# Enhanced Array Patch Antenna Parameters for 5G Applications

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## ABSTRACT

This paper presents a design and simulation of a microstrip array patch antenna operating at 28 GHz for 5G communication with a maximum reflection coefficient of -17 dB, a very wide bandwidth of 1.5 GHz and a high gain of 6.84 dB A Roger RT5880, which has a dielectric constant of 2.2 and a height of 0.2 mm has been used as a transmission line with an inset feed. Antenna dimensions were calculated and simulated results have been performed and analyzed using CST Microwave Studio Package. Moreover, linear array with 3x1 and 5x1, to provide better gain to reach 13 dB and reducing the mutual effect, was developed using decoupling simple slab techniques.

## 1. INTRODUCTION

The fifth Generation Mobile Network or simply 5G is the forthcoming revolution of mobile technology. The features and usability are much beyond the expectation of a normal human being. With its ultra-high speed, it is potential enough to change the meaning of cell phone usability. With a huge array of innovative features, now the smart phone would be more parallel to a laptop. A broadband internet connection can be used; other significant features that fascinate people are more gaming options, wider multimedia options, connectivity everywhere, zero latency, faster response time, and high-quality sound and HD video can be transferred on other cell phone without compromising with the quality of audio and video, The topic covered in this work will be the design of a microstrip antenna for 5G networks [2].

This paper aims at designing mm-wave microstrip antenna deployed in 5G mobile communications. This is achieved through the following approach:

- Simulation of proposed antenna fed by 50 Ω coax-microstrip lines. Modifications are made to get better results either by changing the physical dimensions or substrate material.
- Design a linear phased array with 3×1 and 5×1 for the proposed antenna.
- A simple decoupling slab structure is used to overcome the MC problem that is resulted from the antenna array [5].

- Performance metrics such as measurements of return loss, gain, radiation efficiency, bandwidth, VSWR and full antenna radiation patterns will be evaluated in each case. All results are carried out using CST microwave studio.
- The rest of paper is organized so that section II provides the methodology and the design of proposed antenna. Array antenna with different elements is also developed using CST Microwave Studio. Section III deals with the results obtained as well as discussing these results. The concluding remarks are in section IV.

## 2. Designed Antenna Parameters

There are three essential parameters for designing any antenna, which are the fundamental frequency, dielectric permittivity and thickness of substrate. In this work, a single microstrip patch antenna is proposed for 5G communication. The proposed antenna is designed to resonate at 28 GHz and has a low-profile structure with dimensions of 4.46 mm × 5.6 mm × 0.2 mm.
The dielectric permittivity of the substrate ($\varepsilon_r$ =2.2 in this design) is an essential parameter for evaluating the antenna performance, as it is desirable to have low dielectric constant. This provides a better efficiency, large bandwidth and better radiation. Shifting the frequency to higher values requires the length of patch to be reduced [8].

TABLE 1: The parameters of proposed antenna [9].

| Parameters | Value |
|---|---|
| Dielectric Constant ($\varepsilon_r$) | 2.2 |
| Dielectric Substrate | Roger RT5880 |
| Thickness Substrate | 0.2mm |
| Loss Tangent (tanδ) | 0.0009 |
| $Z_0$ | 50Ω |
| Resonant frequency | 28GHz |
| Feeding method | Microstrip Line Feeder |
| Copper thickness | $35\mu m$ |

## 2.1 Analysis and design procedures

Based on given frequency 28GHz, all parameters, as well as the other physical dimensions of the proposed antenna were calculated using the rectangular patch design equations [1] such as length, width of patch, and substrate. Final design of the antennas is simulated based on the dimensions shown in table 2.

TABLE 2: The dimensions of the proposed antenna [4].

| Parameters | Dimension (mm) |
|---|---|
| The length of patch (Lp) | 3.43 |
| Width of patch (Wp) | 4.4 |
| Length of the substrate (Ls) | 4.64 |
| Width of the substrate (Ws) | 5.6 |

