An Optimized Inset Feed Circular Cross Strip Antenna Design for C-Band Satellite Links

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***Abstract*—This proposed antenna model and progressing the investigation of an inset fed wideband circular slotted patch antenna is suitable for 5.2 GHz satellite C-band applications. A circularly shaped slot has been chosen to be etched on diminutive square patch (4.4cm*5.64cm) of the inset feed antenna. The object of this work is to develop an efficient and inexpensive transducer system to facilitate its compatibility with monolithic microwave integrated circuits; expenses are minimized for its fabrication and trail low profile for C-band satellite links. This paper focuses on the circular profile of the microstrip patch antenna intended for the proficient gain to enhance the performance of the satellite communication. The return loss of -21.79dB with the directivity 8.22dB and gain of 8.17dB have been estimated. The efficiency of 97% with VSWR of 1.22 compensates each other with better simulation results.**

Keywords—Circular slot; high gain; C-band; satellite communication; efficiency

I. Introduction

Rapid progress in modern satellite communication has urged meticulous research concerning high directive single and multiple feed planar antennas. The microstrip patch antenna is selected based on characteristics such as their miniature size, low weight, lower profile, ease to operate simple configuration and fabrication. Many satellite antennas are intended to offer versatility and scope pursuing antenna gain and direction; to face hurdles and hindrances of seasonal variations and enhance the performance of systems in unidirectional and multidirectional scenarios [1]. With the swift progress of worldwide technologies, the worlds of miniature size microwave structures along with low-cost designs are globally appreciated. Therefore, heaps of research work stimulated the expansion of ultra-wideband antennas for diverse areas [2]-[4]; planar circle antennas are utilized for single-band and ultra-wideband procedure which is fed by coplanar lines to prevent from persistent ground current effects. It comprises the slotted circle as the radiating part, the slotted circle to slim the antenna dimension and ameliorate the overall impedance transmission capacity and better impedance matching [5]. Microstrip patch antenna comprises minute directing patch based on the ground plane divided by a dielectric substrate. The radiating patch has been designed with dependable materials, e.g. gold or copper and their ability to adopt any conceivable geometrical patterns [6]. It has been observed on patch antenna for wireless communication, coplanar patch antenna has been used due to its high radiation efficiency and wide bandwidth that suits with satellite transponders [7]; a wideband smaller scale strip patch antenna is intended for satellite correspondence. It accomplished multi-band usefulness throughout the cluster system together with creating circular polarization and greater radiation efficiency for C-band [8]. The unique patch shapes such as E-shaped antenna by [9], [10] found its aptness with wider bandwidth spectrum, multi-band behavior and Wi-Fi applications to minimize the antenna size with glass cum fiber substrate and antenna width appeared to be reduced in the magnitude from 19.2 mm to 15.8 mm.

The transmission capacity of the antenna has been expanded from 8.5% to 17.5% with a coverage frequency range of (5.1-6.0) GHz separately. In satellite communications, a microwave frequency of C-band is defined as the standard range from (4.0-8.0) GHz, approximately the entire C-band communication satellites utilize the band of frequencies from (3.7 - 4.2) GHz for their downlinks whereas uplink takes up the spectrum of frequencies from (5.9-6.4) GHz. The research theme, demands the reduction of antenna size effectively without affecting its radiation pattern and directivity. Therefore the proposed work covers the development of reasonable antenna design that can capture the satellite traffic of C-band by sustaining the efficiency and directivity of the system (Fig. 1).

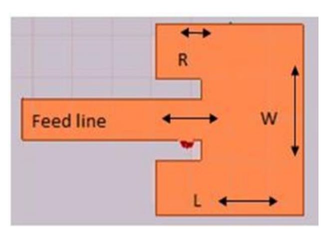

Fig. 1. Basic configuration profile of inset feed patch antenna.

