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Design of CPW fed Square-Wheel Shape Antenna for 5G Applications

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Abstract

This paper is devoted to a CPW fed Square-Wheel Shaped Antenna (SWSA) for 5G Application at mm-wave range. The overall size of the antenna is 18 ×18 × 1.6 mm^3 and is having a simple and compact structure. The designed antenna is fabricated on FR-4 Substrate because this material has good mechanical properties it's εr = 4.3, tanδ = 0.02 and very low cost. This article presents three square shaped antennas with a wheel type structure inserted inside each square which improve the bandwidth and reflection coefficient. The improvement in bandwidth and multiple bands obtained are useful for 5G application at mm–wave range. The multiple bands are obtained at 7GHz, 25GHz and 30 GHz and corresponding reflection coefficient are -23dB, -44dB, -41dB. The proposed antenna stimulation results well suitable for 5G applications.

Keywords: *Co-Planar Waveguide (CPW), Gain, Radiation Pattern, Bandwidth, mm-wave application.*

1. INTRODUCTION

Recently, Antenna technology is seen in most of the research topics because of its vast application in 5G and electromagnetic CAD software's available for its stimulation like CST and HFSS. Wireless communication is moving away from 4G to 5G [1]. Benefits over 4G to new 5G technology like high data rate at high speed, less latency, number of devices can be connected with less interference and better spectrum efficiency.

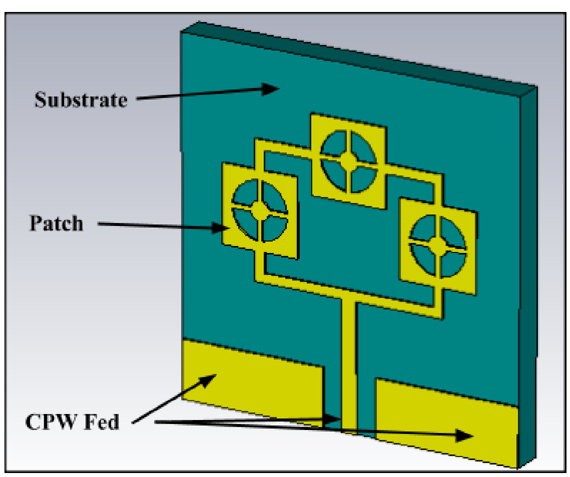

Fig.1.Perspective view of designed antenna

A comprehensive survey on change in network from 3G to 5G over past few years and its architecture detailed [6]. The proposed antenna is designed by dividing it into three parts. Firstly, a fed line with three squares is designed. Secondly, a circle is cut out from each square and thirdly strips are inserted inside the circle. Fig.1. shows the 3D view of CPW fed SWSA antenna designed for 5G applications at mm-wave range. Different shaped monopole antenna referred in [7], [12], [9].The designed system uses FR-4 substrate [permittivity (εr) and tangent loss (δ)] discussed in [12]. The designed antenna has simple structure, good performance and its parameters such as Gain, directivity, VSWR, return loss is enhanced and good bandwidth is obtained. While designing a system, energy consumption is an important factor to be concern about [2]. The proposed antenna is suitable for 5G applications at mm-wave range because of its simple geometry and better performance compared to existing works [2], [3],[5]. Hamad et al designed a UWB antenna which covers (5.5-9.5) GHz of spectrum using substrate Roger 5880[3].

In this paper, section I contains the introduction about 5G networks and how it is useful in designing of different types of antenna [3]. Section I shows the 3D (perspective) view of the designed antenna. In fig.2.1 fed line (conductor) is inserted between the two ground planes and these entire 3 conductors is etched on the same side of dielectric substrate on the same plane so called Coplanar. Three square patches as shown in fig.1.are connected to the CPW fed line using rectangular strip of width 0.50 on both sides. Section II mentions dimension used in designed antenna and their arrangement to get high performance for 5G applications. In section III simulation result and discussion is included. The put forward antenna is designed on time domain based CST studio software which has a high performance 3D EM wave analysis and easily available. Section IV put together the conclusion that various parameters calculated from designed antenna makes it suitable for 5G application at mm-wave range.

