

Design and simulation of a low return loss UWB CPW-fed patch antenna for mobile wireless communications

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Abstract. With the recent development of wireless communication systems and the 5G spectrum, mobile broadband technology (MBB) has been thriving. In this contribution, the design of an Ultra Wide Band T-slotted rectangular microstrip patch antenna is presented which is suitable for high data rate applications. The antenna is fed using a coplanar waveguide and is designed for two central operating frequencies, the lower resonant frequency at 3.6 GHz, an internationally recognized standard for 5G wireless mobile communications and a higher frequency at 6.8 GHz, which is part of the new wifi-6E standards. All data of the characteristic parameters have been obtained by using the Computer Simulation Technology Microwave Studio Student suite 2021 (CST MWS).

1 Introduction

With the great progress in wireless technologies and the apparition of new applications like the internet of things (IoT) and Vehicle to everything communication systems (V2X), came a desperate need for faster communication and stronger connectivity which led to the proposal of a 5th generation [1]. The main advantage of the current 5G is its ability to provide seamless coverage, low latency and high reliability and data rate. 5G's higher performances and better density for network users create the possibility of device-to-device connection and large machine communication, thus embracing a networked world.

Additionally, the release and the commercialization of the ultra-wide band within 3.1-10.6 GHz by the Federal communication commission (FCC) made many in the industry and the academic society devoted in the prototyping and research of UWB antennas [2]. An UWB antenna has many advantages such as a richer spectrum resources, faster transmission rate, stronger security and lower power consumption leading to it becoming a research hotspot.

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Ultimately, an UWB can be defined as any band of 500MHz or more. All over the years many antennas, such as the microstrip line fed and CPW-fed antennas with Ultra-wideband characteristics for wireless applications have been reported. In [3], a wide band characteristic and three resonant frequencies were obtained using planar CPW fed Semi-circular patch on Triangle shaped antenna. In [4], the design of compact CPW-FED dual band notched UWB square ring antenna with a bandwidth was depicted. In addition, an antenna bandwidth could be improved by using slots or adding parasitic patch around a central element [5-7].

The 3rd generation partnership project (3GPP) has allocated the spectrum for 5G in two ranges. One includes frequency bands below 6 GHz and the second includes frequency bands above 24 GHz and into millimeter-wave range (24, 26, 28 and 39GHz) [8]. The 3.6 GHz standard, one for which this contribution was made, is part of a larger band in the 1st range that has been identified by various countries for mobile broadband (MBB) network. In November and December 2018, the Australian communications and media authority (ACMA) conducted the 3.6 GHz band spectrum auction. From there, the 3.6 GHz band was recognized internationally as a pioneer band for 5G services [9]. Nowadays, more and more countries are using this band for wireless mobile communication.

The new Wi-Fi 6E includes the second resonant frequency of the proposed design. It alludes to Wi-Fi services that have been expanded to the 5.9-7.1 GHz (known as the 6 GHz frequency spectrum). The United States was the first nation in the world to allow Wi-Fi to operate in this band with two adopted bands (.5.925-6.425 GHz and 6.525-7.125 GHz) [10]. Since then, other nations have adopted a similar policy, and the Wi-Fi industry has moved very quickly to release interoperable equipment.

The most used antennas in the wireless domain are the microstrip patch antennas. These antennas are considered nowadays one of the most used devices in a multiple of applications in wireless communication system [11]. Their low profile, low cost, easy printability, and fabrication, as well as the capability of being embedded within other devices, make them a great choice for the industry [12]. Patch antennas are planar antennas that are generally made on printed circuits. A microstrip patch antenna (MPA) can be fed using different techniques: microstrip line, coaxial probe, a coplanar waveguide, aperture coupled and proximity coupled.

Here, for the new Wifi-6E and 5G mobile applications, a narrative design of a broadband planar antenna with CPW-fed technology is proposed; this feeding technique has the particularity of having wide band characteristics. Thus, the antenna consists of a rectangular shaped patch element printed on a dielectric substrate, embedded with a T-slot and has curved edges to the inside. By adjusting the height of the substrate and the dimensions of the T-slot, the overall performance of the proposed antenna can be improved. At first, a parametric study of the overall geometry was carried and an antenna of reference was obtained. Then and to improve the return loss coefficient the T-slot was added and parametric studies on the dimensions of some components were carried.

