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A Circularly Polarized Ka-Band Antenna for Continuous Link Reception from GSAT-14

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Abstract

Objective: Design of circular ring patch antenna in Ka-band is described and simulated for receiving the dual polarised beacon continuously from GSAT - 14. **Method:** Circular ring's intrinsic geometry selected in this work leads to circular polarization and high radiation efficiency so making it suitable for implementing on array and as well as for practical application where low losses are salient features. **Findings:** The proposed antenna has shown reliable performance which is measured in terms of Half Power Beam width (HPBW), Side Lobe Level (SLL), cross polarization, gain bandwidth and AR bandwidth at resonant frequency of 20.2 GHz. A truncation in the circle of the circular patch is made in order to meet these performance characteristics of the antenna. **Applications/Improvements:** The proposed antenna exhibits circular polarisation for any polarised incident wave which is desired in most of the communication applications. Results depict that this antennas can be useful in receiving the GSAT-14 beacon.

Keywords: Circular Ring Patch Antenna, Ka-Band, GSAT – 14, Polarised Wave.

1. Introduction

Communication technology, now-a-days is the most fruitful technology behind which the whole world is running after. In the evolution of communication systems from men being used as messengers to an electromagnetic signal for communicating the message, satellite communication is one such area which changed the face of communication sector. Depending on the need for speed of communication, various bands of frequencies being deployed for transferring signals all among the world like L, X, C, Ku, K and Ka bands[1]. The present day in-use frequency band is Ku-band which will be soon shifted to Ka band. The rate of data transmission required in the current applications is very high than to that of which is in regular use. Higher throughput and susceptibility to rain fade are the additional factors that make Ka band superior to other bands[2].

A circular polarized antenna will have the electric field E rotation in either clockwise (Right-Hand-Circular (RHC)) or counter clockwise Left-Hand-Circular (LHC)[3] during one excursion of a wavelength. Such a time-harmonic wave is called to be a circularly polarized wave[4,5]. This circularly polarised wave is expected to have two orthogonal linear components with same magnitude and a time-phase difference of odd multiples of 90^0 [6].

2. Methodology

Initially the design requires two substrates and an air gap stacked one upon other with air gap between two substrates as shown in Figure 1. The substrates we used is Rogers RT5880 (lossy)[7] with a relative permittivity value of 2.2. The proposed antenna operates at a centre frequency of 20.2GHz and accordingly the patch diameters are designed with bottom patch diameter bigger than top patch to support the polarization as desired.

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Firstly the bottom substrate is placed with length and width dependant on ground plane dimensions which in turn are based on the patch diameter as given by the formula in Equation.(1)

$$Ground_{lw} = 2.25 * if\left(patch_{dia_{bottom}} > patch_{dia_{top}},\quad patch_{dia_{bottom}}, patch_{dia_{top}}\right) \quad (1)$$

With metal thickness of $0.001 * wavelength_{center}$, which can be measured from frequency_center, the bottom substrate with height of 0.787mm which meets the result accuracy, bottom circular patch with diameter of 9.0400510mm and a cut out diameter of 2.02088mm in the centre of circular patch are used to make a ring type patch[8].

Second air gap is created with earlier substrate length and width, but having a different height of 0.474mm which is further layered by a top circular patch of slight different diameter of 9.120730mm and a cut out diameter of 3.46705mm. Finally a coaxial feed is given at the ground plane with length of $0.03 * wavelength_{center}$[9] and the feed pin is made to contact with bottom patch as shown in Figure 1 and Figure 2 gives an impression of the multilayered patch which is discussed.

The design parameters considered for developing the antenna element in the CST software are listed in Table 1.

The feed for element is placed at custom radius in order to meet the desired response of the proposed antenna and is further formed as an array antenna where each element is simultaneously fed. For designing the proposed model as shown in Figure 3 and Figure 4, to resonate near the centre frequency of 20.2GHz, a small cut is placed in the ring element which has also improved other parameters like return loss and gain.

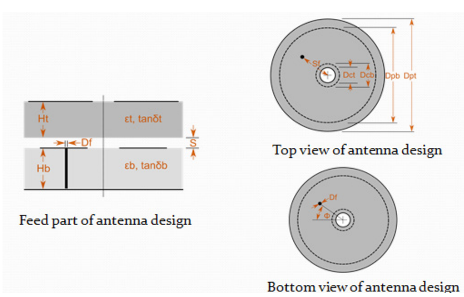

Figure 1. Basic patch element design.