2. DIMENSIONS OF ANTENNA

Here a CPW Square -Wheel shaped antenna (SWSA) is proposed in this paper. Fig.2.3 shows the completed structure of the antenna. A feedline of 0.8mm thickness is taken between the two ground planes then a rectangular strip is designed. Thickness 0.5mm and in each side of the rectangle a square of side 4mm is placed as in fig.2.1. Inside the square patches circles of radius 1.5 mm is separated from the square as fig.2.2. Finally, strips are placed in the circle of thickness 0.4mm, and a mini circle of radius 0.50mm is fabricated over the strip crossing as fig.4. The proposed CPW fed SWSA antenna is having length of 18mm and width of 18 mm with a thickness of 1.6mm. All remaining dimensions are shown in Table.2.1.

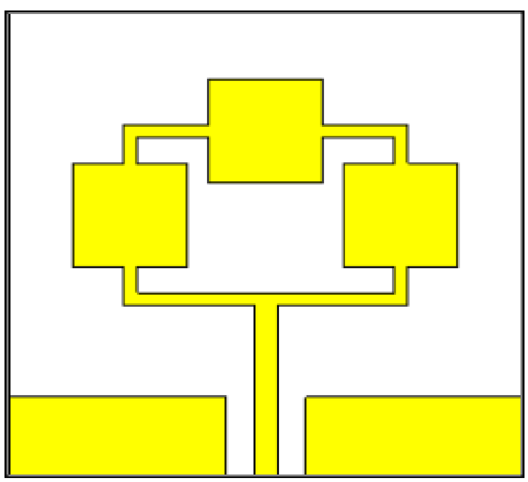

Fig.2.1.CPW antenna with square patches

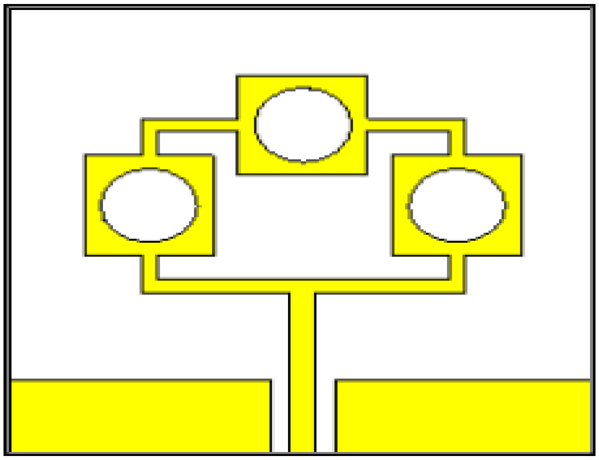

Fig.2.2 CPW fed rectangular antenna with circular slot

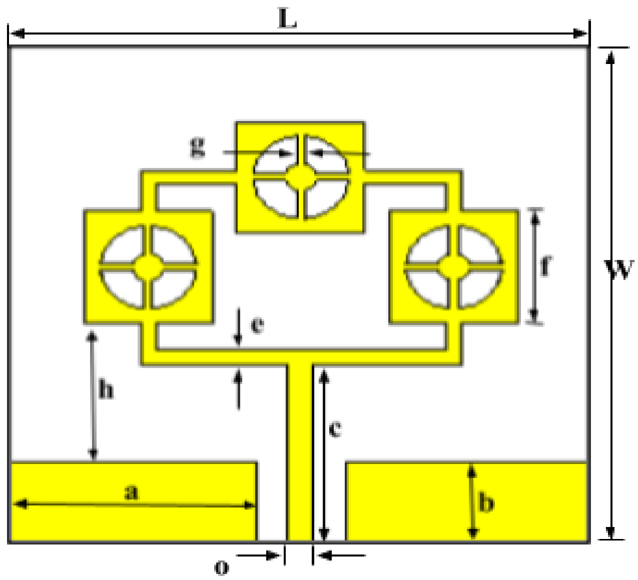

Fig.2.3.Dimensional Representation of Designed antenna

Table.2.1. Dimensions of Proposed antenna

Antenna Dimensions	***Values(mm)***	***Antenna Dimensions***	***Values(mm)***
a	8.00	e	0.50
b	3.00	f	4.00
c	6.55	g	0.40
o	0.80	h	4.00

3. RESULT AND DISCUSSION

In this section, detailed study is done on the VSWR, Return loss (S_{11}), Gain, Directivity, Radiation pattern and 2D plot of both electric and magnetic field after the stimulation of CPW fed square-wheel shaped antenna in CST software. The designed SWSA has more bandwidth comparison compares referred antenna [8], [10], [11]. The table 3.1 indicated the comparison between the reference antennas and SWSA antenna.