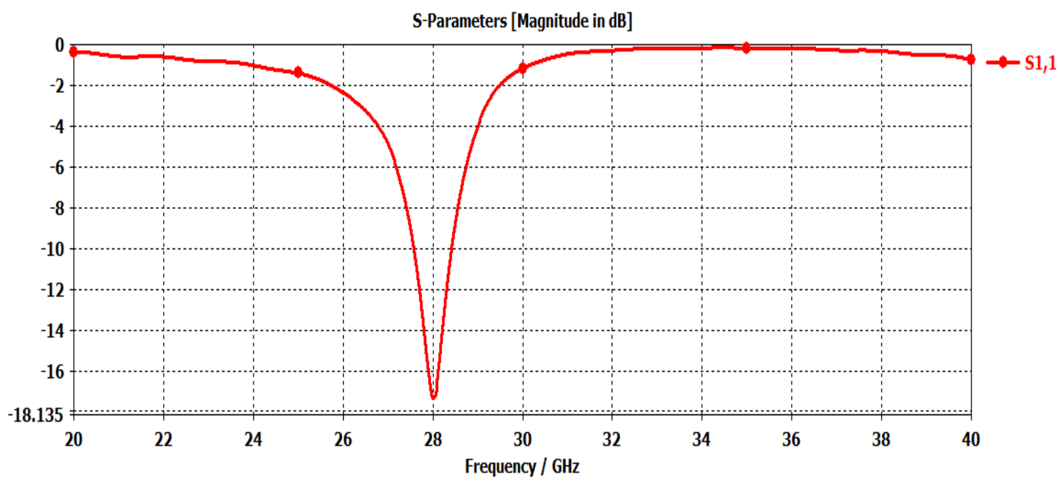
| | |
|---|---|
| Thickness of Substrate (h) | 0.2 |
| Width of Feeder (Wf) | 0.6 |
| Length of Feeder (Lf) | 0.7 |
| Length of gap (Lg) | 0.4 |
| Width of Gap (Wg) | 1.156 |

The performance predictions and simplified analysis was based on a proposed rectangular shaped microstrip patch antenna operating at desired frequency and application as shown in the figure (1)

FIGURE 1: A rectangular shaped microstrip patch antenna

## 3. Results and Discussion

The proposed design was simulated using CST package and the results cannot be properly attained as the mathematical equations are used, so it was important to go for the parametric study, which is




based on changing one of the physical dimensions to get the desired resonant frequency.

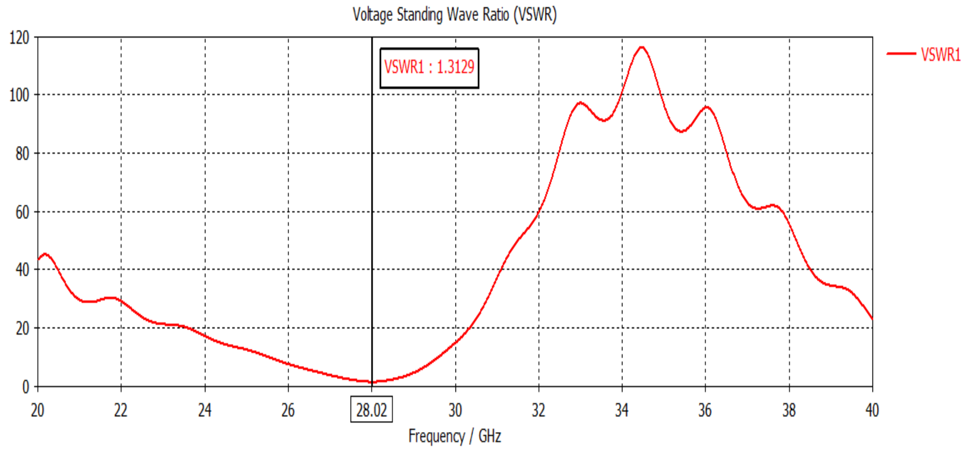



FIGURE 2: The return loss resonating at 28GHz

The standard reference of the return loss is to have power that is less than -10dB to practically transfer more than 90% of the transmitted power in the desired direction figure (2). About -17dB is presented at 28GHz with operating bandwidth of about 1.5GHz laying between 27.2 and 28.7GHz. At this design, it is important to evaluate VSWR which should be between 1 and 2. In this design a suitable result is achieved at the desired frequency giving that VSWR = 1.3129, in this case as the result is closer to 1 meaning that the reflection coefficient tends to zero, meaning lesser power is lost figure (3)[7].

FIGURE 3: The VSWR graph.

As shown in figure (4), the performance of the system reaches 89% of the total efficiency.
Figure (5), presents the radiation pattern, which taking circular polarization geometry with gain of 6.84 dB, as the axial ratio value at 900 is less than -3dBi as in figure (6), then the proposed antenna is circularly polarized, which is one of the main requirements to provide 5G services.

