Microstrip Grid Antenna Array for 5G Mobile Devices

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Abstract —This paper focused on the development of Microstrip Antenna Array, which operates at 28 GHz where this frequency suggested as operating frequency for 5th Generation mobile technology. The proposed antenna structure is constructed with a single patch located in an array configuration within one plane. The antenna is fed from the backside via a coaxial fed. Normally in array antenna technology, researchers use full ground plane approach in order to meet a good antenna performance. The development of proposed antenna involved simulation, optimization, fabrication and measurement to get the best antenna performance at desired frequency. Simulation and optimization phase was done using Computer Simulation Technology (CST) software, which has the capability of giving a better look on performance of antenna in simplest way.

Index Terms—Microstrip antenna array,5G, 28 GHz, Ka Band, single band grid antenna array

I. INTRODUCTION

The 5G will be a model shift that will contain a very huge carrier with enormous bandwidths, device densities and extreme base station and new numbers of antennas [1]. Mobile communications are becoming progressively demanding as far as bandwidth is concerned due to the increased content requirements. In order to face this challenge, the telecommunication community will channel towards higher frequencies where more spectrum could be accessible. The 28 GHz band has not been studied for mobile application and there are very few researchers actively pursuing this topic [2]. Therefore, the need to develop antenna solutions for mobile components at these frequencies is a key enabler. Printed solutions for Ka-band are rare [3].

In this paper, a new Microstrip Grid Array Antennas (MGAA) proposed to work with 5G for the first time. This done by made a high-gain MGAA in the 28-GHz band and apply an amplitude tapering technique utilizing variable line width of the individual radiating element to reduce side-lobe level. The MGAA modified to radiate 45 linearly polarized waves different from the travelling wave MGAA , the new MGAA is a standing wave antenna, which elements the problem associated with the match load and simplifies the antenna design [4]. Also, a wider impedance bandwidth and gain bandwidth are obtained.

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This paper is consisting of three parts: In the first, discussed the microstrip antenna design and calculation by using MATLAB software. the second part of paper showed the Results and discussion the results. last part of paper discussed the Results.

II. MICROSTRIP GRID ANTENNA ARRAY DESIGN AND CALCULATION

The design is shown in Fig. 1. The MGAA can function as either standing - wave antenna or travelling antenna the formulas which are used in designing the antenna as shown below [5] and [6]:

$$L = \lambda g \quad (1)$$

$$S = \lambda g/2 \quad (2)$$

where L represents grid long side length and λ represents guided wavelength [6] and s is the short side length. The radiation is from short sides with the long sides acting mainly as transmission line or guiding.

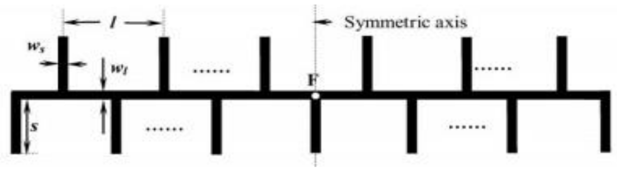

Fig. 1. The configuration of antenna array.

The substrate material is Rogers 5880, which is suited for high frequency spectrum because of its low tangent loss.

l and S are depending on the resonance at the operation center frequency, while the widths of the sort and long sides of the grid (Wl and Ws) can be chosen for better transmission, changing the Bandwidth and desired amplitude taper on the array respectively. In General, the impedance of long sides should lower than 250 in order to decrease the transmission loss and cross polarization. By considering the precision process, wl should not be less than 0.1 mm in this design. WP, LP and t represents the width, the length of substrate and the thickness respectively. The design specifications (in millimeter) are shown in the Table I below:

TABLE I: DESIGN SPECIFICATIONS

Frequency	L	S	Wl	Ws	Wp	Lp	t	M
28GHz	8.02	4.01	0.4	1.6	164	20	0.017	33

where M number of reputations of single array is the number of loops controls the functional Bandwidth and directivity. The directivity increase as increasing the number of loops but the functional bandwidth decreases [7].

