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28 GHz Microstrip Patch Antennas for Future 5G

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Abstract: Recently, the industry and academia there is significant activity in research and development towards the next generation micro and Pico cellular wireless Networks (5th generation). This paper presents, a structure design of microstrip patch antenna array operate at the central frequency of 28 GHz waveband is proposed. The patch antenna array consists of four elements with rectangular patch and uniform distribution. It has a compact size of 26.51 x 20.37 mm with operating frequency at 28 GHz. The inset feed technique is used for the matching between radiating patch and the 50Ω microstrip feedline. The proposed 2x2 antenna array successfully improve the antenna gain up to 8.393dB compare to existing CRLH TL CPW antenna with 2.99 dB, wideband antenna with 7.1 dB and 3.7 dB for broadband elliptical-shaped slot antenna. As a conclusion, the directivity of 10.13 db and efficiency is higher than 80% considered as a potential candidate for the 5G wireless networks and applications.

Key words: *microstrip antenna, array antenna, 5G, directivity, radiation pattern, S parameters, 28 GHz*

INTRODUCTION

An antenna is an electrical device that can converts radio frequency fields into alternating current and vice versa. Recently, future fifth generation wireless communication networks (5G) requires antenna can support wide bandwidth because of higher data rate [1][2][3][4]. The traffic can be identified from the used bandwidth analysis in global mobile data by Cisco [5]. To achieve this goal, the important of milimeter wave frequencies seems to be inescapable because of the large of spectrum that could be mace accessible for that reason [2]. From these milimeter wave bands, the 28 GHz particular interest defined from Ka band as frequencies range 26.5-40 GHz [2] and now low cost antenna are being research and developed [6][7][8][9][10][11][12]. The 28 GHz band is currently available spectrum over 1 GHz of bandwidth [13], and also directions has just begun moving to empower outdoor operation [2]. Base on this reason, low profile antenna are required when the cost, size, weight ease of installation, performance and aerodynamic profile are important. The required not only for the government application but for many other commercial applications [1]. The antenna with low profile design, conformability to planar surface and also non-planar surface, low manufacturing cost, easy to fabricate, mechanically robust when mounted on rigid surface and lastly compatible with MMIC. The advantage from physical view, they are very versatile in operating frequency, pattern and impedance when particular patch and mode are selected. Next issue for milimeter wave radio connections is the inferred little gap of the now substantially smaller antenna. The little gap issue shows itself in the Friss condition as loss proportional to carrier frequency and is frequently incorrectly credited to propagation [2]. The problem of small aperture antenna easily overcomes by antenna array with gains [14][15][16]. This improve gain is require in obstructed radio environment where, among others, human bodies are likely blockers of the milimeter wave interface [17]. Effect on this, low profile antenna are required when the cost, size, weight, ease of installation, performance and aerodynamic profile are important. Microstrip antenna can be a perfect candidate to meet all requirements above [18]. Besides,

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there is requirement for planning antenna array to accomplish higher gain to conquer the way misfortune because of the air ingestion of electromagnetic waves at higher frequencies. However, a few design issues can affect an antenna performance [19]. First of all, commercial substrates used to fabricate antenna do not indicate values of relative dielectric permittivity (Ɛr) beyond 10 GHz. The issue turns crucial when designing the antenna at much higher frequencies, since the Ɛr value partly determines geometrical parameters of the patch. In the remainder of this work, investigation of inside feed square microstrip patch antenna which can operate in Ka band phased array will be carrying out. Simulation results from a commercial 3D electromagnetic simulator are provided. It will be investigated the performance of the single and array antenna in term of bandwidth, gain and radiation pattern.

SPECIFICATION AND MATERIAL SELECTION

Picking a substrate is as vital as the design [20]. The substrate itself is a piece of the antenna and contributes significantly to its radiation properties. Many different factors are considered in picking substrate, for example thickness, dielectric constant, stiffness as well as loss tangent. The dielectric constant should be as low as conceivable to energize fringing and hence radiation. A thicker substrate should also be picking since it increases the impedance bandwidth.

