A Four Slot Dual Feed and Dual Band Reconfigurable Antenna for Fixed Satellite Service Applications

Original Scientific Paper

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Abstract *– A dual feed and dual-band reconfigurable antenna is designed, analyzed, and prototyped in this work for fixed satellite service communication applications. The designed model occupies the compact dimension of 24X21X1.2 mm on FR4 substrate and provides an input impedance of 50 ohms at both ports. The proposed model offers additional circular polarization characteristics at both the resonating bands. The PIN diode-based switching conditions, and the frequency reconfigurability analysis in both simulation and measurement are almost match. The combination of dual-band resonance, frequency reconfigurable nature, and compact dimension makes this model an attractive candidate in the specified field with considerable gain (8.5 dB) and efficiency (80%).*

Keywords*: Circular polarization, Dual Band, Dual feed, Reconfigurability, Satellite application*

1. INTRODUCTION

Recently, several advancements have happened in antennas due to their various applications. Emerging technologies came into existence in wireless communication, and the demand for antennas has increased tremendously. An antenna is the central part of any wireless communication application. The advanced antenna design is very much needed these days for their extensive use in all modern gadgets and devices[1-2]. Several antennas are available in the literature for various applications like Bluetooth, LTE, Wi-Fi, wireless LAN and 5G communication [3-8].

One reconfigurable antenna is equivalent to some antennas; the reconfiguration is based on frequency, polarisation, and pattern of the antenna without regard to physical size. For reconfugaration, varactor diodes, field effect transistors, and PIN diodes are commonly used [9]. PIN diodes are symmetrically positioned to retain the antenna's electrical properties [10]. The dual-band antenna is conceivable depending on the feed position and inset size. Different band reconfiguration and modes of operation can achieved by ON and OFF of the PIN diodes [11]

There are several methods to design the antenna using various feeding techniques. The coaxial probe method is traditional, whereas the microstrip line feed method is another alternative and easy feeding method. The coplanar waveguide fed method is another alternative to design the antennas simply with good impedance matching [12-15]. Antenna with circular polarization has advantages over linear polarization. The researchers made several designs to attain circular polarization in the antenna with different feeding techniques and with the combination of meandered slots [16-18]. The researchers extensively use other methods like metamaterials, electromagnetic bandgap structures, frequency-selective surfaces, and artificial magnetic conductors while designing modern communication-based antennas [19-23].

This work is concentrated on the design of a circularly polarised antenna with a dual feeding technique. The Antenna consists of 4 slots in the radiating structure, fed with coaxial probe feeding. The design considerations and the dimensional characterization is provided in the antenna design section.

2. ANTENNA DESIGN:

The designed slot antenna is prototyped on an FR4 substrate with dual feeding. The coaxial feeding has been used here due to its straightforward approach and ease of exciting the patch antenna. Coaxial feeding done by conecting the condcting wire that terminates at the patch. It has been implemented with the center conductor in the coaxial launcher attached to the ground plane at the bottom side. Based on the feed location, the input impedance varies in the probe feeding, and here, the feed location away from the edge of the patch will affect lower input resistance. To obtain good matching with 50-ohm impedance, the condition should be 0.13 λg. Fig. 1 shows the antenna topside as well as the bottom side structure. Table 1 represents the parameter data of antenna design.

Table 1. Antenna design Parameters data

S. No	Parameter	Value
1	Length of patch (Lp)	8.2 mm
2	Width of the patch (Wp)	8.2 mm
3	L1	2 mm
4	Slot cut S1	2mm, 3mm, 4mm, 5mm
5	Length of slot	7.6424
6	Width of slot	0.155 mm
7	Coaxial length	0.425 mm
8	Coaxial width	0.3267 mm
9	Inset_1	3.94 mm
10	Inset_2	3.94 mm

Two separate probes are required to attain dual polarization with dual feeding, and each probe is responsible for corresponding polarization. The narrow bandwidth that is obtained with dual feeding is due to the high cross-polarization Because of the probe radiation and probe inductance.

