Frequency and Polarization Reconfigurable Antenna for Airborne Application

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***Abstract*—Reducing weight and improving stealth capacity of onboard airborne system is always been a desirable feature. Reduction in number of antennas mounted onboard for communicating with ground system improves both the values of the system. This paper proposes a new design to replace the presently used three antennas working at different frequencies (two at S band, one at C band) and polarization by a frequency and polarization reconfigurable antenna. The microstrip patch antenna is designed and optimized in such a way that interconnection between patches tuned antenna from higher to lower frequency. Three coaxial feed points are provided for three operational frequencies. Polarization reconfigurability from circular polarization (CP) to linear polarization (LP) is achieved through positioning of these feed points and interconnection via switching. Switches ON state have been modeled with microstrip line connection. The Comparison of simulation and measurement result is presented. The measured results are in good agreement with simulation results. The measured return loss is better than 12 dB at three resonant frequencies and axial ratio is 3 dB, which meets the operational requirements.**

Keywords—Axial ratio, Circular polarization, Reconfigurable antenna, Telemetry, Airborne.

I. Introduction

Design of reconfigurable antenna targets transmission of two or multiple spot frequencies with the help of single antenna but shared aperture and switching circuitry. It may be envisage as a group of antenna elements designed to resonate at high frequency and their connection to each other using switches configure it to resonate at lower frequency. It is suitable to use in application where time division multiplexing of transmission is allowed. It avoids the need of multiple antennas and such common aperture antenna provide saving in size, cost and weight [1]. The first patent on reconfigurable antenna published in 1983 by Schaubert [2]. Most of the designs reported [3]-[4] reconfigurability in only frequency or polarization rather than both frequency and polarization. In [5] a microstrip patch antenna with frequency and polarization agility is explained. However, the tuning range and measured results were only shown for linear polarization. In [6]-[7] single feed microstrip antenna for frequency and polarization reconfigurability is described. Diversity from left hand circular polarization (LHCP) to right hand circular polarization (RHCP) and horizontal to vertical is only reported. However, these antenna structures don't support diversity from Linear to circular with high frequency tuning range.

In this paper, the authors present for the first time, the design, fabrication and measurement of antenna having capability of high frequency tuning ratio of 2.5 with polarization diversity from circular to linear. Three coaxial feeds (one for each frequency) and patch interconnection enable antenna to tune from one frequency to other operational frequency.

In this paper, section II describes the antenna design and structure, section III present the measurement results and its comparison with simulation, and final conclusion of the work is addressed in section IV.

II. Antenna design and structure

The antenna patch size length (L) and width (W) is calculated from [8]. RT Duroid 31.0 mil thick substrate of permittivity 2.2 and loss tangent 0.0009 has been used for designing the antenna. Effective relative permittivity $\in_e$ and patch length extension ΔL due to fringing field has been considered for finalizing patch dimensions. The antennas have been modeled and simulated in High Frequency Structural Simulation (HFSS) software. The lower frequency S band telemetry antenna patch is divided into three radiating elements P1, P2 and P3. During EM simulation these patches are connected via high impedance microstrip transmission line to reconfigure the antenna to radiate at other operational frequency. This simulates the condition wherein switches are in ON state. The Smaller patch (P1) is designed to radiate at C band frequency. The L shape metal patch P2 connections to P1 configure the structure to resonate at S band transponder frequency. Five interconnections are used to connect P1 to P2 and P2 to P3 to uniformly distribute the surface current on connected metal patches. Fig.1-2 shows the field distribution on patches during transmission. Three feed points are provided for three spot frequencies and their positions are optimized to radiate efficiently in free space. In case of circular polarization, feed point location is also optimized for axial ratio. Optimization criterion were S11< -15dB, axial ratio<2 dB, beam-width > 80 deg.

Final metal patch sizes used for antenna fabrications are given in Table I. Diagonal feed point P1, P2 is given for circularly polarized radiation at two frequencies. Centre feed point P3 is given for linearly polarized radiation at lowest frequency of operation.

Three antennas were fabricated to measure the design parameters at three frequencies before integrating switches with the antenna structure. Antenna shown in Fig. 3 (a) works at C band, fabricated with single feed point P1 in the presence of adjacent patches not-connected to P1 patch. This simulates the condition wherein diode switches are in OFF state. The fabricated S band transponder antenna is shown in Fig. 3. (b) with two feed points P1 and P2, one is for C band and other is for S band respectively. The antenna parameter measurements are carried out by feeding at port P2 and P1 terminated. The lower frequency S band telemetry antenna was fabricated with three feed point P1, P2 and P3 as shown in Fig 4. The measurement at this frequency is carried out by feeding at port P3 and other two terminated.

