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Research Article

Bandwidth Enhancement of Patch Antenna through Various Techniques for Ku-Band Application

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Abstract: In this study the techniques for enhancement of impedance bandwidth of the microstrip patch antenna were analyzed. The techniques of defected patch, defected ground structure and parasitic patches were implemented to improve bandwidth of the antenna. Size of the substrate/ground plane of the proposed antenna was 17x6.4 mm^2. The impedance bandwidth of the proposed antenna was 5.51 GHz and a return loss of 26.01dB was obtained at the center frequency of 15.9 GHz. This antenna can be implemented for satellite communications in Ku- Band.

Keywords: Return loss, bandwidth, gain, VSWR, Ku-band, DGS

1. INTRODUCTION

Scientists have been working to develop a wireless communication system that would have high speed data rate like satellites communication system [1, 2, 3]. The satellite wireless communication system uses C, X, Ku and K bands. So the microstrip patch antennas can be designed to operate in theses high frequencies bands for its application in satellite communication. Microstrip patch antenna is popular due to its light weight, small size, planar configuration and low profile. They have low cost and can be easily printed on the microwave printed circuits [4, 5]. The patch antenna has more advantages but its bandwidth is very narrow. In order to enhance the bandwidth of patch antenna for satellite applications in the above mentioned high frequency bands, different techniques such as aperture coupling, the introduction of defect in the ground plane and the patch structure and optimization of the feed line have been reported in the literature of [6-8]. Different shapes of the patches such as circular disc, triangle, ring, elliptical, pentagon and hexagonal have been presented in [9-14].

The E shape antenna has been designed on FR-4 substrate with dielectric constant of 4.2. The height of the substrate is reported to be 1.5 mm. The size of the substrate and ground of the above mentioned E shape antenna is 16.5 mm ×22.75mm and it has been concluded that the proposed antenna provides a good bandwidth in Ku-band satellite communication [15]. The patch antenna in [16] has been simulated on Teflon substrate and has a dielectric constant of 2.1. The antenna has achieved a return loss of 26.55 dB, gain of 6.9 dBi, efficiency of 98.99% and a bandwidth of 4.1GHz at the resonant frequency of 12.54 GHz.

The patch antenna has size of 15 mm × 15 mm [17]. The antenna can be operated in the bandwidth of 0.95 GHz with a maximum gain of 7.6 dBi for Ku-band application. A microstrip patch antenna has been reported in [18] which have obtained a bandwidth of 2.1 GHz with a maximum gain of 12.1 dBi. A patch antenna for Ku band has been simulated using FEKO software and this antenna has achieved a fractional bandwidth of 13.3% at resonant frequency of 12.57 GHz [19]

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Table I. The parameters of the proposed antenna.

Name	Description of Parameter	Value
A	Size of the antenna substrate	17x6.4 mm^2
A1	Size of the driven patch P2 without rectangular cuts	4.2x3.2 mm^2
A2	Size of the left parasitic patches P1	3.5x3.2 mm^2
A3	Size of the upper and lower parasitic patches P3 & P4	2x0.8 mm2
A4	Area of each rectangular cut from the corners of Patch P2	1.6x0.4 mm^2
A5	Area of the rectangular slot from the ground plane	1x5.4 mm^2
C	Location of coaxial feed line on the x axis	1.36 mm
G1	The gap between the parasitic patch P1 and the driven patch P2	0.3 mm
G2	The gap between the parasitic patch P3 and the driven patch P2	0.45 mm
G3	The gap between the parasitic patch P4 and the driven patch P2	0.5 mm
T	Thickness of the ground plane and all the three patches	0.035mm
H	Height of the substrate	1.64 mm

Table 2. Gain of the proposed antenna.

Frequency (GHz)	Gain (dBi)
12.88	5.23
13.77	5.46
14.66	6.16
15.15	7.13
16.44	7.05
16.88	6.71
17.60	5.58

Table 4. The gain of the modified antenna.

Frequency (GHz)	Gain (dBi)
13.6	5.57
14.66	6.22
15.55	6.95
16.4	6.8
17.6	6.15
18.4	5.57

Table 3. Diemensions of the ground slots.

