for the band [26.938-28.801GHz] in simple antenna and [27.555-28.509GHz] in antenna arrays, with a reflection coefficient less than -10dB.

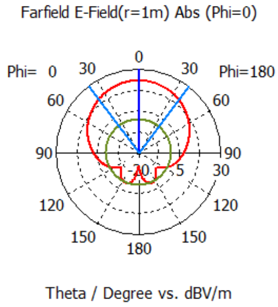
Based on these findings, we make sure that our antenna is tuned closely to the resonance frequency.

B. *Radiation pattern*

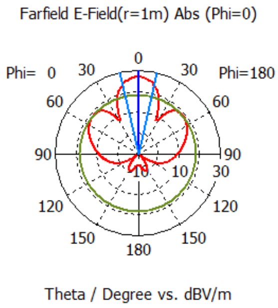
Because radiation is an antenna's primary function, the radiation pattern is a crucial aspect of how well it performs.

An antenna radiation pattern at 28 GHz is shown in figures 5, 6.

Figures 5, 6 show how our antenna's radiation pattern is focused in the antenna's top plane in both planes (E, H).

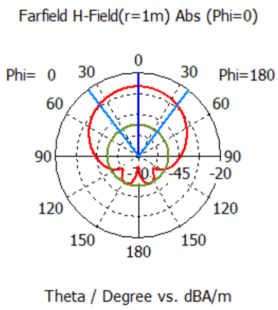


(a)

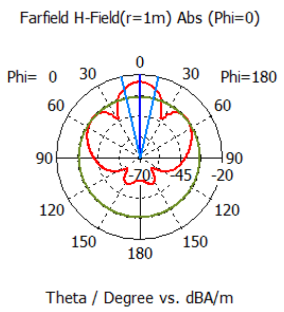


(b)

Fig.5 2D radiation diagram (planes (E). (a). patch . (b). array antenna



(a)



(b)

Fig.6 2D radiation diagram (planes (H). (a). patch . (b). array antenna

C. *Gain*

Figure 7 depicts the planned antenna gain and antenna array's simulated 3D radiation pattern at the resonance frequency of 28 GHz.

Figure 7 demonstrates that the gain attained with the straightforward antenna is 8.52 dB at a frequency of 28 GHz. The increase is not yet high enough to satisfy 5G Mobile's requirements.

As illustrated in figure 8, the antenna array outperforms a straightforward patch antenna by 12.4 dB for f = 28 GHz.

These findings indicate that this antenna satisfies the standards for the fifth generation (gain greater than 12 dB).

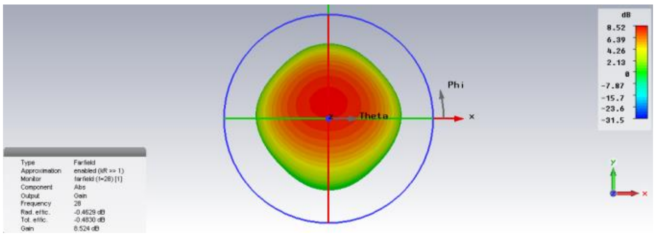


Fig.7 The gain of the patch antenna.

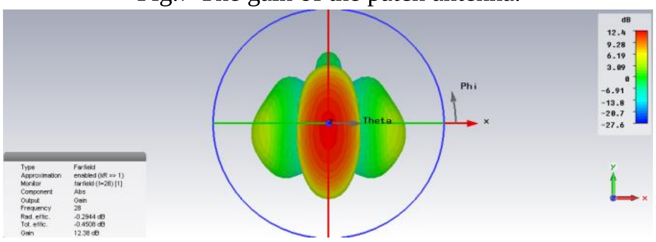


Fig.8 The gain of array antenna.

D. *Directivity*

At the resonant frequency of 28 GHz, the basic patch antenna utilized in 5G applications has directivity values of 8.99 dBi. As seen in figure 9

After employing the 2x1 antenna array, Figure 10 depicts the increase in directivity with a maximum of 12.7 db.

According to these findings, the antenna exhibits a far-directional field pattern.

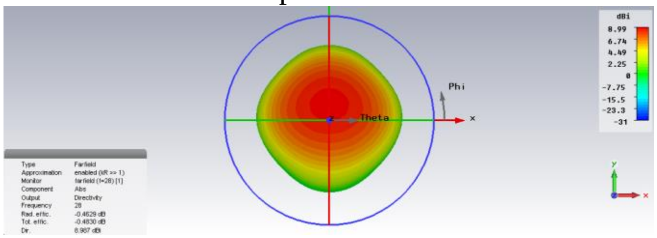


Fig.9 The Directivity of the patch antenna.

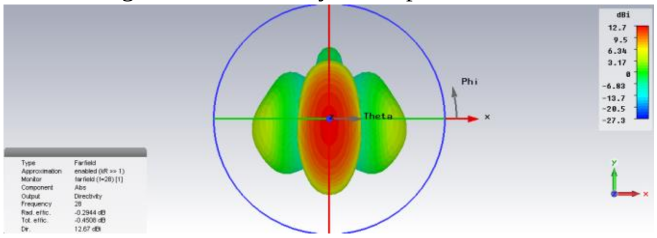


Fig.10 The Directivity of the antenna 1×2.

E. *Surface current*

Figures 11 and 12 depict the surface current distributions at 28 GHz in order to more clearly illustrate how the proposed antenna behaves. The intensity is maximum in the red area.

