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Performance Analysis of Integrated Array Headed for 5G Mid-band Frequencies

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Abstract - *Miniaturized patch antenna with single wideband resonance by covering Sub-6/Sub-7 GHz application for the 5G wireless communication is proposed in this letter. The antenna which is proposed in this letter is designed with radiating patch of 1x3 arrow array on the FR4 dielectric material in Quarter wave transmission line (QWTL-DGS) in-ground with an overall dimension of 35.6x35.6x1.6mm is simulated in ANSYS Electromagnetic Suite version 2021, and all the electromagnetic parameters for the proposed antenna in this letter is analyzed & discussed. The simulated antenna is resonated at the 4.2 GHz with the bandwidth from 3.35 GHz to 5.17 GHz, which comes under international standards of IEEE P 802.11 ax / ay/D 4.O (Sub-6/Sub-7 GHz) applications-5G mid-band frequency with high efficiency in working as it is fabricated and tested in Vector Network Analyzer and obtained the similar results in tested &measured.*

Keywords — *Arrow array, IEEE P 802.11 ax/ ay/D 4.O,5G-mid-band frequency, sub-6/sub-7GHz, QWTL- DGS.*

I. INTRODUCTION

IN the last few years, the designing of antennas has [2] been paying attention to, and it is also mandatory for this modern wireless communication [7]. In this letter, an array of 1x3 [1, 3] with arrow-headed is taken into account for the application of 5G communications [10] by resonating at 4.2 GHz with bandwidth from 3.35 GHz to 5.17 [9] GHz, so it covers the 5G mid-band frequencies [11]. Initially, the spectrum allocated for the 5G communication is mm waves above 24 GHz and found some drawbacks like very less coverage in signaltransmission[20]. To overcome this International Telecom Union (ITU) allocated a new promising spectrum in 2019 as Sub-6 GHz frequency with bandwidth from 3.4 GHz to 3.8 GHz [13], and most of the antennas are simulated for both frequencies, and most of them claimed [16] the antenna resonating above 4 GHz [14]also as Sub-6 GHz [12], but in later 2020 the ITU allocated another spectrum frequency band for the voice over 5G (Vo5G) application between 4.17 GHz to 4.7 GHz frequency band, and it was named as Sub-7 GHz with an international standard as *IEEE P802.11 ax/ay/D4.O*, and *ITU n77, 79* standards [15] the above mentioned two application comes under the 5G mid-band frequency applications [16] as the advancement happened in modern wireless communication in recent years, so simulation array antenna becomes more popular [7]. Here the simulated antennaisdesignedinthearraystructure[4.5.6]thisstructure plays a crucial role in the resonating frequency of the particular antenna discussed here [8]. The main reason to specify the simulated antenna as the array is here the combination of three radiating arrow patches in the simulated patch antenna is interconnected to the feed-line [4]. A QWTL – DGS architecture [17,21] is implemented in the ground of the proposed antenna, by implementing this technique in a patch antenna can able to suppress the overall thickness as well as the sounds of the copper in the patch antenna [18]. In the next subheading, a survey carried out related to the work discussed in this letter [19]

A Low-profile dual-band filtering antenna for 5G-Sub-6 GHz applications is discussed by Yapeng Li in 2019. As he mentioned it as a dual-band in the paper title, his simulated antenna resonated between 3.32-3.65 GHz and 4.67-5.15 GHz, so the simulated antenna can able to work in 5G and voice over 5G (Vo5G) applications with an overall dimension of 50x45x0.5 mm^3. The dimensions seem to be high when compared to the proposed design in this letter. The gain of the antenna is mentioned in dBi it is around 7.17 dBi. To obtain this value in dB multiply with 0.4 from the calculation, the gain of the antenna is 2.86 dB, and the simulated antenna by Yapeng Li is good in unidirectional radiation pattern [15]. The next design in this survey is a Compact patch antenna array for 60 GHz is discussed by Ayad Shohdy W in 2020. He simulated the patch antenna using array and EBG structure on Rogers 5880 dielectric substrate in rectangular structure to work in frequency at 60 GHz as it is mentioned in the paper tile for broadband application with an overall dimension of 17.5x22x1.262 mm^3 and the maximum gain of the antenna mentioned is 16 dBi[20].