Slots	Slots	Values (mm)
1st Ground Slot	The minimum and maximum value of x	(5,8.2)
	The minimum and maximum value of y	(-3,3)
2nd Ground Slot	The minimum and maximum value of x	(-4.5,4.9)
	The minimum and maximum value of y	(2,3.1)
3rd Ground Slot	The minimum and maximum value of x	(-5,-5.5)
	The minimum and maximum value of x	(0.5,2.6)

2. DESIGN OF ANTENNA

A rectangular patch antenna with three parasitic patches has been designed using the technique of defected ground structure (DGS) as shown in Fig. 1. The patches have been made on Preperm L-450 and this dielectric substrate has a dielectric constant of 4.4. The height of the aforementioned dilectric substrate is 1.64 mm. The antenna substrate has a size of 17×6.4 mm^2. The radiating patch P2 has a size of 4.2x3.3 mm^2. The parasitic patch P1 is located on the left side of the driven patch. The parasitic patch P3 is located on the top of the driven patch and the parasitic patch P4 is located at the bottom of the driven patch. The gap G1 between the parasitic patch P1 and the driven patch P2 has been adjusted to 0.3 mm. The gap G2 between the parasitic patch P3 and the driven patch P2 has been adjusted to 0.45 mm. The gap G3 between the parasitic patch P4 and the driven patch P2 has been adjusted to 0.5 mm. Four equal rectangular slots have been removed from the driven patch P2 and the area of each slot is equal to 1.6×0.4 mm^2. The ground plane has been converted to Defected Ground Structure by etching a rectangular slot in it. Th rectangular slot on the ground is located at a distance of 7 mm from the center of the antenna. The material used in all the patches and the ground plane is pure copper that has a thickness of 0.035 mm. The coaxial feed line is located on the x-axis at a distance of 1.36 mm.

The driven patch is excited by a 50 Ω coaxial cable. The parameters of the proposed antenna are given in Table 1.

3. RESULTS AND DISCUSSION

3.1 Bandwidth and Return Loss

The reflection coefficient of the antenna as a function of the frequency is shown in Fig. 2. An impedance bandwidth of 5.1 GHz has been acheived by the antenna. The maximum Return loss of 19.79 dB has been obtained at the centre frequency of 14 GHz. The bandwidth of the antenna is in the Ku-band and it ranges from 12.88GHz to 17.99 GHz.

3.2 Voltage Standing Wave Ratio

The Voltage Standing Wave Ratio of the proposed antenna is sketched in Fig. 3.with respect to the frequency. The VSWR of the proposed antenna is less than 2 in the above mentioned operating band.

3.3 Efficiency

Sketch of the efficiency as a function of frequency is shown in Fig. 4. The total efficiency of the antenna is greater than 90% in the entire operating bandwidth. The total efficiency of 97.4% has been achieved at the frequency of 13.77 GHz. Maximum value of the radiation efficiency is 99% and it has occurred at the frequency of 15.96 GHz.

3.4 Gain

The gain of the antenna is given in Table 2. The sketch of the gain is shown in Fig. 5. The maximum value of the gain is 7.13 dB with respect to the isotropic radiator and it has taken place at the frequency of 15.15 GHz.

4. MODIFICATION IN DEFECTED GROUND STRUCTURE

The Defected Ground Structure (DGS) has been modified as shown in Fig. 6. The dimensions of the 1st ground slot have been changed and two additional ground slots have been etched on the ground plane. The dimensions of all the three ground slots are given in Table 3.

An improvement in the bandwidth of the antenna has been observed that has been explained in the forthcoming sections of the paper.

4.1 Bandwidth of the Modified Antenna

The Bandwidth of the antenna has been enhanced due to the above mentioned changes in the DGS of the proposed antenna. The bandwidth was enhanced from 5.1 GHz to 5.51 GHz (Fig. 7). The lower frequency of the given BW is 13.38 GHz while its upper frequency is 18.89 GHz.The return loss has been improved from 19.79 dB to 26.01 dB. This return loss has occurred at the center frequency of 15.90 GHz.

