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A TWO-ELEMENT MICROSTRIP ANTENNA 28/38 GHZ FOR 5G MOBILE APPLICATIONS

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Abstract

A two-element antenna system is designed and fabricated with good isolation in this manuscript. The offered antenna gets two resonance frequencies at 28 GHz and 38 GHz which are allotted for the upcoming 5G mobile applications. The offered antenna is designed and simulated using industry-standard software CST MWS program. The basic antenna design is conventional microstrip antennas placed at the lower edge of the mobile substrate. The obtained reflection coefficient is -27.908 dB from (26.961 - 29.266) GHz with impedance bandwidth 8.19 % and -20.58 dB from (36.646 – 40.297) GHz with impedance bandwidth 6.09%. The mutual coupling between two antenna ports is less than -30 dB. The achieved directivity, far-field gain, and efficiency are 7.581 dBi, 7.182 dB_i and 91.24 % at 28 GHz and 9.716 dB_i, 9.24 dB_i and 89.63 % at 38 GHz, respectively. The size of the Rogers 5880 substrate is 55 x 115 mm^2 with h = 0.508 mm and ε_r =2.2 which is low cost substrate and small size patches best suited for miniaturized devices.

Keywords- Two element, 28 GHz, 38 GHz, mm-Wave, 5G, microstrip.

I. INTRODUCTION

Mobile communications technology is the new revolution in mobile markets. The evolution of mobile phone technology occurs very fast and tremendously since it was introduced in the early 1990s. The technology grows from the first generation, known as 1G to 2G, 3G, 4G and soon to be realized 5G. The fifth generation (5G) technology is expected to complete the fourth generation technology and provides solutions to the scarcity arising from 4G such as limited bandwidth and speed [1]. 4G and 5G technologies provide efficient mobile user services with lower consumed battery, higher data rates in larger parts of the coverage area, lower outage probability (better coverage), less expensive or no traffic fees due to low infrastructure costs, or higher aggregate capacity for many simultaneous mobile users [2]. As 5G is developed and implemented there will be a major requirement especially on the user equipment and base station infrastructures. The focus to date, therefore, is directed towards successful hardware demonstration that achieves required functionalities for mm-Wave technologies such as high gain, low profile, and low cost or the potential for low manufacturing costs. In recent years, with the increasing attention in 5G mm-Wave mobile communications, the antennas based on the exploit of frequency bands above 6 GHz are exaggerated investigated. The 28 GHz and 38 GHz bands have been considered as one of the nominated 5G communication systems that can be used at base stations and mobile handsets [3]. Some work done by other authors on the designing of 5G antennas/arrays have been recently introduced. A microstrip antenna and an array of 4-element are used in [4]. A dual-band slotted waveguide antenna array for 5G networks was introduced. The construction of the array is based on two groups of radiating slots to provide two frequency bands 28 GHz and 38 GHz [5]. A dual-band antenna operates at 10.15 GHz and 28 GHz in [6]. The anticipated 5G antenna is worked in the 25 GHz, the 28 GHz and the 38 GHz bands by employing two patch antennas and an EBG superstrate [7]. A slotted antenna was presented for the operation at 28 GHz, 38 GHz, and 61 GHz. It consists of a square patch having an L- and F- slot for the tri-band operation [8]. It is perceived that some of these antenna configurations are complex in a fabrication process, besides having low radiation efficiencies, and low gains. We have recently designed, simulated and fabricated a two-element antenna configuration which is designed and simulated in the 3D electromagnetic simulator CST Microwave Studio and measured using Vector Network Analyzer ZVA 67 (measure up to 67 GHz frequency) with a port impedance of 50 Ω and utilizes the parameters of commercially Rogers 5880 substrate. The antenna is simple, easy to fabricate and has a planar design. This work supports simultaneous operation in the 28 and 38 GHz bands using microstrip antenna having high bandwidth, high directivity, high radiation efficiency, and high gain. The manuscript is prepared in three sections. Section II accounts the development of the single element antenna for 28/38 GHz frequency bands. Section III accounts the configuration of the two-element antenna for 28 and 38 GHz frequency bands over the same substrate. Section IV describes the numerical analyses, simulation and measured results, whereas Section V provides the conclusions.