II. Related Studies

To acclimatize with the increasing demands of wireless communication and to compensate the extended application prerequisites, it turns into a very strong issue to configure and design low profile, portable, wider bandwidth planner antenna at minimum cost. Many design goals have been achieved by the researchers in few decades. Circular radiation polarization antennas have been discovered with wider applications in satellite communication because of their inattentiveness to the polarization rotation of ionosphere. Helical antennas with axial mode are known for a long time offer circular polarization over a wide transmission capacity and eliminate the need for polarizer [11], [12]. The authors have investigated the performance of microstrip patch antenna for C-band satellite communication. The concept represented in this paper was based on resonant frequency to achieve multiband operations. The tradeoff was highlighted that if the width of patch increases the radiation efficiency, bandwidth and power radiation decreases [13]. In [14], F-shaped antenna is proposed for satellite communication. Simulation results were not quite suitable to accommodate the c-band traffic. The circular slotted antenna was recommended for wireless communication. The achieved gain was 4.3dB over the 3 GHz to 8 GHz frequency band. It is demonstrated that the lower the voltage standing ratio for better the transmission capacity with more power deliverance [15]. The effects of ground and patch length were optimized at different lengths and to get optimum value for better impedance matching. This work has not optimized the gain and return loss improvements. In [16], authors proposed a triple equalitarian triangular slot antenna for Ku-band satellite communication. Although results were shown good but gain and bandwidth efficiency is low. Divesh Mittal et al. [17] has discussed the performance of microstrip antenna for c-band communication. The authors failed to provide high gain and directivity. The satellite antennas ought to be directive with better gain results. The step structured slots added on the patch was proposed to provide broadband and smaller size antenna [18]. The circular slot microstrip patch antenna reported in many papers [19] but the circular slot with plus sign was not introduced in the presented literature. The multiband antenna was proposed for different wireless applications. The simulation results were better to accommodate WiMax traffic [20]. Microstrip patch antennas have many applications as E-shaped antenna proposed for intelligent transportation traffic data transfer and the Yagi shaped microstrip was designed for telemedicine applications [21], [22]. This paper [23] presents the arc-shaped strips along dual inverted L-shape partial ground plane antenna for X-band and WLAN applications. Sharma, et al. [24] demonstrated a tri-band nature of antenna used for C, X, and Ku Satellite communication and recommends that cutting the corner of the antenna with defective ground offer a solution for patch antenna drawbacks. The results satisfy the bandwidth need.

In this paper, we have proposed an antenna for satellite communication with improved gain, directivity and the effects of tuning the slot positions for getting optimum position for better return loss and VSWR.

III. Antenna Design

There are numerous methods to design and analyze a microstrip patch antenna such as transmission line pattern hollow designs. The selected antenna utilizes transmittal line design where the width W and length of patch L are analyzed as broadening the transmittal line to resonate through an electric field varying sinusoidal as well as its length L [25]. There are three factors for the configuration of a rectangular small-scale patch antenna, Firstly the resonance band of the antenna besides the high polarization material with steady Rogers 5880 (tm) substrate; the substrate thickness (h) controls the fringing effects of the structure. Fig. 2 demonstrates a comprehensible planar rectangular Small scale strip patch antenna that operates at a frequency of 5.2 GHz with measurements of length and width are given in Table I. Rogers 5880 (tm) substrate bears the relative permittivity of 2.2 with loss tangent 0.001; selection has been made due to its ease, simple accessibility, the simplicity of fabrication. The radiating patch is aligned with an inset feed line crossing the center of the patch along the line of symmetry. The winding of the patch is adjusted by cutting one spherical slot and a pair of rectangular slots are combined together to minimize the impedance mismatching losses for satellite C-band applications, one of which is imprinted into the non-radiating center of the patch and two are united together. Pair of Slots is symmetrical in nature due to the fact that it reduces the cross polarization. The slits initiate boosting the current streak and reduce frequency operation.

A. Design Calculation of Inset Feed Patch Antenna

The inset fed antenna has been designed to resonate at 5.2 GHz. The Patch antenna length and width has been calculated by (1) and (2); whereas λ_0 & μ_0 are the wavelength and permeability of free space respectively with f_r defines the resonance frequency of the antenna. Using following formulae (1)-(8) essential parameters for design has been calculated.

$$W = \frac{\lambda_o}{2}\left(\frac{2}{\epsilon_r+1}\right)^{\frac{1}{2}} \quad (1)$$

$$L = \frac{1}{2f_r\sqrt{\epsilon_{eff}}\sqrt{\mu_o\epsilon_o}} - 2\Delta L \quad (2)$$

The extension length ΔL h is the height of patch and ϵ_{reff} effective permittivity are given as [12].

$$\Delta L = 0.412h\left[\left(\frac{\epsilon_{reff}+0.3}{\epsilon_{reff}-0.258}\right)\left(\frac{\frac{W}{h}+0.264}{\frac{W}{h}+0.813}\right)\right] \quad (3)$$

Where,

$$\epsilon_{eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[\left(1+\frac{12W}{h}\right)\right]^{\frac{-1}{2}} \quad (4)$$

According to the dimension of the width (W) of the patch, the dimension for the inset length of the patch is to be calculated. Conductance G_1 is given by [26].