4.2 VSWR of the Modified Antenna

VSWR of the modified antenna is shown in Fig. 8. The ratio of 1.1 has been obtained at the center frequency of 15.9 GHz. The ratio has been confined to the slot between 1 and 2. When this ratio becomes equal to 1 then there is no reflection from the antenna and the reflection coefficient becomes equal to zero. The antenna is said to be perfectly

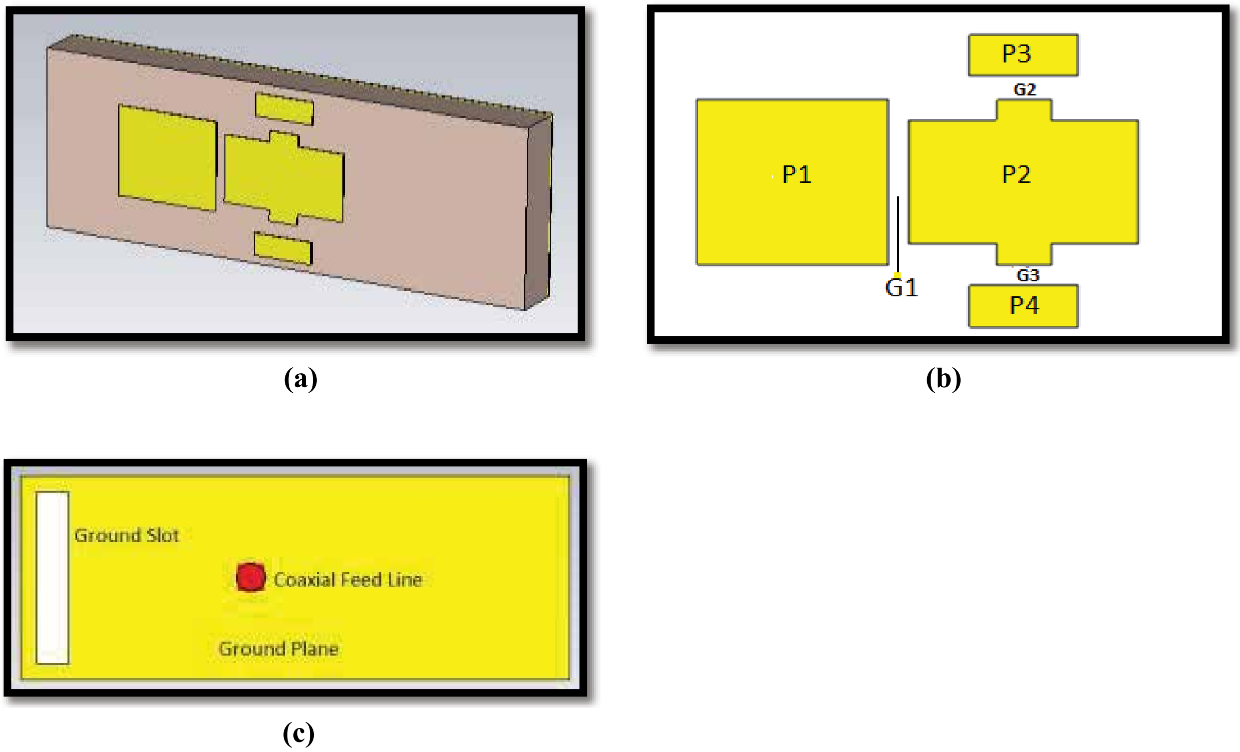

Fig. 1. The Antenna: (a) Perspective view; (b) Front view; (c) Back view.

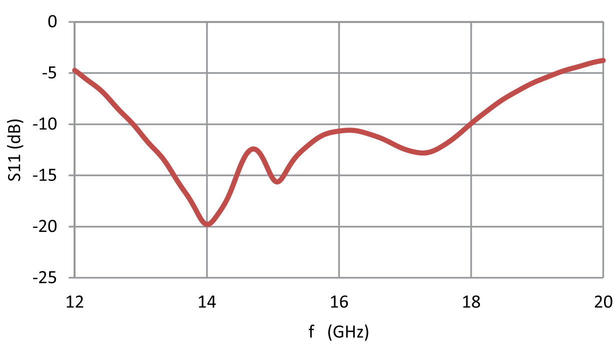

Fig. 2. Bandwidth of the antenna.

