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CPW fed Wideband Spiral Shape Monopole Antenna for mm-wave Applications

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Abstract

This paper presents an innovative CPW fed Spiral Shape Monopole Antenna (SSMA) for fifth-generation (5G) applications. In this design spiral structure is inserted inside two circular rings placed on both sides of the CPW fed line to improve performance. The overall dimension of the antenna is 20x13x0.6 mm^3 which provided a very small return loss, and VSWR in the frequency range 20 to 30 GHz provides a bandwidth of 10.3GHz. Flame retardant Four (FR- 4) substrate of thickness 0.6 mm was used for fabrication of antenna which had a dielectric constant of 4.3 (epsilon value) and loss tangent (tanδ) of 0.02. The maximum gain of the antenna is 4.3 dBi, and all the resultant parameters of SSMA are suitable for 5G and mm-wave applications.

Keywords: *Co-planar wave guide fed, Bandwidth, Radiation Pattern, mm-wave, 5G applications.*

1. INTRODUCTION

In the world of fast data processing and transmission, wireless networks play a dominant role. For efficient data computation, more information has to exchange at a faster rate [1], [5].Fig.1.1.shows the transformation of cellular systems, in which 1G is the wireless network designed for voice and messaging. Due to the increased number of users and their requirements, current technology upgraded to the second generation of mobile telephony services. After a long time, this service is also insufficient for the clients, and they are required to stream the video and music. Hence the current system is upgraded to third-generation (3G), which supports social media access also. As time goes, this also becomes inadequate, thereby to 4G and now moving towards 5G for improved capabilities. Numerous researches are going on the same upcoming field of the same areas were provides a wide bandwidth of 24 to 54 GHz frequencies [8]. Antenna plays unavoidable importance in the field of wireless networks [1]. The antenna design is also a challenging task because the world is now at the phase of miniaturization of systems. So it compels to reduce the size, weight, and cost of antenna fabrication, moreover it should be capable of multi-band frequency of operations [9]. Here these requirements can easily be reached by using CPW antennas. This antenna was fabricated upon thin dielectric substrate on one side and by etching on the other side some shapes for radiating electromagnetic waves. Which will not reduce the performance instead we can reduce the volume and heaviness of the system [7].

Many CPW antenna studies have been existed and analyzed the performance in [2], [3]. Ajeesh K et al [2] put forward a multi-band microstrip antenna using FR- 4 substrate of folded dipole shape, and it was a triple-band antenna with bandwidth 6.3GHz, 7.2GHz, and 1.5GHz centered at frequencies 32GHz, 40GHz, and 47GHz frequencies respectively. Aswanth M et al [3], a multi-band monopole antenna made up of 1.6 mm thickness FR- 4 substrate resonates at 3GHz, 7GHz, and 16GHz, 25GHz, and 28GHz frequency band. Bijubal NB et al [10] offers a triband CPW fed antenna for 5G application in the shape of VEL resonates at 3 GHz,14 GHz, and 24 GHz , constructed by the FR4 substrate material, and thickness is 1.6 mm. Adithya et al [11] introduced a trident shaped multi-band antenna resonate at 8 GHz, 16 GHz, 25 GHz, and 32 GHz frequencies. G. S. Karthikeya et al designed a CPW fed wideband corner bent antenna made up of the substrate NY9220 f thickness 0.508 mm and obtained a bandwidth of 6 GHz [6].

In this paper, part I explains a basic theme about mm-wave based 5G application, and the literature survey of reference paper related to previous work in the same area. Part II described the design of a CPW fed spiral-shaped monopole antenna made up of a substrate known as FR-4 of thickness 0.6mm that provides sufficient bandwidth for many of the 5G applications. Part III spells out the performance of the SSMA in terms of return loss, VSWR, directivity, and E and H field patterns. Part IV consolidated the overall performance of SSMA.

