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Original Research Article

Circular polarized high-gain antenna by coaxial feed for 5G mobile applications

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ABSTRACT
In this paper, we present the designing analysis of a simple micro-strip antenna according to TRAI 5G band for mobile communication applications. A single feed on diagonal of rectangular patch circularly polarized wave in free space is created by degenerated orthogonal mode with π/2 phase shift. Up to 6-dB axial ratio of wave is obtained from 3.40 to 3.65 THz for practically circular polarized wave and up to 3-db axial ratio from 3.45 to 3.56 THz range for ideally circular polarize wave. It may be used as a transmitter and receiver for 5G. Left-handed or right handed circular polarization characteristics and as well as good gain (7.56 dBi) holds the prospect of 5G antenna in efficient sensing applications.

1. Introduction

An aerial is a transducer it exchanges electron energy (RF) to photon energy (EM waves) or vice versa and then radiated into free space. The representation of electric-field vector of an electromagnet wave in free space called wave of polarization it means physical Orientation of antenna in space again called wave of polarization [1–3]. Antenna polarization of wave is an imperative thought when selecting and installing the aerial above the tower. The majority of wireless communication arrangements use both linear (vertical or may be horizontal polarization) and circular polarization. Polarizations improve system performance or efficiency for the user or communication system [4-6]. There are a lot of applications where circular polarization is necessary. Linear polarized (vertically and horizontally) signals will be very weak reception (due to reflectivity, absorption by contact, phasing, multi-path and line of sight) [7-9]. In Circular polarization, after reflection from hard objects, the common sense of polarization reverses from right hand circular polarization (RHCP) to left-hand circular polarization (LHCP) or vice versa to create predominantly orthogonal polarization [10-15].Circularly-polarized signals are much superior for penetration and bending around obstacles. Therefore, circular polarization is valuable for a number of applications, like RFID (Radio-frequency identification) tag, RFID readers, WLAN, radar, WiMAX, navigation, GPS (Global Positioning System), and communication systems due to the versatile orientation of the receiver or transmitter antenna [16-20]. Polarization of wave show by axial ratio, for CP AR will be 1.

$$Axial\ Ratio = \frac{major\ axis}{minor\ axis} \quad \text{(Figure 1)}$$

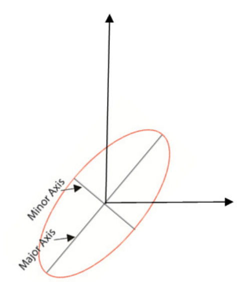

Figure 1 Axial ratio

S.N.	Polarization	Axial Ratio	In CST(dB)
1	Linear	Infinite	40
2	Circular	1	3-6
3	Elliptical	∞<AR>1	6 TO 40

When thicker substrate material is used to enlarge VSWR bandwidth its axial ratio degrade. Circularly polarized shaped by two orthogonal modes are identical magnitude with phase quadrature ($1\angle 0^o$ and $1\angle 90^o$), this is simplest way to obtained CP means two feeds are positioned orthogonal to each other with equal power and isolation between two feed more than 30 db. For dual feed we used offset line or 3db branch line coupler, so antenna size will be increased by extra components. A radiating patch feed by four orthogonal port yield an excellent axial ratio [21-23].

According to TRAI 5G band for mobile communication is 3.3 to 3.67 GHz, so if mobile aerial has circular polarization it provide strong signal for users and call drop problem will be eliminated also [24].