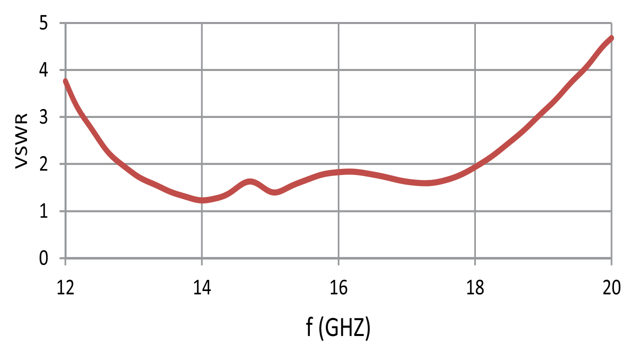

Fig. 3. VSWR of the antenna.

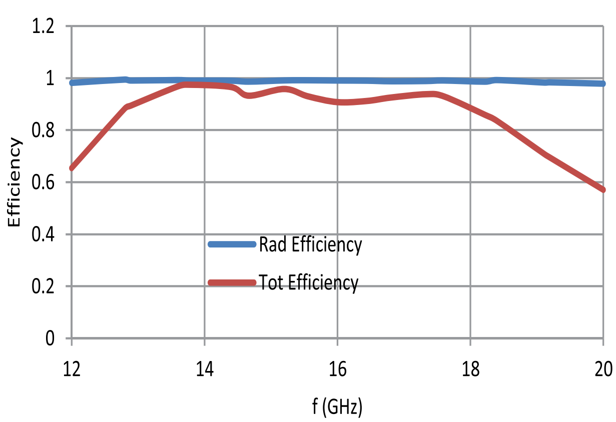

Fig. 4. Efficiency of the antenna.

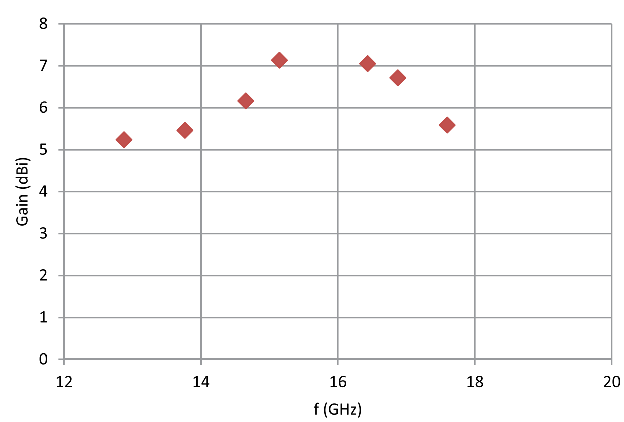

Fig. 5. Gain of the antenna.

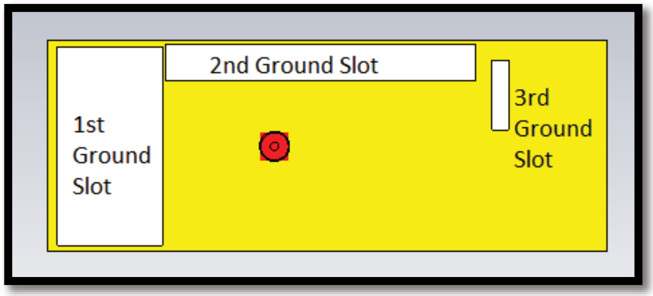

Fig. 6. View of the Modified DGS.

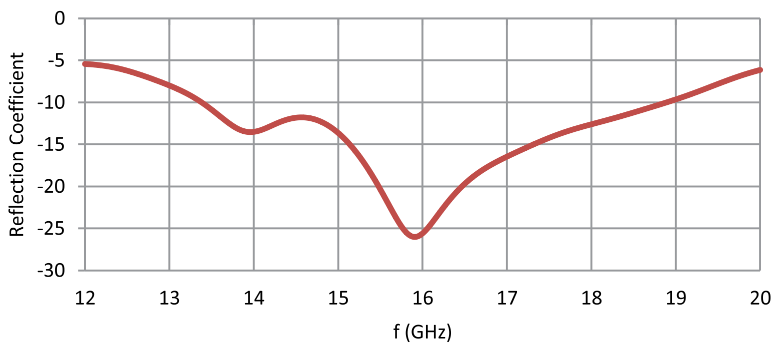

Fig. 7. Band Width of the Modified antenna.