2 Antenna design

The proposed antenna was designed using a PTFE (lossy) with a relative permittivity of 2.1 and a thickness of 1.37 mm. On this substrate, a T-slotted rectangular patch element with itched in corners was printed. Moreover, the antenna has a partial ground etched on the same plane as the patch and the feed. The coplanar waveguide feed (CPW) is divided into two rectangular sections and deposited on both sides of the line, like the patch and the feed line; they're built using a copper layer with a 0.035mm of thickness. Fig.1 depicts the geometry of the antenna while in Table 1, its dimensions was cited.

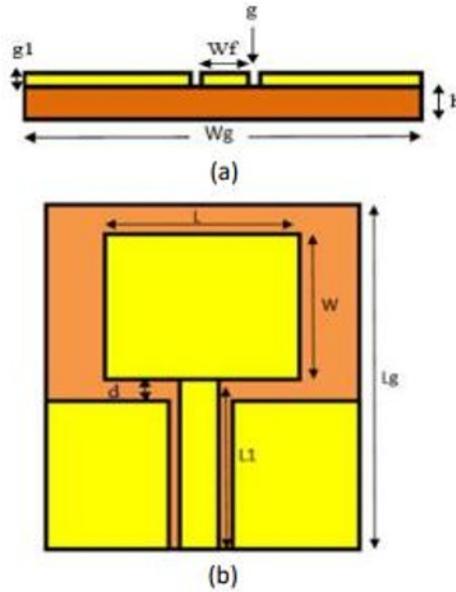


Fig. 1. Antenna of reference (a) side view (b) front view.

Table 1. Dimensions of the antenna of reference

| Parameters | Value (mm) |
|------------------------------|------------|
| Rectangular patch width (W) | 18 |
| Rectangular patch length (L) | 14 |
| Substrate width (W_g) | 30 |
| Substrate length (L_g) | 35 |
| Substrate height (h) | 1.6 |
| Line's length (L_r) | 20 |
| Gap rectangular/ground (d) | 3 |
| Gap Line/ground (g) | 0.25 |
| Line width (W_f) | 3.5 |
| Thickness of copper (g1) | 0.035 |

3 Results and discussion

3.1 Return Loss coefficient S_{11}

In this contribution, CST Microwave studio student suite 2021 is used to simulate the design and to investigate the performance of the antenna. Fig.2 displays the simulated return loss

coefficient for the antenna. It can be observed that it has already a broadband performance from 2.3-8.03 GHz (at -10dB), covering more than 4 GHz of a band and providing dual resonant frequencies of 3.4 and 6.4 GHz. However, it is also shown that the S11 coefficient has only reached the -20dB for the notch frequencies. Fig.3 shows that at the resonance, an approximately impedance of 50 ohm is achieved.