II. DESIGN ANALYSIS

In this part, the design of the simulated antenna is analyzed in an iterative manner; this helps prove that the final simulated design is good in all circumstances when compared to the other iteration. Initially, the antenna is simulated using FF4 dielectric material on the parasitic Defected Ground Structure (P-DGS), where the radiating patch is constructed using a 1x3 arrow array structure, and this design is simulated in ANSYS EM suite version 2021 and analyzed all the electromagnetic parameters. All the electromagnetic parameters are tabulated, and the comparative S11 parameter is placed below in a comparative manner. From the analysis, the frequency resonated 4.2 GHz with a return loss of -24 dB. All the obtained results in acceptable in range, but another iteration was carried out to get betterment/improvement in the obtained first iterative results. Figure 1 represents the first iterative design simulated using the parasitic ground.

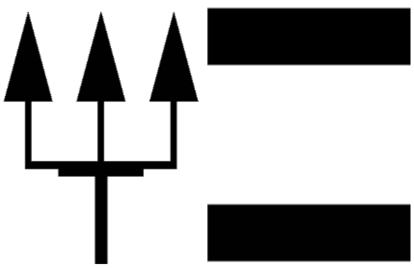

Fig 1. Represents the first iterative design

Now the second iteration is carried out to get improvement in all obtained simulated results in the first iteration. In the second iteration also the antenna is simulated using the FR4 dielectric material with the same radiating patch as followed in the first iteration. In this iterative design, the ground is modified to Quarter Wave Transmission Line Defected Ground Structure (QWTL-DGS), and it is simulated in ANSYS EM Suite version 2021. All the electromagnetic parameters are analyzed tabulated, and the S11 parameter in the 2D graph is placed below in a comparative manner. From the analysis, the frequency resonated 4.2 GHz with a return loss of -56.5 dB. All the obtained simulated results are good when compared to the first iterative results and considered it as the final design. Figure 2 represents the second iterative design simulated using QWTL- DGS, and figure 4 represents the comparative S11 parameter for both iterations.

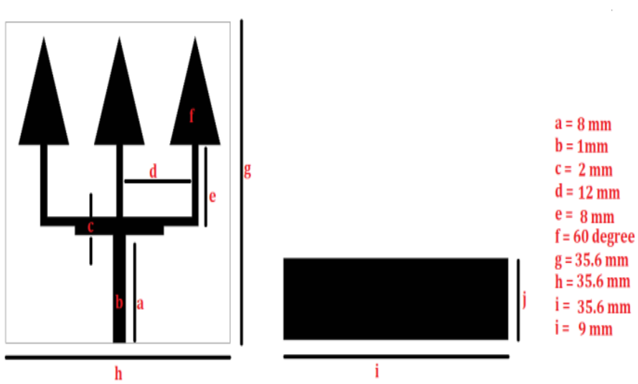

Fig 2. Represents the proposed antenna

TABLE I
REPRESENT THE OBTAINED COMPARATIVE SIMULATED RESULTS

Parameters	P-DGS (iteration - 1)	QWTL-DGS (final)
Resonated Frequency	4.24 GHz	4.24 GHz
VSWR	1.12	1.0
Gain	3.54 dB	3.85 dB
Directivity	4	4.5
Radiation Efficiency	90	98

From the above tabulation, all the obtained simulated results are much improved in QWTL-DGS design, so it is considered as the final simulated design, and the fabrication process is carried out. This fabricated piece is analyzed in vector networkanalyzerandplacedthetestedresultsandfigure3 represents the fabricated piece of the proposed antenna in this letter.