3.1 Reflection Coefficient

Return loss or reflection coefficient mostly represented by S_{11} is the amount of power reflected back from antenna [2]. Antenna with only three squares has S_{11} of -31dB at 7GHz, -34dB at 24GHz, and -36 dB at 29GHz. When slots are added the return loss values are -26 dB at 7GHz, -35dB at 24GHz and -29dB at 29GHz. The proposed antenna with wheel structure have the following Reflection Coefficients -23dB at 7GHz, -44dB at 25GHz and -41dB at 30GHz. Graphical representation of reflection coefficient in dB versus frequency is shown in fig.3.1. A better return loss is obtained when strip are inserted with a mini circle at the center, the S_{11} should be lower value preferred for practical applications [5].

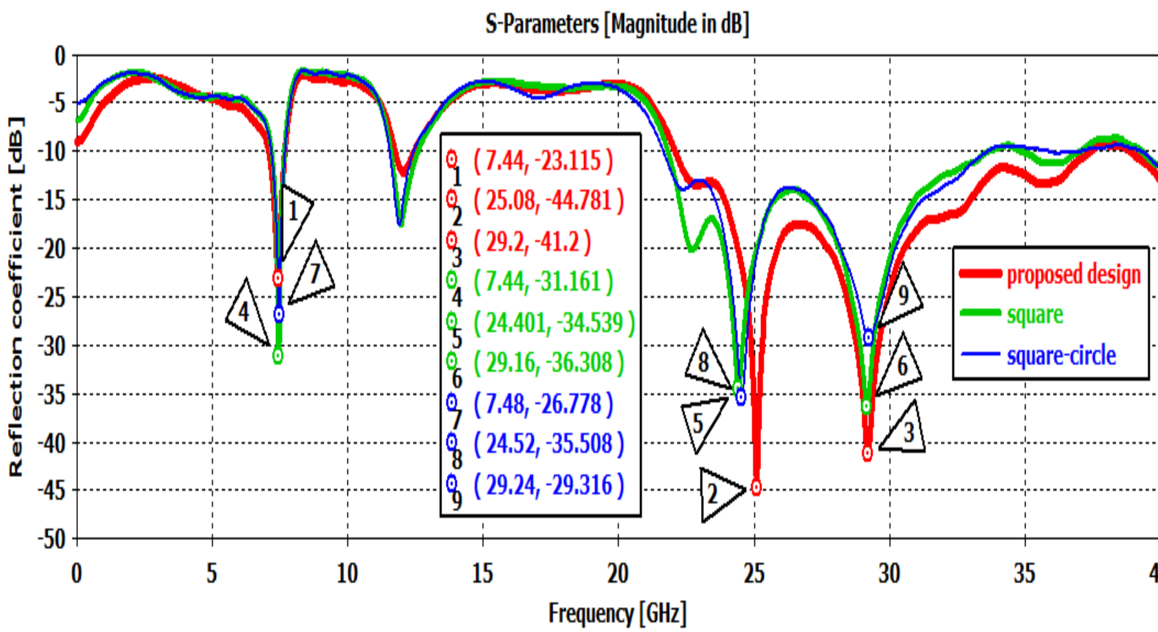

Fig.3.1. S_{11} in dB versus frequency in GHz plot

3.2 VSWR

Fig.3.2 shows the VSWR (Voltage Standing Wave Ratio) Versus Frequency Plot of designed CPW SWSA multiband antenna. VSWR is a dimensionless quantity same as return loss but expressed in different scale and must be always real and positive value [7]. VSWR value equal to 1 is said to be ideal and its value up to 2 is acceptable for practical applications. The VSWR value of 1.05, 1.03 and 1.03 is obtained at frequencies 7GHz, 24GHz and 29 GHz when square patches are taken. For the circular slot the VSWR values are 1.09, 1.03 and 1.07 at frequencies 7GHz, 24GHz and 29GHz. For the final designed antenna VSWR values are 1.16 at 7GHz, 1.01 at 25GHz and 1.01 at 30GHz.