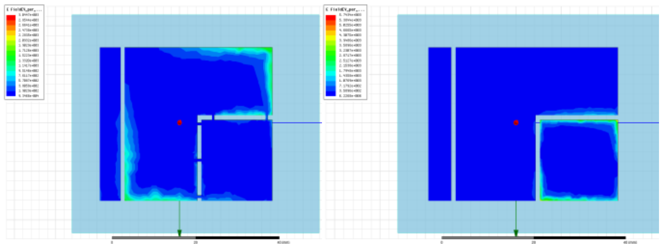


Fig. 1. Field on patches when antenna radiating at S band transponder and C band frequency.

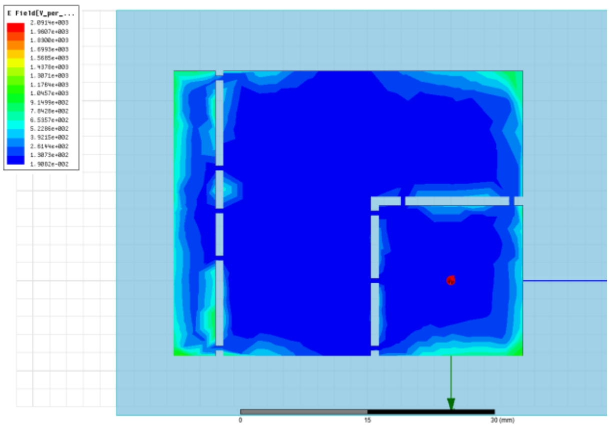
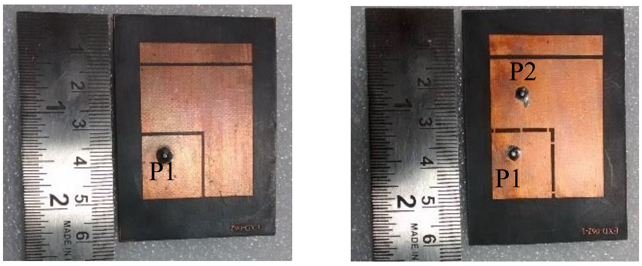


Fig. 2. Field on patches when antenna radiating at lower S band frequency.



(a) (b)

Fig. 3. Photograph of fabricated a) C band and b) S band antenna

TABLEI Dimensions of reconfigurable antenna in mm

L1	L2	L3	L4	W1	W2	W3
17.2	17.6	5	35.8	16.7	13.9	31.6

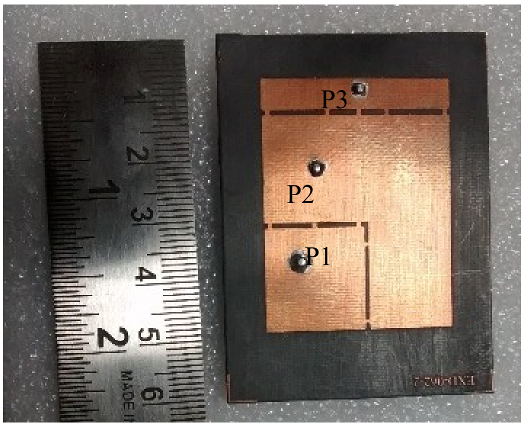


Fig. 4. Photograph of fabricated S band telemetry antenna

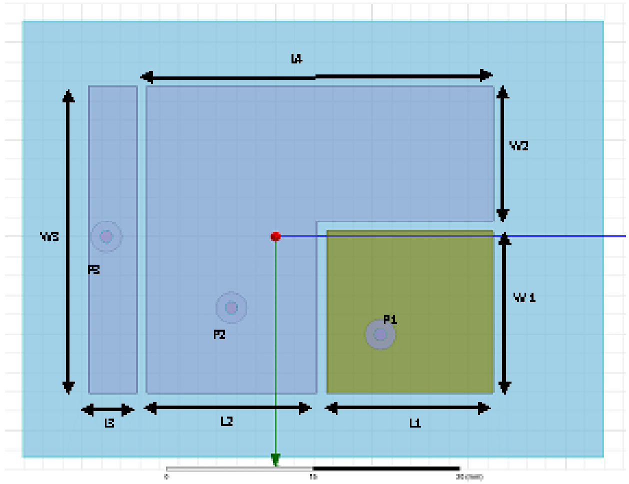


Fig. 5. Antenna structure and dimensions

III. RESULT AND DISCUSSION

The comparison of simulation and measurement results are shown in Fig. 6 – 11 and in Table II. Simulation results are in close comparison with measured results. The return loss for S band operational frequencies is better than 15 dB and for C band it is better than 14 dB. The simulated C band antenna gain and axial ratio at boresight is 6.0 dBic and 3 dB respectively. The cross polar levels are less than -20 dB at the bore-sight. Simulated antenna directivity at both the S band frequencies is 2.5 dBi. However realized gain is observed to be lower than typical patch antenna at these frequencies. This may be due to the presence of slots and high impedance transmission line used for connection which increases the losses. The distribution of surface current on connected metal patches is also not similar to single continuous radiating patch. The mounting arrangement for antenna radiation pattern measurement is shown in Fig. 12.