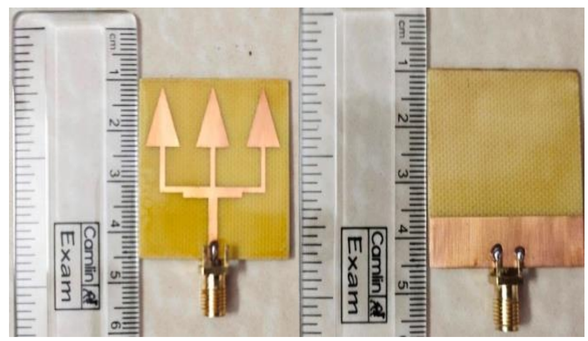

Fig 3. Represents the fabricated piece of the proposed antenna

III. RESULT ANALYSIS

Here the most important electromagnetic parameters are analyzed for both the iterations and placed in a comparative manner in a 2D graph, and some electromagnetic parameters are analyzed for only the proposed design.

Figure 4 represents the comparative S11 parameter which was analyzed in ANSYS EM Suite and placed the obtained simulated results below. The below 2D graph represents the scattering parameter for the first iteration and for the proposed antenna. From the below graph both the simulated design resonates at 4.2 GHz but variation occurs in S11 parameter in first iterative design (P-DGS) the obtained S11 parameter value is -24.6 dB, but in the proposed design (QWT-DGS) the value of S11 parameter is -56.5 dB so very less signal scattering is obtained in the proposed simulated antenna design when compared to the first iterative design.

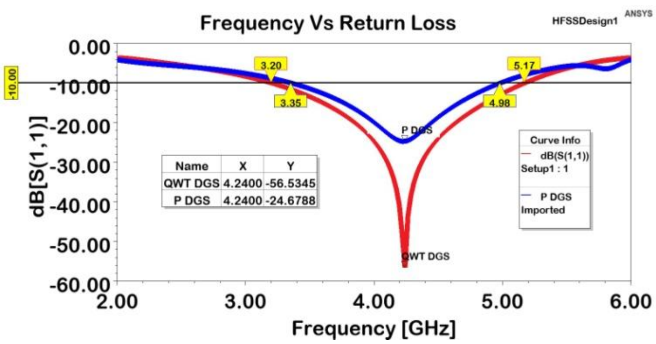

Fig 4. Represent the comparative S11 parameter

Figure 5 represents the comparative VSWR which was analyzed in ANSYS EM Suite and placed the obtained simulated results below. The below 2D graph represent the obtained simulated Voltage Standing Wave Ratio values for the first iteration and for the proposed antenna. As we know that each design resonates at the same frequency, but from the below graph, variation occurs in VSWR values in the first iterative design (P-DGS). The obtained VSWR value is 1.12, but in the proposed design (QWT-DGS), the value of VSWR is 1, so the impedance of the antenna is matched exactly.

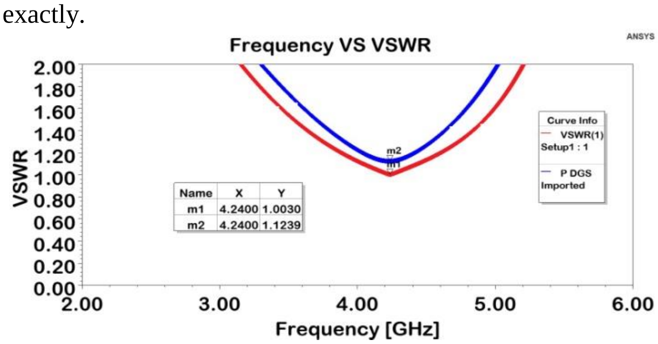

Fig 5. Represent the comparative VSWR in the 2D plot

Before being analyzed, electromagnetic parameters are represented in a comparative manner for both the designs but here impedance plot is represented in the Smith chart graph for the proposed antenna only. Y parameters, Z parameters for the proposed antenna are marked in this smith chart graph. This graph can able to prove that the proposed antenna's impedance is matched.

