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Original Research

Design and analysis of wideband sub-6 GHz microstrip antenna

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Abstract

In this work, design, analysis, and simulation of microstrip patch antenna for Sub-6 GHz application has been investigated. The research method is based on the Sonnet Suites software. The aim of the study was to design and analyze microstrip patch antenna for Sub-6 GHz antenna for 5G applications and usage. The antenna is designed with the help of using partial ground architecture. Design architecture consideration and analysis of different parameters and simulations were investigated. The antenna operates at 4.32 GHz and the results are compact design area of 21.5 x 36.9 mm^2, reflection coefficient is of -18 dB, and the gain in the range from 4.30 to 4.32 dB.

Keywords: Microstrip patch antenna, Design, Wireless communications, Antenna architecture, Operational analysis

1. Introduction

Over the past 25 years, the wireless communications industry and mobile industry has evolved significantly, starting from analog to digital systems. And finally, 5G is called the 5th Generation Mobile Network. In first work that I've used as a reference paper, the proposed antenna was designed in the frequency range of 3.4 GHz to 5.2 GHz. The total dimensions of their antenna are 16.2mm x 18.1mm x 0.254mm, and the copper used in the mentioned work is approximately 0.0355mm thick [1][2].

In other paper impedance bandwidth was achieved with the device's structure of $0.73\lambda 0 \times 0.79\lambda 0$ from 2.84 to 5.15 GHz. In addition, in this paper, authors explain wave propagation and bandwidth, the 3-5 GHz band is advertised for 5G service [3]. In the next work available online, E-shaped a novel wide-band microstrip antenna is designed and presented. The resonableness of the design concept is explained and presented in two examples with widths of 22,2% and 33.3%. Eventually, they design, manufacture and measure a 33% E-shaped patch antenna device that operates at 1.9GHz and 2.4GHz wireless communication frequencies [4].

Another work presents a compact patch device (printed wideband antenna device) for sub-6 GHz 5th generation usage. At the intended sub 6GHz 5G frequency band. The designed antenna is wide-31.15dB low reflectance bandwidth (700MHz) [5]. Also, in one interesting paper, their authors describe the design and simulations of a (3x3) microstrip patch antenna array. It is modified to operate in the 5.25GHz range [6].

Also, in some other paper, a layout of very small sized, low-profile device is designed for Bluetooth packages at 2.7 GHz frequency. This designed device is H-fashioned and extraordinary parameters like go back loss, benefit alongside directions, radiation sample in 2-D and 3-D, E and H Field Distributions, Current Distributions are designed and simulated [7]. In another paper accessible online, authors designed and presented one very simple antenna with small dimensions for sub-6GHz applications.

Performance was confirmed with HFSS and the results Sub6GHz communication applications at 4.85GHz [8]. In another work, the creators presented an antenna which has a wide operating bandwidth and very huge anteroposterior radiation level due to its device configuration. The proposed device also has a single layer antenna structure for ease of manufacture and thinness. The proposed device includes an operating bandwidth of 55.2% (46.579.5 GHz) and fully covers the new band of the new technologies in wireless and mobile communication [9].

In the following interesting reference paper, authors presented and demonstrated a grounded designed device with a new feeding structure. For sub 6GHz applications of 5G technologies covering 3.24.5 GHz [10]. The next reference paper presents a substructure analysis of circularly polarized device designs. The antenna device operates at frequency of 4.90 GHz, and it has a bandwidth of 550 MHz [11]. The next document of reference papers covers all sub 6GHz bands of 5G technologies, also including Bluetooth, WiFi radio with a factor of 50x19.75x0.8mm3 for supported mobile devices [12]. Another article introduces a compact wideband elliptical radiator with a defective grounding structure for sub 6GHz applications, dimensions: 23.885 × 23.885 × 1.405 mm^3 [13].