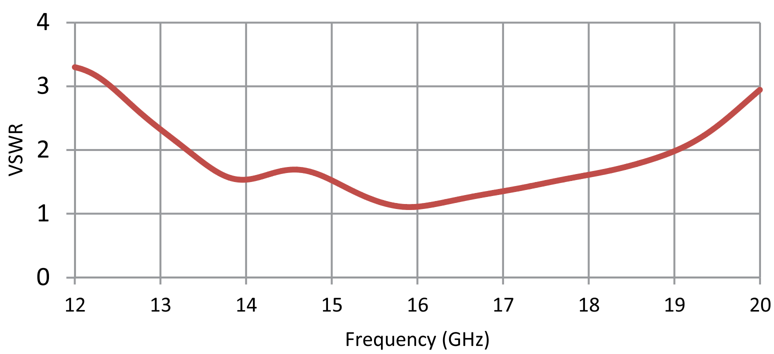

Fig. 8. VSWR of the Modified antenna.

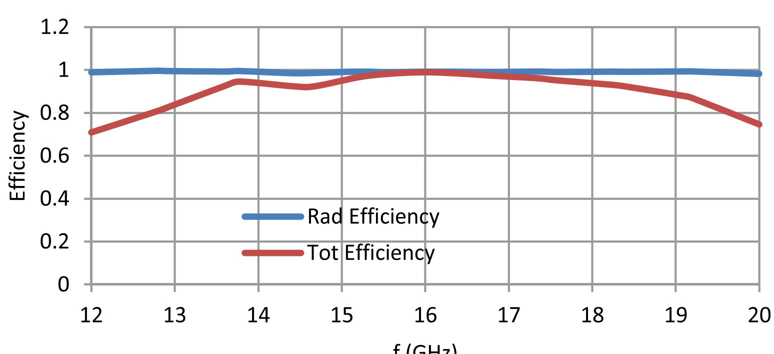

Fig. 9. Efficiency of the modified antenna.

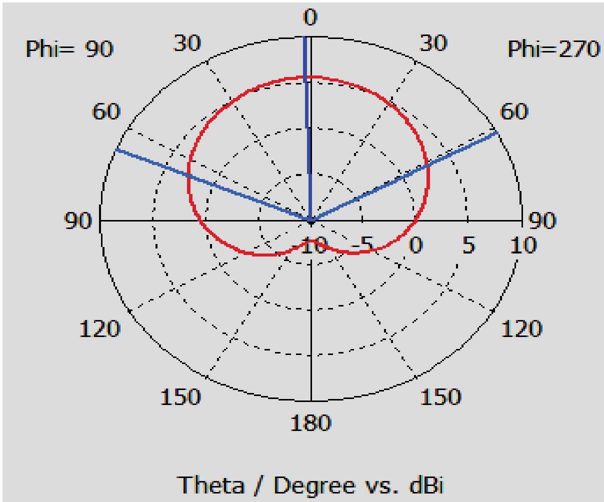

Fig. 10a. Radiation pattern at 13.6 GHz.

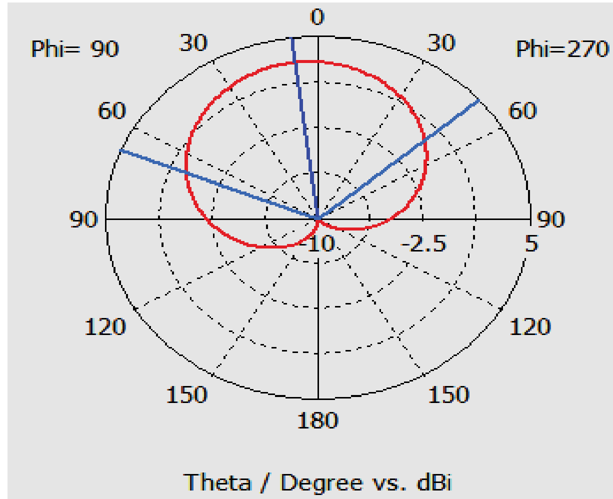

Fig. 10b. Radiation pattern at 14.66GHz.