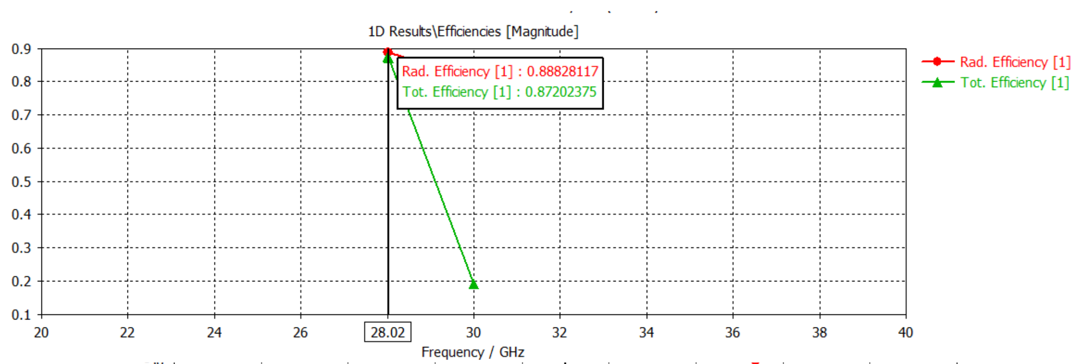



FIGURE 4: Proposed design efficiency

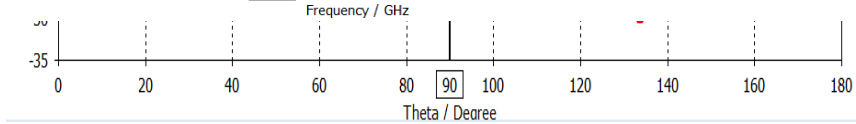
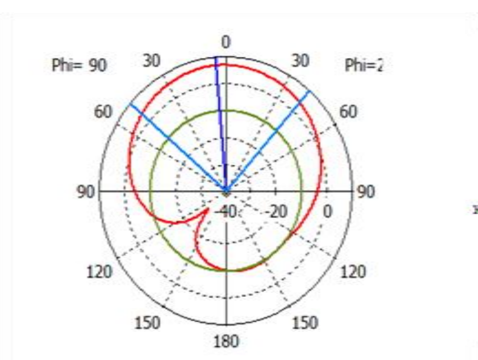



FIGURE 5: Radiation pattern of proposed design.



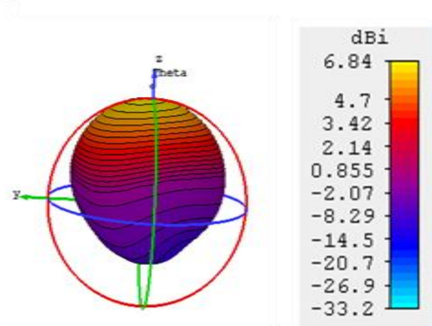
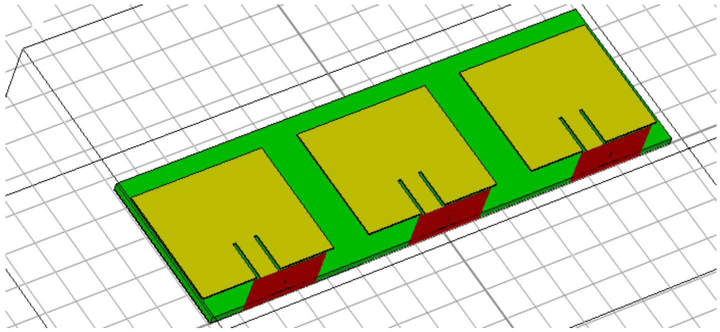




FIGURE 6: The axial ratio.

Figure (7) represents the surface current distribution with different colors. The current should be densely distributed at the edges of the slot placed on the substrate; this reflects that the edges are responsible for dominating the antenna performance [6].