The next following paper presents a new approach of designing a patch antenna for 5th generation mobile systems below 7 GHz. This 5G antenna is made for the range of frequencies starting from three to four GHz [14]. The 15^{th} reference paper demonstrates how to use the Integrated Waveguide technology in mobile systems of communication to improve radiation gain. The simulated device has dimensions of 33.1×6×0.9 millimeters and has a very huge range. The presented frequency range goes from 2 GHz to 5 GHz [15].

Another interesting paper available online shows a global frame analysis of circularly polarized microstrip antenna designs with a frequency of 6.70 GHz and a its bandwidth is 450 MHz [16]. In the next article the authors introduced broadband microstrip antennas for sub 6GHz usage. This antenna is designed with dimensions of 40 x 30 x 1.6 mm and is manufactured on a Fr4 board. The proposed antenna keeps the reflection attenuation from 3GHz to 5.64GHz below 10dB. Gain varies from 1.9 to 4.1 dB, with a highest radiation efficiency of 90%. The radiation pattern is characteristic of the antenna [17]. The next study describes some dielectric substrates to improve the device efficiency of traditional 5G antennas [18].

In the 19^{th} reference paper that I've used in my research, designed antenna is modified for industrial science and medicine. Antenna design is developed from traditional antenna rectangular patch antenna using stubs for reinforcement antenna bandwidth [19]. Finally, the last paper introduces a very low-profile patch antennas device for Long Term Evolution (LTE) and mobile communication network. The new approach of design and usage antenna in this purpose was presented and shown in this paper [20].

2. Method

In this work the presented antenna is designed by the usage of partial ground architecture. The compact design's area is 21.5 x 36.9 mm^2 and the antenna operates at 4.32 GHz with the reflection coefficient of -18 dB. Its gain is changing from 4.30 to 4.32 dB. This presented device contains a dielectric steady (εr) of 4.4 and its thickness is 1.55 mm. The box size is 200 mm x 400 mm and cell size is 0.25 mm. On the picture below (Figure 1), 2D view of this antenna is shown, while Figure 2 below shows 3D view of the presented antenna device.