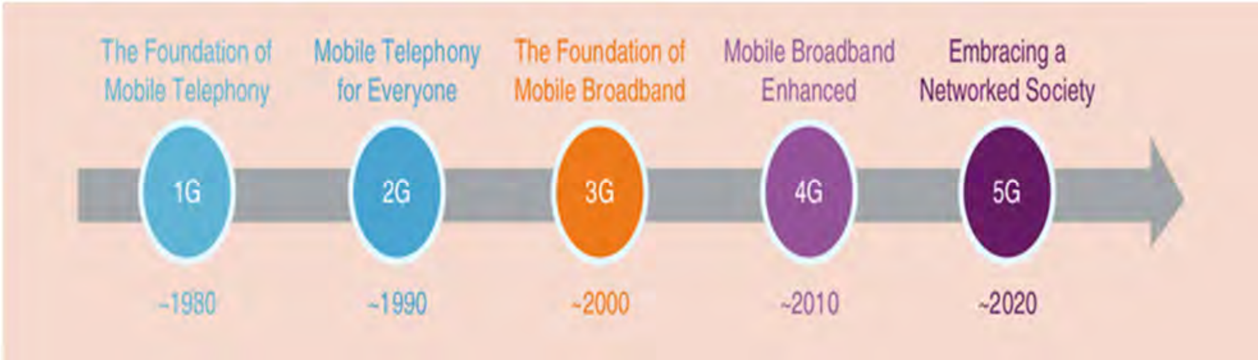

Fig.1.1.Evolution of wireless communication [8]

2. DESIGN OF SSMA

Fig.2.1 reveals the geometrical structure of the CPW fed wideband SSMA antenna in the shape of circular rings loaded with spiral structure, two ground planes were placed on the top of the substrate, and in between the ground plane in there exist a metallic strip fed line. A single-layered FR- 4 substrate of 0.6 mm thickness was designated as a dielectric material for this antenna. Here there was no ground plane in the bottom side of the antenna and hence it is called the ungrounded CPW fed antenna.

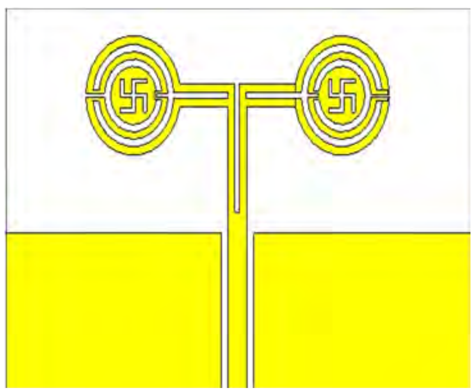

Fig.2.1 Front view of SSMA

Fig .2.2 is the perspective view of the designed SSMA antenna. The dimensions of the SSMA antenna are marked in Fig.2.3. Table 2.1 given detailed information about the dimensions of the antenna proposed. Here L indicated the length and W indicated the width is 20x13mm, with a thickness patch, ground, and CPW Fed is 0.1mm. The fed line is of width 0.8mm.

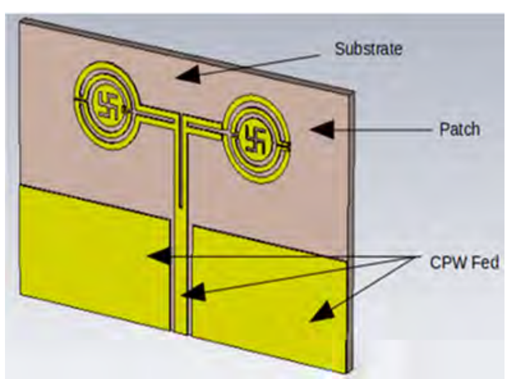

Fig.2.2 Perspective view of SSMA

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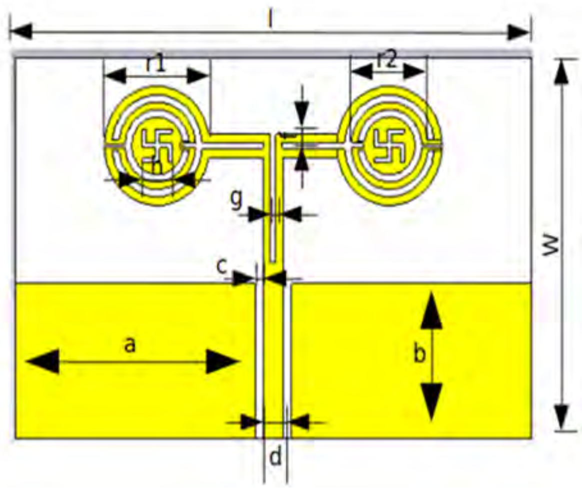

Fig.2.3.Dimension of SSMA antenna

Table 2.1. Dimension and notation of SSMA antenna

Antenna Measurement	*Magnitude(mm)*	*Antenna Measurement*	*Magnitude(mm)*
l	20	e	10.5
w	13	f	0.2
a	9.3	g	0.2
b	4.3	h	1
c	0.3	r1	2.05
d	0.8	r2	1.5

3. RESULTS AND DISCUSSION

In this section, detailed studies were done on VSWR, Reflection coefficient, Gain, Radiation pattern, and the 2D plot of both electric and magnetic fields after the simulation of CPW fed wideband spiral shaped monopole antenna in CST studio software. The proposed antenna has more bandwidth than the referred antennas [4], [9], [6]. The geometry of the ground plane at the top of substrate and the fed line was not changed till the final step of the simulation. Comparison of different reference antenna with the proposed antenna was explained in Table.3.1.