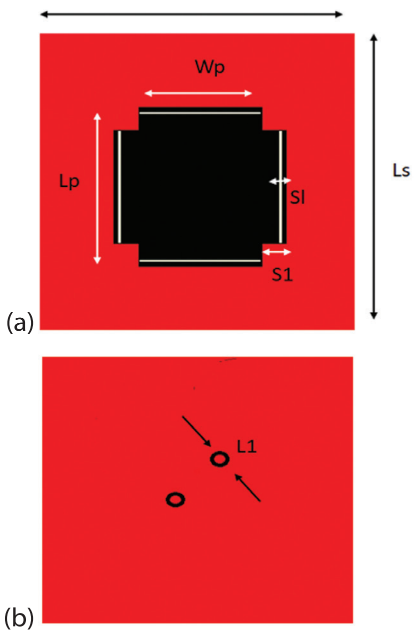


Fig 1. Dual Fed Slot Antenna, (a) Top View, (b) Bottom View

3. RESULTS AND DISCUSSION:

3.1. DUAL FEED SLOT ANTENNA:

Fig. 2 shows S-parameters and VSWR plots for the dual-feed antenna model. Antenna resonating at the dual-band of 9.4 GHz and 13.3 GHz, respectively.

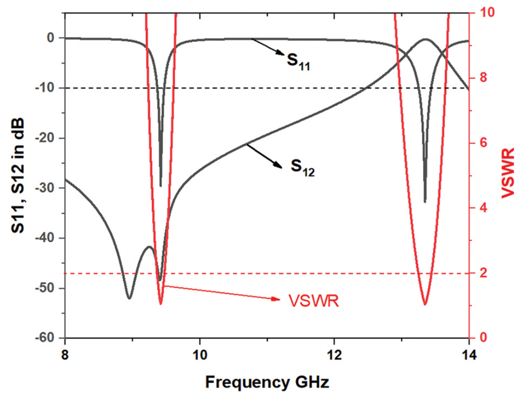


Fig 2. S-Parameters and VSWR Vs Frequency

Antenna showing dual band characteristics with reflection coefficient less than -10 dB and VSWR of 2:1 ratio. The transmission coefficient result indicates a value less than-25 dB at the first resonant band -10 dB at the second resonant band.

The parametric analysis has been done for the slotted monopole antenna and presented the results in Fig. 3. It has been observed that for S1 of 2 mm and L1 of 2 mm, the antenna shows dual band characteristics with good impedance matching.