Moreover, using a thick substrate would in accuracy since most microstrip antenna models use a thin substrate approximation in the analysis. Substrates which are lossy at higher frequencies not be used for obvious reasons [21]. The choice of a stiff or soft board basically depends on the application at hand. In this project, Ultralam@3850HT from Rogers is chosen as the dielectric material base on good performance on more 10 GHz [22].

PROPOSED ANTENNA DESIGN AND DEVELOPMENT

A. Single Microstrip Patch Antenna

Working at 28 GHz, microstrip patch antenna one of ideal solution for cost sensitive radio applications because of small size, low profile, simplicity of coordination and ease of integration in portable wireless devices [23][24]. In this case, it has tendency to be less effective and restricted in data transmission and range to cover.

Fig. 1 show the geometry of the proposed single patch microstrip antenna used as a building block for the 2x2 array antenna. The antenna with a ground width of 7.6mm and a ground length of 5.4mm is fully copper grounded set the resonance frequency at 28 GHz. This future proposed antenna has geometric size is 3.8 mm x 2.9 mm in width and length.

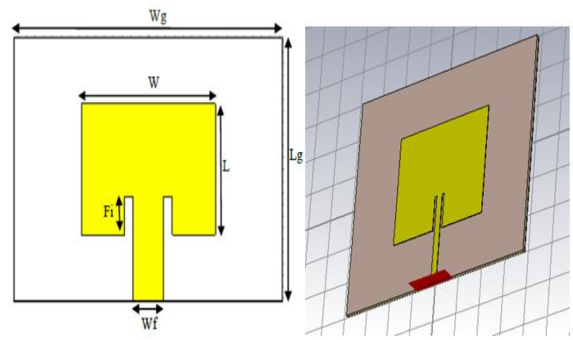

Fig. 1: Geometry and dimensions of the proposed 5G single microstrip patch antenna, (a) Geometry. (b) Illustrated in CST.

Table 1: Proposed Single Antenna Dimensions

Parameter	Value(mm)
Ground Plane Length	5.4
Ground Plane Width	7.6
Patch Length	3.05
Patch Width	4.4
Line Length	1.0
Line Width	0.2
Substrate	2.9

The rectangular patch is chosen because it is convenient to design and analyze. The rectangular patch also has large impedance bandwidth due to it broader shape compare to other types. To legitimately match single patch antenna and the feed transmission line which is 50Ω, 0.9mm is picked for an inset to move the feed position far from the edge. While for the gap between feed line and patch is 0.2mm to patch keeps small effect in coupling. Table 1 demonstrates the physical parameter and optimization that might be considered in designing single element patch antenna.

B. Microstrip Antenna Arrays

On future (5th generation) applications, the antenna need a higher gain and directive beam that can be controlled in specific direction. It may be difficult to accomplish such high gain by used a single antenna [25]. However, several small antennas can be gathered together in array antenna to obtain such high increase gain directive pattern that can be electronically checked in a specific direction. Forming the array antenna radiation pattern can be accomplished by fitting the magnitude and phase of the current feeding individual elements of the array antenna.

Linear arrays have narrow radiation beam in the plane containing the array axis while have a wide beam in the orthogonal plane. This pattern of linear array is helpful in the case of (5th generation) mobile applications as it requires 1-D checking to cover large area.

Total dimension of array antenna with four elements is 26.51 mm x 20.37 mm in width and length. Fig. 2 is the geometrical configuration of the proposed four elements antenna array is presented. The uniform distribution is used in this array with the same value of amplitude for each is done by providing equal input impedance for each patch. The transmission line that connects to each patch has an input impedance of 50Ω.