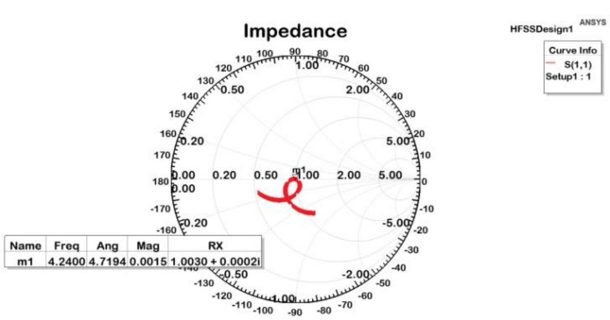

Fig 6. Represent the impedance plot for the proposed antenna

The next most important electromagnetic parameter to be analyzed is the gain of the microstrip patch antenna, so the gain is analyzed for both the iterative designs, and the obtained simulated results are represented in figure 7 with unit value dB. From the analysis, the gain of the first iterative design (P-DGS)is3.54dBandgainvaluefortheproposedantennais3.85 dB. From this reported value, the gain of the proposed fabricated antenna is very high, so the fabricated antenna (QWTL-DGS) has the capability of converting input power into radio waves more efficiently.

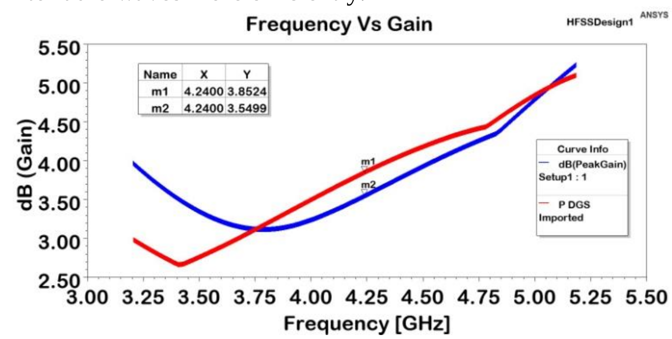

Fig 7. Represent the comparative Gain in the 2D plot

Figure 8 represents the directivity of the proposed antenna in a 3D plot. This result is obtained by analyzing it in the ANSYS EM Suite version 2021. From the obtained result, the directivity of the proposed antenna is high in range, so the beam of the signal is radiated in a particular direction without any loss in transmitting the signal in that direction.

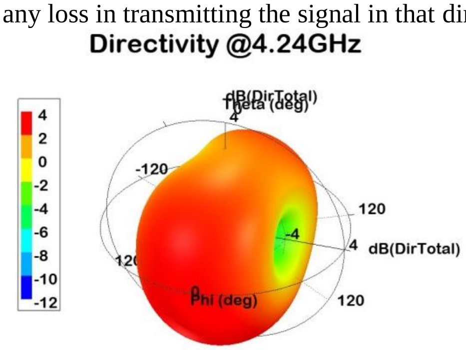

Fig 8. Represent the 3D directivity for the proposed antenna

The most important parameter to be analyzed is the radiation pattern for the proposed antenna, which helps to describe the polarization of the particular antenna. So figure 9 represents the radiation pattern of the proposed antenna by analyzing using ANSYS EM Suite version 2021. From the obtained simulated radiation pattern, the polarization at zero degrees is linear polarization, and it is also analyzed in ninety degrees.

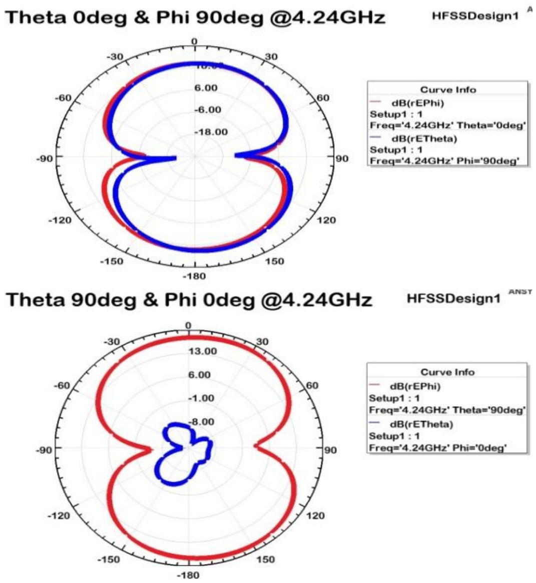

Fig 9. Represent the Radiation pattern for the proposed antenna

The next important parameter to be analyzed is power because in this modern wireless communication power consumption range of the patch is taken into an important analyzing factor so initially surface current of the proposed antenna is analyzed and represented the pictorial representation in the below figure and also analyzed the accepted & radiated power of the proposed antenna by representing in the 2D plot. The obtained results are denoted in dBm, so table 2 represents the obtained power value in watts. From the analysis, the proposed antenna power range is around 1Watts.