2. Antenna designing and results

The complete construction of the planned design of aerial with coaxial feeding (for 50 ohms impedance) is shown in figure 2. The proposed design has evolved from a rectangular radiating patch (copper material) on top of the Rogers RT/Duroid 5880 substrate with electric tangent 0.0009 & dielectric constant 2.2. Radiating patch and reflecting ground have same thickness (0.035 mm).The width and length of ground plane and substrate materials are same here. Material of the radiating patch and the reflecting ground plane are similar. Feed points are positioned at diagonal of patch for circular polarization. The coaxial feed dimension of interior conductor radius is 0.7 mm, and the external conductor radius is 1.6 mm and insulator between them is vacuum. We can optimize impedance (50 ohms) by CST parametric study calculations. All dimensions become optimized in the CST Microwave Studio 2019, a commercially accessible electro-magnetic field simulator software tool for design and analysis of antenna. Table 1 is shown optimized antenna parameters like patch, substrate, and ground dimensions. Table 2 shows the results of radiation properties with circular polarized antenna when size of patch length is 26.4 mm (L_2) and width 27.6 mm (L_1) when different width and length of substrate and different feed point locations. The ratio of L_1/L_2=1.045. Here this rectangular patch aerial resonates at two dissimilar nearby two frequencies f_1 and f_2 due to different length and width of antenna for coaxial feed on diagonal of aerial. Diagonal single feed point resonates at two different frequencies for length and width of patch. Two different lengths are used for two nearby resonance, but magnitude level of two orthogonal modes is identical to centre resonance, so antenna bandwidth is normally restricted for single feed microstrip antenna here coaxial feed points varies 3.7 mm to 4.0 mm.

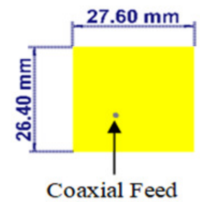

Figure 2: Radiating patch dimensions.

Table 1: Optimized antenna dimensions

Parameter	Patch Length	Patch Width
Value	26.40 mm	27.60 mm
Parameter	Substrate Width	Substrate Thickness
Value	Vary	1.57 mm
Parameter	Patch & Ground Thickness	Substrate Length
Value	35 µm	vary
Parameter	Ground Length	Ground Width
Value	Equal to Substrate	Equal to Substrate

Some best results show in table 2 by different parametric variations, when diagonal at (0.145L_1, 0.1515 L_2) and (0.145 L_1, 0.143 L_2) feed point location at 50 ohm is selected when two orthogonal modes are excite by phase differentiation +45^o and -45^0.At feed point S (-4,-3.8) antenna bandwidth 0.11 GHz at 3 dB axial ratio and 0.15 GHz bandwidth for 6 dB axial ratio.

Table 2: Optimized antenna dimensions (substrate and feed point) with results.

	Width and Length of Ground and Substrate in mm		Feeding Location in mm		Radiation Properties			Remark
S.N.	W	L	X	Y	S_{11} range in GHz	AR <3	AR<6	
1	55	50	4	4	3.42-3.61	NA	NA	AR>6.8
2	60	50	4	4	3.42-3.61			AR>12.6
3	65	50	4	4	3.42-3.60	NA	NA	AR>19
4	55	55	4	4	3.42-3.61	3.4585-3.560	3.4-3.63	AR=.761 at 3.5 GHz
5	60	55	4	4	3.42-3.61	NA	3.49-3.5GHz	AR>5.82
6	65	55	4	4	3.42-3.60	NA	NA	AR>10.44
7	55	60	4	4	3.42-3.61	NA	3.38 -3.57	Cover small range
8	60	60	4	4	3.42-3.61	3.47-3.54	3.41-3.61	Cover almost 5G
9	65	60	4	4	3.42-3.60	NA	3.46-3.51	Cover small range
10	55	55	3.7	3.7	3.42-3.614	3.46-3.55	3.40-3.62	AR=.80 at 3.5 GHz
11	55	55	3.7	3.8	3.42-3.614	3.46-3.55	3.40-3.62	AR=1 at 3.5 GHz perfect impedance matching at 50 ohm
12	55	55	3.7	3.9	3.42-3.61	3.46-3.54	3.41-3.61	AR =1 at 3.5 GHz
13	55	55	3.7	4	3.42-3.61	3.46-3.54	3.4-3.6	AR=1.28 at 3.5 GHz
14	55	55	3.8	3.7	3.42-3.61	3.45-3.56	3.39-3.63	AR=0.50 at 3.5 GHz
15	55	55	3.8	3.8	3.42-3.61	3.45-3.56	3.40-3.63	AR=0.66 at 3.5 GHz
16	55	55	3.8	3.9	3.42-3.61	3.45-3.55	3.40-3.63	AR=0.56 at 3.5 GHz
17	55	55	3.8	4	3.42-3.61	3.45-3.55	3.39-3.61	AR=0.73 at 3.5 GHz
18	55	55	3.9	3.7	3.42-3.61	3.45-3.56	3.4-3.64	AR=0.56 at 3.5 GHz
19	55	55	3.9	3.8	3.42-3.61	3.45-3.56	3.4-3.64	AR=0.50 at 3.5 GHz
20	55	55	3.9	3.9	3.42-3.61	3.45-3.56	3.4-3.63	AR=0.65 at 3.5 GHz
21	55	55	3.9	4	3.42-3.61	3.45-3.56	3.39-3.63	AR=0.56 at 3.5 GHz
22	55	55	4	3.7	3.42-3.61	3.45-3.56	3.4-3.64	AR=0.40 at 3.5 GHz
23	55	55	4	3.8	3.42-3.61	3.45-3.56	3.4-3.65	AR=0.45 at 3.5 GHz
24	55	55	4	3.9	3.43-3.61	3.45-3.56	3.39-3.64	AR=0.42 at 3.5 GHz