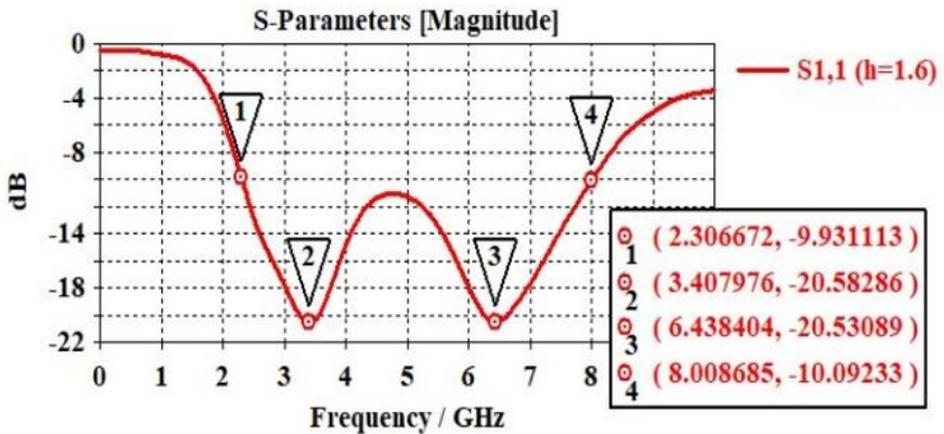


Fig. 2. Return loss coefficient for the antenna of reference

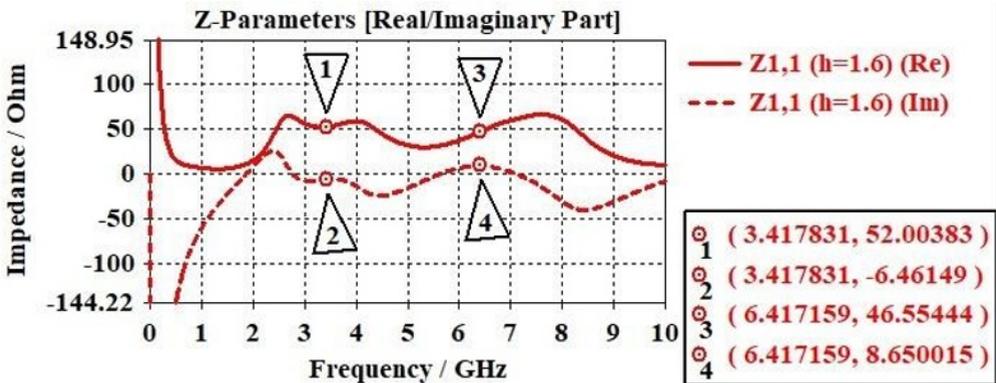


Fig. 3. Impedance matching

3.2 Parametric study of the return loss

After the retrieve and the analysis of the reference antenna performance, it became obvious that the return loss coefficient should be improved. For this end, a comparative study of the effect of different substrate's thicknesses was carried, it is important to note that the substrate used for this design, the PTFE (lossy), can be produced with a thickness going from 0.2mm to 100mm for thin substrates as shown in [13]. Fig.4 presents the return loss coefficient S_{11} for different thicknesses of this substrate.

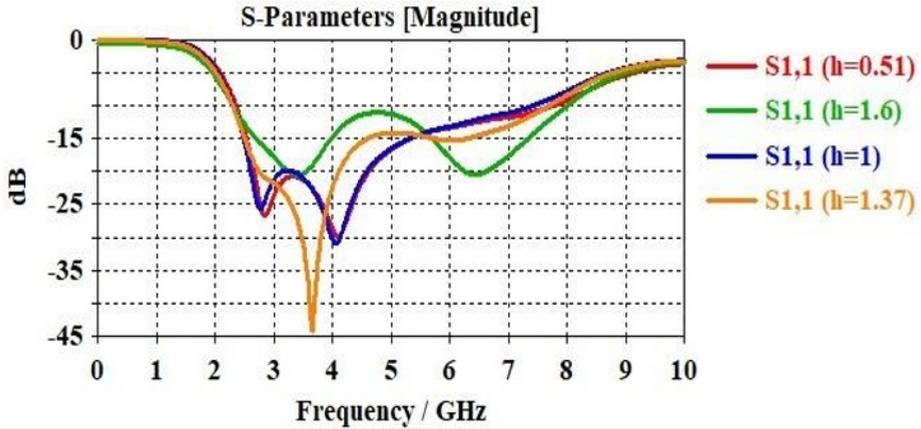


Fig. 4. Substrate's thickness effect on the S11 coefficient

At the height of 1.37mm, a great improvement of the return loss coefficient was noted. The desired frequency of 3.6 GHz was obtained with an $S_{11} = -45$ dB approximately, a VSWR less than 2 of 1.013 which is quite appropriate, and an impedance of $46.22 - 0.47i$ were achieved.

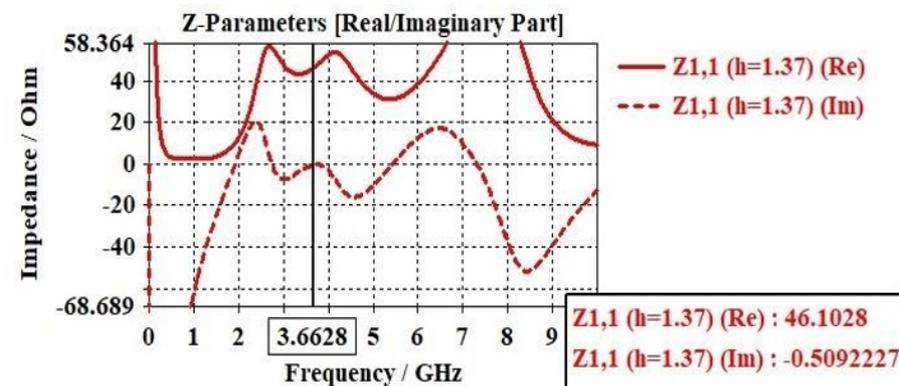


Fig. 5. Z-parameters for the chosen substrate's thickness $h=1.37$ mm

Next, and to obtain further improvement of the S_{11} coefficient, thus the performance of the antenna, curved edges with a radius r was introduced. It is presented in Fig.6 that the return loss coefficient has improved slightly.