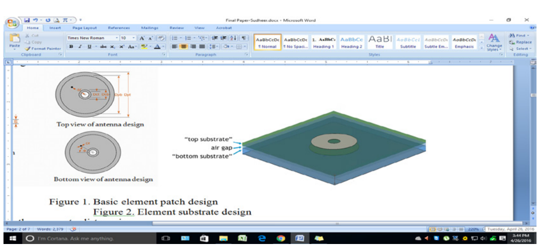

Figure 2. Element substrate design.

Table 1. Design parameter and their description

Name	Value	Description
C0	C light □1E-06	Speed of light (Corrected for the model units used in simulation)
Wavelength centre	C0/frequency centre	
Coaxial length	0.03□wavelength centre	
Frequency centre Maximum Minimum	20.2 1.15□frequency centre 0.85□frequency centre	centre frequency
Ground*lw*	Calculated from Eq.(1)	Ground plane dimensions
Metal thickness	0.01□wavelength centre	
Num ff monitors	7	
Patch diameter bottom bottom_2 top top_2	9.04005108489112 patch_diameter_bottom 9.12073039044476 patch_diameter_top	Bottom patch diameter Top patch diameter
Relative permittivity bottom top	2.2 1.1	Relative permittivity of bottom substrate Relative permittivity of top substrate
Spacing substrates	0.574827179216437	Spacing between substrates (air gap)
Substrate height Bottom Top	0.787 0.787	Height of bottom substrate Height of top substrate
Tan delta Bottom Top	0 0	Loss tangent of bottom substrate medium Loss tangent of top substrate medium
Velocity factor Bottom Top	1/sqrt(relative permittivity bottom) 1/sqrt(relative permittivity top)	

Later a small notch is made on patch and an array of four such elements is constructed to check for variation in gain and radiation efficiency as shown in Figure 5.

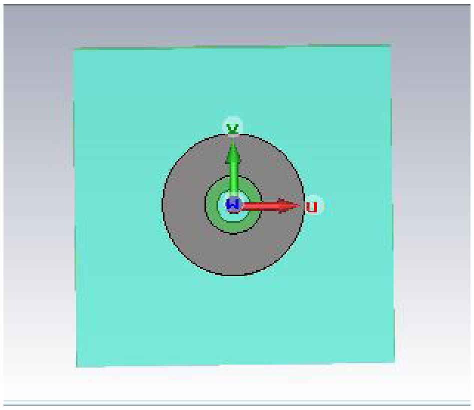

Figure 3. Top view of proposed antenna.

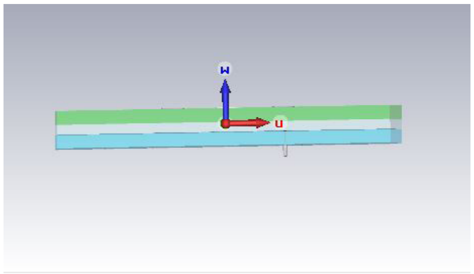

Figure 4. Side view of proposed antenna.

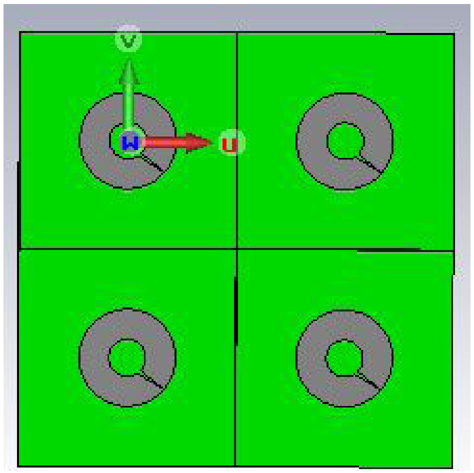

Figure 5. Array of proposed antenna.

3. Results

The antenna parameters as obtained from the simulation results are presented in this section.

3.1 Return Loss (SNN):

According to the design specifications, the return loss to be maintained at an input port N is represented by S_{NN} and in the proposed model it is desired to be −12dB or less, at each and every element port in the configuration as array. The results meet the expected value more satisfyingly where the return loss at four elements is represented by S_{11}, S_{22}, S_{33} and S_{44} respectively. These results are shown in Figure 6, Figure 7, Figure 8 and Figure 9.

At the element 1, it is observed that the return loss is as −14.67 dB at required frequency 20.2GHz and met the desired specification as shown from Figure 6. The

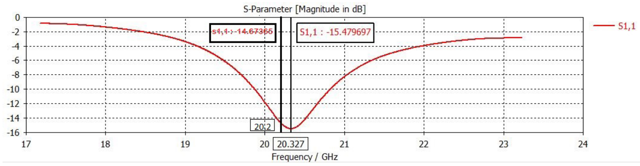

Figure 6. Return loss at element 1.

