January - February 2020
ISSN: 0193 - 4120 Page No. 1572 - 1581

Wideband Reconfigurable Polarization and Beam Sweeping Antenna for Satellite Applications

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Abstract:
A wideband antenna with polarization reconfigurable and beam sweeping capability has been presented in this paper which is very useful for the Fixed and mobile satellite systems working at Ka frequency band. Proposed antenna is having a impedance bandwidth of 5.36GHz covering the frequencies of 26.22GHz to 31.58GHz. Polarisation reconfiguration is possible by having two feed points which are fed to the patch in orthogonal directions. A feed network system is designed so as to regulate the power transferred to the patch from the feed and by exciting the patch with the appropriate feed polarisation reconfiguration and beam sweeping can be achieved. Proposed antenna is having a maximum gain of 5dB which is almost flat for the entire operating frequency range. Axial ratio of the proposed antenna is 3dB for single port excitation which represent circular polarisation. Proposed antenna is having a compact size of 11.6mm×10mm and is having a good isolation of -10dB in between the two ports.
Keywords: *Wideband; Feed Network; Orthogonal feed; Reconfigurable Polarization; Beam Sweeping.*

I. INTRODUCTION

To meet the requirements of the modern communication systems like multi function and miniaturization we need to have wideband antennas by which we can integrate multiple applications into single systems. So we need to have diverse characteristic in antenna parameters in terms of polarization and radiation pattern to decrease the coupling and interference effects[1-2]. By using diverse polarization antennas we can reduce coupling in between the communication channels[3]. To reduce the effects of interference caused by the unwanted radiations the best way is to employ a antenna with diverse radiation patterns which will enhance the performance of the communication system by reducing the reception of the unwanted signals[4].

A number of methods were reported in recent times to design reconfigurable radiation pattern antennas, one of the conventional method is to use phased array antennas[5]. But the heavy feed networks and individual transceiver systems makes the system bulky and expensive. Reconfigurable radiation pattern can also be obtained by introducing active components into the antenna design by using which we can alter the directions of the currents and accordingly vary the radiation characteristics[6-7]. In remote sensing applications antennas with different polarizations will be useful to identify and classify different objects as most of the objects on earth have different reflection coefficients with respect to different polarizations[8]. Due to integration of many applications in a single system the effects of cross talk has also to be addressed and antennas with different polarization can be used to reduce the cross talk effect by taking the information of polarization of the received signals into account in signal processing stage[9].

January - February 2020
ISSN: 0193 - 4120 Page No. 1572 - 1581

Feeding techniques like aperture coupling, substrate integrated wave guides are been used to get circular polarization[10-20]. But both the techniques have its own set of disadvantages, In aperture coupling feeding the alignment between the radiating element and the feed slot has to be perfect other it will effect the radiation characteristics of the antenna. In substrate integrated wave guides a lot of vias has to be incorporated in the substrate which will increase the complexity of the fabrication process.

To address the needs of the modern multi functional communication system which require polarisation diversity and radiation pattern sweep within a single compact antenna we propose a wideband antenna with polarization reconfigurable and beam sweeping capability by using dual feed network which are placed orthogonal to the radiating patch. The feed network and the radiating element are to be designed and optimized carefully such that they will produce diverse polarizations and radiation patterns. The feed network comprises of impedance transformers which are helpful to regulate the power flow to the radiating patch. Here reconfigurable pattern and polarization are successfully implemented by making use of the feed network by exciting the antenna in two modes. In mode 1 only port of the antenna is excited and it will lead to circular polarization. In mode 2 both the antenna ports are excited and this will result in the linear polarization. In the same way in both the modes of operation the radiation pattern is also changing along with port excitation which will result in sweep of radiation pattern. The impedance values of the strip lines in the feed network are chosen such that wide impedance bandwidth is produced by the antenna.

In section II, the detailed design steps of the radiating element, the feed network impedance transformer used in the antenna and the schematic of the proposed antenna are presented. The final optimized dimensions of the proposed antenna are also presented in the section II.   In section III the performance analysis of the proposed antenna in terms of different antenna characteristics for the two different modes of operation are presented.

The significance of beam sweeping that At the point when, at the reference time t = 0, the vulnerability width achieves a basic esteem u0 = uth, the BS as of now connected with the MU clears the whole vulnerability interim U0 utilizing $\eta \geq 2$, $\eta \in N$ pillars, transmitted successively over η microslots, every one of length δS. Amid this interim, the vulnerability width increments after some time because of MU portability. With the end goal to adjust for it, the BS examines more extensive locales over progressive microslots, as nitty gritty underneath. Hence, we let ωi be the beamwidth of the ith bar, where I = 1, 2, η.