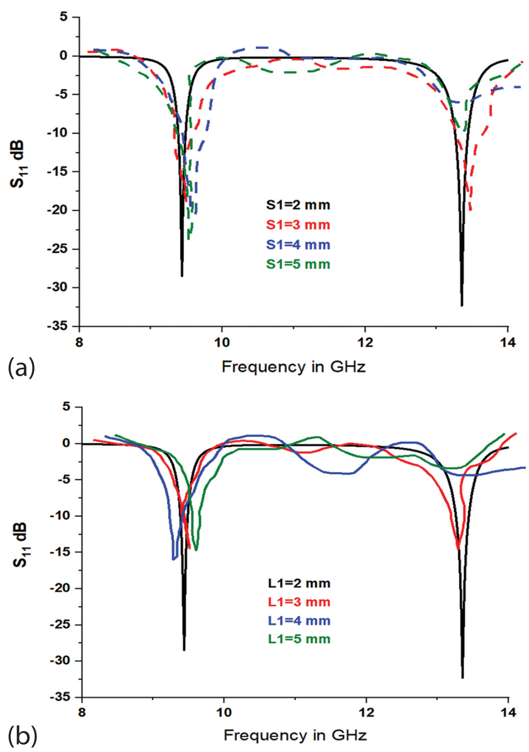


Fig 3. Parametric Analysis, (a) Change in S1, (b) Change in L1

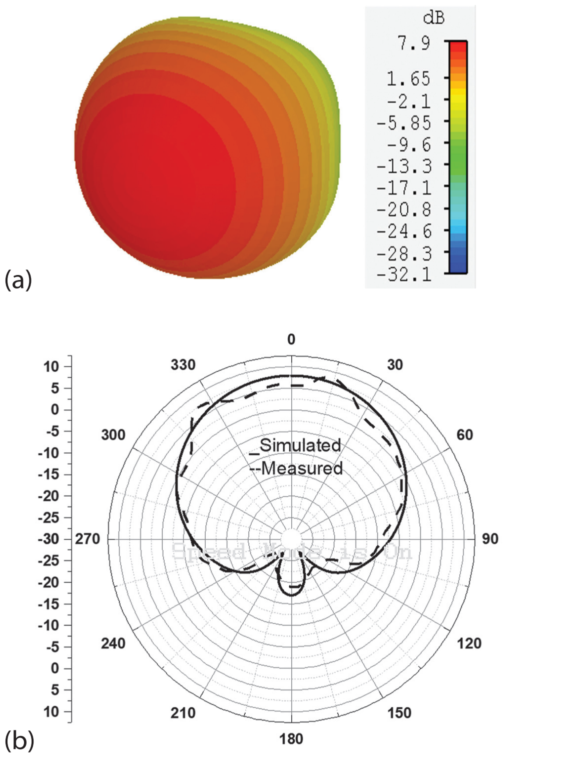


Fig 4. Radiation Pattern at 9.4 GHz,
(a) Three-dimensional, (b) E-Plane Pattern

Fig. 4 and 5 display the slotted monopole antenna's radiation characteristics. A maximum gain of 7.9 dB is attained at 9.4 GHz and a maximum gain of 7.91 dB is attained at 13.3 GHz. Antenna exhibiting low backlobe, monopole-like radiation in the E-plane. A nulling is occurred for 210 degrees at 13.3 GHz and the antenna showing good radiation characteristics at dual band.

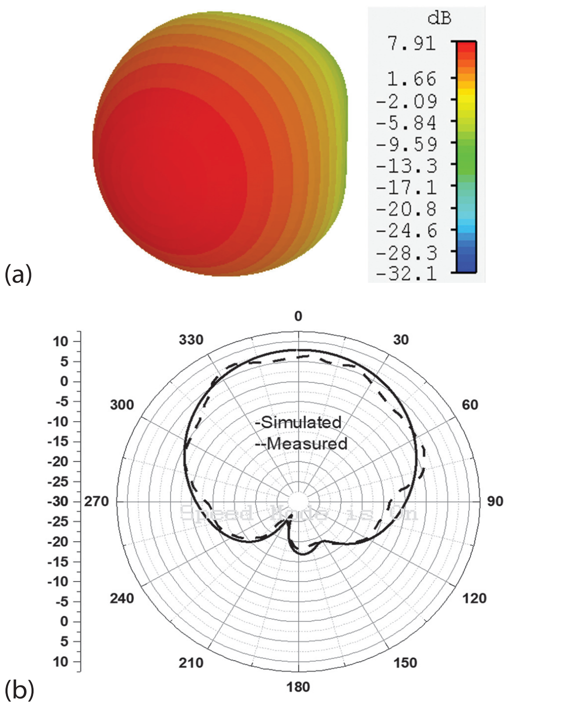


Fig 5. Radiation Pattern at 13.3 GHz,
(a) Three-dimensional, (b) E-Plane Pattern

3.2. RECONFIGURABLE ANTENNA

The slotted monopole antenna is converted into a reconfigurable antenna with the placement of pin diodes at four slots, as shown in Fig. 6. The equivalent circuit model for PIN diode ON and OFF conditions is presented in Fig. 6(c). The parameters like reflection and transmission coefficients concerning the diodes on and off conditions are analyzed and presented in this section.