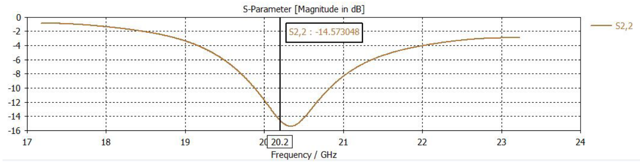

Figure 7. Return loss at element 2.

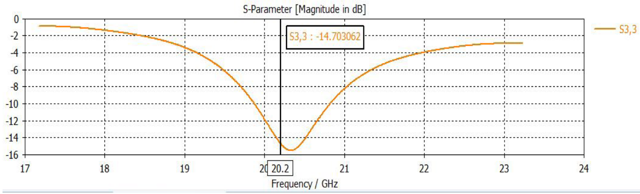

Figure 8. Return loss at element 3.

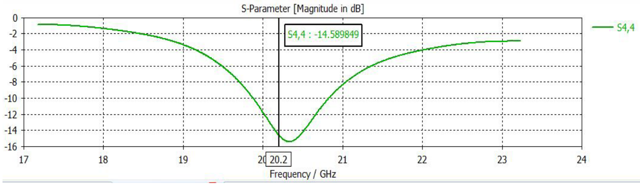

Figure 9. Return loss at element 4.

actual resonating frequency of the element is observed to be 20.327GHz which is +0.127GHz upon the designed frequency. Since the resonating frequency is within the limit, the results are considered to meet the design specifications.

In the case of element 2, the return loss observed at 20.2GHz is –14.57 dB as shown from Figure 7, which also meets the desired specification. Similarly, from Figure 8 and Figure 9, the return loss observed is –14.70 dB and –14.588 dB respectively at the same frequency.

3.2 Voltage Standing Wave Ratio (VSWR):

For a good design of an antenna to work in a real time, the VSWR maintained must be less than 2 in the frequency of operation[6] which is 20.2GHz for the proposed design. It is observed from the Figure 10, that the VSWR of the proposed antenna has the value of 1.45dB approx., which is considered to be good (VSWR < 2) in terms of commercial applications for any antenna to work in an environment.

3.3 Radiation Efficiency(η):

The preferred direct method to measure real antenna performance[10] which shows total amount of radiated power in a particular direction is given by radiation efficiency and this must be 100% so that total amount of power is radiated in an ideal case. The measurement of this radiated power is plotted as radiation pattern as shown in Figure 11. It shows the radiation efficiency of 1.000 at 20.2GHz indicating the greater efficiency of proposed antenna.

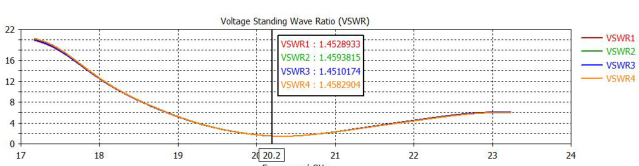

Figure 10. VSWR at the designed frequency 20.2GHz.

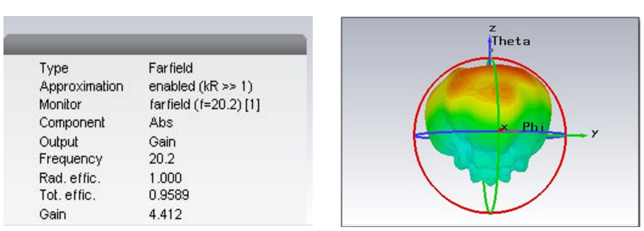

Figure 11. Radiation pattern and the various values observed for the proposed antenna.

3.4 Directivity (D):

To perform analysis of any antenna Directivity is one of the important aspects to be considered which shows the maximum radiated power density of peak lobe in radiation pattern. It is measured in dB or dBi. From observation of Figure 12, main lobe has a directivity of 4.412 which is sufficient for the designed antenna performance.

3.5 Gain(G) vs Frequency:

For an antenna to work in the communication applications, the main desired parameter in the design is its Gain. Gain is directly proportional to square of frequency[8] due to which two different antennas with equal gain may vary in their size depending on the frequency of operation[7,11]. Here the gain of our antenna at 20.2GHz is observed as 9.999 from the Figure 13.

3.6 Polarization:

For a non-circular polarised incident wave, according to the design of proposed antenna, circular polarization over the top layer is the expected result and it is as shown in Figure 14 and Figure 15.

