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A Millimetre Wave Antenna for Micro Spacecraft Applications

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Abstract: This paper presents a microstrip patch antenna for Micro space craft applications in the frequency range of 31GHz-33GHz. The patch is loaded with multiple circular slots to improve the radiation property of the antenna. It consists of RT duroid substrate with low dielectric loss tangent 0.0009, dielectric constant 2.2 and thickness 0.5mm, PEC ground and PEC patch. Four various m x n array-based antenna has simulated on A soft HFSS (High Frequency Structural Simulator) Platform. The overall dimensions of designed antenna are 6mm x 6mm x 0.5mm. The performance of antenna is analysed by using simulated results of reflection co-efficient, VSWR, gain, bandwidth and directivity and antenna parameters are compared with four antennas.

Keywords: Millimetre Wave Antenna, Massive Slot Array, Perfect Electric Conductor.

I. INTRODUCTION

The fifth generation is elevating the mobile network to not only interconnect people, but also interconnect machines and devices. It produces a high efficiency and next level of performance. It delivers ultra -low latency of 1ms, high peak rates and massive capacity due to availability of high bandwidth. This type of antennas is currently considering the development of micro spacecraft for future deep space missions in order to meet NASA's goal of having small and inexpensive space craft. Millimetre wave band of frequency spectrum is between 30 GHz-300 GHz. It is also known as extremely high frequency (EHF) or very high frequency (VHF). It allows data rates up to 10Gbps; Millimetre wave has a range of 1mm to 10mm wavelength. RT/Duroid5880 is a microwave material which offers superior electrical and mechanical property. It has a highly depressed thermal coefficient of dielectric constant of -55^{o}C to +150^{o}C. RT/Duroid5880 substrate is mainly used for antenna design because it has low electrical loss, low moisture absorption and stable frequency. It is mainly used in applications such as airborne and ground based radar systems, millimetre wave application, and military radar systems. Micro strip patch antennas are becoming more important for mobile phone market. It can be printed directly on to a circuit board. This type of antenna is low cost and easily fabricated and designed. They have simple construction, it consists of dielectric substrate, patch and ground. There are so many possible shapes like circular, rectangular and triangular. They have very large bandwidth, higher efficiency and better radiation. The circular slots loaded in the patch will improve the bandwidth and impedance hence enhances the radiation pattern and it also allows to compact the size of antenna significantly suit for the specific applications. Here in this paper a comparison is made between the simple rectangular structure and proposed rectangular microstrip patch antenna loaded with various slots. Those various slots are 67 slots load antenna, 36 slots load antenna and 16 slots load antenna.

II. DESIGN EQUATIONS OF MICROSTRIP PATCH ANTENNA

It consists of patch which is usually a thin metallic strip placed on the dielectric substrate. Patch can be of any shape but here the shape of patch is rectangular. The design parameters of rectangular patch antenna are length (L) and width(W). These two parameters depend on dielectric constant, height of substrate and resonant frequency.

Width of patch (W) is given by,

$$W \leq \frac{c}{2f_r}\sqrt{\frac{2}{1+\varepsilon_r}} \quad (1)$$

Where c is the speed of light and f_r is the resonant frequency. In this design f_r is 32GHz.

The length of patch(L) is determined by ,

$$L = \frac{c}{2f_r\sqrt{\varepsilon_e}} - 2\Delta l \qquad (2)$$

where ε_e is the effective dielectric constant

$$\varepsilon_e = \frac{1}{2}\left[\varepsilon_r + 1 + (\varepsilon_r - 1)\sqrt{\frac{1}{\left(1+\frac{12h}{W}\right)}}\right] \qquad (3)$$

$$\Delta l = 0.412\frac{(\varepsilon_e + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_e - 0.258)(\frac{W}{h} + 0.8)}h \qquad (4)$$

From (1) & (2) we get W=3.32 mm and L=2.45 mm.

In this design the microstrip feed line width is 0.46mm and length is 1.57 to match the input impedance of patch element which should be close to 50Ω.

III. ANTENNA DESIGN AND CONFIGURATIONS

A. Rectangular patch antenna

The structure of antenna is shown in the figure 1. This has a length of 2.75mm and width of 3.32mm. It has a microstrip feed line of length=1.57 and width=0.46 attached to the rectangular patch. The dielectric material used in this design has a εr=2.2 and substrate height=0.5mm.