II. PROPOSED ANTENNA DESIGN

A. *Single Element Antenna Configuration*

The configuration of the basic design of the single element microstrip antennas is demonstrated individually in Fig.1. The offered patches are constructed on Rogers RT5880 substrate of 0.508 mm thickness, dielectric constant $\varepsilon_r = 2.2$ and loss tangent $\tan \delta = 0.0009$ with dimensions of w x L=15 x15 mm^2. Primarily, the dimensions of the main radiating patches are calculated rendering to the preferred resonant frequency. There are two dissimilar operative frequencies for dual-band operation. As antenna theory [9], the 28 GHz antenna acquires patch size of $W_{28} \times L_{28} = 3.44 \times 3.35$ mm^2 with inset feed of $g \times d_1 = 0.2 \times 1.2$ mm^2 and the 38 GHz antenna acquires patch size of $W_{38} \times L_{38} = 3.3 \times 2.4$ mm^2 with inset feed of $g \times d_2 = 0.2 \times 0.7$ mm^2. The patches are fed by a microstrip transmission line to motivate the appropriate set with dimensions $W_F \times L_F = 1.55 \times 2.61$ mm^2 to accomplish 50 Ω input impedance matching. The feeding is not built straight on the patch edges but by using multiple quarter wavelength transformers of 75 Ω with dimensions $W_T \times L_{T28} = 0.8 \times (3 \times 1.98)$ mm^2 and $W_T \times L_{T38} = 0.8 \times (3 \times 1.74)$ mm^2 for 28 GHz and 38 GHz, respectively. The width and length of the inset feed effect on the resonant frequencies and return loss levels so the best results should be gained. Based on optimization and several parametric studies, the final parameters are listed in Table 1.

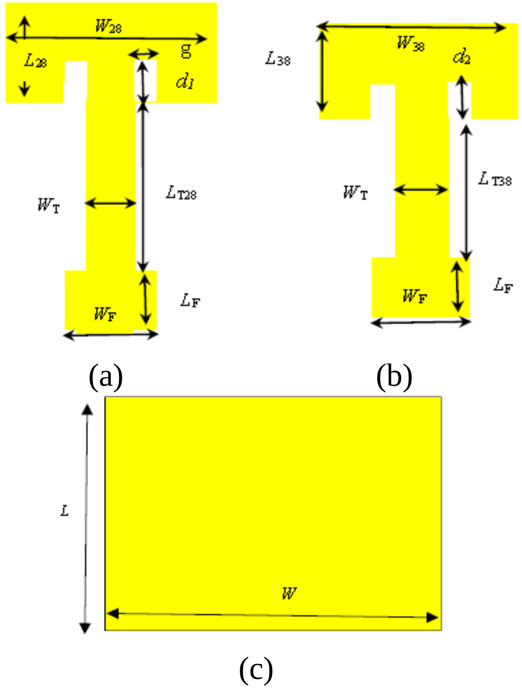


Fig.1 The Recommended Antennas for (a) 28 GHz Antenna, (b) 38 GHz Antenna, and (c) Ground Plane.

TABLE 1
TOTAL DIMENSIONS OF SINGLE ELEMENT ANTENNA

Parameter	Dimension (mm)	Parameter	Dimension (mm)
W	15	W_T	0.8
L	15	L_{28}	5.94
W_{28}	3.44	L_{38}	5.22
L_{28}	3.35	g	0.2
W_{38}	3.3	d_1	1.2
L_{38}	2.4	d_2	0.7
W_F	1.55	h	0.508
L_F	2.61		

B. Results and Discussion

The dimensions of the antenna patches were optimized to provide the anticipated resonance frequencies at 28 GHz and 38 GHz, The simulated reflection coefficients S_{11} of the single antennas are -27.908 dB from 26.961 GHz to 29.266 GHz with impedance bandwidth 8.19% and BW of 2.305 GHz and -20.58 dB from 36.646 GHz to 40.297 GHz with impedance bandwidth 9.49 % and BW of 3.6507 GHz for the upcoming 5G mobile communications as presented in Fig.2.