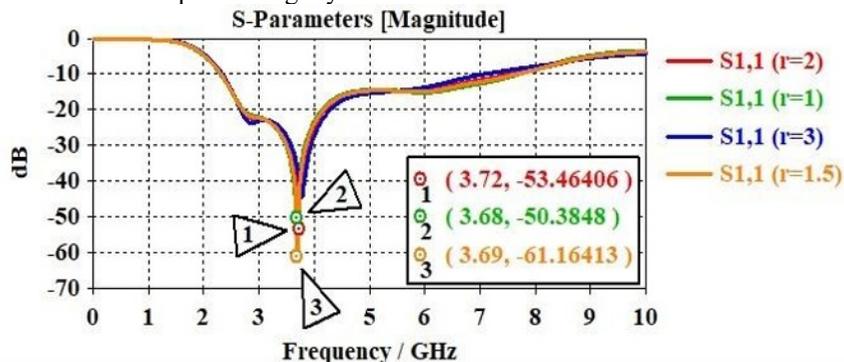


Fig. 6. Etched corners effect on the antenna's S_{11}

One of the most known techniques for antenna performance enhancement is adding slots as to lengthen the current lines. In this case, a T-slot was proposed which resulted to the presented geometry in fig7.

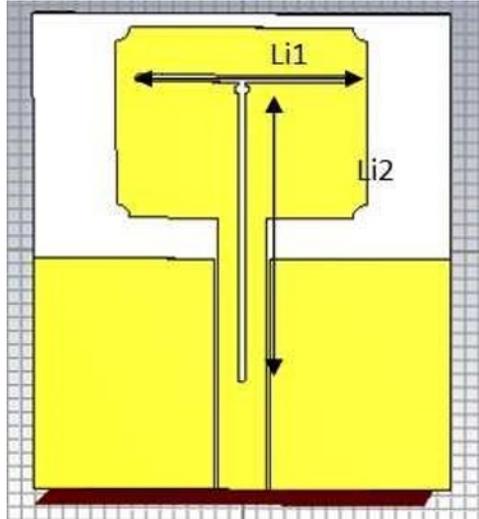


Fig. 7. Geometry of the proposed antenna

Lastly, a parametric study of the geometry for the T-slot was conducted. Fig.8 presents the return loss coefficient over frequency for different values of L_{i1} while fig.9 depicts that same coefficient for different L_{i2} values.

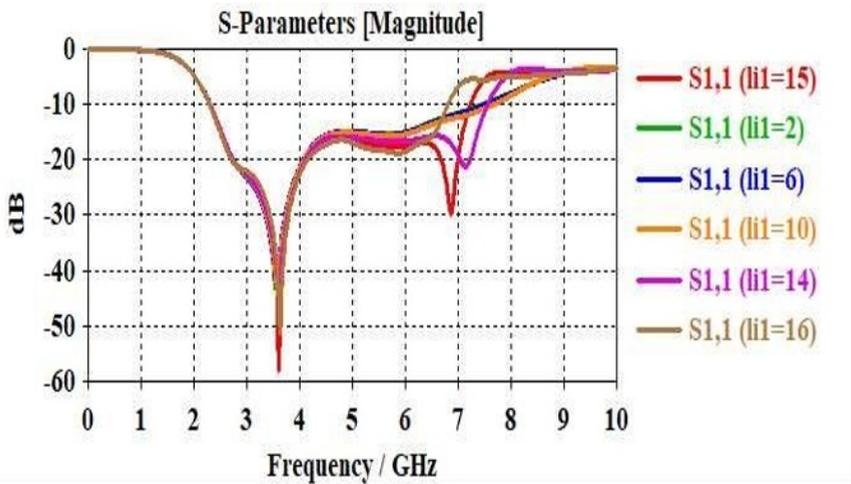


Fig. 8. S11 over frequency for different L_{i1} (mm)