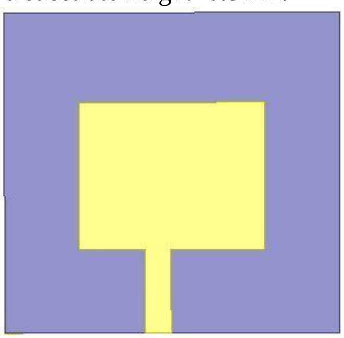

Fig1. Rectangular patch antenna.

B. Rectangular microstrip patch antenna with 16 slots

The antenna is shown is Figure 4. It is loaded with 16 circular slots of each having a radius 0.05mm and a uniform spacing of 0.2mm between them on the rectangular patch. Insertion of slot improves the input bandwidth. Thus the return loss, vswr, gain increases compared to rectangular patch antenna.

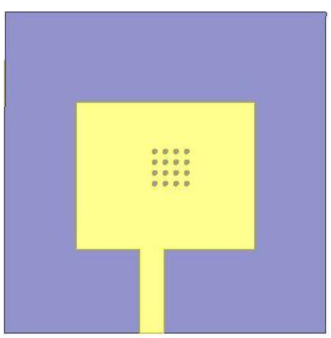

Fig2. Rectangular patch antenna with 16 slots.

C. Rectangular microstrip patch antenna with 36 circular slots

The antenna is shown in Fig7. It is loaded with 36 circular slots of each having radius of 0.05mm and 0.2mm spacing between them on the rectangular patch antenna. Rectangular microstrip antenna with 16 circular slots, Rectangular microstrip patch antenna with 36 circular slots has a improved return loss, VSWR and gain.

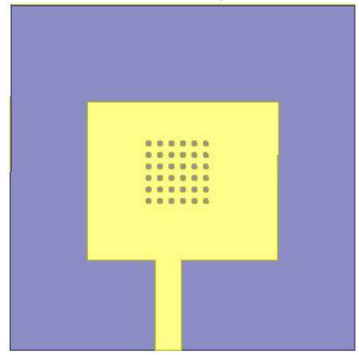

Fig3. Rectangular microstrip patch antenna with 36 slots.

D. Rectangular Microstrip patch antenna with 67 circular slots

The proposed antenna design and configuration is shown in Fig.10. with the patch length of 2.75mm and width of 3.32mm. It is loaded with 64 circular slots of radius 0.05mm. Ground of 6mm x 6mm is placed below the substrate (Fig.4(b)).

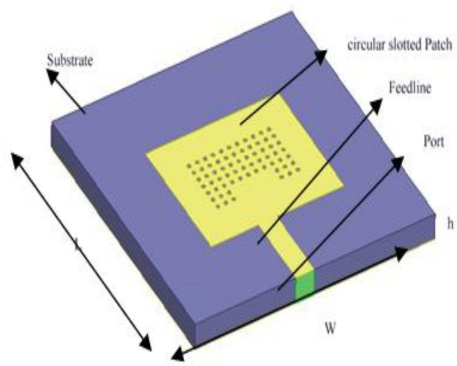

Fig4(a). Proposed antenna.

Compared to rectangular patch antenna and Rectangular microstrip antenna with16 circular slots and Rectangular patch Antenna with 36 slots, antenna with 64 slots have the best return loss (S11 parameter), VSWR and gain.

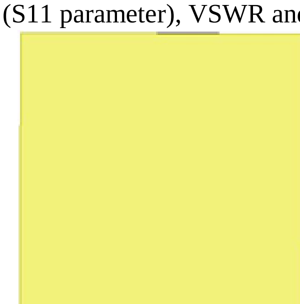

Fig4(b). Ground plane.

IV. RESULTS

Fig5(a) shows the S11 parameter and VSWR for conventional rectangular patch antenna. It can be seen that the reflection coefficient is -26.3464dB and VSWR is 1.1012 at the resonant frequency 32GHz. From Fig.5(b) E-plane and H-plane gains can be seen, it is 7.6968 dB.