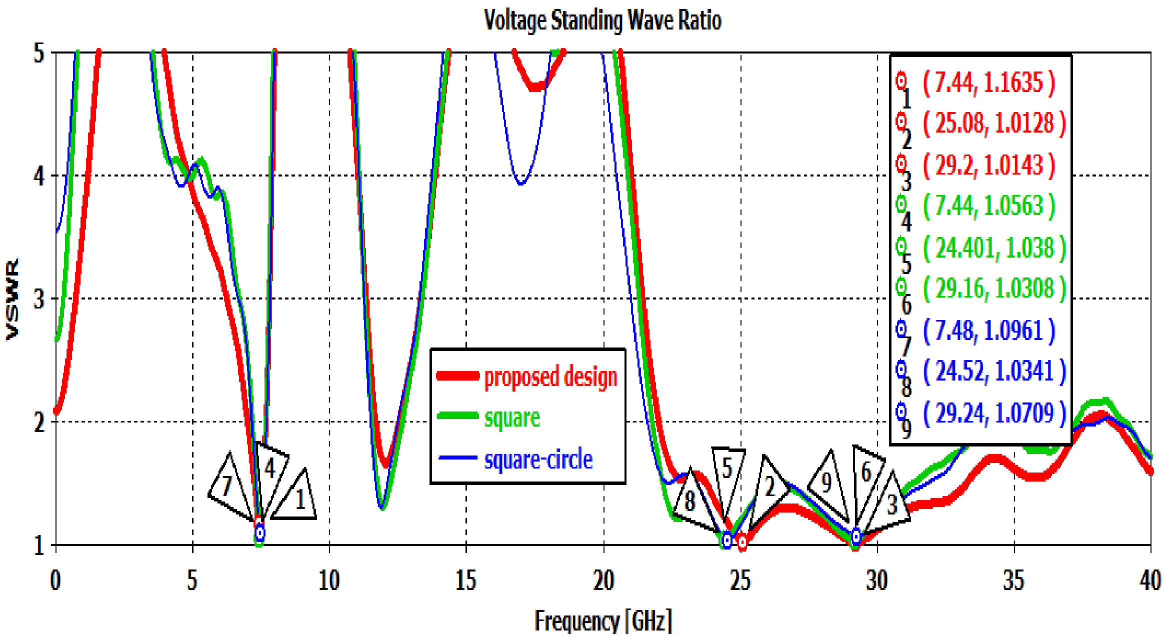

Fig.3.2. VSWR versus frequency plot of proposed antenna

3.3 Directivity of proposed antenna

The Gain of an antenna is simply defined as the ability of the antenna to convert the input power to RF power in desired direction [4].It is an important factor which gives both directivity and efficiency of the antenna. The relation between gain (G) and efficiency (E) is given by G = E × D, Where D is the directivity [11]. Fig. (3.3-3.5) shows the 3D view of the put forward antenna with a directivity of 3.6dBi at 7GHz, 6dBi at 25GHz, 5.2dBi at 30GHz respectively.

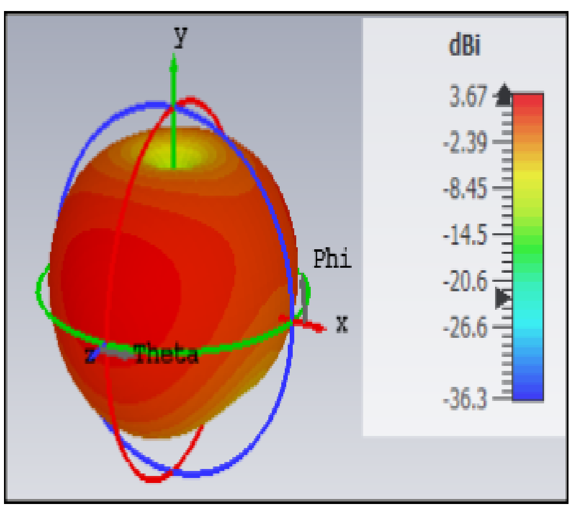

Fig.3.3. 3D plot of Directivity at 7GHz

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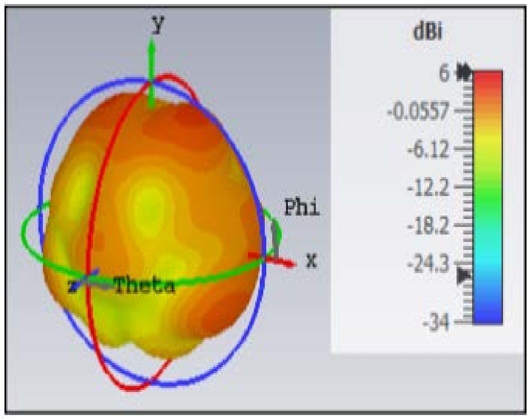