The significance of polarization reconfiguration is that Polarization reconfigurable reception apparatuses are equipped for exchanging between various polarization modes. The ability of exchanging between level, vertical and round polarizations can be utilized to lessen polarization confuse misfortunes in versatile gadgets. Polarization reconfigurability can be given by changing the harmony between the distinctive methods of a multimode structure.

II. ANTENNA DESIGN AND CONFIGURATION

The geometry of the proposed wideband patch antenna is shown in the Fig. 1. The antenna consists of circular radiating element to which two feed elements are connected which are orthogonal to each other. The feed network consists of impedance transformer which is used to regulate the power flow from input port to the radiating element. The feed network consists of a 50Ω impedance line in the input followed by a 100Ω line which is joined to a 50Ω line via a balun. The 50Ω line is followed by a pair of 100Ω and 50Ω lines. The complete structure can be observed form the Figure 1. The input impedances of the transformer lines and their lengths are optimized such that the antenna will have wideband characteristics.

TEST Engineering & Management
January - February 2020
ISSN: 0193 - 4120 Page No. 1572 - 1581

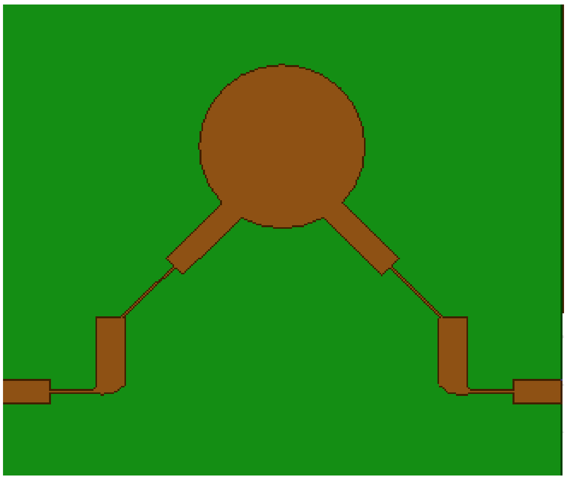


Fig. 1 Proposed antenna

The feed point selection between the radiating patch and the feed element also plays a crucial role in impedance characteristics of the antenna. Proposed antenna is designed on a Rogers RO 4350 substrate which is having a dielectric constant of 3.6 and a thickness of 1.524mm. The overall dimension of the antenna is 11.6mm×10mm. Figure 2 below shows the schematic of the patch of the proposed antenna. Table 1 below gives the final optimized values of the proposed antenna.

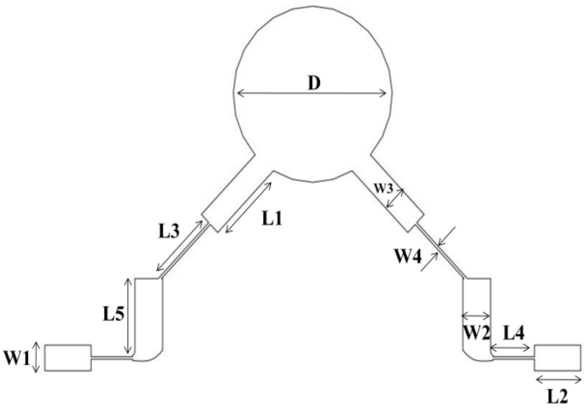


Fig. 2 Geometry of the patch

TABLE 1

OPTIMIZED DIMENSIONS OF THE ANTENNA (Unit:mm)

Parameter	**Value**
D	3.44
L1	1.81
L2	1
L3	1.72
L4	0.9
L5	1.525
W1	0.5
W2	0.6
W3	0.5
W4	0.05

The design considerations for the feed network is given below.

For planning a variety of microstrip fix radio wires you can pursue these means.

1. As a matter of first importance plan a solitary fix component reverberating in the required recurrence band of intrigue.
2. At that point pick the feed type, either corporate feed or power divider/splitters can be utilized. (Do the writing concentrates to get the thought regarding the system feed types and mictostrip radio wire clusters).
3. At that point you can structure 2-fix radio wire cluster with the dispersing of 1/2 wavelength utilizing the proper bolstering strategy.
4. Later you can recreate and see the outcomes for 4-way or 8-fix cluster as needs be.

The dimension of the circular radiating element has been calculated using the formulas below.

$$a=F\{1+\frac{2h}{\pi F\varepsilon_r}[\ln(\frac{\pi F}{2h})+1.7726]\}^{-1/2} \qquad (1)$$

Where

$$F=\frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}} \qquad (2)$$

$$a_e = a\{1+\frac{2h}{\pi a\varepsilon_r}[\ln(\frac{\pi a}{2h})+1.7726]\}^{1/2} \qquad (3)$$

III. RESULTS AND ANALYSIS

To analyze the performance of the proposed antenna 3D model simulator Ansys HFSS software has been used. The antenna characteristics are been analyzed for two different modes of operations. Mode 1 presents antenna characteristics with single port excitation and mode 2 presents the antenna characteristics with dual port excitation. By varying the port excitations the proposed antenna can be used for linear polarization and circular polarizations. Along with polarizations we can also observed the sweep in the radiation patterns with the change in port excitations.