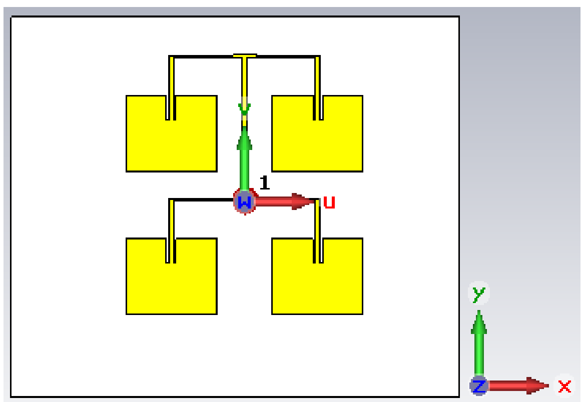

Fig. 2: Geometrical configuration of the proposed four element 5G antenna array.

C. Feed Network

To accomplish more directivity and gain, arrays of patch elements can be utilized as part of combination with a feed network. Methods of distributing electrical energy to each patch include microstrip line, aperture coupling and proximity coupling [25].

The array antenna is fed from the bottom using 50Ω coaxial line and the input feed lines for the patches are chosen to be at the radiating edge. Thus, no mismatch exists at the input of the patches. The quarter wavelength transformer is used to fix the 100Ω line to the 25Ω equivalent resistance of the parallel two 50Ω lines.

RESULT AND DISCUSSION

Designing and simulation of the proposed single patch antenna and array antenna is performed using Computer Simulation Technology (CST) Microwave Studio [3].

A. Simulation Single Antenna

The characterization result of a single element antenna in term of reflection coefficient and radiation pattern is shown in Fig. 3 and Fig. 4. The calculated reflection coefficient shows the designed antenna operating at a frequency of 28 GHz with a value of |S11| is better than 15 dB at 28 GHz. The -10 dB working bandwidth of the designed antenna is about 400 MHz ranges from the frequency 27.8 GHz to 28.2 GHz as shown in Fig 3. The designed antenna has a directional radiation pattern with the antenna gain of 6.22 dB as shown in Fig. 4. A half power (3 dB) beamwidth of 84.5° and side lobe level of -15.7 dB are achieved by the single element antenna. VSWR for a single element antenna is shown in Fig 5. From this result, the value of VSWR is 1.022294 at frequency 28 GHz which is very efficient in manufacturing process. It should be less than 2. The minimum VSWR can get the better performance for the antenna.

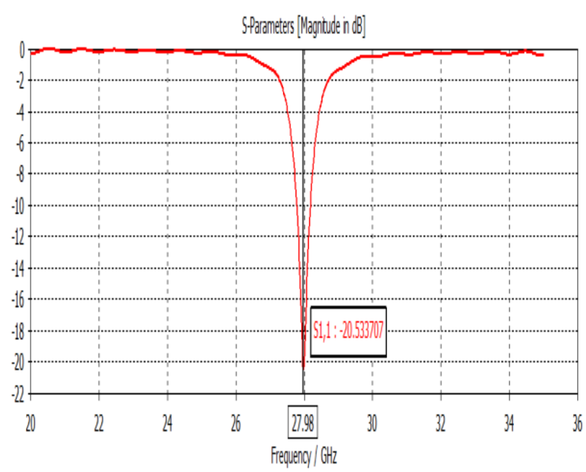

Fig. 3: Reflection coefficient |S11| versus frequency of proposed single element 1 x 1 antenna at 28GHz.

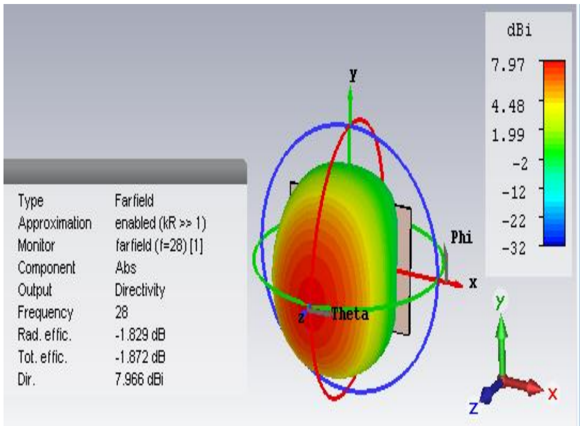

Fig. 4: Radiation patterns of proposed single element antenna at 28GHz.