Figure 3 and 4 show the scattering parameters (S_{11}) of above designed antenna for dissimilar length and width of substrate with different feed locations of coaxial feed at radiation patch.

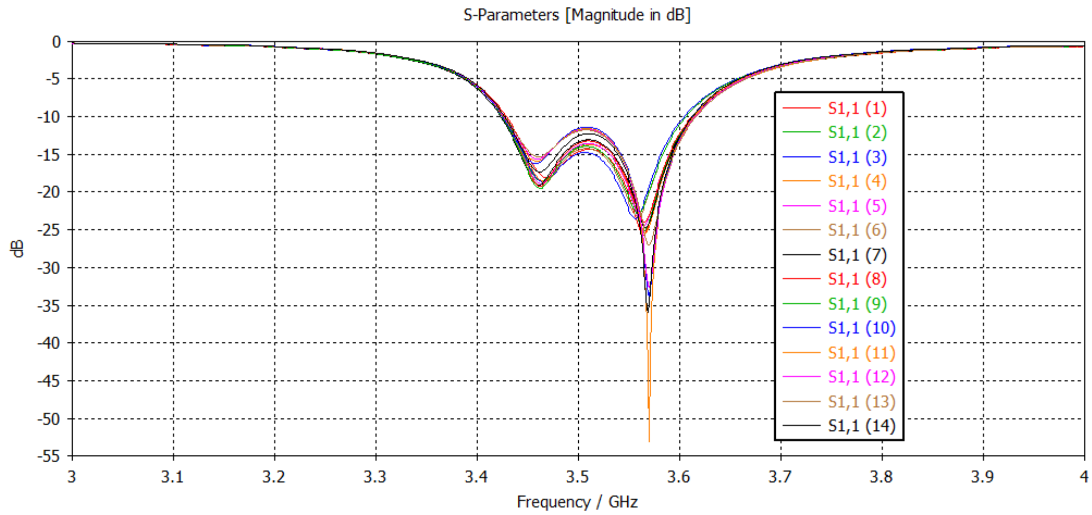

Figure 3: Scattering parameters (S_{11}) parameters of the aerial (reading 1 to 14).