The relationships between number of array and the gain can be calculated by this equations[8]:

$$g_1(n) = 216 - 0.52n + 0.1n^2 \quad (3)$$

$$g_2(n) = -143.2 - 1.13n + 0.058n^2 \quad (4)$$

$$g_{3(n)} = 30.3 - 0.74n \quad (5)$$

$$For\ 0.0375 \leqslant \frac{h}{\lambda 0} \leqslant 0.0625 \quad (6)$$

$$g_1(n) = -505 - 72.6n - 2.3n^2 \quad (7)$$

$$g_2(n) = 133.57 - 26.52 + 0.83n \quad (8)$$

$$g_3(n) = 17.43 - 1.77n - 0.038n \quad (9)$$

$$For\ 0.0625 \leqslant \frac{h}{\lambda 0} \leqslant 0.0875 \quad (10)$$

$$g_1(n) = -362 - 22n - 0.59n^2 \quad (11)$$

$$g_2(n) = 141 - 10n + 0.24n^2 \quad (12)$$

$$g_3(n) = 9 - 1.46n - 0.024n^2 \quad (13)$$

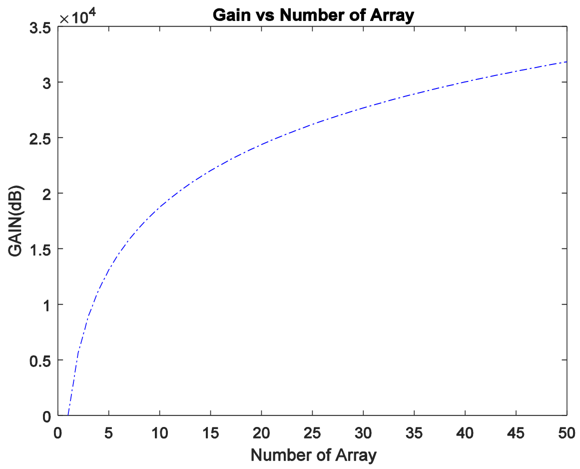

Fig. 2. Number of array vs Gain for h=0.254mm.

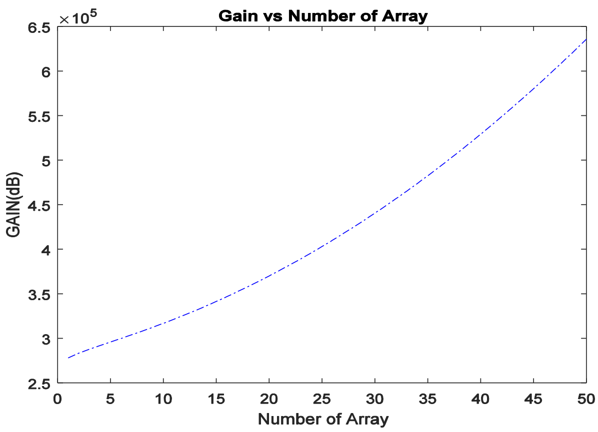

Fig. 3. Number of array vs Gain for h=0.508mm.

The relationship between numbers of array and the gain for h=0.254 shown in Fig. 2. The relationship is increased exponentially; the relationship is stable when it reaches the Gain =30 dB so increasing the number of array more than 50 will make less effect on the Gain. By changing the thickness to 0.508mm as shown in Fig. 3, Gain increased dramatically to 60dB for n=50, so that it will be chosen h=0.508 in proposed antenna.

The optimum number of array is 33 which is provide good gain with small size. Increasing the number of array will provide small change to gain and will increase the size and the cost of the antenna.

III. Fabrication Process

To check the simulation results of the design in CST Microwave studio, the measurement process is desired. The first step of the fabrication is the printing phase. The printing phase involves exporting the CST file into AutoCAD software file. This software traces the copper parts of the proposed antenna to be printed onto a transparency-film in accurate dimension as designed in CST.

This process has to done accurately because the antenna's dimension has to be exactly as the simulation of antenna performances. The dimension of the patch in AUTOCAD software with the dimension obtain in CST (Microwave Studio software) must have a same value before go through the next step of fabrication process. The second step of the fabrication process encloses exposing the Rogers board with printed transparency-film in UV exposure machine.

This process starts with overlaying the printed transparency-film on both back and front side of the Rogers board. The patch antenna printed on the transparency-film will be placed at the back side of Rogers board while the ground plane will be at the back side of Rogers board will be located at the back side of Rogers Board. Finally, the printed film and Rogers's board will be exposed inside the machine of UV exposure for a while this process.