B. Simulation Array Antenna

A broader match is achieved for the 2x2 array as shown in Fig. 5. More than 15 dB of return loss is available over a bandwidth of 400 MHz and the antenna usable frequency range is also extended.

The simulated results of the reflection coefficients |S11| for the proposed for element 5G antenna array is illustrated in Fig. 6. The uniform distribution is used in this array with the same value of amplitude for each patch is done by providing equal input impedance for each patch. It is apparent that the proposed antenna array has a good impedance matching at the desired frequency band of 28 GHz for |S11| less than -10 dB.

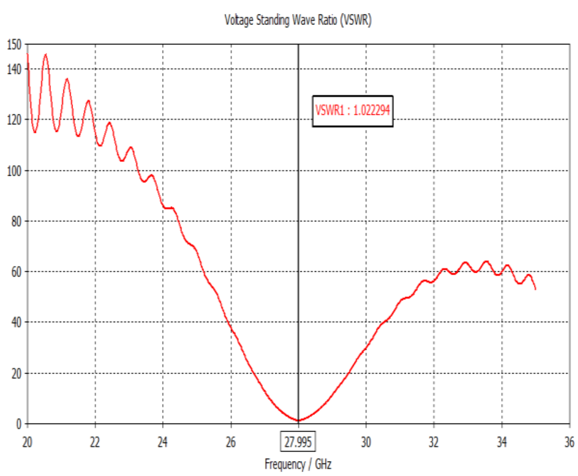

Fig. 5: VSWR of proposed single element antenna at 28GHz.

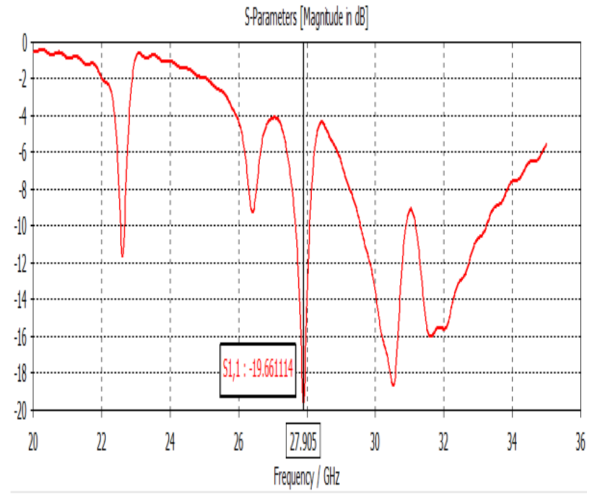

Fig. 6: Reflection coefficient |S11| versus frequency of proposed four element 2 x 2 antenna array at 28GHz.

Fig. 7 is result for the simulated radiation pattern of the proposed antenna array. A stable gain with a value of 8.393 dBi (+2.174 dBi compared to a single antenna element) at 28 GHz us observed. This obtain gain is improved which is 126.83% higher compared to [10], 180.70% higher than [11] and 18.21% better to [12]. Simulated results demonstrate that the antenna array is characterized by bidirectional patterns. VSWR for proposed antenna array is shown in Fig 8. From this result, the value of VSWR is 1.2320898 at frequency 28 GHz which is also efficient in manufacturing process. From the result, it less than 2 and consider as a good result.

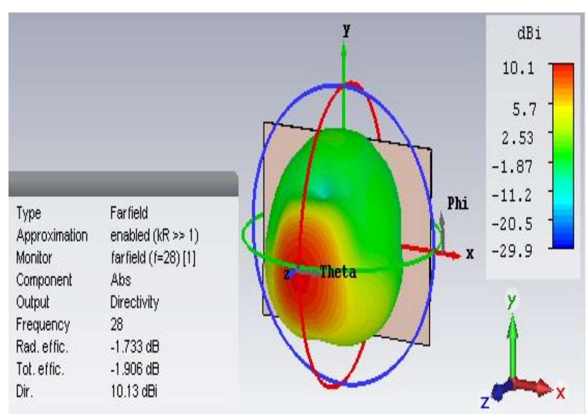

Fig. 7: Radiation patterns of proposed four element antenna array at 28GHz.