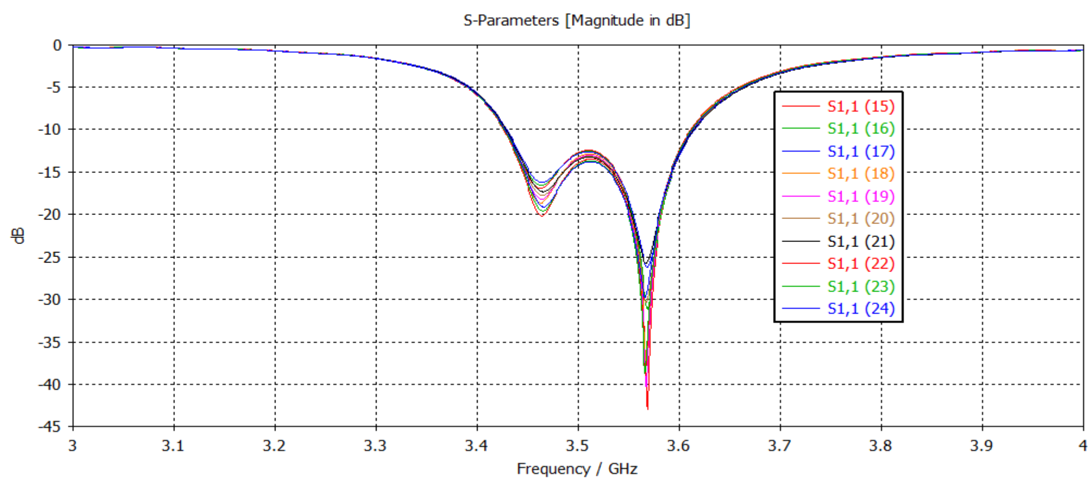

Figure 4: Scattering parameters (S_{11}) parameters of the aerial (reading serial no. 15 to 24).

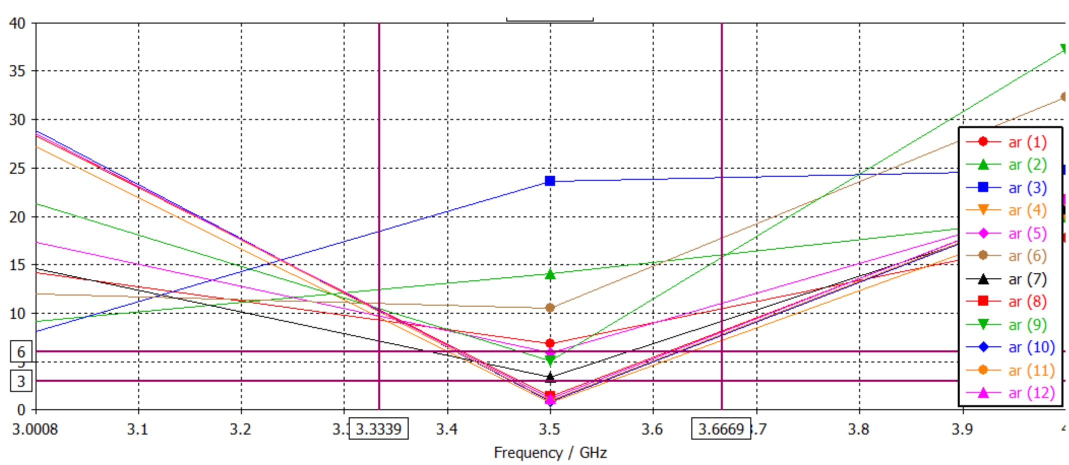

Figure 5: Axial ratio of the aerial (reading serial no. 1 to 12).