Fig.3.4. 3D plot of Directivity at 25GHz

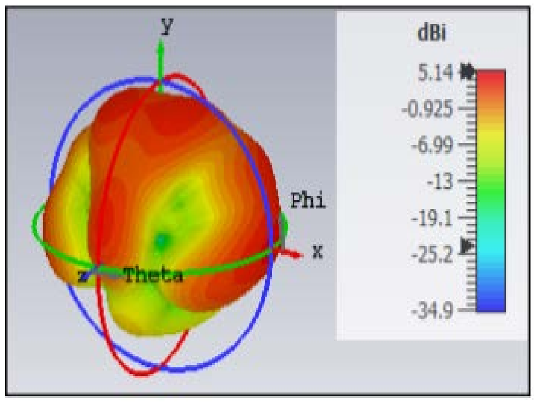

Fig.3.5. 3D plot of Directivity at 30 GHz

3.4 E-field and H field patterns

Electromagnetic waves are formed by a combination of electric and magnetic field. To find E-field keep theta 90 degree and phi constant. For a well designed antenna E field pattern would be in a shape of dumbbell or doughnut shape, and to obtain the magnetic field pattern assign theta as constant and phi with 90 degree. Fig.[3.6-3.8] shows the E-field and H-field pattern at 7GHz, 25GHz, 30GHz frequencies from which its polar variations can be studied.

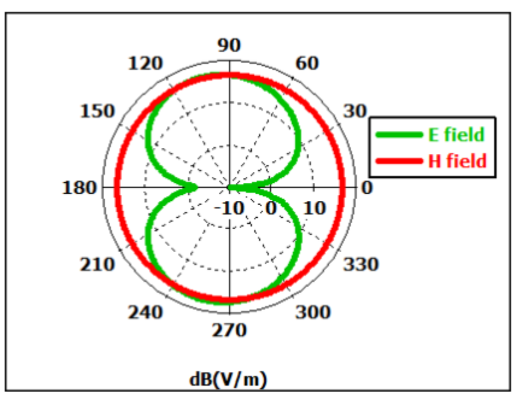

Fig.3.6. Electric and Magnetic field at 7GHz

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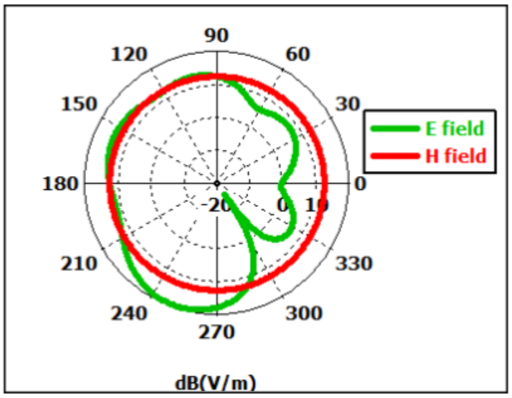

Fig.3.7. Electric and Magnetic field at 25GHz

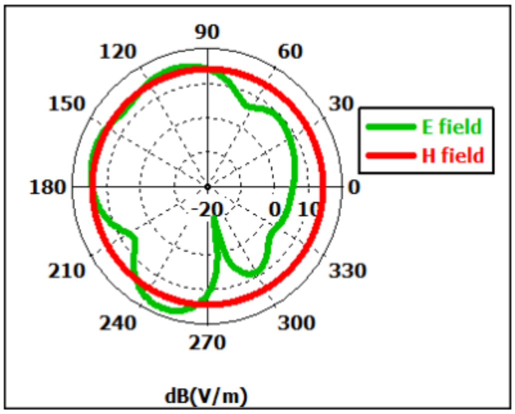

Fig.3.8. Electric and Magnetic field at 30GHz

Table.3.1.Comparison of designed and reference antenna

Reference	*Dimension (mm^3)*	*Bands*	*BW(GHz)*	*Substrates*
[1] Aswanth et.al	25	3	1.3, 7.2, 10.5	FR-4
[3] Fatah et, al	30	2	1.3, 2.5	Roger 5880 RT
[7] Karthikeya et.al	320	1	6	Nelco NY9220
Prop. Ant. SWSA	25	3	1,2.1, 15	FR-4

4. CONCLUSION

A simple structure and compact size (18 ×18×1.6 mm^3) CPW fed Square-Wheel Shaped Antenna (SWSA) is designed, which is preferable for 5G applications (24-40GHz) at mm-wave range. Multiple resonating frequencies 7GHz, 25GHz and 30 GHz are observed for the proposed antenna design. The maximum value of reflection coefficient S_{11} is -44 dB with VSWR value is 1.01 at 25GHz frequency. Bandwidth of nearly 15GHz is obtained. The designed antenna parameters are well suitable for 5G applications.

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