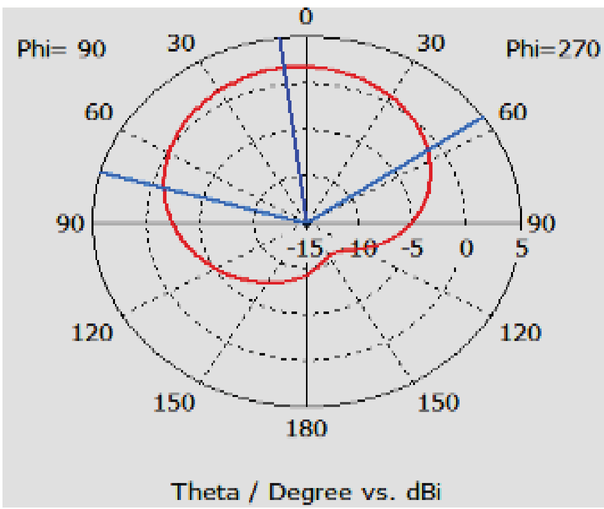

Fig. 10c. Radiation pattern at 15.55GHz.

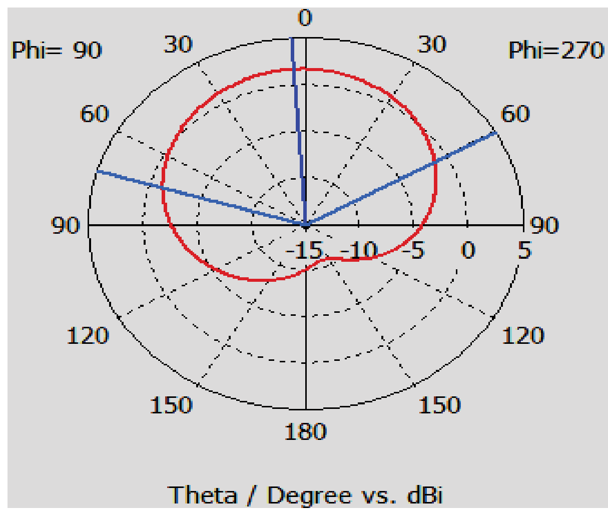

Fig. 10d. Radiation pattern at 16.6GHz.

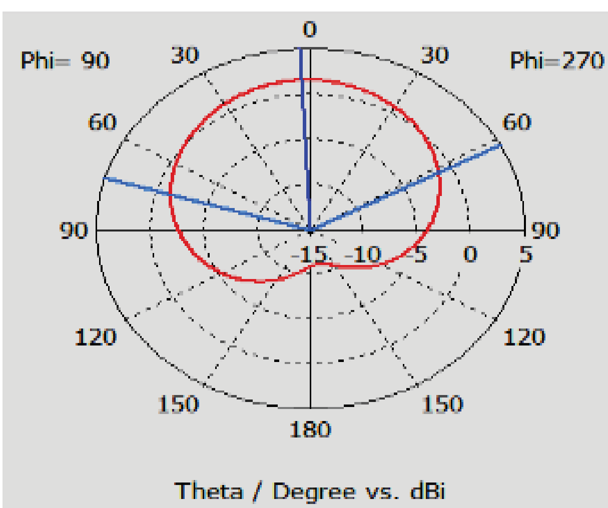

Fig. 10e. Radiation pattern at 17.6 GHz.

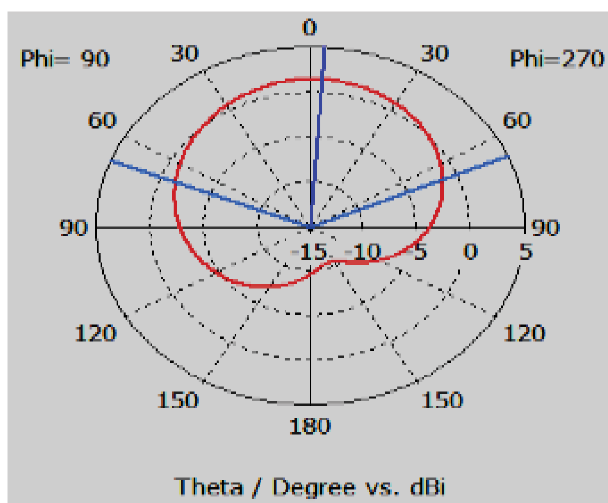

Fig. 10f. Radiation pattern at 17.6 GHz.