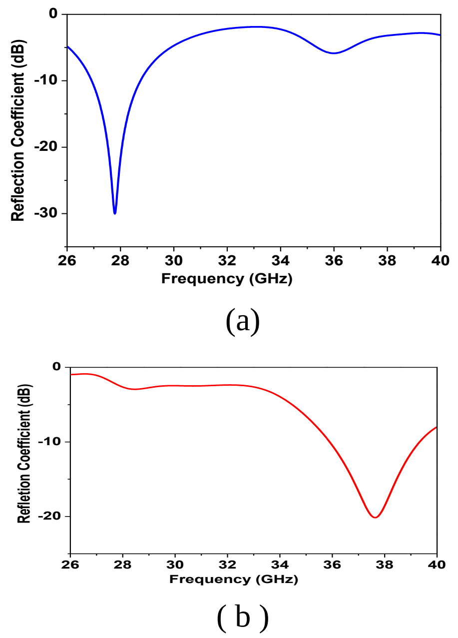
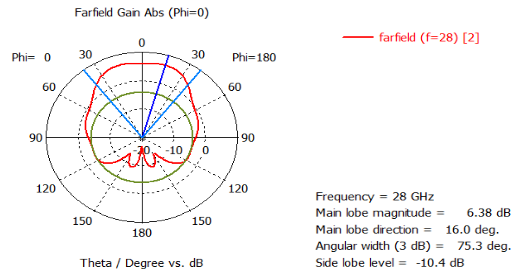
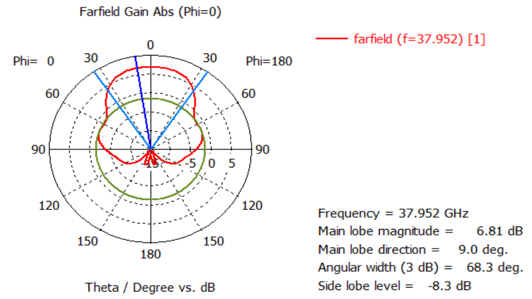


Fig.2 S-Parameters of Single element Antennas. (a) $|S_{11}|$ at 28 GHz and (b) $|S_{11}|$ for 38 GHz.

The radiated far-field patterns are displayed in Fig.3, the simulated directivity, gain and efficiency of the single element antenna reached 7.095 dB_i, 6.639 dB_i and 90.03 % for 28 GHz and 9.02 dB_i, 8.578 dB_i and 90.32 % for 38GHz, respectively.



(a)

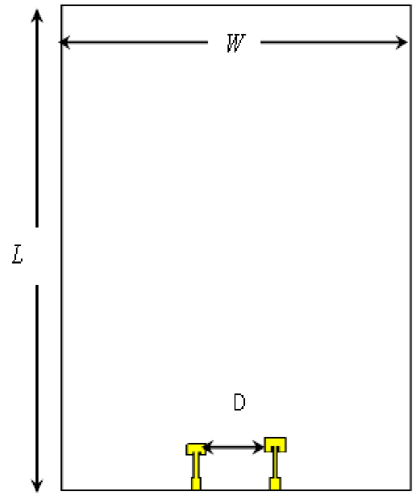


(b)

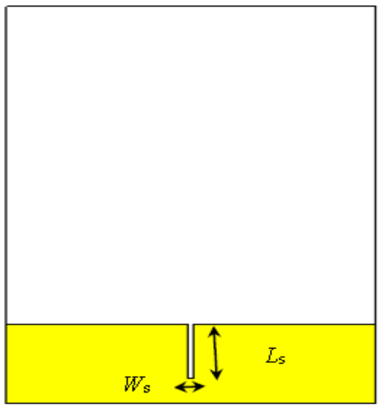
Fig.3 Radiated Farfield Pattern at (a) 28 GHz and (b) 38 GHz.