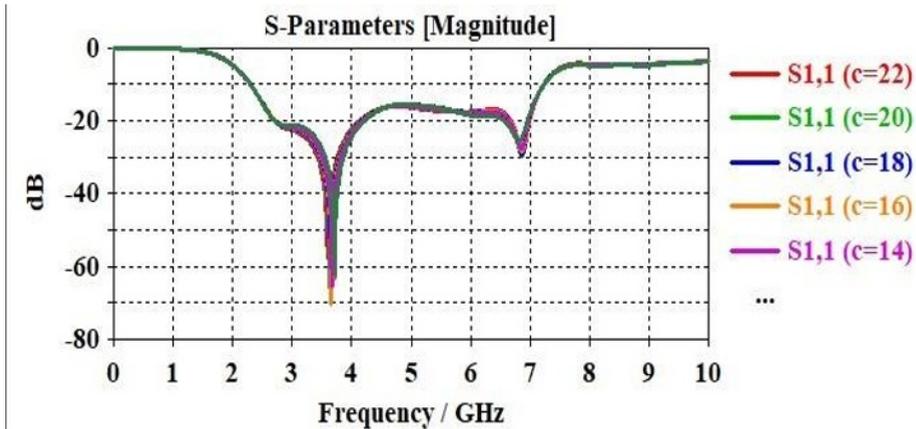


Fig. 9. S11 over frequency for different Li2 (=c in mm)

It can be observed that there is no difference of the S_{11} coefficient when L_{i1} is less than 14mm and that the second resonant frequency appears for the same value. It is also shown that the optimized results are obtained for $L_{i1}= 15$ mm (Fig.8).

Fig.9 shows that with $L_{i2}=16$ mm an improved return loss coefficient of -70dB for the central frequency 3.6 GHz could be attained. Fig.10 shows clearly the final return loss coefficient for the resonant frequencies of the proposed scheme. As stated previously, the antenna possesses two resonant frequencies. One in the 5G wireless standard at 3.66 GHz with an S_{11} coefficient of -70dB and a second in the new Wifi-6E standard with an S_{11} of approximately -30dB.

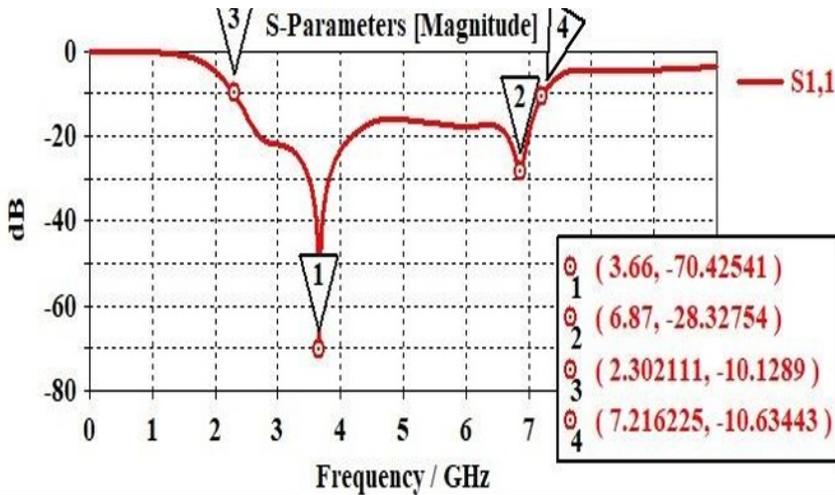


Fig. 10. Return loss coefficient for the proposed antenna

Fig.11 represents the proposed antenna impedance as a function of frequency.