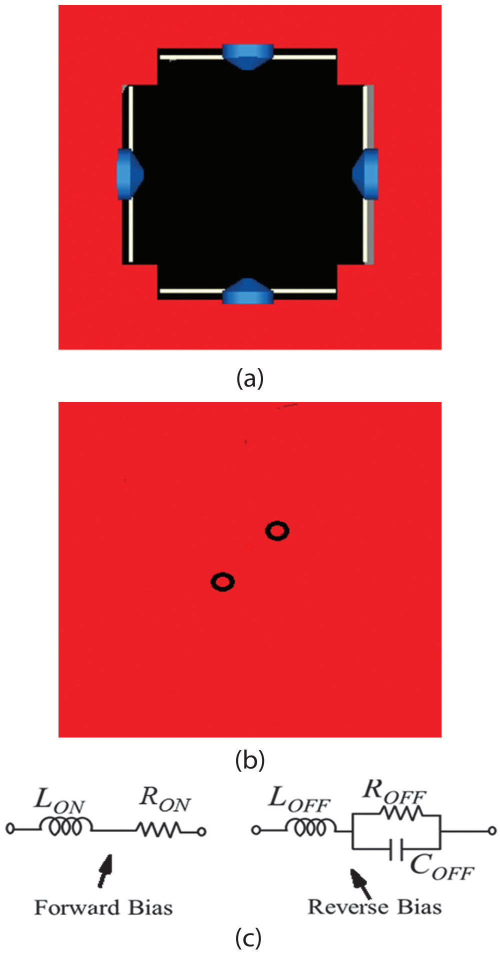


Fig 6. Reconfigurable Dual Fed Slot Antenna with Diodes, (a) Top View, (b) Bottom View (c) PIN diode equivalent circuit for ON and OFF

The fabrication of the antenna is shown in Fig. 7. Dual feed slot antennas and dual feed slot antennas with diodes are displayed here. The S-parameters are analyzed with diodes ON and OFF condition is presented in Fig. 8 and 9. Four diodes are used in the design to verify the performance characteristics of the antenna in reconfigurable conditions. When four diodes are in an off state, antenna shows dual band characteristics at 9.4 GHz and 13.3 GHz, respectively. Diode 4 in the ON condition and remaining diodes in the OFF condition also provide dual-band characteristics with resonance at 9.6 GHz and 13 GHz, respectively. When diode 3 is in ON condition and the remaining diodes are in OFF condition, providing a single resonance at 9.7 GHz. When diode 2 is in ON condition, the remaining diodes are in OFF condition, providing a single band with resonance at 9.8 GHz.

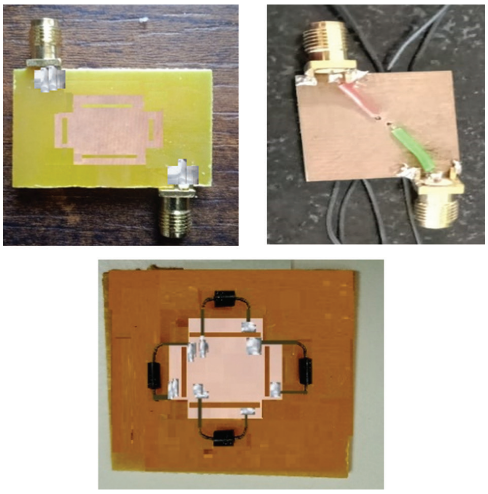


Fig 7. Fabricated a) dual Fed Slot Antenna b) feed line c) Dual Fed Slot Antenna with Diode