III TWO ELEMENT ANTENNA DESIGN

In this section, the two element antenna is designed and fabricated at 28 GHz and 38 GHz for 5G mobile applications. The antenna architecture is explained in Fig.4. It is fabricated on a W x L = 55 X 110 mm^2 Rogers RT5880 substrate of 0.508 mm thickness, dielectric constant ε_r = 2.2 and loss tangent tan δ = 0.0009. The top and bottom patches printed on the substrate are the two radiating configurations and the ground plane both are made of copper material. The back view is publicized in Fig. 4 (b) which is the ground plane of dimensions W x L_g = 55 x 22 mm^2 with slot dimension W_S x L_S = 1 x 15.07 mm^2. The slot is engraved to enhance radiation and isolation characteristics of the antenna. The main principle for system design are the mutual coupling, which mostly increases due to the small distance amongst the elements, by enlarging the spacing amongst the two antenna elements, the mutual coupling can be decreased. The separation amongst the two antennas edges is D = 10.13 mm which is about λ to evade grating lobes. The antennas in the array have the dimensions as mentioned in Section II.



(a)



(b)

Fig. 4 Two-Element Antenna Geometry. (a) Top View and (b) Back View.

TABLE 2
TOTAL DIMENSIONS OF TWO-ELEMENT ANTENNA

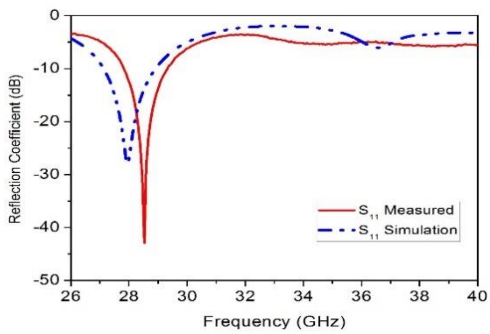
Parameter	Dimension (mm)	Parameter	Dimension (mm)
W	55	Lg	22
L	115	L_S	15.07
W_S	1	D	10.13

IV. EXPERIMENTAL RESULTS AND DISCUSSION

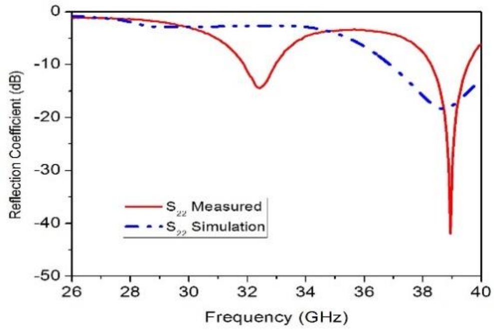
The two port antenna system is simulated on CST Microwave Studio simulation software and measured using Vector Network Analyzer ZVA 67 (up to 67 GHz frequency range measurement) with the port impedance of 50Ω. The array is further analyzed and fabricated for the following parameters.

A. *Return Loss*

Fig.5 displays the S_{11} and S_{22} plots after simulation and fabrication. It is observed that S_{11} and S_{22} < -10 dB for the 28 GHz and 38 GHz band frequencies. The results in Fig.5 recommend that there is an agreement between the simulated and measured values except for little difference in the bandwidth and the values of reflection coefficients at 28 GHz and 38 GHz. Both antennas are meeting the anticipated requirements of return loss. The simulation gives 27.946 GHz and 37.83 GHz frequencies and the measurement gives 28.3 GHz, 32 GHz and 38.9 GHz frequencies and all of these bands are used in 5G wireless communication.