Figure 3,4 and 5 below shows the impedance characteristics of the proposed antenna. Figure 3 shows the reflection coefficient plot where we can observe a impedance band width of 5.36GHz covering the frequencies of 26.22GHz to 31.58GHz.

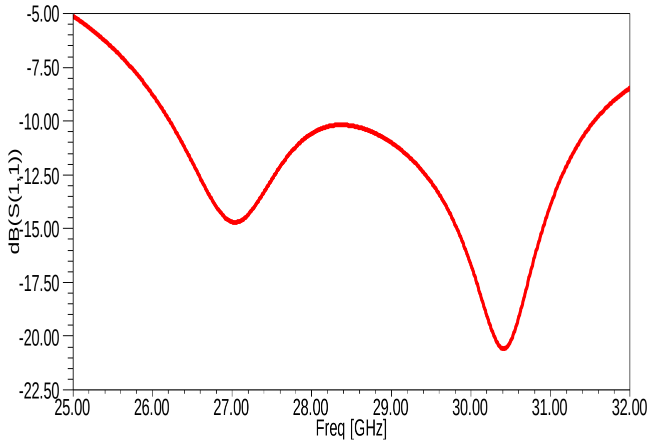


Fig. 3 Simulated reflection coefficient plot of proposed antenna

Figure 4 shows the VSWR plot of the antenna where we can observe a VSWR value of less than 2 covering the entire operating bandwidth of 26.22GHz to 31.58GHz.

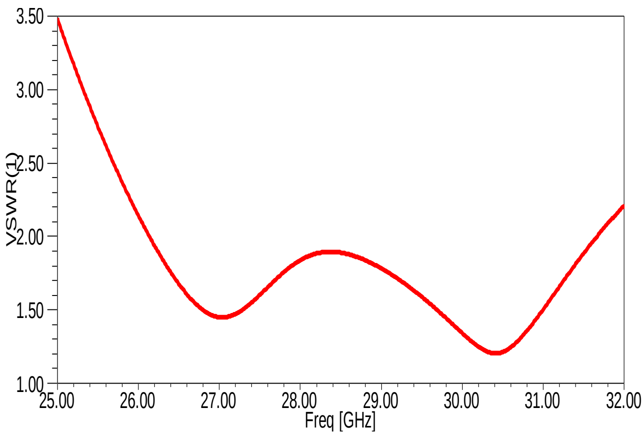


Fig. 4 Simulated VSWR plot of proposed antenna

Figure 5 shows the isolation plot of the proposed antenna where we can observe a minimum isolation value of -10dB and maximum isolation value of -17.5dB between the ports

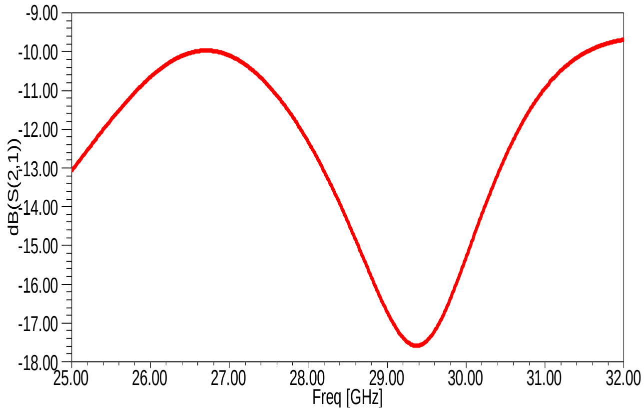
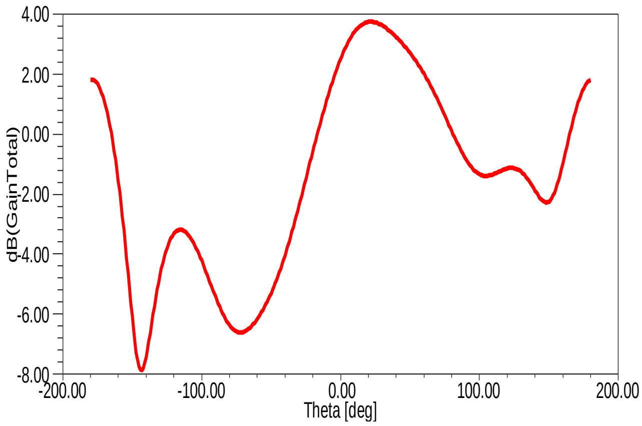