IV. Simulation and Measurement Results

The Microstrip antenna array is shown in Fig 4. During operation, it operates as standing wave antenna or as a travelling wave. In this paper the length of the longest side is (L=λg), where λg represents the wavelength at the desired frequency.

Fig 4. Fabricated design

The radiation is primarily from the short side while the long side acts essentially as transmission line or guiding lines because the current on short sides is essentially in phase. On the other hand, each long side supports a full wave length current. In this case the maximum radiation would be concentrating on the array.

Many variables are important in designing the Microstrip antenna array (MGAA) such as substrate and the dimensions of the antenna. For the grid dimensions, the length of short and long side (s and l) is controlled by the operating frequency; on the other hand, the width of short and long sides of the grid (Ws and Wl) can be used for changing the bandwidth and Gain. In General, the impedance should be less than 250 ohms for the long sides to decrease the transmission loss and cross polarization. The minimum value for Wl is 0.4 mm because of precision of process.

The loops' number governs the functional Bandwidth and the directivity. The directivity increases with increasing the number of loops, but the Bandwidth decreases. Let N and M indicate the routine of eyelets on the y-axis and x-axis, respectively. Fig. 5 shows the fabricated design. It consists of 33 short sides in the symmetric to the symmetric-axis. The array is splinted into 11 parts. The short sides (Ws) in each part have the same width of Ws. The width of short sides can be calculated as shown in Table II. This figure plotted in MATLAB according to data, which exported from CST Software.

The simulated and Measurement values for Return loss illustrates in Fig. 5. The simulation and measurement values presented in Table II, which meet the specifications for antenna. However, the measured S_{11} has been shifted by 500 MHz approximately from the simulated results because of the fabrication process. The simulation bandwidth is equal to 1.725 GHz at 28 GHz and for the measurement result, the Bandwidth is 1.6 GHz was obtained.

TABLE II. SIMULATION AND MEASUREMENT RETURN LOSS VALUE

Frequency (GHz)	$\|S_{11}\|$ Data		Bandwidth Data		Gain
	Simulation (dB)	Measurement (dB)	Simulation	Measurement	Simulation (dBi)
28	-23.459	-27.0	1.725	1.60	17.70

The measured data provides that the proposed antenna gives 5.79 of bandwidth percentage. The Bandwidth can be increased by increasing the Short side of the antenna but this will reduce the value of the gain. As presented in Table II the value of the gain is 17.7 dBi which is very high for this type of the antenna. The gain can be increased by increasing the number of slots or by increasing the operating frequency. A very high gain (17.76 dB) at 28GHz which is shown in the simulated gain Fig. 6.

The gain data (see Fig. 7) imported from CST software to calculate the minimum, maximum operating frequency and the operational Bandwidth, the return loss, where the first operating frequency is 26.87 GHz and the highest frequency is 28.87 GHz. The total calculated Bandwidth is 1.725 GHz. For Fig. 8, which shows the calculated gain 3.75 GHz which is higher than 12 db.

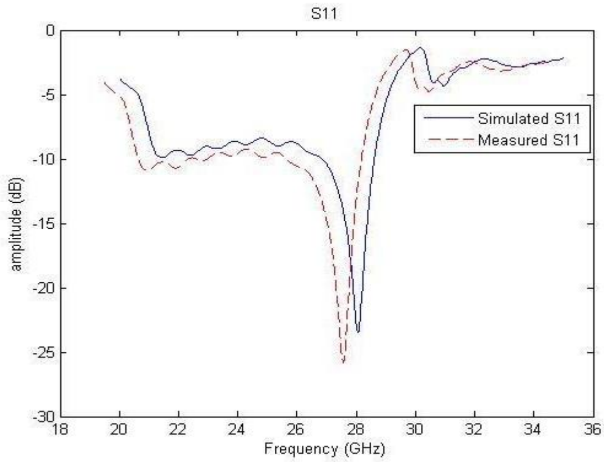

Fig. 5. Simulation and Measurement for the proposed antenna.

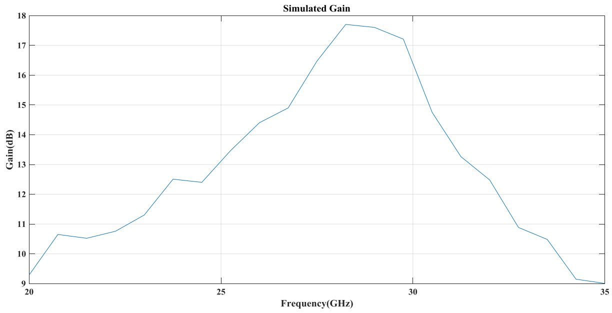

Fig. 6. Simulated gain.