(a)

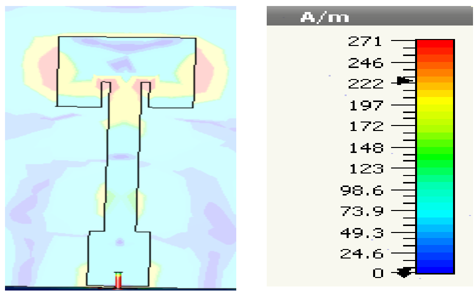


(b)

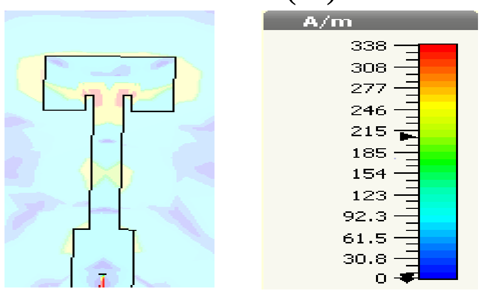
Fig.5 Reflection Coefficients for Two element Antenna (a) $|S_{11}|$ and (b) $|S_{22}|$.

B. *Surface Current Distribution*

To get a better insight into the operation of the offered antenna, the surface current distributions are inspected at the frequencies of 28 and 38 GHz using CST software as publicized in Fig.6. It is obvious that the surface currents predominantly focus on the main patches at 28 GHz and 38 GHz.



(a)



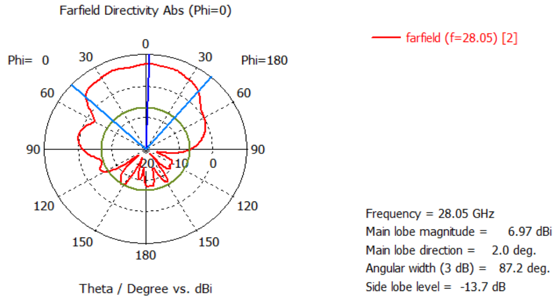
(b)

Fig.6 Current Distributions of the Two-Element Antenna at (a) 28 GHz and (b) 38 GHz.

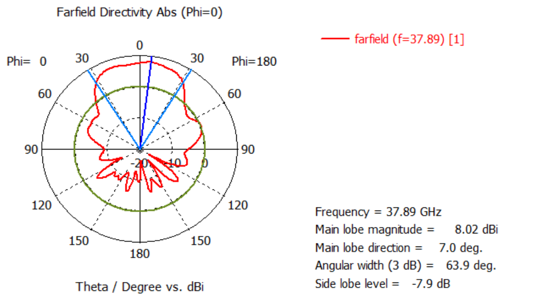
C. *Gain and Radiation Pattern*

The radiated far-field patterns for Phi = 0^o and Phi = 90^o are presented in Fig.7 and

Fig.8, the simulated directivity, gain and efficiency of the mm-wave two element antenna reached 7.581 dBi, 7.182 dBi and 91.24 % at 28 GHz and 9.716 dBi, 9.24 dBi and 89.63 % at 38 GHz, respectively. The attained results from two element antenna design are better than that attained from single element and there is an enhancement in all antenna parameters.

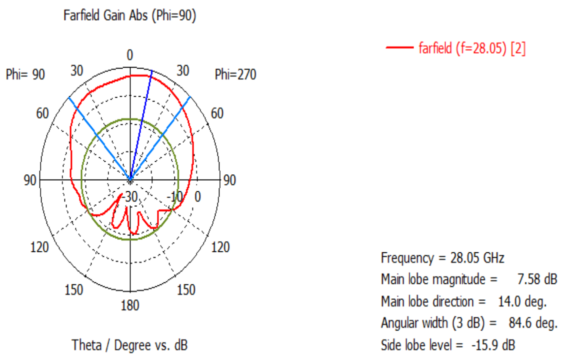


(a)

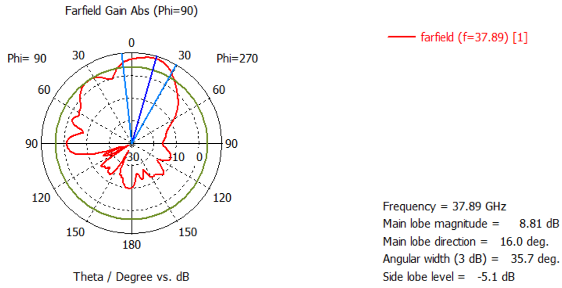


(b)

Fig.7 Radiated Farfield Pattern for the Two-Element Antenna for Phi = 0 ^{o} at (a) 28 GHz and (b) 38 GHz.