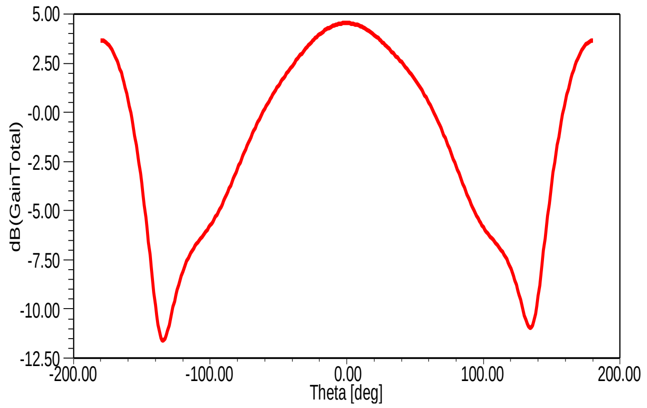
Fig. 5 Simulated port isolation plot of proposed antenna

Impedance characteristics of the antenna are not effected with the number of port of excitation only the radiation characteristics of the antenna are been effected with the different modes of operation with different port excitations. Figure 6 below shows the gain plots of the proposed antenna at a intermediate frequencies of 27.03GHz for both the modes of operation. Observed a gain of 3.8dB for mode 1 of operation and a gain of 4.8dB for mode 2 of operation.



(a) Single port excitation

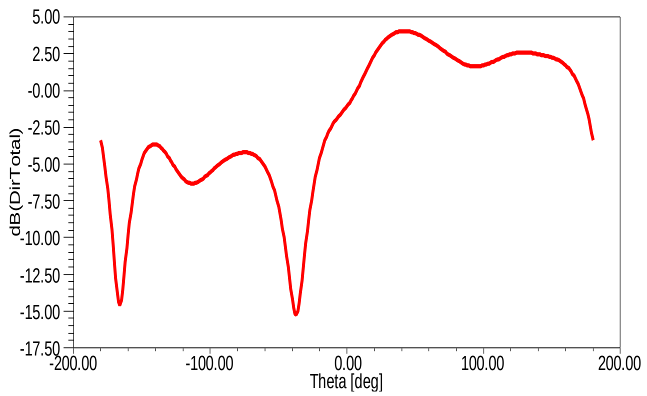
January - February 2020
ISSN: 0193 - 4120 Page No. 1572 - 1581



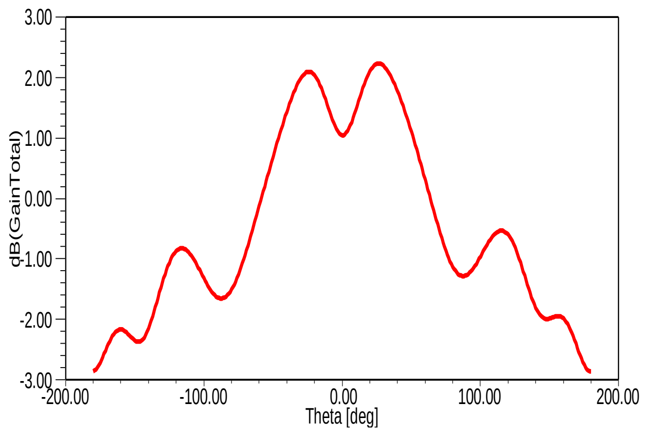
(b) Dual port excitation

Fig. 6 Simulated Gain plot of proposed antenna at 27.03GHz

Figure 7 below shows the gain plots of the proposed antenna at a intermediate frequencies of 30.43GHz for both the modes of operation. Observed a gain of 4dB for mode 1 of operation and a gain of 2.2dB for mode 2 of operation.