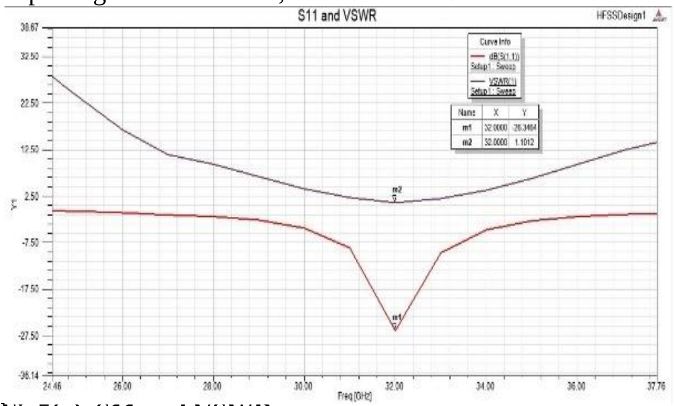

Fig5(a). S11 and VSWR.

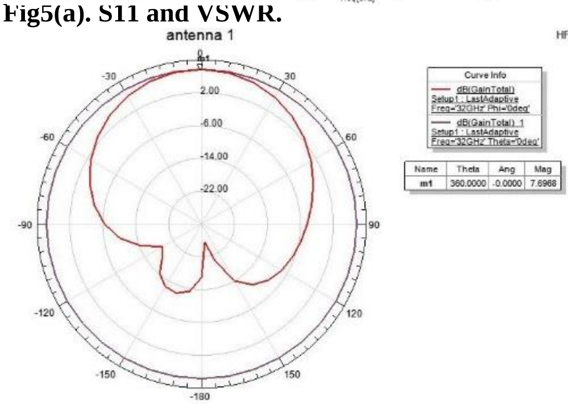

Fig5(b). E-plane and H-plane gains.

Fig6(a) shows the conventional rectangular patch antenna's maximum radiated Electric field strength of 6.0014e+004 V/m and Fig.6(b) shows the maximum radiated magnetic field strength of 4.7201e+002.

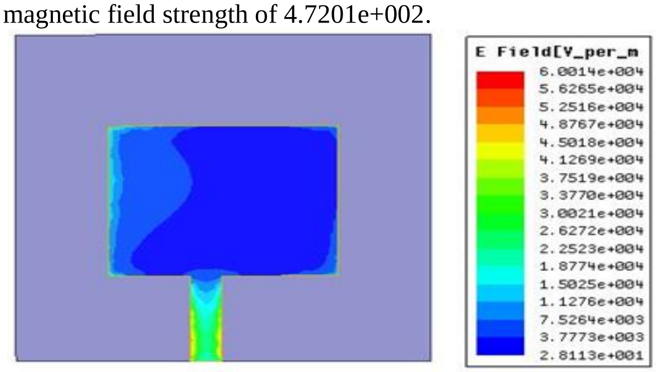

Fig6(a). Electric field.

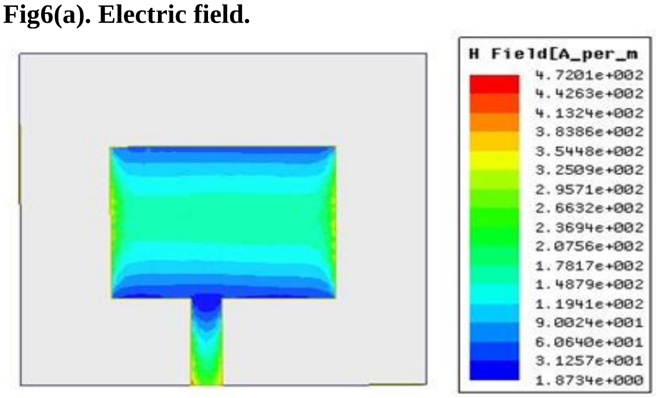

Fig6(b). Magnetic field.

Fig7(a) shows the S11 parameter and VSWR for rectangular patch antenna with 16 slots. It can be seen that the reflection coefficient is -26.5895dB and VSWR is 1.0983 at the resonant frequency 32GHz. From Fig.7(b) E-plane and H-plane gains can be seen as 7.6968 dB.

Fig7(a). S11 and VSWR.

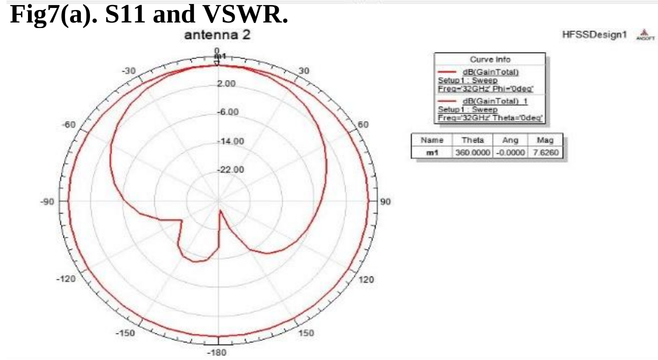

Fig7(b). E-plane and H-plane gain.