A linear or plane wave is sent through the port at ground plane as it passes through the first layer of substrate and bottom patch polarizes the capacitive part or vertical part of signal and at air gap which is second layer causes polarization of inductive part or horizontal part of signal. Again at third layer that is the top substrate (top layer),

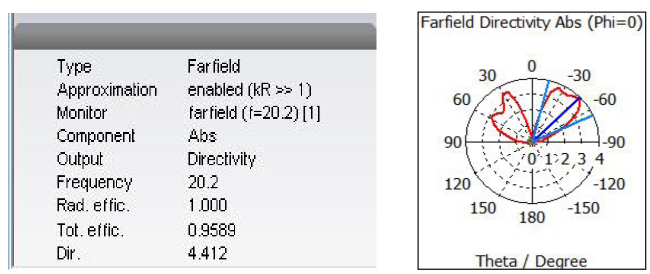

Figure 12. Polar plot of directivity.

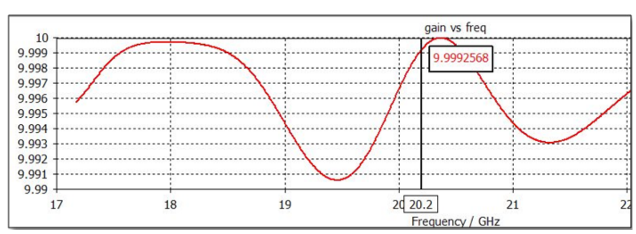

Figure 13. Gain vs frequency of the proposed antenna.

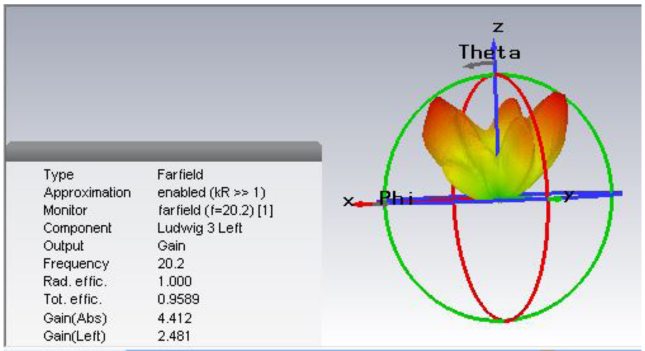

Figure 14. LHCP of the proposed antenna.

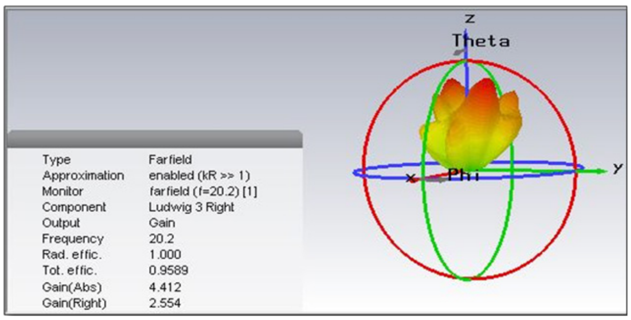

Figure 15. RHCP of the proposed antenna.

Table 2. Observed antenna parameters

Name	Symbol	Value(dB)
Return loss	S_{11}	–14.67
Voltage standing wave ratio	VSWR	1.4583
Radiation efficiency	η	1.000
Directivity	D	4.412

causes polarization of capacitive part, finally producing a circularly polarised output. Figure 14 shows left hand circular polarization of the proposed antenna with gain(left) of 2.481 dB and is obtained from the observation of far field radiation. Similarly Figure 15 represents the right hand circular polarization of the proposed antenna with gain(right) of 2.554 dB. The observed parameters of the proposed antenna are tabulated in Table 2.

4. Conclusion

An elliptical ring patch antenna with a notch is proposed and tested for various input feeds and the results are discussed in this work. The design has exhibited circular polarisation with centre frequency of 20.2GHz for any type of polarisation of the signal fed to the proposed antenna, which is very useful in the latest satellite communications. The GSAT-14 satellite which transmits the dual polarisation seasonally can be received upon this antenna without the necessity of employing dual polarised Low Noise Block converters (LNBs) because of its advantage of circular polarization. It is also observed that within the Ka band, as the patch radius increases the centre frequency decreases without the change in its performance. Thus the proposed antenna can be used over a good bandwidth which is required in communication applications. From the results it is observed that this antenna exhibits good return loss and an acceptable gain individually and even when it is used as an element in a planar array.

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