(a)



(b)

Fig.8 Radiated Farfield Pattern for the Two-Element Antenna for Phi = 90 ^{o} at (a) 28 GHz and (b) 38 GHz.

D. *Mutual Coupling*

Fig.9 illustrates the S_{12} and S_{21} plots for the two port antenna system, it's perceived that both S_{12} and S_{21} < -29 dB for the 28 GHz and 38 GHz frequencies, thus the two antennas are independent of each other and the mutual coupling values between the two antennas are very low. There is an agreement between the simulated and measured results. Furthermore, we do not use any separate isolating techniques between antenna elements.

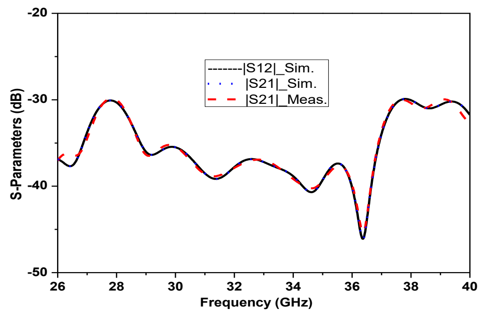


Fig.9 Transmission Coefficients for the Two Element Antenna.

A comparison between different substrate and ground lengths with S-Parameters and gain is introduced in Table 4.3. It is obvious that, the best results obtained in the case of using L_g = 22 mm and L_S = 110 mm and these lengths are selected to be fitted to the mobile handset dimensions.

TABLE 3
COMPARISON BETWEEN DIFFERENT SUBSTRATE AND GROUND LENGTHS WITH S-PARAMETERS AND GAIN

Different lengths with S-Parameters and gain		L_g=22 mm & L_s=22 mm	L_g=22 mm & L_s=110 mm	L_g=110 mm & L_s=110 mm
S_{11} (dB)	28	-31.938	-40.18	-27.984
	38	-24.256	-35.86	-25.978
Gain (dBi)	28	6.935	7.182	6.987
	38	7.882	9.24	8.212

E. *VSWR of the Introduced Two-Element Antenna*

Fig.10 displays the VSWR of the two-element antenna. VSWR is very low that means very less miss-match loss thus better impedance matching throughout the operating bandwidths. The attained VSWR are 1.08 at the 28 GHz and 1.27 at the 38 GHz. With these values achievement, the antenna is whispered to be already matched.

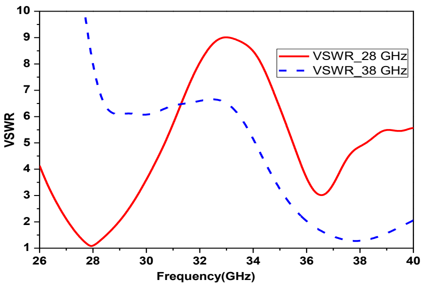


Fig. 10 VSWR Vs. the Frequency of the Two-Element Antenna.

This design can be very attractive to be integrated with prospect handsets for short-range communications. The simulated values of the resonance frequency, reflection coefficient, directivity, gain, and radiation efficiency of the offered single and two-element antenna at the two chosen frequencies are presented in Table 4. Fig. 11 demonstrates the fabricated two-element 5G antenna.