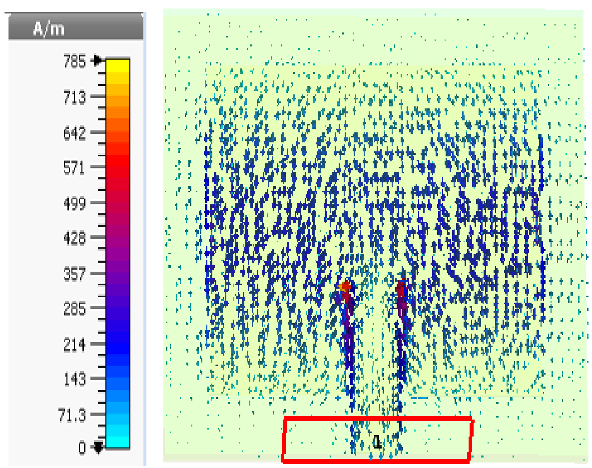



FIGURE 7: Current distributions.

To improve the design performance of the proposed antenna an array was constructed. An array of a group of single elements that is used to improve the directionality of the antenna beam and therefore achieving better efficiency. There are different types of the array configurations such as, a linear phased shape, planar and phased array [10]. The main reason for applying array scheme is to generate tiny beam and avoid pattern of side lobes. In this work, 3x1 and 5x1 identical linear array elements is designed with d= $\lambda/4$ mm of spacing in between elements.

FIGURE 8: Antenna Array

Figure (9) represents the mutual return loss array of the with mutual coupling of -19 dB for $S_{21}$.

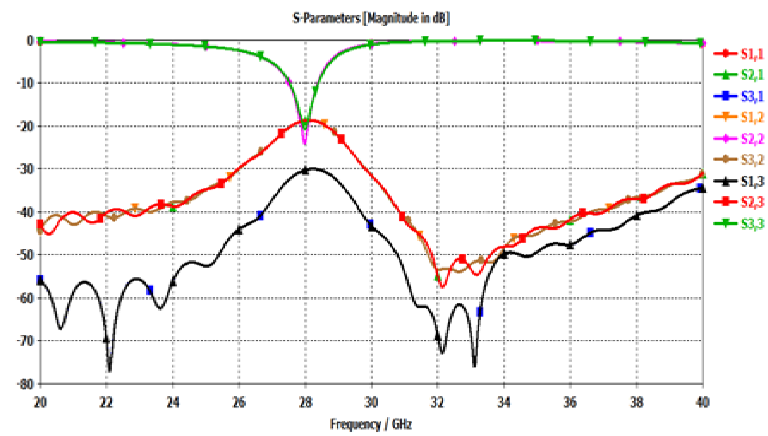



FIGURE 9: The mutual return loss array with mutual coupling of -19 dB for $S_{21}$.

Figure (10) represents the VSWR for all elements in the array, which exhibits the desirable results at the resonant frequency of interest.

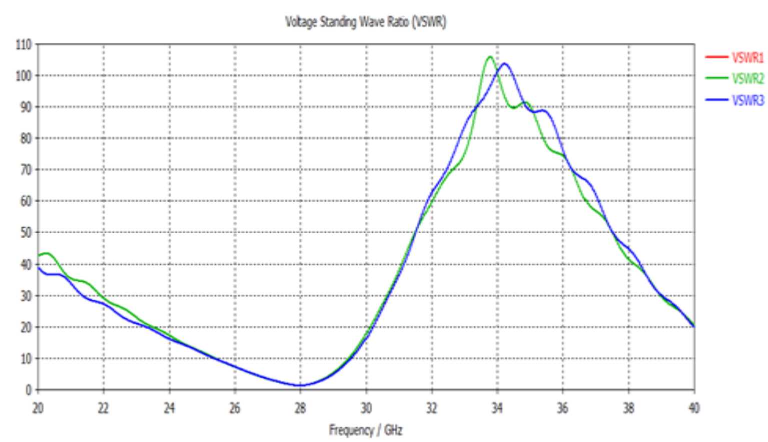



FIGURE 10: The VSWR for all elements in the array

Figure (11) represents the radiation pattern of the array and demonstrates improvement in the gain by 4 dB compared with the single element. This is due to adding the decoupling slab between elements to reduce the mutual effect.