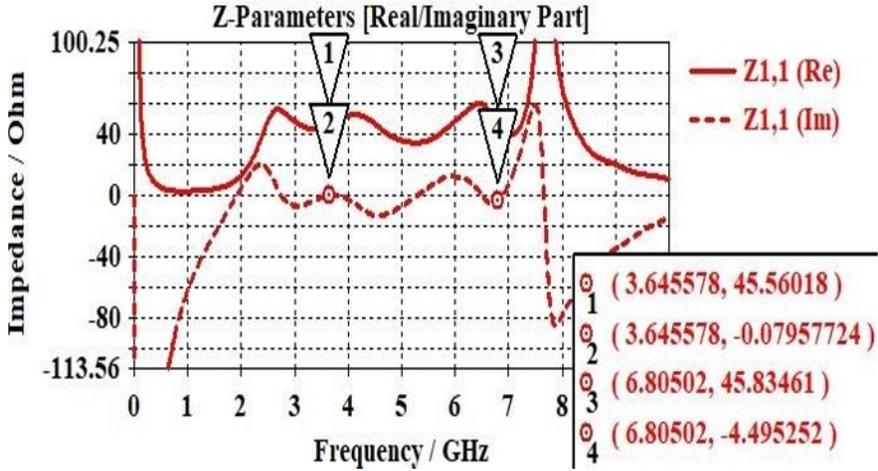


Fig. 11. Z-parameters for the resonant frequencies of the proposed antenna

From the results and observation stated previously, it can be confirmed that an UWB antenna of about a 4.9 GHz band was obtained using a T-slot and an optimized height of the substrate.

3.3 Radiation patterns

From a close consideration of the 2D and 3D radiation patterns for the resonant frequencies shown below in Fig.12, Fig.13, Fig.14 and Fig.15, the following results of the simulated gain are announced: 1.73 dBi and 4.02 dBi in the 3.66 GHz and 6.86 GHz respectively. It is also easily confirmed that the antenna has a near omnidirectional nature and a maximized gain in the 90 deg.