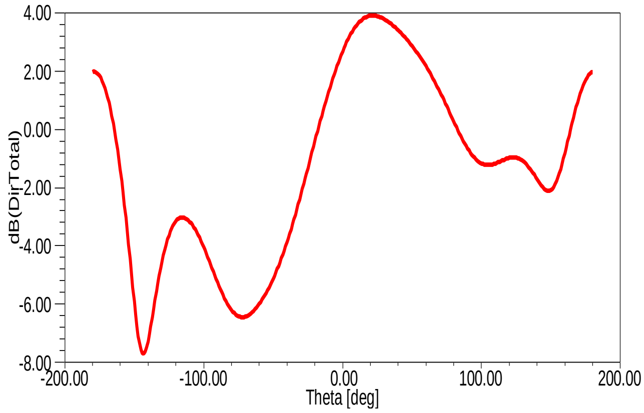
(a) Single port excitation



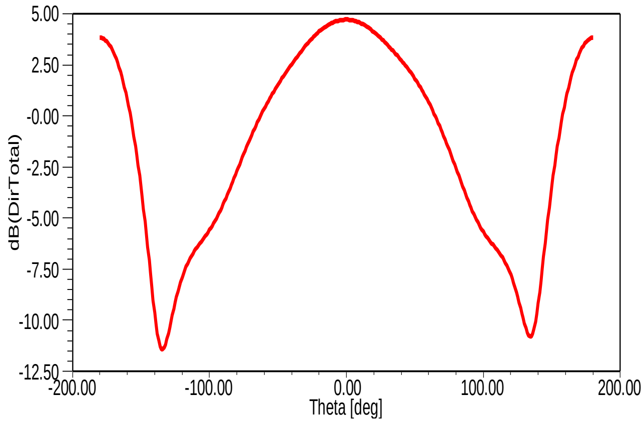
(b) Dual port excitation

Fig. 7 Simulated Gain plot of proposed antenna at 30.43 GHz

Figure 8 below shows the directivity plots of the proposed antenna at a intermediate frequencies of 27.03GHz for both the modes of operation.



(a) Single port excitation



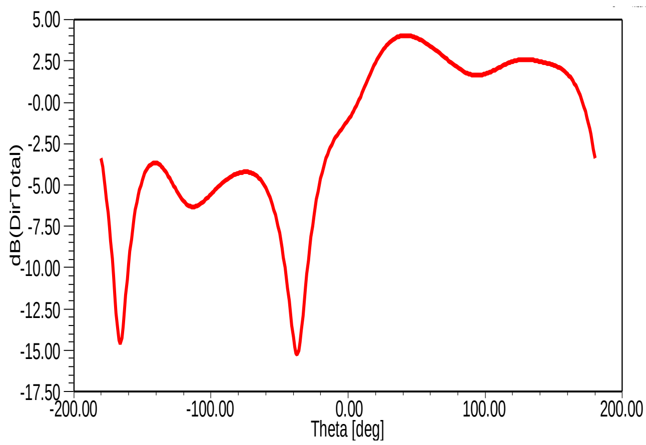
(b) Dual port excitation

Fig. 8 Simulated Directivity plot of proposed antenna at 27.03GHz

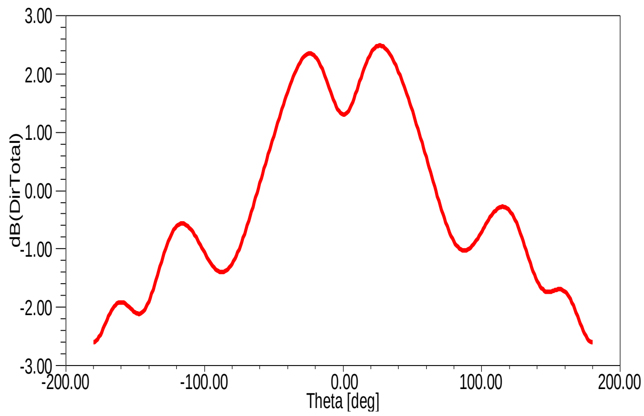
Observed a directivity of 4dB for mode 1 of operation and a directivity of 4.9dB for mode 2 of operation from Fig. 8.

Figure 9 below shows the directivity plots of the proposed antenna at a intermediate frequencies of 30.43GHz for both the modes of operation. Observed a directivity of 4dB for mode 1 of operation and a directivity of 2.5dB for mode 2 of operation.

January - February 2020
ISSN: 0193 - 4120 Page No. 1572 - 1581



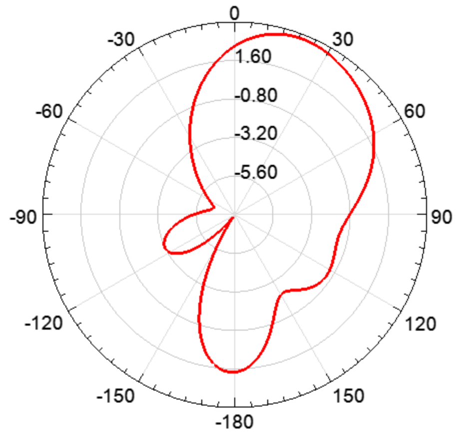
(a) Single port excitation



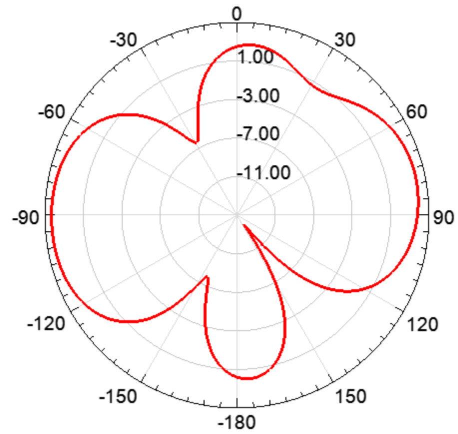
(b) Dual port excitation

Fig. 9 Simulated Directivity plot of proposed antenna at 30.43GHz

Figure 10 below depicts the radiation pattern plots of the proposed antenna at a intermediate frequencies of 27.03GHz for both the modes of operation. Here we can clearly observe the sweep in the radiation pattern coverage area for both the modes in both the elevation plane and azimuthal planes with the change in the number of ports of excitation to the proposed antenna.