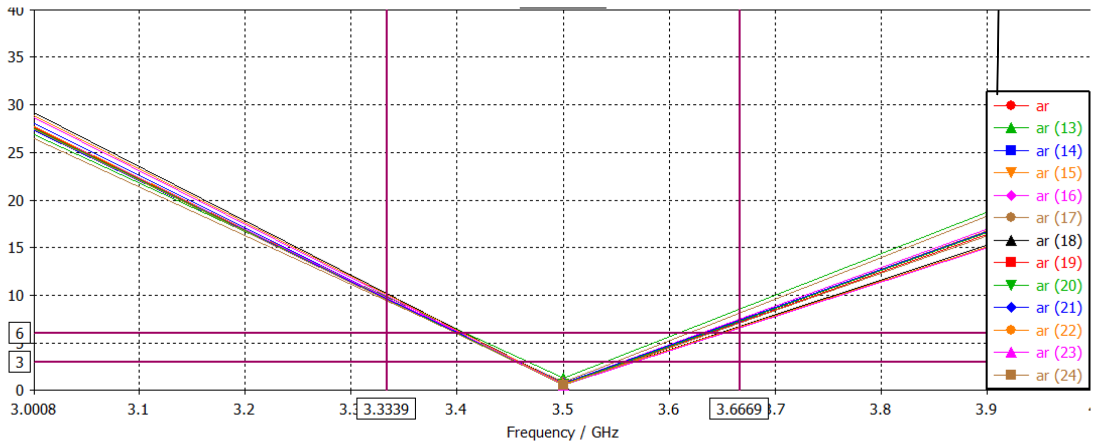

Figure 6: Axial ratio of the aerial (reading serial no. 13 to 24).

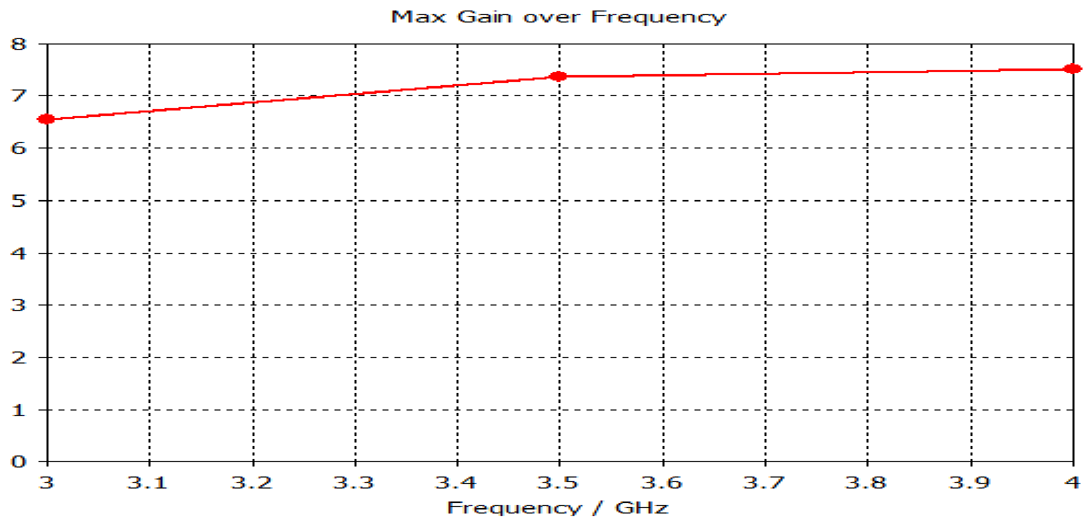

Figure 7: Max. gain v/s frequency.

Figures 3 and 4 show the two lower peaks (s_{11}) below -10 dB of 5G mobile communication for uplink and downlink frequencies for different dimensions like length and width of substrate (ground) plane shown in Table 2.

Figures 5 and 6 show the axial ratio (AR) for different dimensions like length and width of ground or substrate with different feeding location at antenna diagonal. Lot of dimension satisfied the condition of below 3dB and below 6dB for circular polarization at 5G mobile applications in table 2. Figure 7 shows graph between max gain over frequency.

Here some best results are shown in table no. 3 they come from table no. 2 and also figure 3, 4, 5 and 6.

Table 3: Some best results.

Results Parameters	Table No. 2	Remarks
Max peak of s_{11}	Serial no. 11	Best impedance matching
Max bandwidth	Serial no. 10, 11	Highest data transfer rate
Min axial ratio	Serial no. 22	Good circular polarized wave

3. Conclusions

This aerial is simple in construction (rectangular shaped) with efficient coaxial feeding. Major advantage of circular polarized antenna is user free from call drop due to receiver antenna receives strong signal strength from free space. The gain of CP aerial is more than 7 dBi and it has below 6 dB axial ratio in full range of 5G mobile communication so, it is sufficient for long distance communication for mobile networks.

Authors' contributions

The author read and approved the final manuscript.

Conflicts of interest

The author declares no conflict of interest.

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Data availability

No new data were created.

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