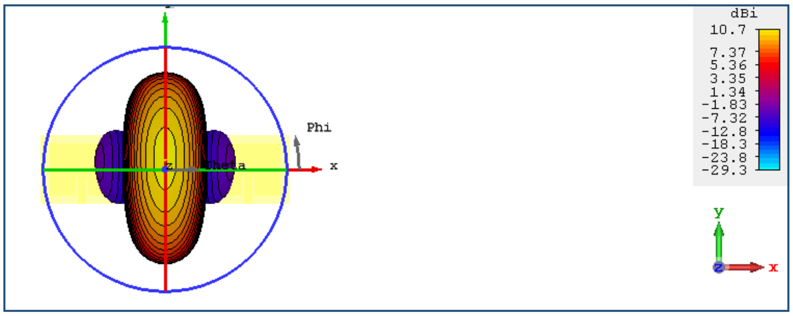



FIGURE 11: The radiation pattern.

Whenever, the number of elements is increased, the overall gain increases as well as the return loss reduces to provide more beam as shown in figures (12), (13) and (14).

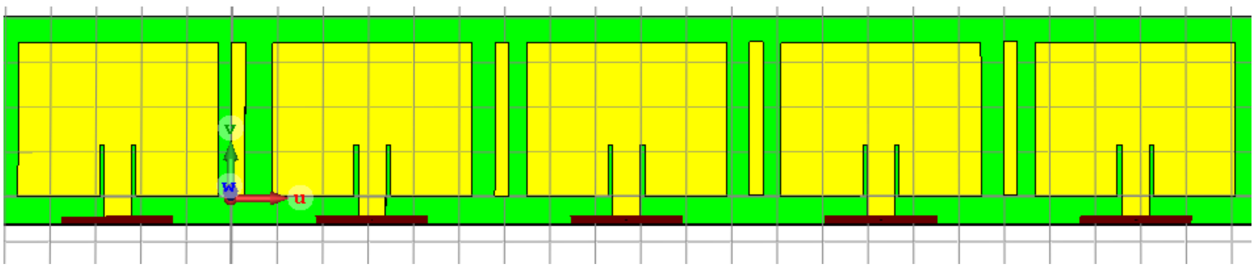


FIGURE 12: 5x1 linear antenna array.

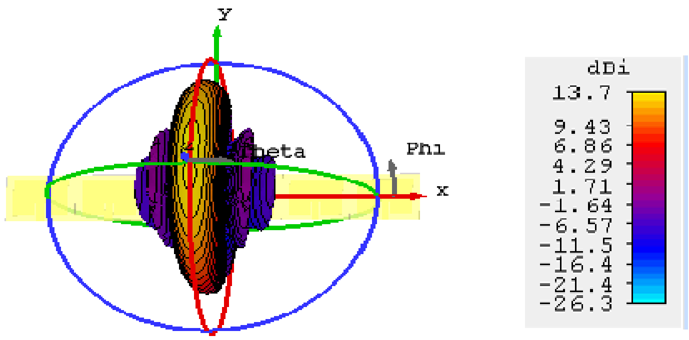



FIGURE 13: 5x1 linear antenna radiation pattern and gain.

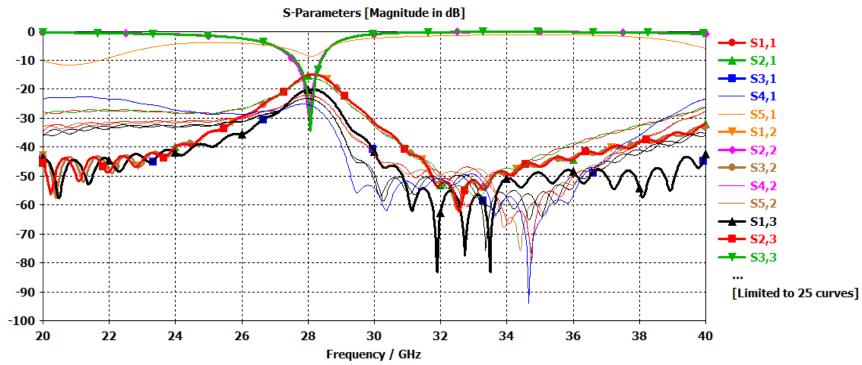



FIGURE 14: Return loss and mutual coupling effect of antenna array with 5x1

## 4. Conclusions

According to the design and observed results, the proposed antenna characteristics can meet the requirements of 5G and wideband communication applications. Initially the parametric study was conducted on the design to have an antenna working or resonating at 28GHz, which is a target frequency for 5G applications. Then, an array structure was designed to improve the antenna performance; where gain has been improved from 6,10 and 13 dB for single, 3x1 and 5x1 arrays respectively.

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