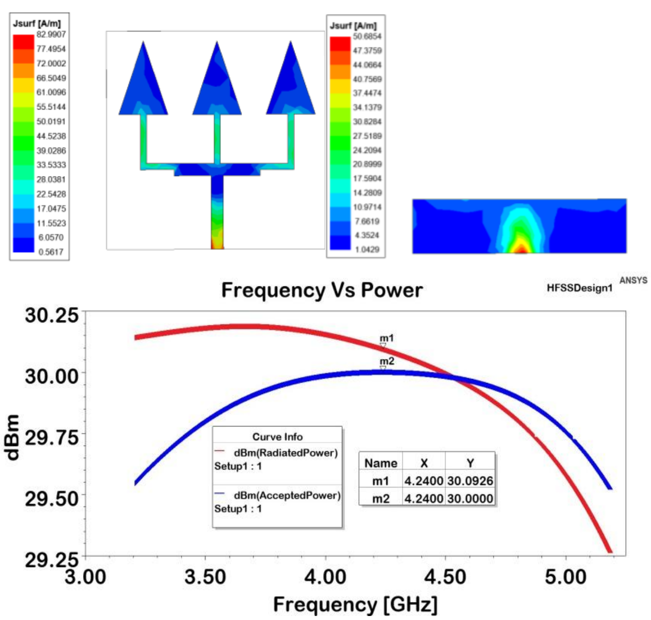

Fig10. Represent the Surface current and Power graph for the proposed antenna

TABLE II
REPRESENT THE POWER VALUES

Frequency	4.24 GHz	
Radiated Power	30.09 dBm	1.02 Watts
Accepted Power	30.0 dBm	1 Watts

Figure 11 represents the comparative graph on measured and tested results where both the results are similar. From deep analysis scattering parameter value of the proposed antenna is improved when compared to obtained simulated results.

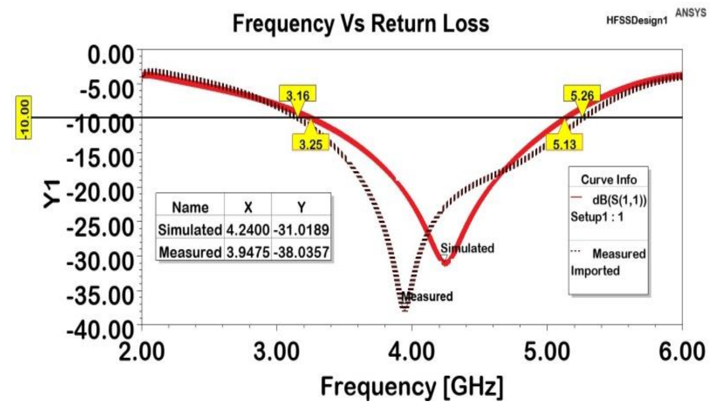

Fig 11. Represent the comparative graph on measured and tested results for the proposed antenna

IV. CONCLUSIONS

In this letter, the performance analysis of integrated array headed for Sub-6/Sub-7 GHz frequency with a Quarter Wave Transmission Line using DGS (QWTL-DGS) has been presented to achieve the designed antenna to work in 5G wireless communication. The iterations which are taken place during simulation are also discussed by analyzing its obtained simulated results. Here the proposed antenna (QWTL-DGS) simulated results agreed well with the measured results. The simulated antenna is fabricated as per the simulated design, so the overall dimension of the fabricated antenna is 35.6x35.6x1.6 mm^3 using the FR4 dielectric substrate. From the study of all the discussed electromagnetic results, we conclude that the proposed design can able to work most efficiently on wireless 5G/Vo5G communication (Sub-6/Sub-7 GHz).

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