If $W \gg \lambda_o$

$$G_1 = \frac{1}{120}\left(\frac{W}{\lambda_o}\right) \quad (5)$$

If $W \ll \lambda_o$

$$G_1 = \frac{1}{90}\left(\frac{W}{\lambda_o}\right)^2 \quad (6)$$

Now, take into account that the characteristic impedance of the microstrip line feeder is R_{in}.Therefore, equating the given equations [26] to get similarities between the input impedance R_{in} of the patch and feeder (i.e. inset length, Y_o).

$$R_{in}(y=0) = \frac{1}{2(G_1 \pm G_2)} \quad (7)$$

And then

$$R_{in}(y=y_o) = \frac{1}{2(G_1 \pm G_2)} cos^2(\frac{\pi}{L} y_o) \quad (8)$$

B. Simulation of Inset Feed Patch Antenna with a circular slot

It has been simulated small-scale strip inset fed patch antenna by means of defined parameters of an inset fed patch antenna and employing those parameters for the simulation work. The physical measurements of proposed antenna are specified in Tables I and II separately. Fig. 2 demonstrates the configuration of a microstrip patch antenna structure in the HFSS simulation software with activation of electric fields.

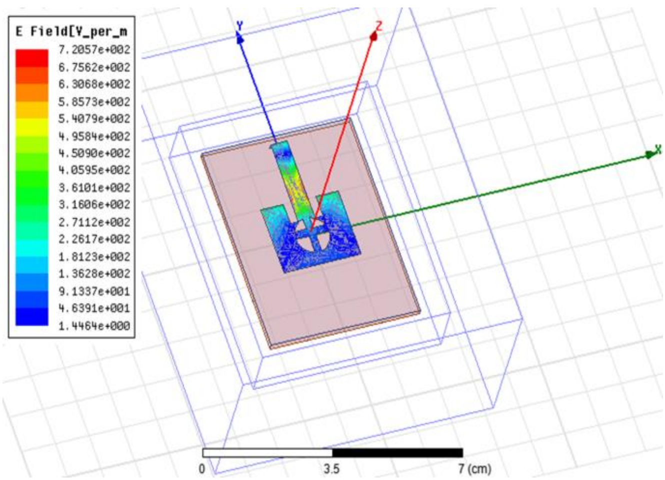

Fig. 2. Circular cross slot patch antenna with the emission of E-field distribution.

TABLE I. SPECIFICATION LIST OF INSET FED PATCH ANTENNA

Parameters	Units
Operating frequency	5.2 GHz
Ground plane dimension (L*W)	4.4cm*5.64cm
Patch length	1.85 cm
Patch Width Value	2.28 cm
Dielectric Constant Value	2.2
Dielectrical Material	RogersRT/duroid 5880(tm)
Substrate Thickness height	0.15784 cm
Input impedance	50Ω
Effective permittivity	1.23
The wavelength of free space	0.05769 cm

TABLE II. SPECIFICATIONS FOR LENGTH OF INSET FED PATCH ANTENNA

Parameters	units
Inset Distance	0.566cm
Inset Gap	0.243cm
Feed width	0.485cm
Feed length	2.257cm
Slot position	0,0,0.4

IV. RESULTS AND DISCUSSION

This segment furnishes the simulation results. The return Loss S_{11} of the circular dimension antenna is shown in Fig. 3. The transmission capacity is accomplished from 4.9 GHz to 5.3 GHz of 8.7%. The improved transmission capacity has resulted in the effects of the operating frequency. The efficiency of the antenna is 97%. The Directivity accomplished is 8.22 dB and the gain of the antenna is 8.04 dB at 5.2 GHz. The distinctive simulation results incorporate 2D and 3D radiations as appeared in Fig. 4 to 7.