The measured axial ratio of C band antenna is higher than 3.0 dB at one sided half power beam width from 10° to 40° (Fig.11). This is due to the presence of asymmetric unconnected patch around C band antenna. This behavior has been seen in both the planes of antenna radiation pattern.

It has been found out during simulation that while designing the C band antenna presence of nearby metal patches needs to be considered, to include the coupling effect.

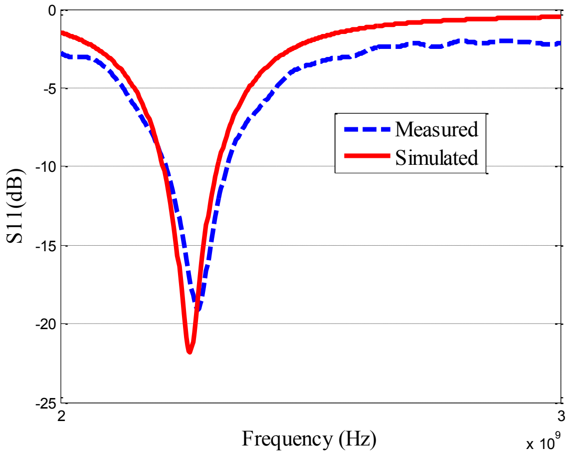


Fig. 6. S11 plot of S band telemetry antenna.

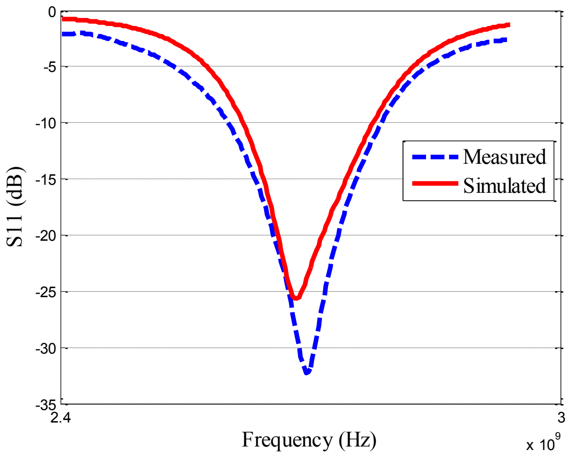


Fig. 7. S11 plot of S band transponder antenna.

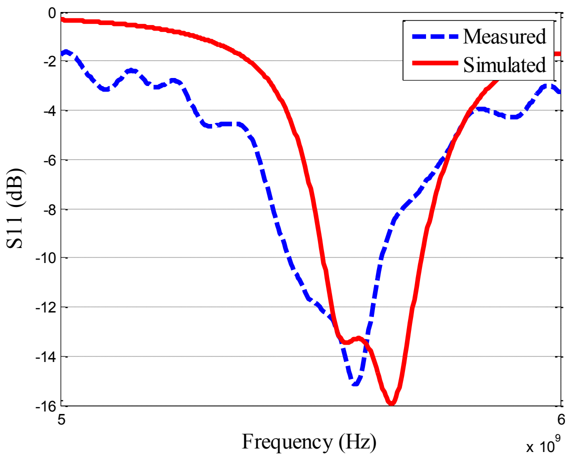


Fig. 8. S11 plot of C band antenna.

The presence of other frequency feed points doesn't affect the simulation. However at S band both have to be considered for antenna design.

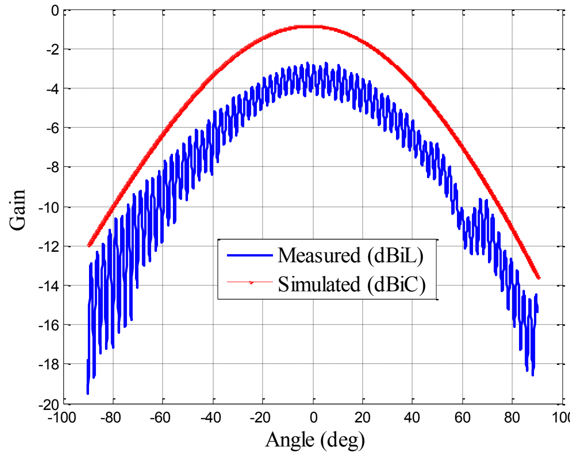


Fig. 9. Radiation pattern of S band CP antenna at 2.65GHz.