TABLE 4
FINAL PARAMETERS OF PROPOSED ANTENNA

Antenna Design	Resonance Frequency (GHz)	Reflection Coefficient (dB)	Directivity (dBi)	Gain (dBi)	Radiation Efficiency (%)
Single Antenna	28.02	-30.02	7.095	6.639	90.03
	37.952	-20.15	9.2	8.578	90.32
Two-Element Antenna	27.946	-27.84	7.581	7.182	91.24
	37.83	-18.35	9.716	9.24	89.63

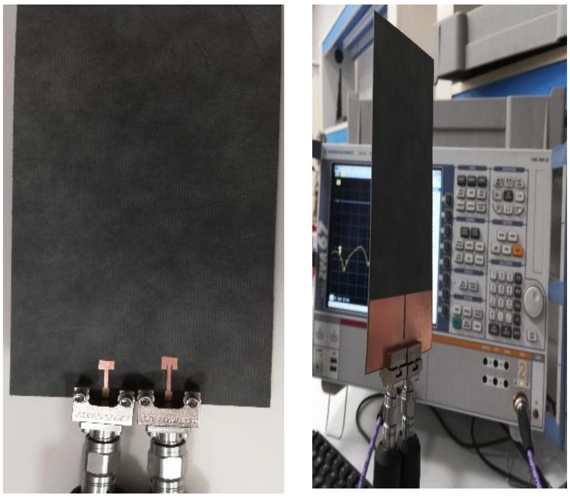


Fig. 11 Photograph of the Fabricated Two-Element 5G Antenna.

V. CONCLUSION

An integrated two-element antenna system was presented fulfilling with the upcoming 5G mobile systems. The integrated design contains two antennas operate at 28/38 GHz set at the lower verge of the mobile handset. The condensed two-element antenna covered wide frequency bands of (26.961- 29.266) GHz and (36.646 - 40.297) GHz. Typical results such as S-parameters, gain, and radiation pattern were intended and measured, and they can encounter the necessities of 5G systems. The achieved directivity, far-field gain and efficiency are 7.581 dBi, 7.182 dBi and 91.24 % at 28 GHz and 9.716 dBi, 9.24 dBi and 89.63 % at 38 GHz, respectively. The mutual coupling between two antenna ports is less than -30 dB. The simple arrangement of the planar antenna elements permits for practical integration with other electronic circuitry.

REFERENCES

1- M. Abirami, "A Review of Patch Antenna Design for 5G," in Electrical, Instrumentation and Communication Engineering (ICEICE), 2017 IEEE International Conference on, pp. 1-3, 2017.
2- P. Sharma, "Evolution of Mobile Wireless Communication Networks-1G to 5G as well as Future Prospective of Next Generation Communication Network," International Journal of Computer Science and Mobile Computing, vol. 2, pp. 47-53, 2013.
3- T. S. Rappaport, S. Shu, R. Mayzus, Z. Hang, Y. Azar, K. Wang, et al., "Millimeter Wave Mobile Communications for 5G Cellular: It Will Work!," IEEE Access, vol. 1, pp. 335-349, 2013.
4- D. Imran, Farooqi, M. M., Khattak, M. I., Ullah, Z., Khan, M. I., Khattak, M. A., & Dar, H. , "Millimeter Wave Microstrip Patch Antenna for 5G Mobile Communication," Presented at the Engineering and Emerging Technologies (ICEET), 2018 International Conference, 2018.
5- A. C. S. J. a. D. H. S. I. F. da Costa, "Dual-band Slotted Waveguide Antenna Array for Adaptive Mm-wave 5G Networks," presented at the 2017 11th European Conference on Antennas and Propagation (EUCAP), 2017.
6- Y. Jandi, F. Gharnati, and A. O. Said, "Design of a Compact Dual Bands Patch Antenna for 5G Applications," in Wireless Technologies, Embedded and Intelligent Systems (WITS), 2017 International Conference on, pp. 1-4, 2017.
7- A. K. Sanae Dellaoui, Mustapha El Halaoui and Adel Asselman "Patch array antenna with high gain using EBG superstrate for future 5G cellular networks," presented at the 11th International Conference Interdisciplinarity in Engineering , INTER-ENG 2017, Tirgu-Mures, Romania, 2017.
8- M. Ur-Rehman, M. Adekanye, and H. T. Chattha, "Tri-band millimetre-wave antenna for body-centric networks," Nano Communication Networks, vol. 18, pp. 72-81, 2018.
9- C. A. Balanis, Antenna theory – analysis and design: A John Wiley & Son, Inc., Publication, 2005.