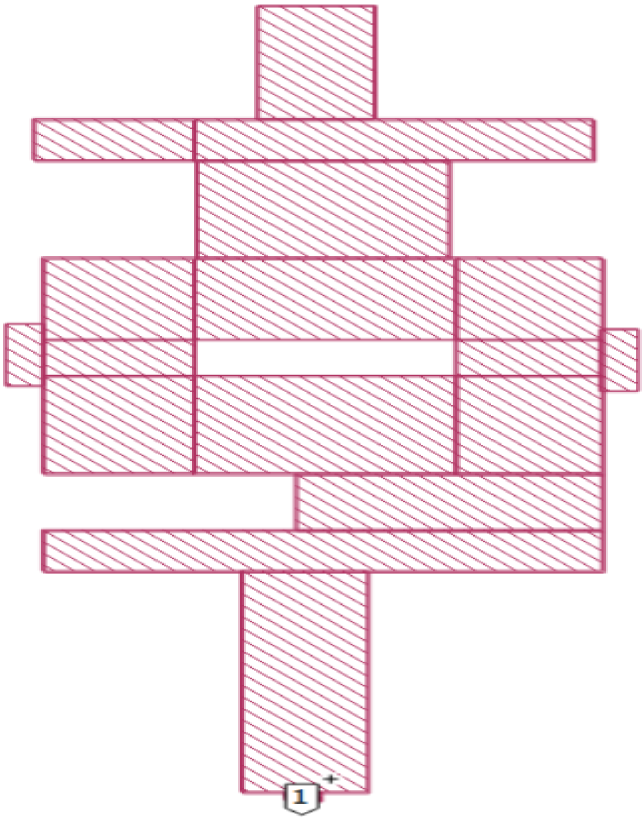

Figure 1. 2D view of the proposed antenna

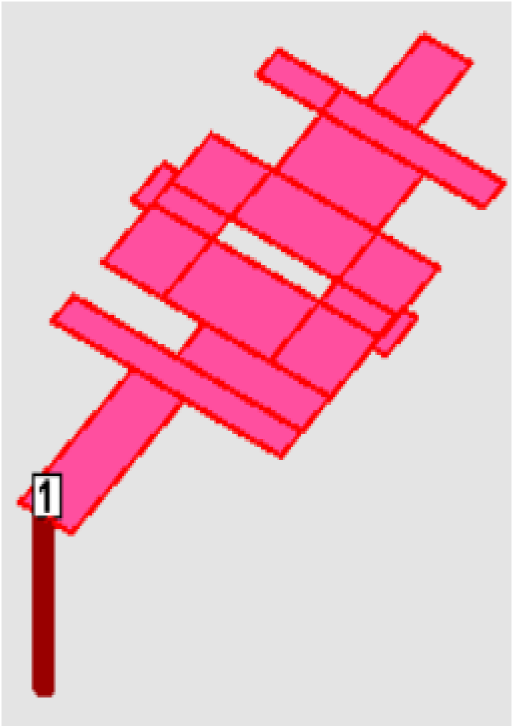

Figure 2. 3D view of the proposed antenna

3. Results and discussion

On the next 3 pictures below, graph S11, gain plot of the antenna and E-Theta are shown.