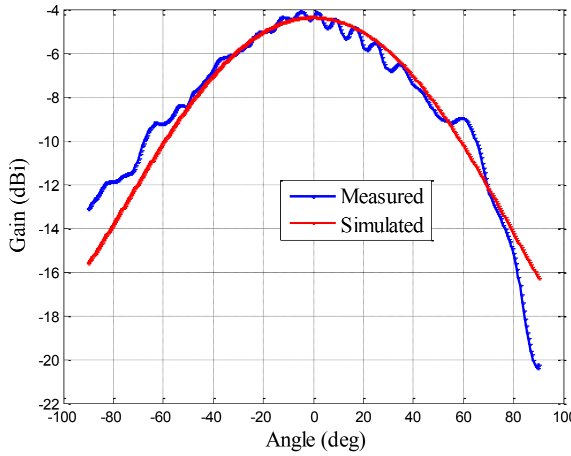


Fig. 10. E plane radiation pattern of S band LP antenna at 2.2GHz.

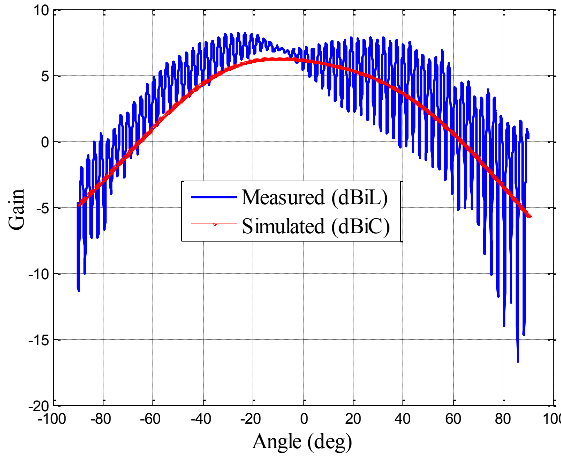


Fig. 11. Radiation pattern of C band CP antenna at 5.8GHz.

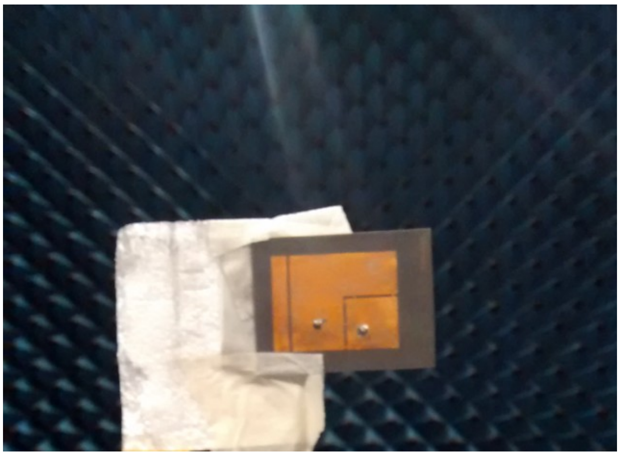


Fig. 12. Photograph of Antenna mounted for pattern measurement

TABLEII SIMULATION AND MEASUREMENT RESULTS COMPARISON

Frequency (GHz)	Simulated		Measured	
	Realized Gain	***Beam width (deg)***	***Gain***	***Beam width (deg)***
2.2	-4.4 dBi	80	-4.1 dBi	85
2.65	-0.8 dBic	80	-0.9 dBic	85
5.8	6.0 dBic	90	8.0 dBic	80

IV. CONCLUSION

The antenna is designed for an application where reduction in number of antenna was priority than the gain of antenna. The proposed antenna meets all the operational requirements, may be used in airborne telemetry and other communication application where continuous transmission is not essential. It will avoid the requirement of three antennas which not only provide space and weight saving but also reduces the integration complexity and radar signature of the system.

The reconfigurable performance may be realized by replacing microstrip connection with switches. The switches may be operated sequentially or based on requirement from command issued by a onboard computer to transmit different frequency signals.

This antenna configuration provides capability to radiate at any two spot frequencies which are widely separated or multiple spot frequencies by a single antenna. Method of improving the gain will be the area where work may be done in the future.

V. ACKNOWLEDGMENT

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