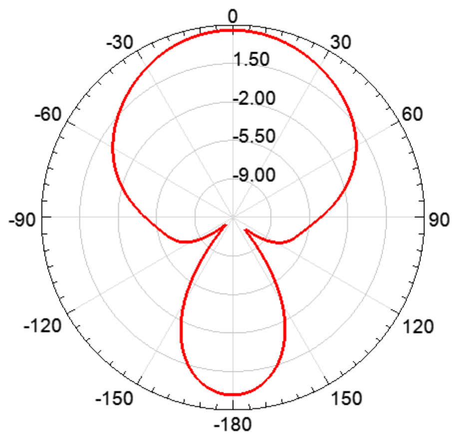


E-Plane



H-Plane

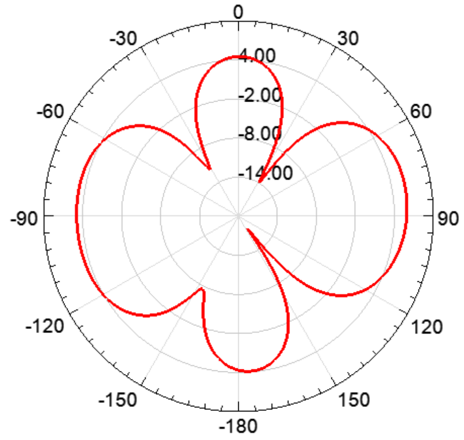
(a) Single port excitation



E-Plane

TEST Engineering & Management

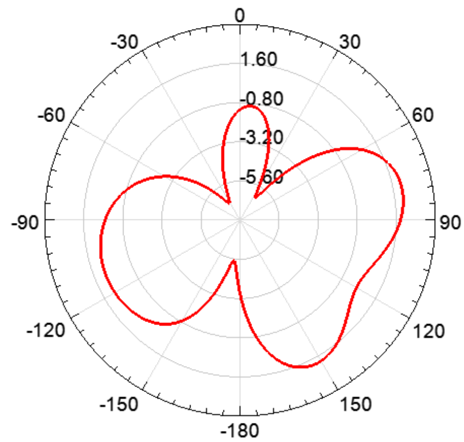
January - February 2020
ISSN: 0193 - 4120 Page No. 1572 - 1581