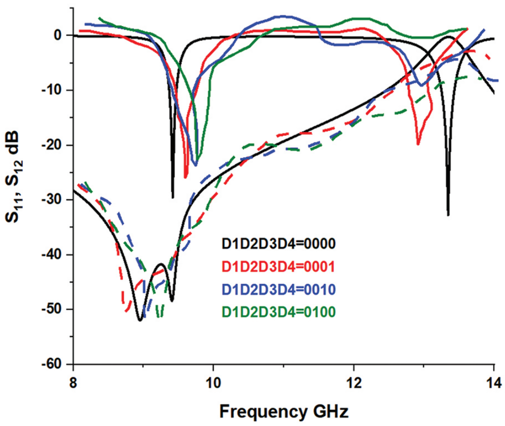


Fig 8. Reconfigurability Conditions 1

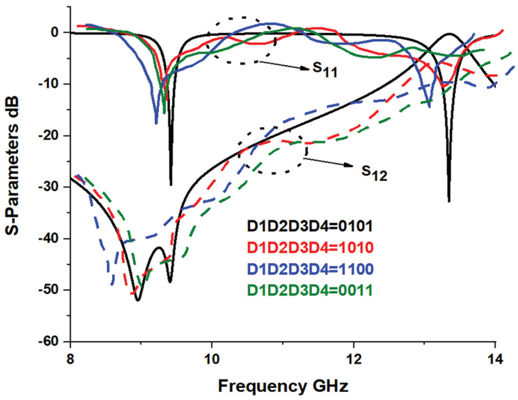
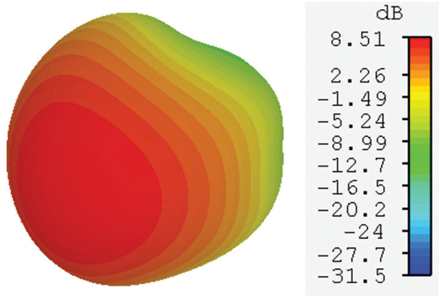
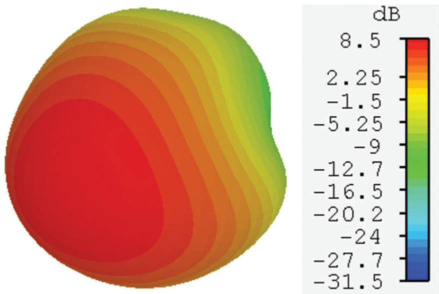


Fig 9. Reconfigurability Conditions 2

The reconfigurable conditions for 0101, 1010, 1100, and 0011 are presented in Fig. 8. When diodes 2 & 4 are in ON condition, and the remaining diodes are in OFF condition, antenna provides dual-band characteristics with resonance at 9.3 GHz and 13.4 GHz, respectively. When diodes 1 & 3 are in ON condition, and the remaining diodes are in OFF condition, antenna provides dual-band characteristics with resonance at 9.1 GHz and 13 GHz, respectively. When diodes 1 & 2 are in ON condition, and the remaining diodes are in OFF condition, antenna provides dual-band characteristics with resonance at 9.4 GHz and 13.1 GHz, respectively. When diodes 3 & 4 are in ON condition and remaining diodes are in OFF condition, the antenna provides single band characteristics with resonance at 9.2 GHz.

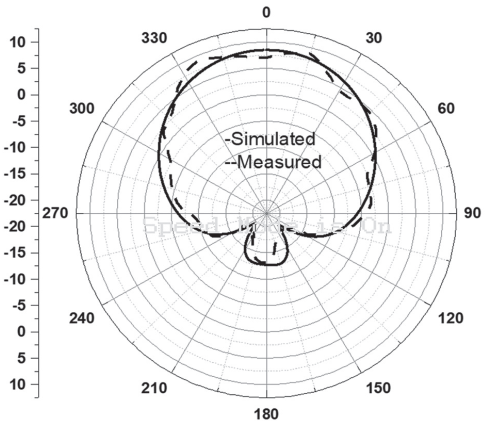


(a)

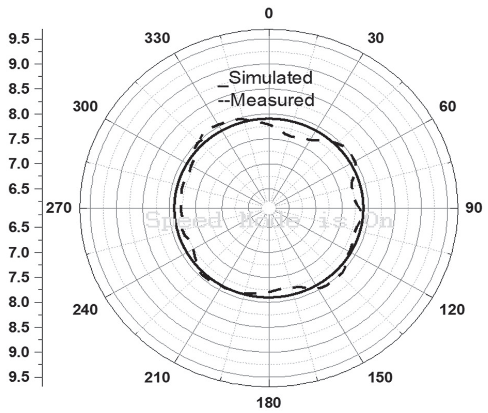


(b)

Fig 10. 3D-Radiation pattern, (a) At 1010, (b) At 0101



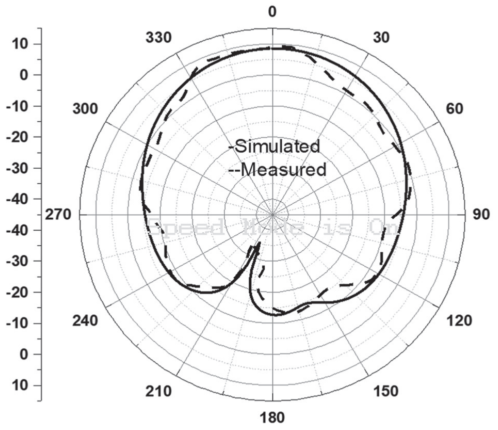
(a)