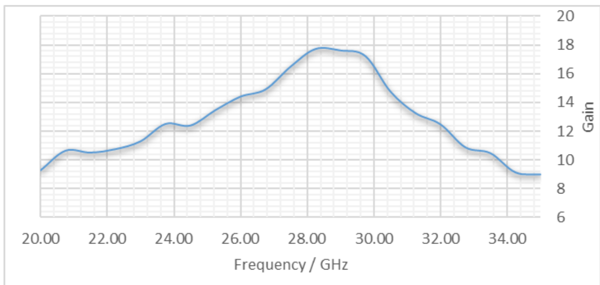

Fig 7. Data gain

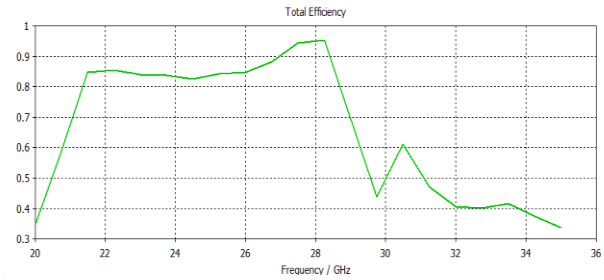

Fig 8. The efficiency.

The radiation pattern cannot be measured due to lack of instrument and facilities at the laboratory. That is why only the simulated results are presented. In this paper it will be shown the radiation pattern of E-field and H-field.

The Characteristic of the radiation pattern for the E-plane co-polarization is shown in Fig. 9, under wide-band configuration at 28GHz. The radiation pattern is omnidirectional. the gain is equally distributed with maximum amplitude of 31 dBV/m.

The radiation pattern of E-field cross polarization was obtained with non-equally gain magnitude for the simulated results. The main lobe magnitude and main lobe direction are 8.74 dB/m, 170 ° respectively. the angular width is 32 °(see Fig. 10).

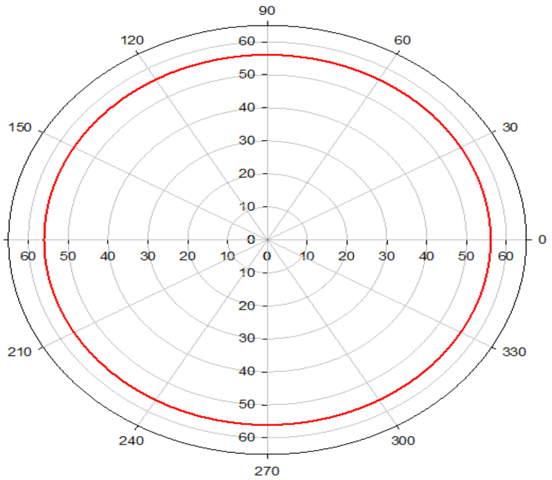

Fig. 9. Radiation pattern (E-co-polarization).

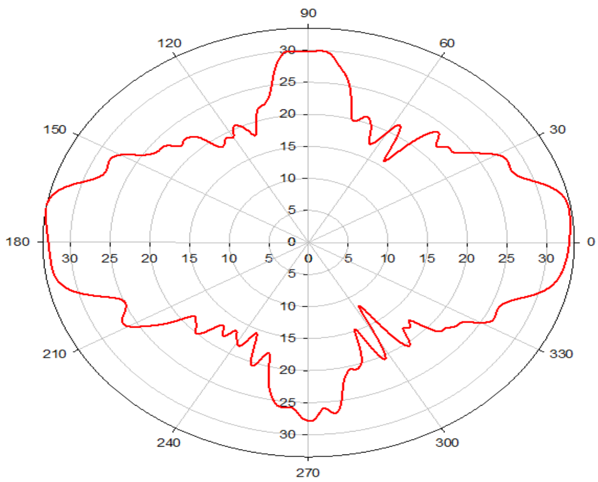

Fig. 10. Radiation pattern (E-cross radiation).