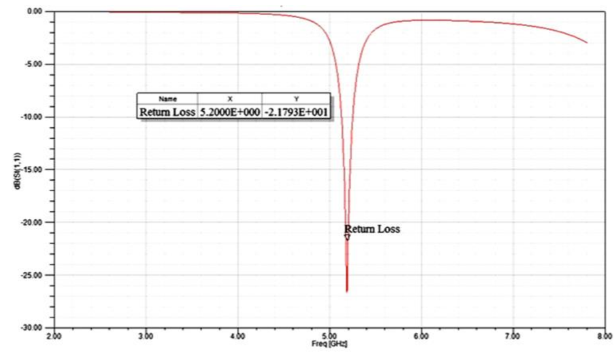

Fig. 3. Simulated Return Power Loss of circular slotted patch antenna with 5.2 GHz resonance frequency.

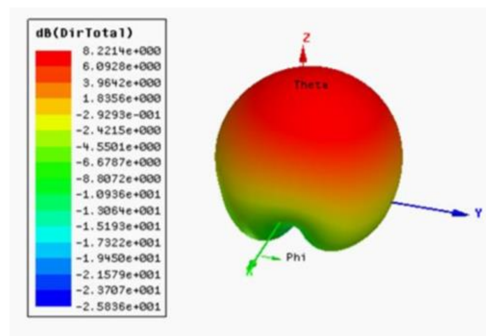

Fig. 4. 3D radiation pattern of the circular slotted inset fed patch antenna with directive value at the resonance frequency of 5.2GHz.

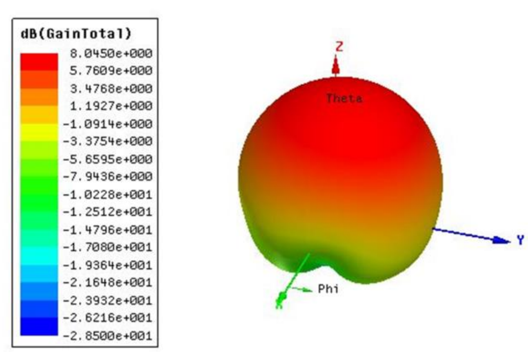

Fig. 5. The 3D radiation pattern of the circular slotted inset fed patch antenna with Gain values at the resonance frequency of 5.2GHz.

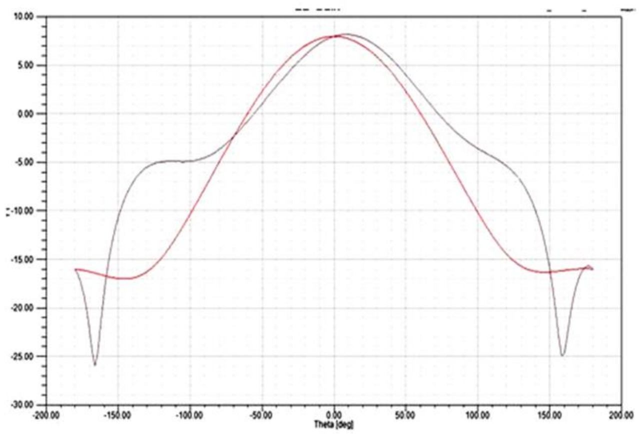

Fig. 6. Simulated 2D radiation pattern and with a Co-polarization pattern of the circular slotted Inset fed patch antenna.

TABLE III. TUNED CIRCULAR SLOT SHAPED ANTENNA

Radius	0.4	0.4	0.5
Slot Position	0,0,0	0,-0.5,0	0,-0.2,0

The impact of the different measurements such as slots width and position of the circular slotted antenna with simulation results has examined and discussed. The expansion in width of the slot would tune the return loss S_{11} execution to higher operating frequency. Correspondingly, this impact is quite obvious as the antenna is resonating at a higher frequency given that current flows through the center while the lower frequency exists owing to the movement of current through the circular region; another important circular slotted patch antenna design parameter is the slot location, which can alter the results for different return losses. The effects are shown in Fig. 8 and 9. The radius of the slot escalates from (0.4-0.5) cm indicated in Table III suggest slot positions, it shows results at the same frequency.