Fig.8(a) shows the maximum radiated Electric field strength of 5.6682e+004 V/m and Fig.8(b) shows the maximum radiated magnetic field strength of 5.2674e+002 of rectangular patch antenna with 16 slot.

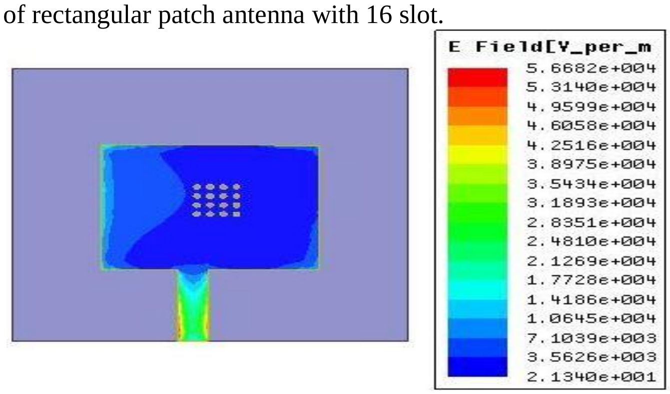

Fig8(a). Electric field strength.

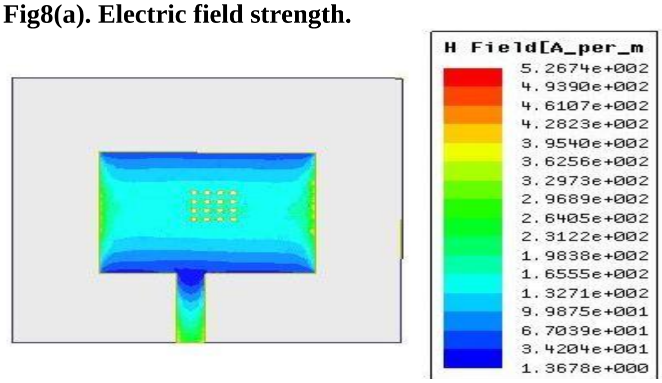

Fig.8(b) Magnetic field strength.

Fig9(a) shows the S11 parameter and VSWR for rectangular patch antenna with 36 slots. It can be seen that the reflection coefficient is -27.5427dB and VSWR is 1.0876 at the resonant frequency 32GHz. From Fig.9(b) E-plane and H-plane gains can be seen as 7.5494dB.

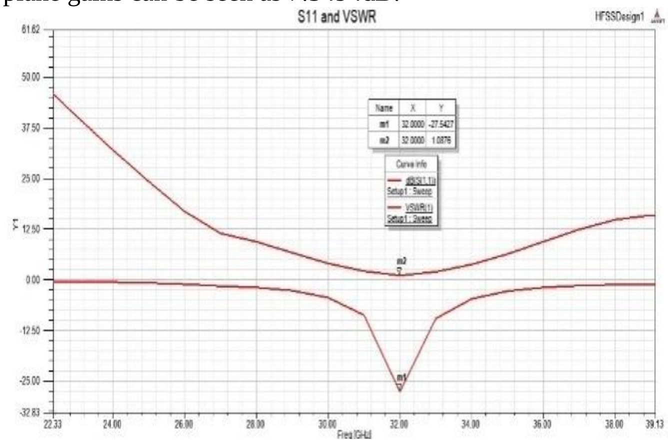

Fig9(a). S11 parameter and VSWR.

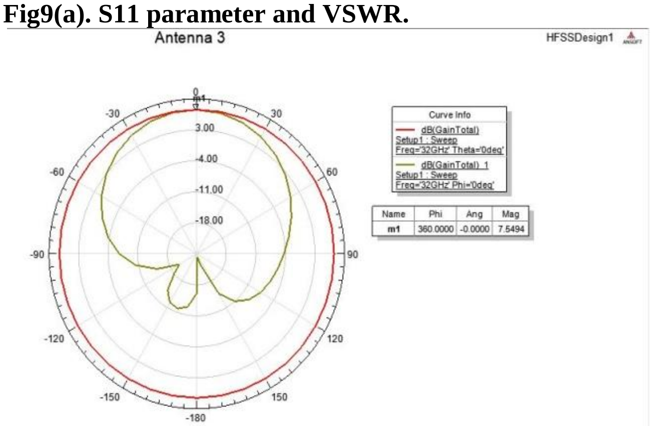

Fig9(b). S11 parameter and VSWR.