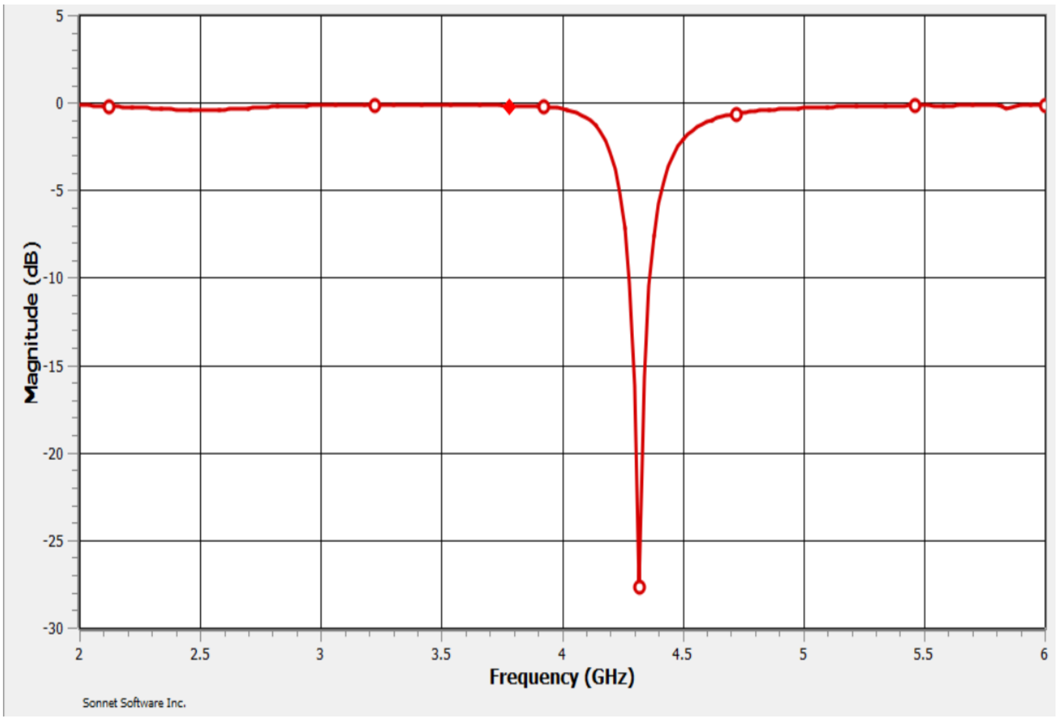

Figure 3. S11 graph – Magnitude frequency

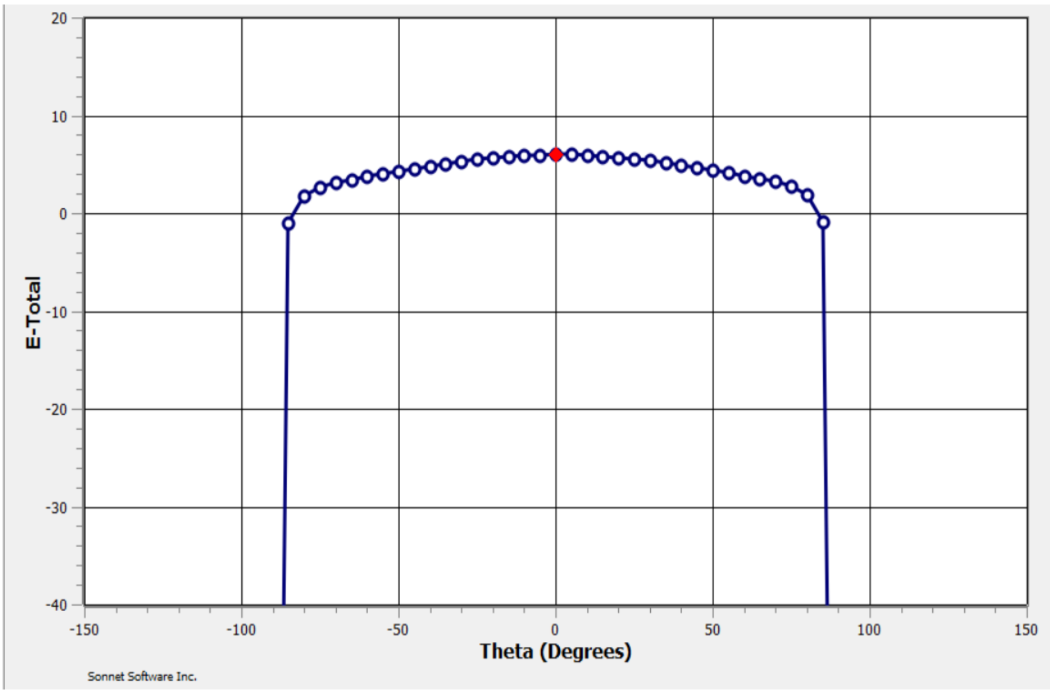

Figure 4. E-Total

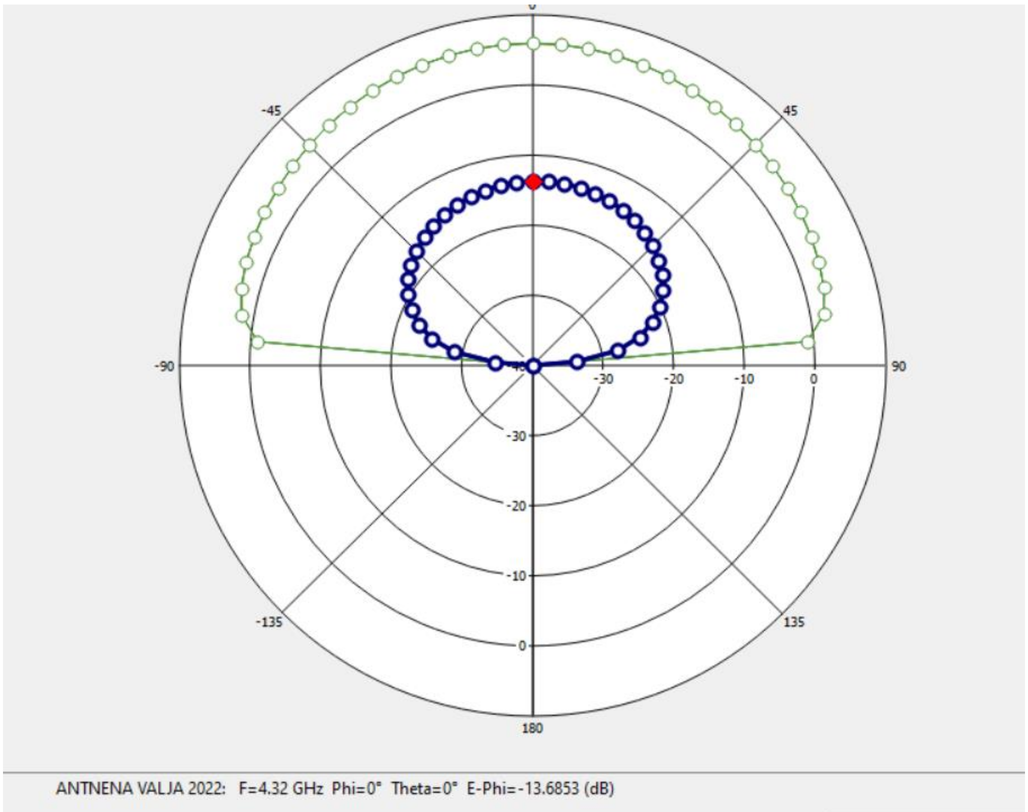

Figure 5. E-θ and E-Φ of the Microstrip Patch Antenna

In this section, parametric study is presented. After experimenting with different properties of this antenna for Sub-6 GHz applications design and making many simulations, all of the results have been shown in the following tables. The total size of antenna is 17.5 x 38.93 mm. In Table 1 the change in width and lenght of center slot is shown. S11 and also the change of the gain is shown.

Table 1. Change in width and lenght of center slot

Center slot(mm)	Frequency (GHz)	S11(dB)	Gain (dB)
7.25 x 3.75	4.31	-17.2	5.93
7.25 x 3.25	4.22	-18	5.94
3.75 X 1.75	4.31	-20.5	5.97
5.5 X 1.75	4.32	-25.31	5.98
7.25 x 1.75	4.32	-27.6	5.99

In Table 2 the change in width and lenght of indendation (outer rectangles of the antenna) is shown.