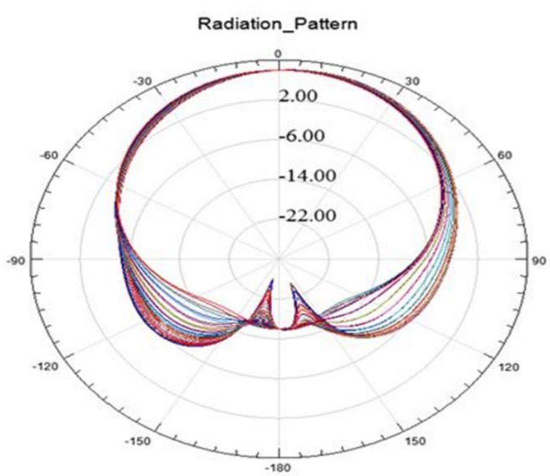

Fig. 7. Polarization Simulated radiation pattern at 5.2GHz for circular slotted inset fed antenna.

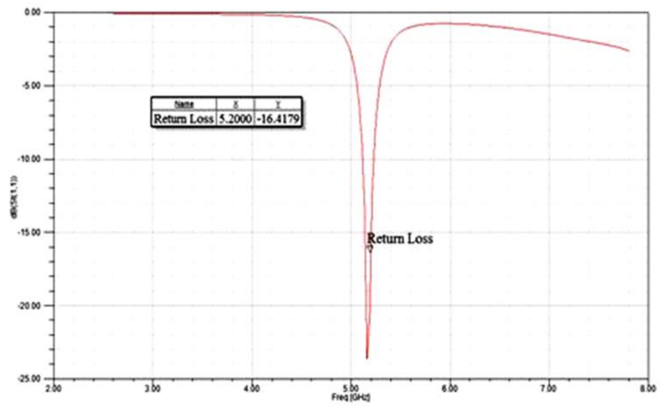

Fig. 8. Simulated return power loss of circular slotted patch antenna with the resonant frequency of 5.2 GHz.

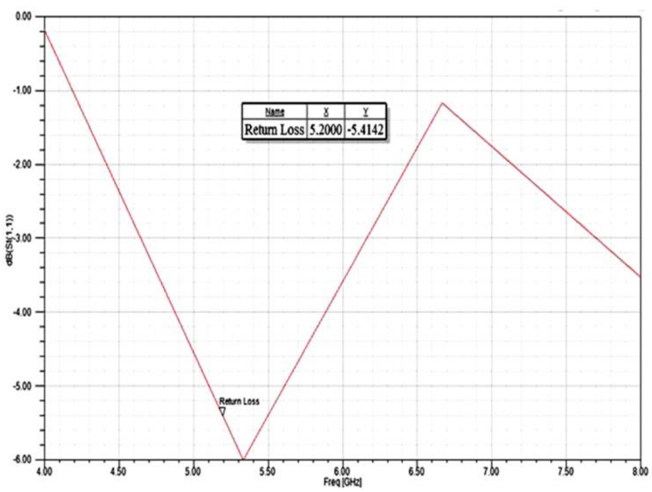

Fig. 9. Simulated return power loss of circular slotted patch antenna with 5.2 GHz.

TABLE IV. COMPARAITVE SUMMARY OF SATELLITE COMMUNICATON ATNENNAS

Ref	Frequency [GHz]	Return loss [dB]	Gain [dB]	VSWR
[13]	5.2	-15	4.4	1.5
[14]	4.1	-13.11	-	1.56
[15]	4.4	-32	1.8	1.2
[18]	5	-19.74	4	1.25
[20]	6.2	-15	-	<2
This work	5.2	-21.79	8.04	1.22

V. CONCLUSION

In the proposed work, a substantial structure of circular slot rectangular microstrip patch antenna has been designed successfully that manifests the efficiency of 97% with operating frequency of 5.2 GHz. This exclusive design and profile of the antenna mostly serve the role of improved results for the satellite C-band application as shown in Table IV. The simulated results are good which validate proposed antenna for C-band traffic. Adequate outcomes have been found including directivity of 8.22dB with the high gain of 8.04 dB; VSWR of 1.22 compensates with a return loss of -21.79dB to facilitate the efficient transmission of electromagnetic energy from earth station to transponder antenna and then headed for receiving station which confirms the suitability of circular cross-sectional patch antenna for C-band satellite links. In future, According to obtained simulated results of proposed design will be fabricated and simulated in other simulators for the performance test. The intended method may be extended and modified for other type satellite bands antennas.

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