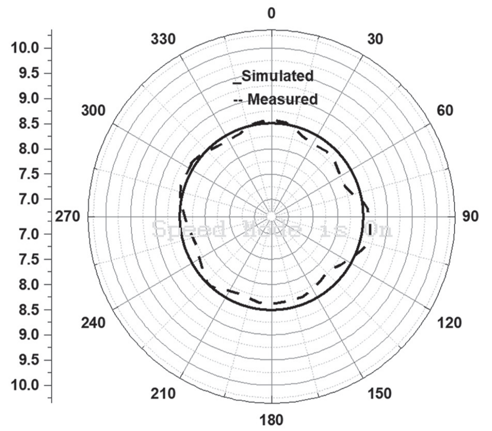
(b)

Fig 11. Radiation Pattern in Polar, (a) E-Plane at 1010 Condition, (b) H-Plane at 1010 Condition

Fig. 10. displays the antenna's radiation properties in both 3D and polar coordinates. A peak gain of 8.51 dB at 1010 conditions and 8.5 dB at 0101 conditions can be observed from Fig. 11. The radiation characteristics in polar coordinates are presented in Figs. 10 and 11 for 1010 and 0101 conditions. A directive pattern with low back lobe radiation can be observed from Fig. 11(a) of the E-plane and quasi-omni directional patterns in the H-plane from Fig. 11(b) for 1010. A directive pattern with nulling between 190 to 210 degrees can be observed from Fig. 12(a) of the E-plane and quasi-omni directional patterns in the H-plane from Fig. 12(b) for 0101.



(a)



(b)

Fig 12. Radiation Pattern in Polar, (a) E-Plane at 0101 Condition, (b) H-Plane at 0101 Condition

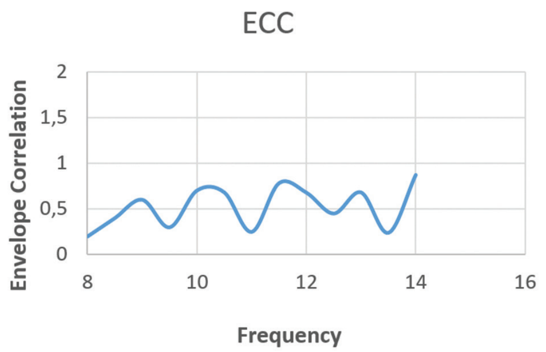


Fig 13. Relation between Envelope correlation to the frequency

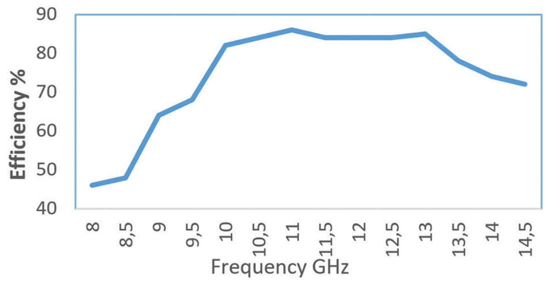


Fig 14. Efficiency of the Dual Fed Slot Antenna w.r.t frequency

Table 2. Comparision of Proposed work with standrad literaure.

S.no	Frequency	Gain	Efficiency
1 [24]	5.45 GHz	7.55dB	-
2 [25]	4.63 GHz	1.02dB	-
3 [26]	6.4GHz	1.87dB	70%
Proposed work gain	9.4 GHz	7.9dB	83%
	13.3 GHz	7.91dB	

Fig. 13. shows the envelope correlation factor with frequency, the maximum value of 0.8 obtained is good enough for a practical case. Fig. 14 represents the antenna's efficiency, which is almost above 80%. Table 2 compares the proposed work with the standard and obtained a maximum gain of 7.91dB

4. CONCLUSION

In this paper, a dual-feed, dual-band, reconfigurable antenna is designed and studied. The designed antenna resonates at 9.4 GHz and 13.3 GHz, respectively, with a gain of more than 8 dB. Antenna shows excellent radiation characteristics with monopole-like radiation in the E-plane and omnidirectional radiation in the H-plane with low cross-polarization. The resonant frequencies are changed concerning the diodes on and off conditions, and a remarkable gain change of 0.5 dB is observed in the reconfigurable antenna. There is a good match between the simulated and measurement results obtained from the prototype antenna with reconfigurable conditions.

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