3.1. Return Loss

The return loss or reflection coefficient (S_{11} or S_{22}), is the measure of how much amount of power is reflected from the antenna [3]. The first phase was designing a dipole antenna at the top of the fed line. Then, this has changed by introducing circular rings on both sides, as shown in Fig.2.1 without the spiral structure. A similar design has been done in [2], where it was a square shape. Thereby obtained a single band antenna with bandwidth 8.9 GHz in the 5G band, at frequency 26 GHz provides the lowest return loss of 28 dB. The current design added a spiral structure. For the first time, the height of the ground in the antenna was of length b= 5.5 mm (b1), and hence it provides a much small bandwidth and then increased the value of b to 6.5 mm (b2), thereby obtained a bandwidth of 10GHz, but the return loss was much smaller value. To decrease return loss changed the value of b=6mm. Thereby obtained attractive output in the frequency spectrum of 5G with bandwidth 10 GHz with lowest reflection coefficient -38dB as in Fig.3.1.

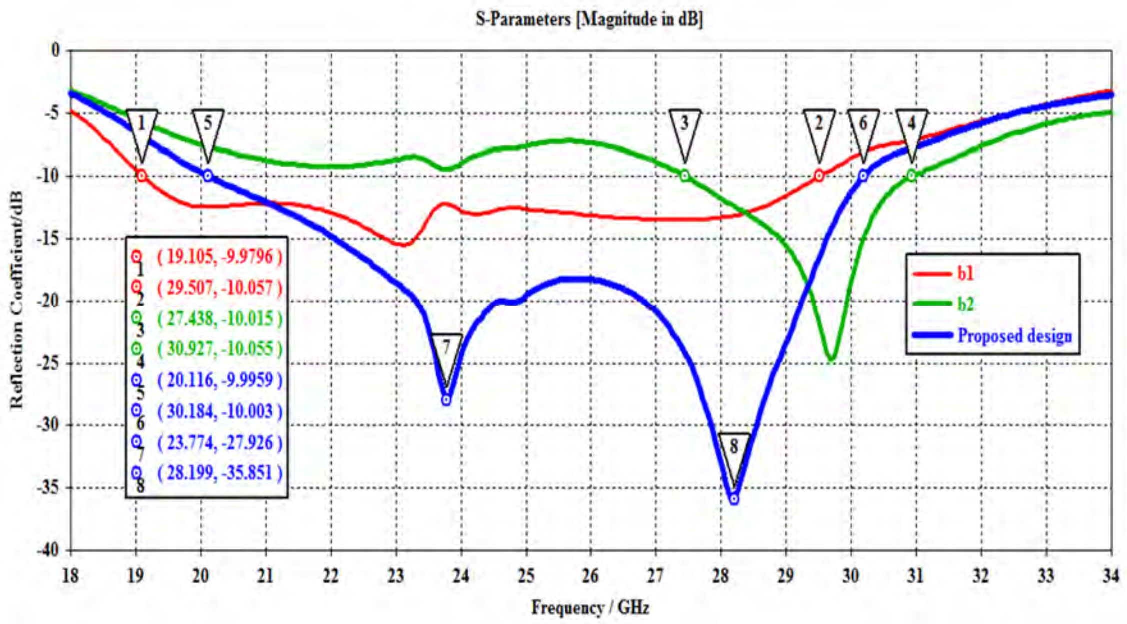

Fig.3.1. S_{11} versus frequency plot of SSMA.

3.2. VSWR

The voltage standing wave ratio is a dimensionless quantity similar to return loss. VSWR is always positive and in ideal cases, it falls below unity. The VSWR value beyond 2 is not acceptable. For the proposed SSMA, VSWR value 1.11 and 1.05 were obtained at frequencies 23.7 GHz and 28.2 GHz respectively, as shown in Fig.3.2.while b1=5.5mm and b2=6.5mm,VSWR values are not as much better as the case of the proposed design.