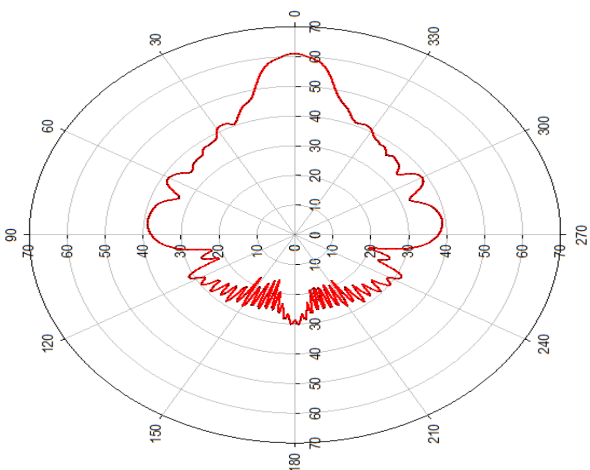

Fig. 11. Radiation pattern (H-co radiation).

For the simulated results of radiation pattern (H-co radiation pattern). The main lobe magnitude and main lobe direction are 31 dB/m, 0 respectively. the angular width is 14°, width small side lobe about -14 dB, the maximum Gain at main lobe of radiation pattern as shown in Fig. 11 is 17 dBi which is more than 5G reconfiguration.

The simulated Radiation pattern (H-cross radiation) is shown in Fig. 12 at 28 GHz with wide angular width (3 dB) is 55 °.The side lobe is relatively small (-31.2 dB).

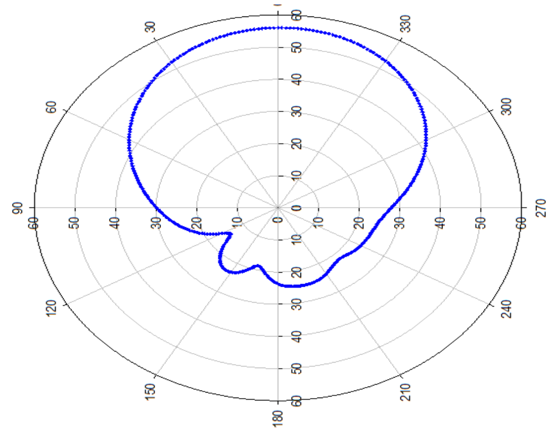

Fig. 12. Radiation pattern (H-cross radiation).

Fig. 13 and Fig. 14 illustrated 3D radiation-pattern picture at 28 GHz of the designed antenna. As it can be seen that red areas represent the maximum gain for beam pattern. The radiation pattern of proposed antenna can have radiated Omni direction beam-pattern. The author tries to display that this antenna can generate narrow beamwidth at perpendicular to surface of antenna.

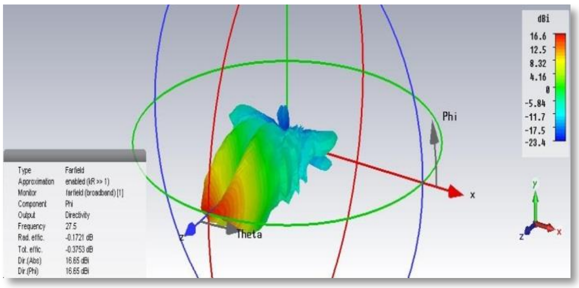

Fig 13. 3D plot for phi.

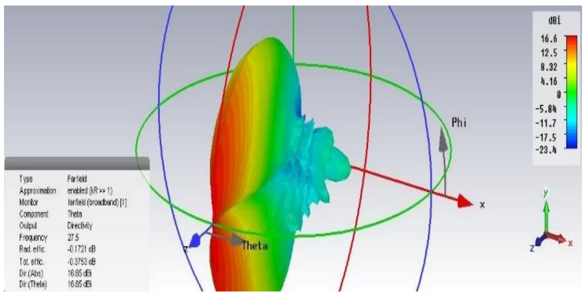

Fig 14. 3D plot for theta.

V. CONCLUSION

In summary, the contribution of this research can be stated as follows:

Designing the Single Band Grid Antenna Array with single ground structure to generate a single band with narrow beam capabilities. This includes introducing of slot technique in the radiating element in getting good performance in term the return loss. Achieve High gain more than 17 dB with high Efficiency more than 92%.

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