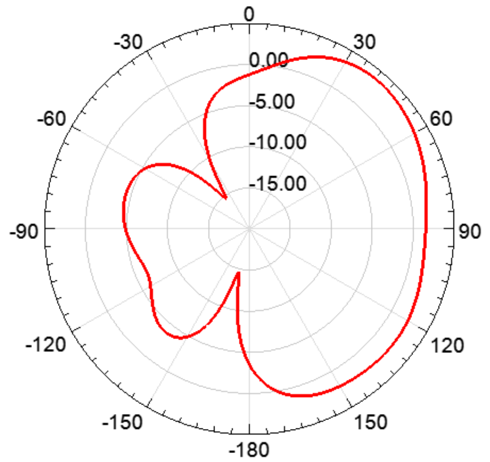
H-Plane

(b) Dual port excitation

Fig. 10 E-plane and H-plane pattern of proposed antenna at 27.03GHz

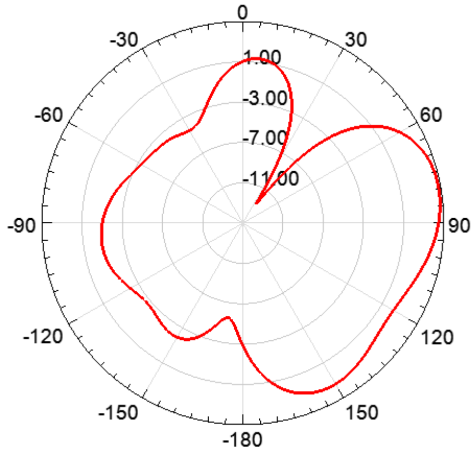


E-Plane

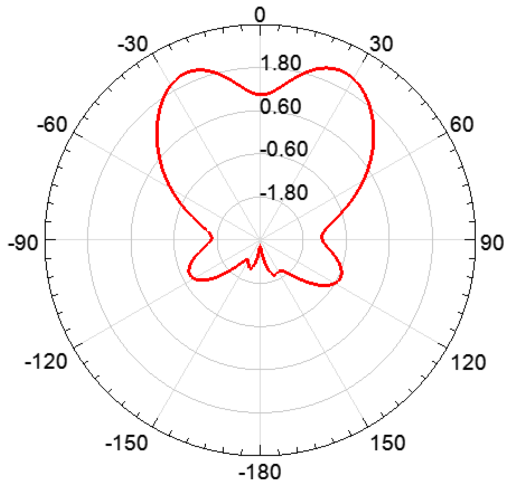


H-Plane

(a) Single port excitation



E-Plane



H-Plane

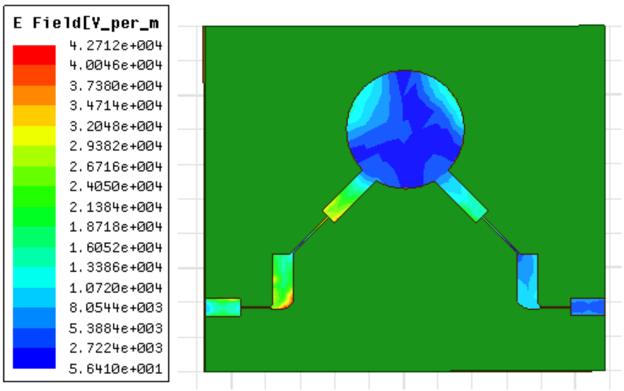
(b) Dual port excitation

Fig. 11 E-plane and H-plane pattern of proposed antenna at 30.43GHz

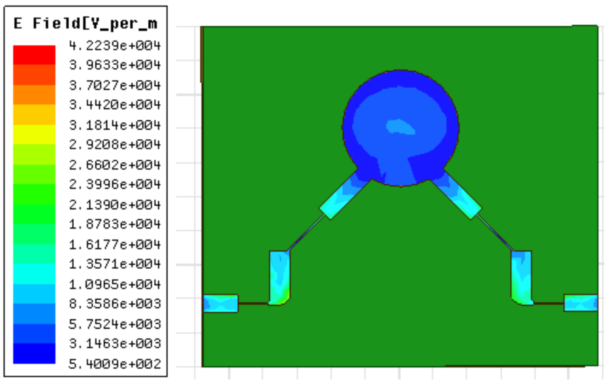
Figure 11 below shows the radiation pattern plots of the proposed antenna at a intermediate frequencies of 30.43GHz for both the modes of operation. Here we can clearly observe the sweep in the radiation pattern coverage area for both the modes in both the elevation plane and azimuthal planes.

Figure 12 below depicts the current flow direction plots of the proposed antenna at a intermediate frequencies of 27.03GHz for both the modes of operation.

January - February 2020
ISSN: 0193 - 4120 Page No. 1572 - 1581



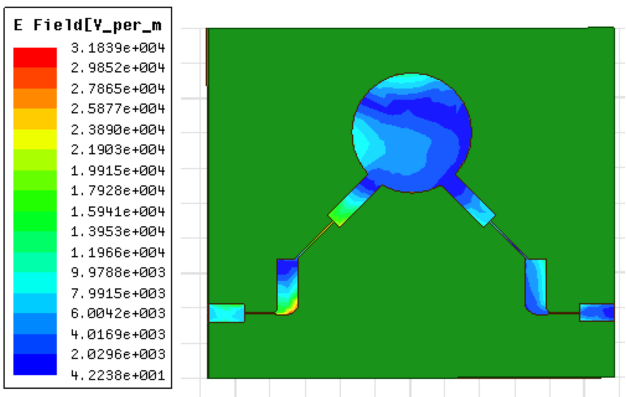
(a) Single port excitation



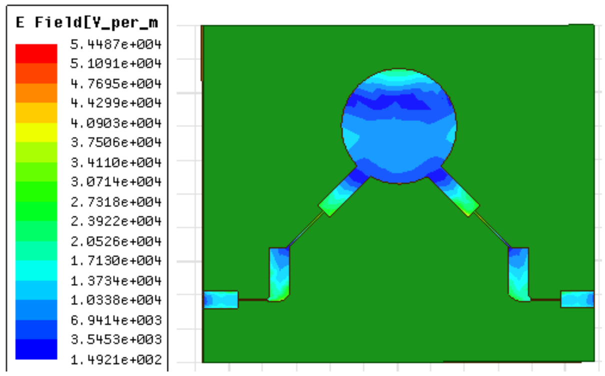
(b) Dual port excitation

Fig. 12 Current Distributions in Proposed antenna at 27.03GHz

Figure 13 below depicts the distribution of currents in the proposed antenna at a intermediate frequencies of 30.43GHz for both the modes of operation.