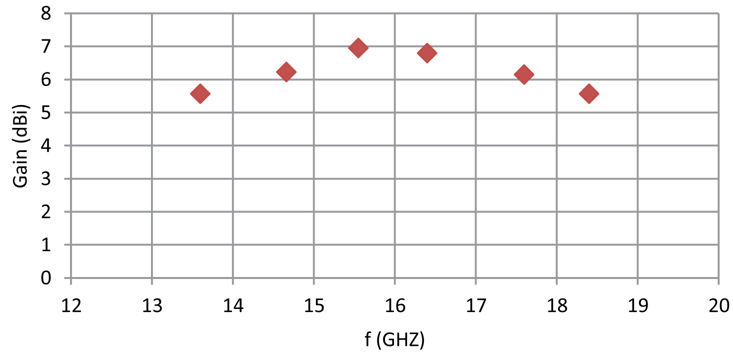

Fig. 11. Gain of the Modified antenna.

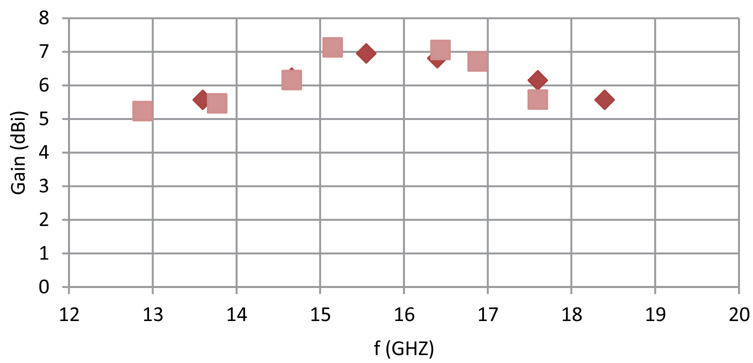

Fig. 12. Comparison Between the Gains of the two antennas.

matched and maximum power is transferred to the antenna under this condition.

4.3 Efficiency of the Antenna

The above mentioned modification in the ground plane has improved the total efficiency of the antenna as well. The maximum value of the total efficiency of this modified antenna is 98.85% and it corresponds to the frequency of 15.96 GHz. The maximum value of the radiation efficiency at the same frequency is 99.13%. The efficiencies of this antenna are shown in Fig. 9.

4.4 Radiation Patterns

The 2-D radiation pattern at the frequency of 13.6 GHz is shown in Fig. 10a. The angular width of the pattern is 128.9 deg and there is no side lobe.

The radiation pattern shown in Fig.10b has an angular width of 117.3deg and it has no side lob at all. The 2-D radiation pattern shown in Fig. 10c has been sketched at the frequency of 15.55 GHz with a 3-dbB angular width of 129.7 deg and there is side lob.

The radiation pattern at the frequency of 16.6 GHz has been shown in figure 10d.The angular width of the pattern is 133.8 deg and no side lob is associated with it. Fig.10e shows the 2-D radiation pattern of the propsed antenna at the frequency of 17.6 GHz and it has a 3-dB angular width of 135.7 deg. Finally, radiation pattern at the frequency of 18.4 GHz has been shown in Fig.10f. This radiation pattern has an angular width of 135.3 deg.

4.5 Gain of the Modified Antenna

The gain of the Modified antenna is given in Table 4 and it has been sketched in Fig. 11.The comparison of the gains before and after the modification in the DGS has been shown in Fig.12. Obviously the modification in the DGS has slightly degraded the gain of the antenna.

5. CONCLUSIONS

A Ku band antenna that can be implemented for satellite applications in Ku band has been proposed. The bandwidth of the antenna with one ground slot in the ground plane is 5.1 GHz. The maximum efficiency of 97.1% has been obtained before the modification. This single band antenna has a maximum gain of 7.13 dBi and it has occurred at the frequency of 15.15 GHz. After the modification in the ground structure of the antenna, the bandwidth of the proposed antenna has been enhanced from 5.1 GHz to 5.51 GHz.The maximum value of the efficiency is 98.85% and it corresponds to the frequency of 15.96 GHz .The efficiency has been improved due to the modification. The maximum gain of the proposed antenna after the modification is 6.95 dBi and it has occurred at the frequency of 15.55 GHz.The return loss has been enhanced to 26.01 dB and this return loss has been achieved at the center frequency of 15.9 GHz. The VSWR of the antenna before and after the modification in the ground plane is less than 2 in the entire bandwidth. The overall size of this patch antenna is 17x6.4 mm^2.

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