Fig.10(a) shows the maximum radiated Electric field strength of 7.2671e+004 V/m and Fig.10(b) shows the maximum radiated magnetic field strength of 5.1103e+002 of rectangular patch antenna with 36 slot.

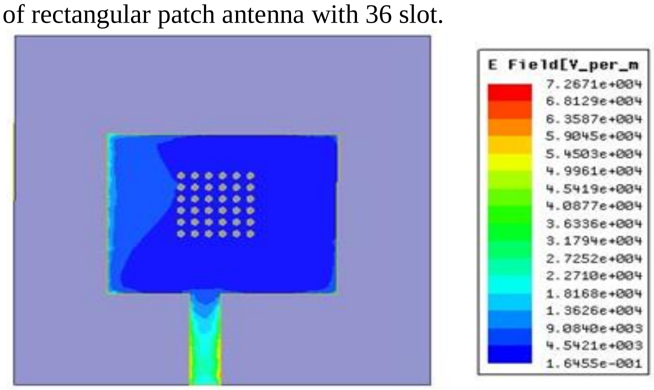

Fig10(a). Electric field strength.

Fig.11(a) and Fig.11(b) shows the S11 parameter and VSWR for proposed rectangular patch antenna with 67 slots. It can be seen that the reflection coefficient is -28.4701dB and VSWR is 1.0784 at the resonant frequency 32GHz. From Fig12 E-plane and H-plane gains can be seen as 7.6300dB.

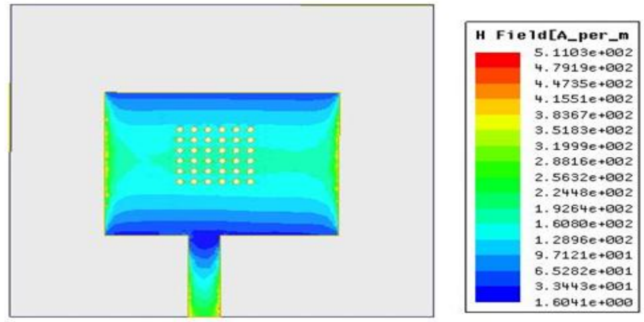

Fig10(b). Magnetic field strength.

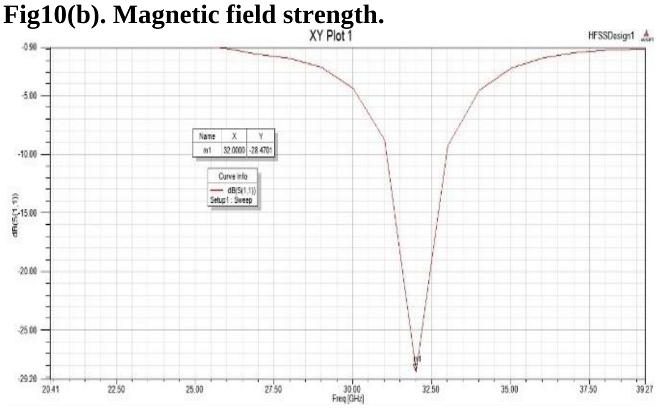

Fig11(a). S11 parameter.

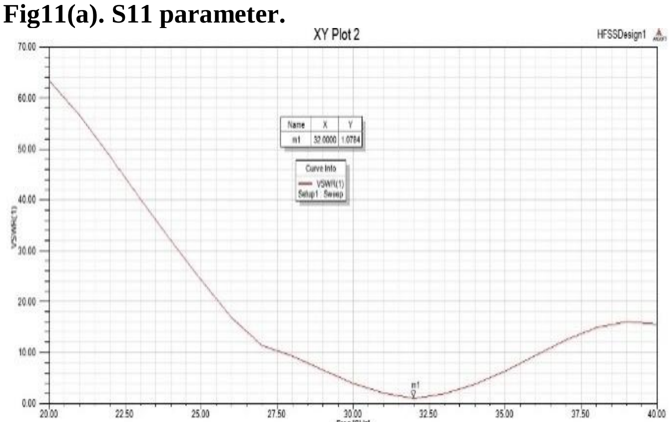

Fig11(b). VSRW.