Table 2. Change in width and lenght of indendation

Indendation(mm)	Frequency (GHz)	S11(dB)	Gain (dB)
1.06 x 3.03	4.31	-27.7	5.99
1.06 x 3.03	4.32	-27.6	5.99
2.06 x 3.03	4.14	-18.5	5.95
2.3 x 3.03	4.12	-18.3	5.9
2.3 x 3.78	4.10	-18.1	5.89

In the next following table, Table 3 the change in the upper rectangle is shown

Table 3. Change in the upper rectangle

Upper rectangle(mm)	Frequency (GHz)	S11(dB)	Gain (dB)
3.25 x 5.5	4.32	-27.6	5.99
3.25 x 6.5	4.32	-25.1	5.99
3.25 x 7.5	4.31	-24.9	5.97
4 x 5.5	4.32	-24.7	5.98
4.5 x 5.5	4.31	-24.2	5.96

In Table 4 the change in the lower rectangle is shown.

Table 4. Change in the lower rectangle

Lower rectangle(mm)	Frequency (GHz)	S11(dB)	Gain (dB)
3.5 x 10.75	4.32	-27.6	5.99
3.75 x 10.75	4.33	-23.1	5.98
4 x 10.75	4.34	-20.9	5.97
3.5 x 11	4.32	-27.9	5.99
3.5 x 11.5	4.33	-28.2	5.99

And finally, in the last table, the change in the rectangle that connects 2 parts of the shape is shown.