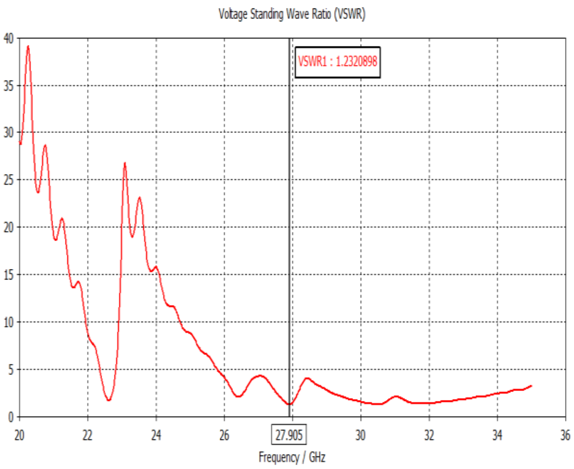

Fig. 8: VSWR of proposed four element 2 x 2 antenna array at 28GHz.

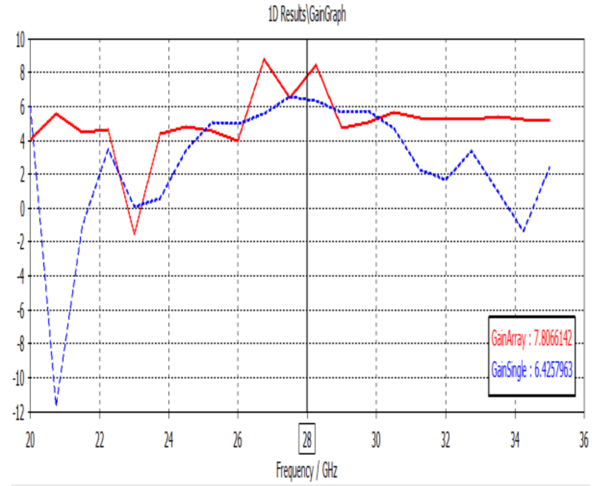

Fig. 9: Numerical results of realized gain vs. frequency.

C. Comparison Single and Array Antenna

Larger array size will transform to higher gain and directivity of the array antenna but also increasing the feed networks. But, ever increasing feed networks introduce additional losses between the feed point and radiating patch elements.

Table 2: Proposed Antenna Simulation Results

Simulation Results	Single Element 1 x 1	Four Elements 2 x 2
Gain (dBi)	6.219	8.393
Directivity (dBi)	8.002	10.130
Beamwidth (Deg)	84.5	79.0
Efficiency (%)	77.72	82.85
Bandwidth (MHz)	400	400

Simulated result between single element antenna and four element antenna is shown in Table 2. This results are calculated for nominal values of Rogers Ultralam@3850HT substrate with dielectric constant εr=2.9 and loss tangent tanδ=0.0025. Fig. 9 is show the simulated realized gain for single and array antenna with respect of frequency. The result show that the array antenna is above than the single antenna and it is suited for 28 GHz.

CONCLUSION

In this work, the simple printed patch antenna array was proposed. The antenna was designed for 28 GHz operation with four elements in array structure using microstrip methods. Impedance and phase matching techniques were designed using a quarter wavelength transformer and transmission line. The antennas with single and four elements in array were analyzed using electromagnetic analysis software. The results at 28 GHz show that 8.393 dB can be achieved for antenna gain compared to the previous work: 3.7 dB in [9], 2.99 dB in [13] and 7.1 dB in [14]. Caused by enhanced performance, this proposed antenna quality serve as a good option for 5G which requires low topology and high gain.

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