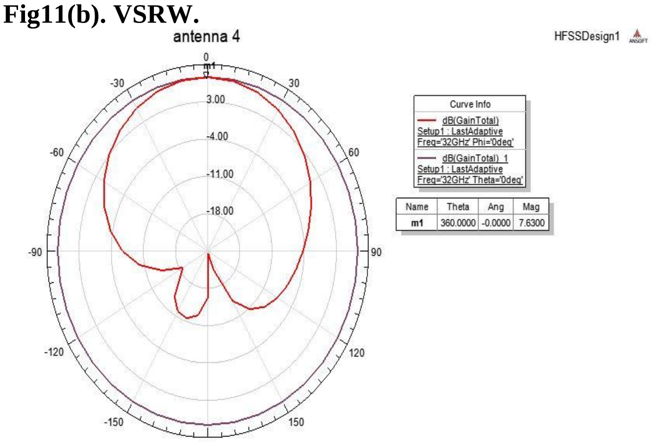

Fig12. E-plane and H-plane gain.

Fig.13(a) shows the maximum radiated Electric field strength of 7.2671e+004 V/m and Fig.13(b) shows the maximum radiated magnetic field strength of 5.1103e+002 of proposed rectangular patch antenna with 67 slot.

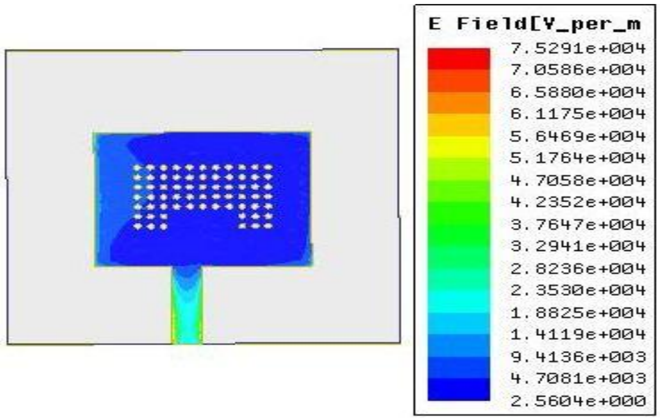

Fig13(a). Electric field strength.

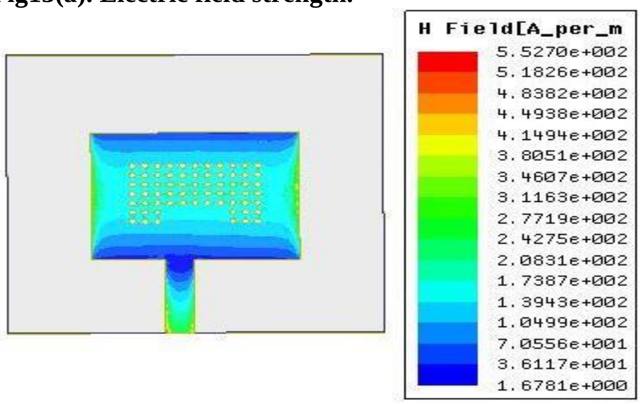

Fig13(b). Magnetic field strength.

A. Comparison Table of proposed antennas

The antenna parameters of all the four design have been compared in the Table.1

Table.1

Parameter	Antenna (3.1)	Antenna (3.2)	Antenna (3.3)	Antenna (3.4)
Bandwidth (GHz)	1.591	1.898	1.899	1.900
Directivity	7.6755	7.6395	7.6252	7.6328
Incident power(W)	1	1	1	1
Accepted power(W)	0.9976	0.06153	0.86364	0.06127
Radiated power(W)	1.0025	0.08595	0.86398	0.10463
Radiation efficiency	1.0049	1.397	1.0004	1.7078
LHCP (V)	13.96	2.9138	13.037	2.2163
RHCP (V)	18.667	3.1681	11.423	3.2841
Return loss(dB)	-26.346	-26.589	-27.542	-28.470
VSWR	1.1012	1.0983	1.0876	1.0784

V. CONCLUSION

A milli meter micro spacecraft antenna has been designed with 32GHz resonating frequency. It is intended as a downlink spacecraft antenna. Each patch element is circularly polarized with a single feed. One of the frequency bands under investigation for use with micro spacecraft in the ku-band. in this range of frequency components ane smaller and larger bandwidth. a higher bandwidth will result in higher data rate.

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