(a) Single port excitation

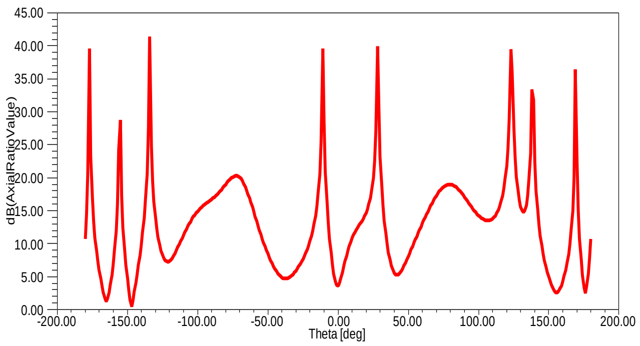


(b) Dual port excitation

Fig. 13 Current Distributions in Proposed antenna at 30.43GHz

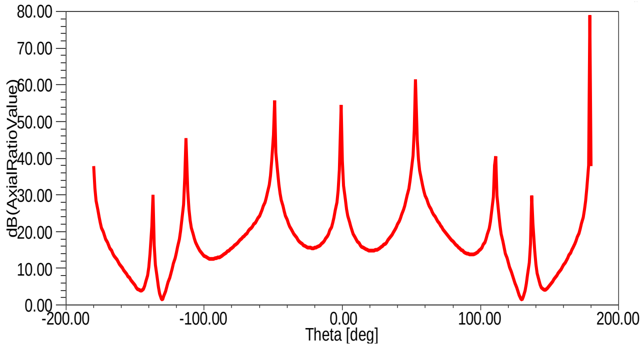
From figures 12, 13 we can observe that the current direction in the antenna for single port excitation is circulating with in the patch which resembles the circular polarization and for the dualport excitation the currents are flowing in a single direction which resembles linear polarization.

To determine the polarization we have taken Axial ratio plots for two different intermediate frequencies in the operational bandwidth for both the modes of operation. It is observed that the proposed antenna when excited with only one port is having a axial ratio value of 3dB at both the frequencies which indicated that the proposed antenna is producing waves with circular polarization.



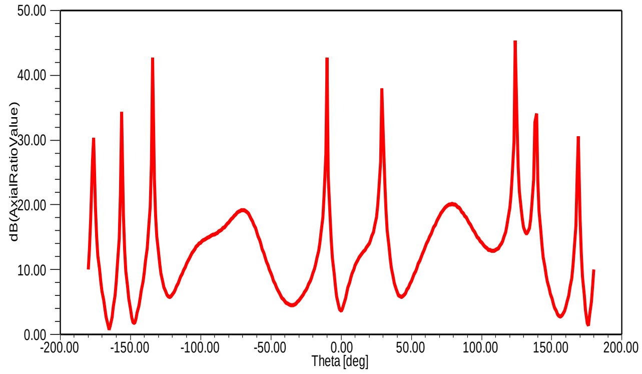
(a) Single port excitation

January - February 2020
ISSN: 0193 - 4120 Page No. 1572 - 1581

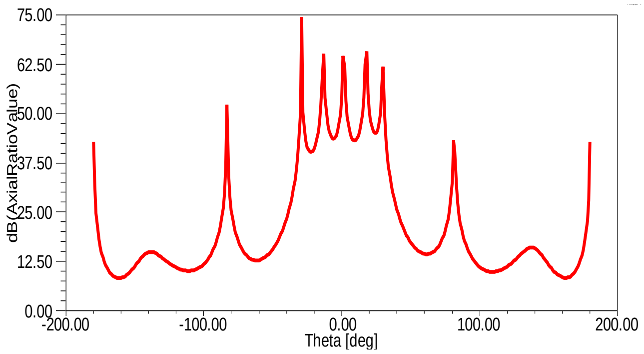


(b) Dual port excitation

Fig. 14 Axial Ratio Plot of proposed antenna at 27.03GHz



(a) Single port excitation



(b) Dual port excitation

Fig. 15 Axial Ratio Plot of proposed antenna at 30.43GHz

When the proposed antenna is excited with two ports it is having a axial ratio value of more than 55dB at both the frequencies which indicated that the proposed antenna is producing waves with linear polarization which is shown in the above figures 14, 15.

IV. CONCLUSION

A wideband antenna with polarization reconfigurable and beam sweeping capability has been presented in this paper. Proposed antenna is having a impedance bandwidth of 5.36GHz covering the frequencies of 26.22GHz to 31.58GHz. Simple Techniques to produce Polarisation reconfiguration and beam sweeping are successfully demonstrated. Proposed antenna is having a maximum gain of 5dB and a axial ratio of 3dB for single port excitation which represent circular polarisation. Proposed antenna is having a compact size of 11.6mm×10mm and is having a good isolation of -10dB in between the two ports. Proposed antenna is a best candidate for the Fixed and mobile satellite systems working at Ka frequency band.

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January - February 2020
ISSN: 0193 - 4120 Page No. 1572 - 1581

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