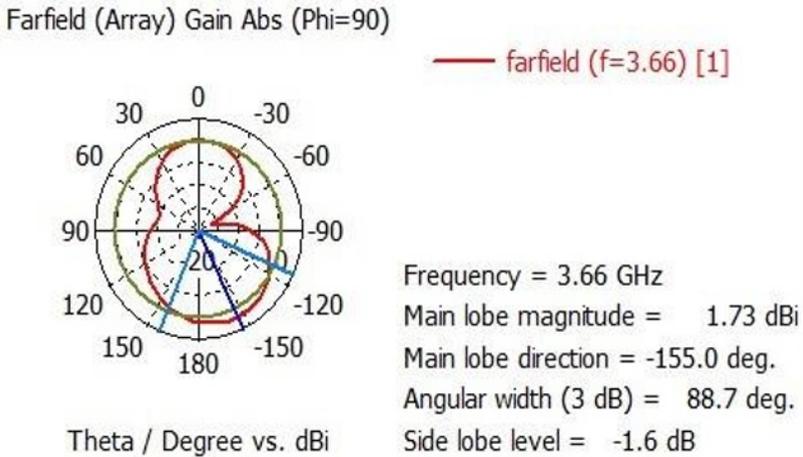


Fig. 12. 2D radiation pattern at 3.66 GHz

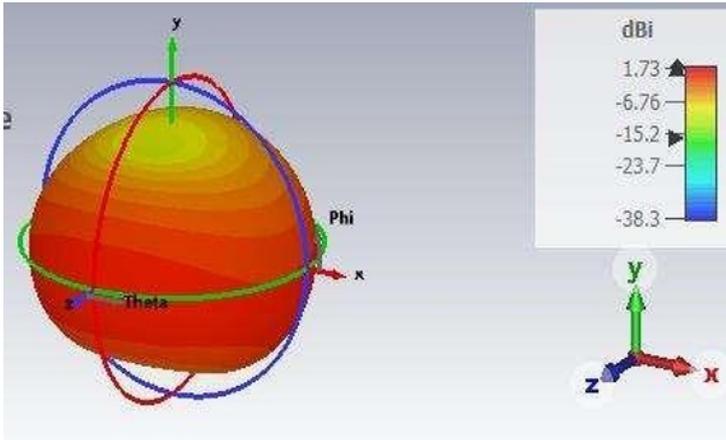


Fig. 13. 3D radiation pattern for the 3.66 GHz

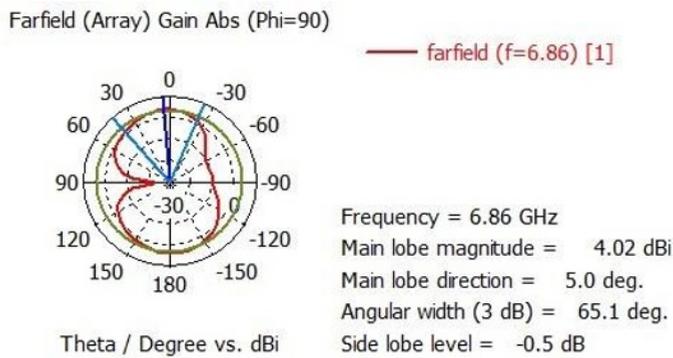


Fig. 14. 2D radiation pattern for the 6.86 GHz

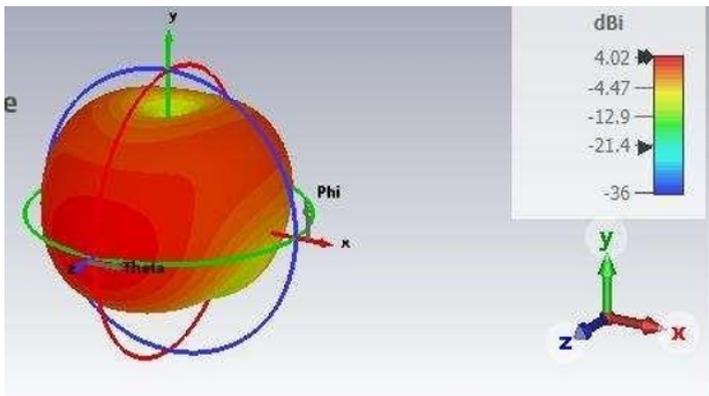


Fig. 15. 3D radiation pattern for the 6.86 GHz

3.4 Comparison of the S_{11} coefficient of the reference antenna and the proposed antenna

As stated above, a significant improvement of the return loss coefficient can be clearly observed between the proposed antenna and the reference antenna. Fig.16 and table 2 shows the distinct difference and upgrade between them.

Table. Comparison of the S_{11} Coefficient of Reference Antenna and the Proposed Antenna

| Parameters | Antenna of reference | Proposed antenna |
|----------------|----------------------|------------------|
| F_{R1} (GHZ) | 3,4 | 3,66 |
| S_{11} (dB) | -20,5 | -70,42 |
| F_{R2} (GHZ) | 6,43 | 6,87 |
| S_{11} (dB) | -20,53 | -28,32 |

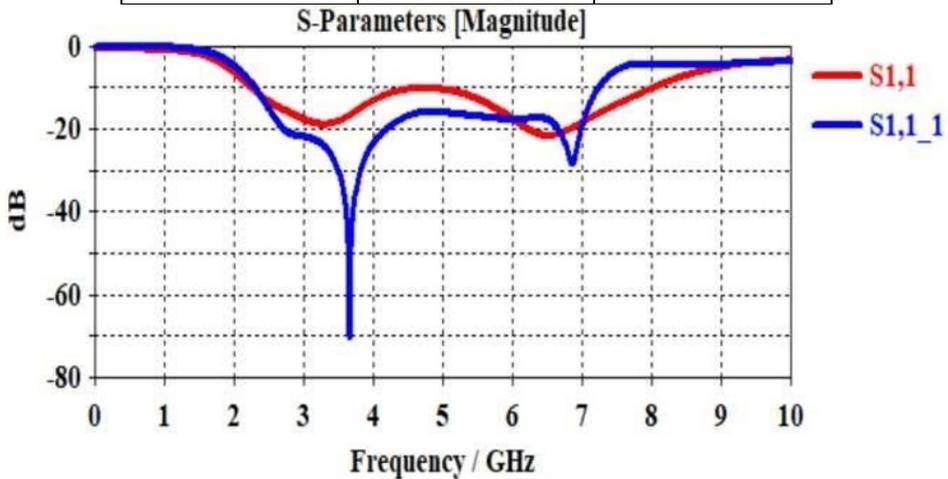


Fig. 16. The reflection coefficient of the reference antenna (red) and the proposed antenna (blue)

4 Conclusion

In this study, an ultra-band CPW-fed patch antenna for applications in the 3.6 GHz frequency band and the Wifi-6E has been designed and implemented using CST Microwave studio software. In the proposed antenna, PTFE (lossy) substrate with a permittivity of 2.1 was used. The antenna demonstrated promising results during the simulation. The antenna possesses a bandwidth of about 4.9 GHz (2.32-7.23 GHz) with a resonant frequency at 3.66 GHz for 5G wireless mobile applications. With a corresponding return loss coefficient of around -70dB, a VSWR of 1.002, a directivity of 3.28 and a positive gain of 1.73 dBi for the 3.66 GHz and 4.02 dBi for the 6.86 GHz, this antenna presents good performances for mobile applications. In a future work, the enhancement of the gain and the miniaturization of the antenna using reflective surfaces or metamaterials will be discussed.

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