Table 5. Change in the middle rectangle

Rectangle (mm)	Frequency (GHz)	S11(dB)	Gain (dB)
7 x 4.75	4.32	-27.6	5.99
7.5 x 4.75	4.31	-24.1	5.98
8.1 x 4.75	4.29	-21	5.97
7 x 5	4.32	-26.9	5.99
7 x 5.25	4.33	-26.1	5.99

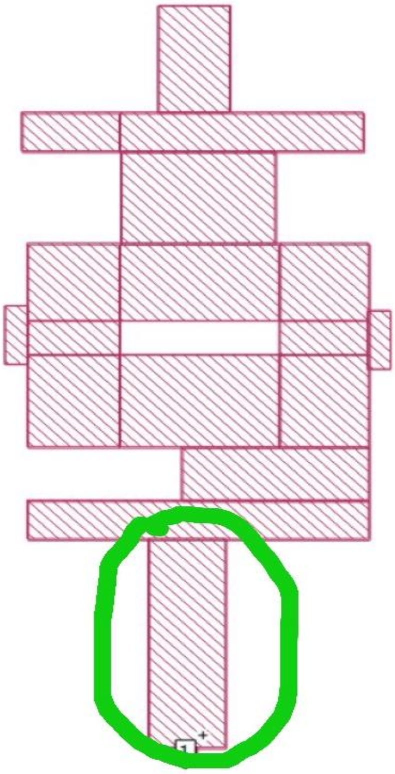

Figure 6. Lower rectangle

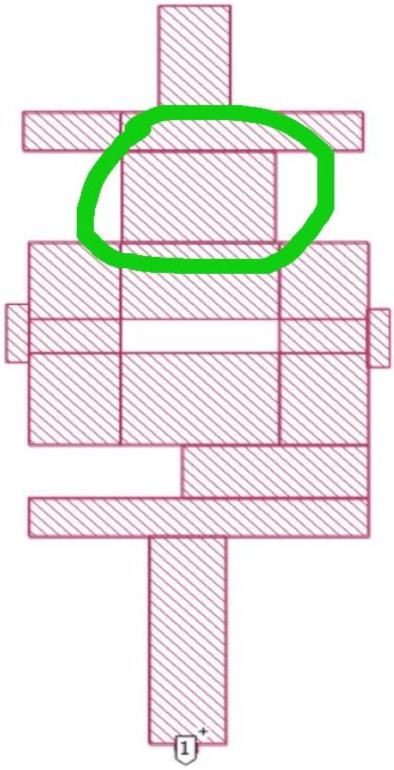

Figure 7. Middle rectangle

The next following figure, Figure 8, shows the surface current distribution of my antenna. Currents are crowded in the area around the lower rectangle of the presented device and in the middle part of it.

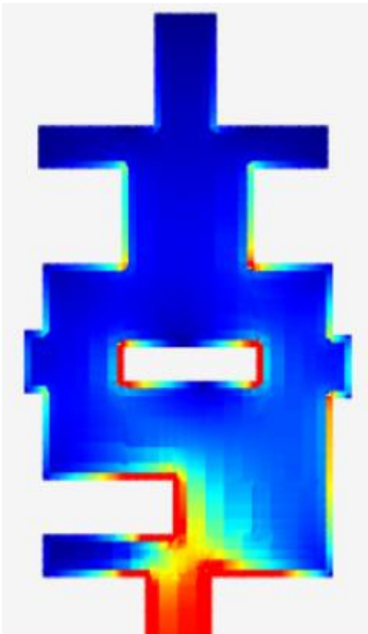

Figure 8. Current distribution

4. Conclusion

In this work, I have presented a design and analysis for the patch antenna for Sub-6 GHz antenna. The presented antenna device is suitable for 5G applications. Simulations were obtained in a high-frequency electromagnetic software called Sonnet Suites, version 18.52. The antenna has shown pretty good performances and size characteristic. Various methods were included during the research and design of the microstrip patch antenna such as antenna architecture, operational analysis, parameter variation and analysis. Minimum input match is at 4.30 GHz where S11 is -18 dB and the maximum gain, and E-θ is 5.9 dB. This paper is distinguished from the other published work starting with its unique shape and other good performances which makes this antenna suitable for many kinds of Sub 6-GHz applications like Internet of Things, Wi-Fi, etc. The tests which were used to achieve as better results as possible include changing dimensions and concluded the test by combining the best results.

Declaration of competing interest

The authors declare that they have no known financial or non-financial competing interests in any material discussed in this paper.

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