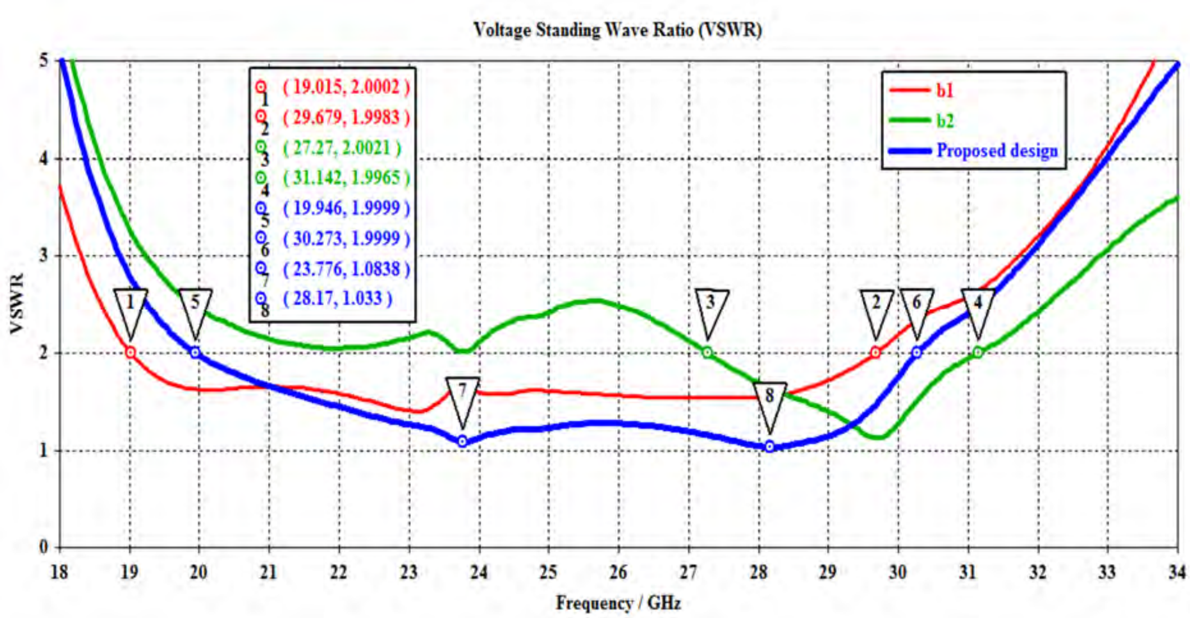

Fig.3.2. VSWR versus frequency plot of SSMA.

3.3. Radiation pattern and E and H field pattern.

SSMA antenna is not backed by the ground surface, and hence the transmit beam is uniform in all directions [6]. The directivity of SSMA are 3.6dBi, 3.49dBi, 4.2dBi, 2.49dBi, and corresponding frequencies are 20GHz, 23.5GHz, 28.2GHz, and 30.2GHz are as indicated in Fig (3.3-3.6).Similarly, the electric and magnetic field patterns in the primary plane that is the XZ plane and YZ plane are represented in Fig.(3.7,3.8) , for the frequencies of 23.5 GHz, and 28.2 GHz.