We see that the most crucial regions of the antenna are covered in the radiation (red radiation) (openings and at the beginning of the line and on the patch). This proves that everything is operating as it should.

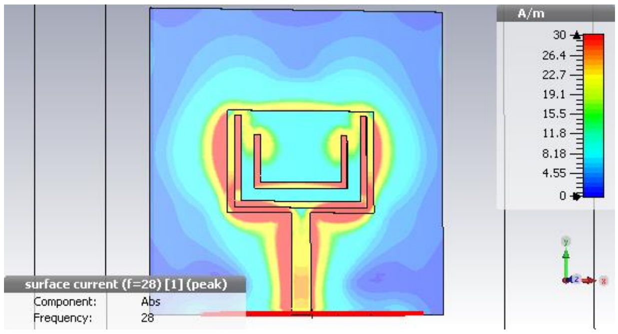


Fig.11 Surface current of the antenna

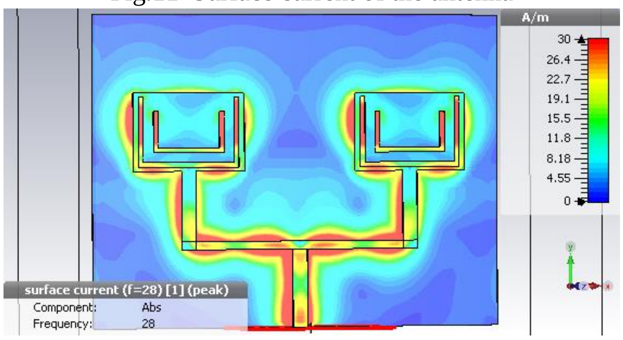


Fig.12 Surface current of the 1×2 antenna

The planned antenna performance is summarized in the table below:

Table 3. Summary of proposed antenna performance.

Antenna Type	F (GHz)	S11 (dB)	VSWR	Gain	Directivity	η %	BW (GHz)
Single antenna	28	-25.84	1.14	8.52	8.99	94.7	1.863
Antenna arrays	28	-14.18	1.48	12.4	12.7	97.6	0.954

F. *Efficiency*

The design has a radiation efficiency of over 94.7% for single antennas and 97.6% for antenna arrays. At resonance frequency of 28.0 GHz,

V. CONCLUSION

A compact, low-profile millimeter wave microstrip patch antenna is recommended for potential 5G applications. The antenna has an array resonance at (28) GHz and a single band resonance at 27.95 GHz. They are all within the 5G range of frequencies. The 5G antenna array exhibits a substantial improvement in directivity as well as gain, which will aid in overcoming the difficulties caused by the propagation losses in the millimeter regime. These characteristics show how reliable our array is at 28 GHz, making this set up an excellent option for 5G applications. Future studies will involve the validation of results using HFSS.

REFERENCES

[1] J. G. Andrews, S. Buzzi, W. Choi, S. Hanly, A. Lozano, A. C. Soong, y J. C. Zhang, ”What will 5G be?”, 2014.

[2] ERICSSON, ”5G: What is it? More than just improved performance and greater flexibility, the next generation is a shift in mindset”, 2014.

[3] F. Gutierrez y others, ”Millimeter-wave and sub-terahertz on-chip antennas, arrays, propagation, and radiation pattern measurements”, 2013.

[4] J. Helander, K. Zhao, Z. Ying, y D. Sjoberg, ”Performance Analysis of Millimeter Wave Phased Array Antennas in Cellular Handsets”, 2015.

[5] T. S. Rappaport, S. Sun, R. Mayzus, H. Zhao, Y. Azar, K. Wang, G. N. Wong, J. K. Schulz, M. Samimi, y F. Gutierrez, ”Millimeter Wave Mobile Communications for 5G Cellular: It Will Work!”, pp. 335-349, 2013.

[6] M. El Shorbagy, R. M. Shubair, M. I. AlHajri, and N. K. Mallat, “On the design of millimetre-wave antennas for 5g,” in *Microwave Symposium (MMS), 2016 16th Mediterranean*. IEEE, 2016, pp. 1–4.

[7] T. S. Rappaport, S. Sun, R. Mayzus, H. Zhao, Y. Azar, K. Wang, G. N. Wong, J. K. Schulz, M. Samimi, and F. Gutierrez Jr, “Millimeter wave mobile communications for 5g cellular: It will work!” *IEEE access,* vol. 1, no. 1, pp. 335–349, 2013.

[8] D. Imran, M. Farooqi, M. Khattak, Z. Ullah, M. Khan, M. Khattak, and H. Dar, “Millimeter wave microstrip patch antenna for 5g mobile communication,” in *Engineering and Emerging Technologies (ICEET), 2018 International Conference on*. IEEE, 2018, pp. 1–6.

[9] Merlin Teresa, P., and G. Umamaheswari. "Compact slotted microstrip antenna for 5G applications operating at 28 GHz." IETE Journal of Research 68.5 (2022): 3778-3785.

[10] Kamal, Mian Muhammad, et al. "A novel hook-shaped antenna operating at 28 GHz for future 5G mmwave applications." Electronics 10.6 (2021): 673.

[11] Constantine A.Balanis, ”Antenna theory: Analysis and Design”, Fourth Edition. John Wiley Publications. 2016