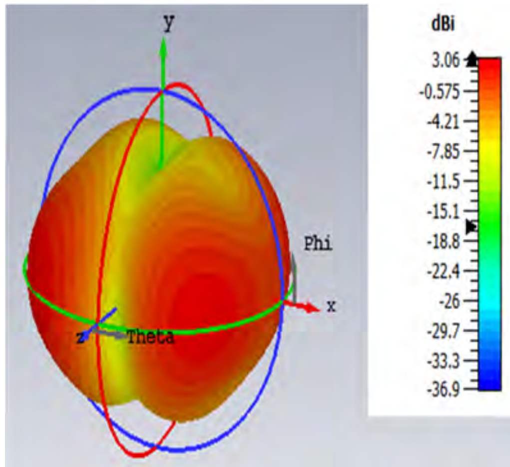

Fig.3.3.Directivity plot at 20 GHz

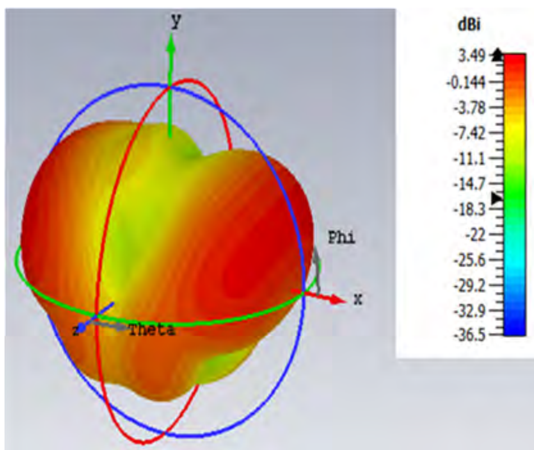

Fig.3.4.Directivity plot at 23.7GHz

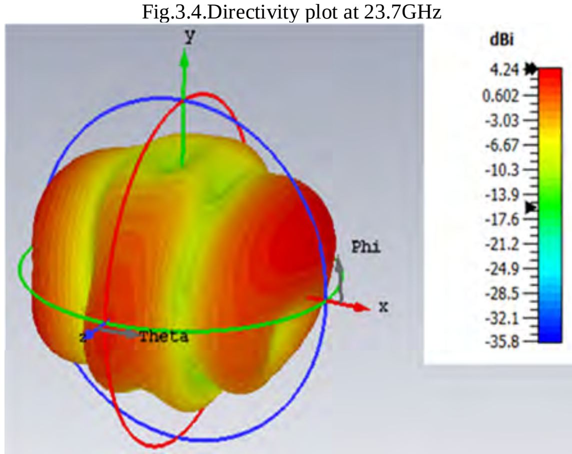

Fig.3.5.Directivity plot at 28.2GHz

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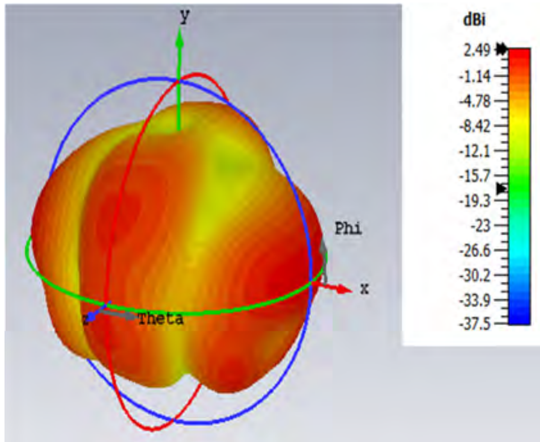

Fig.3.6.Directivity plot at 30GHz

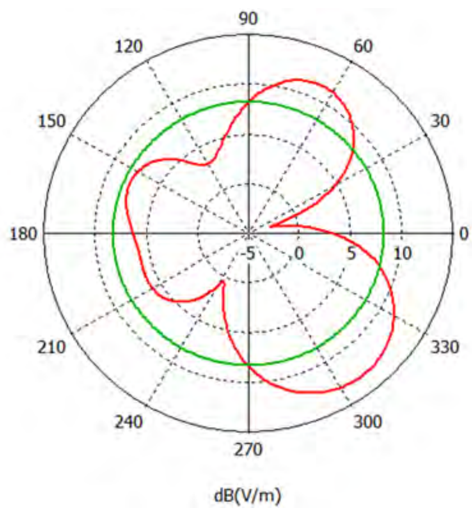

Fig.3.7. E and H Field plot at 23.7GHz

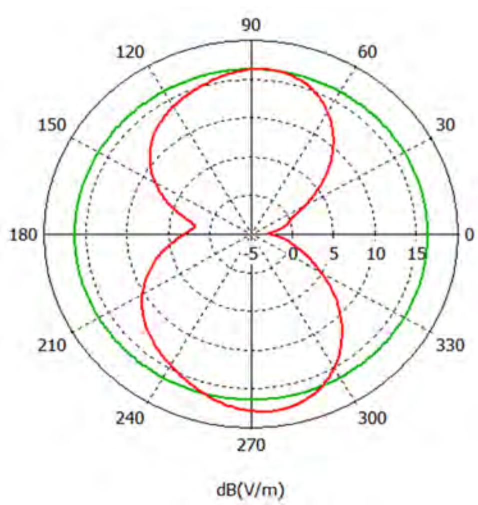

Fig.3.8. E and H Field plot at 28.2 GHz

Table 3.1.Comparison of proposed and reference antenna.

Ref.	***Size(mm^3)***	***Bandwidth(GHz)***	***Number of Bands***
[4] Fang et al.	30x20x1.6	1.2	1
[6] Karthikeya et al	20x16x0.508	6	1
[9] Zhendong et al	40x40x1	3.3	1
Prop. SSMA	20x13x0.6	10.3	1

4. Conclusions

The CPW fed spiral shape monopole antenna (SSMA) for fifth-generation (5G) applications has been introduced. The designed antenna had a high gain 4.2dBi; VSWR values are almost equal to unity at resonating frequencies of 23.7 GHz and 28.2GHz. This is a compact geometry with 156 mm^3 volume and low profile construction. Which is very much use full for 5G applications due to its wide bandwidth around10.3GHz in their 5G-spectrum.

Acknowledgments

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