AN EFFICIENT PATCH ANTENNA WITH IMPROVED BANDWIDTH FOR FUTURE APPLICATIONS

Gulzar Ahmad[1], M. Inayatullah Babar[2]

ABSTRACT

In this article the inherent demerits of the patch antenna like low bandwidth and low efficiency have been addressed. A wideband and efficient microstrip patch antenna of 9×18mm^2 size has been proposed for satellite and other fields of communications in future. The size of the antenna is very small and will definitely require a small space in the electronic equipment. An efficient substrate material was employed in the antenna that is known as Preperm L-450. Dielectric constant of this mentioned material is 4.4 and its height or thickness is 1.64mm. Different methods were engaged to expand its bandwidth from 9.07GHz to 13.13GHz. The reflection coefficient of -45dB at the central frequency, a gain of 7dBi and total efficiency of 0.99 have been demonstrated by this proposed design of the patch antenna. This novel structured wide band and high efficient antenna can be engaged in various types of wireless applications in near future.

KEYWORDS: *Return Loss, Bandwidth, Gain, VSWR, Ku & K Bands, DGS*

INTRODUCTION

Microstrip patch antenna has the inherent characteristics of low profile, compact size and easy fabrication. Different structures of patch antennas just as U-patch, E-patch, hexagonal patch, M-patch, A-patch and defected patches have been presented in (Dwivedi *et al.*, 2013; Yang *et al.*, 2001; Mandal *et al.*, 2016; Srivastava *et al.*, 2014; Khandelwal *et al.*, 2014) for the improvement of the different features of the patch antenna. The polygonal patch and creation of triangular slots on patch of the antenna have been discussed in different literature. The bandwidth (BW) and Gain of the patch antenna has been enhanced with the implementation of Defected Ground Structure (DGS) technology (Guha *et al.*, 2011; Guha *et al.,* 2014). A defected patch with defected ground plane was concluded in (Singh *et al.*, 2017). Flame Retardant (FR4) dielectric material was used in the substrate of this antenna. This substrate material was 1.6×10^{-3}m thick. The bandwidth of the patch antenna under discussion is 5.9GHz and it ranges from 10.5GHz to 16.4GHz. The size of the above mentioned antenna was 25 × 23 ×1.6 mm^3 and it was recommended that this antenna can be a good candidate for satellite communication. The resonant frequencies of the aforementioned antenna were in the X-band and Ku- Band. A G-patch antenna with defected ground structure has been explained in (Singh *et al.*, 2013) and the defects in the patch as well as in the ground have improved some desirable characteristics. In (Bhadouria *et al.*, 2014) size of the antenna was 17 × 17mm^2. Flame Retardant (FR4) dielectric material was used in the substrate of this antenna as well and this material was 1mm thick. Well-known mechanism of DGS was implemented during the investigation. Slots were etched on the patch and thus the proposed antenna had achieved a BW of 1.23GHz. The DGS structured antenna of (Ebyiy *et al.*, 2017) had reduced the size. The material of dielectric substrate was the same as employed in (Singh *et al.*, 2017) and (Bhadouria *et al.*, 2014).This material was 1.6×10^{-3}m thick. This antenna was 27× 10^{-3}m long and 30×10^{-3}m wide. Miniaturization of the mentioned antenna was accomplished successfully. A circular defect was introduced in the ground of the antenna of (Khandelwal *et al.*, 2013).Transmission Feed line was used to energize this antenna. It has been concluded in this work that the antenna has obtained a BW of 56.6 % with lower frequency of 9.8GHZ and higher frequency of 17.55GHz and its gain is 12.08dB.U slot was created on the basic patch of (Wu *et al.*, 2013) and it has been reported that this antenna has improved the BW significantly.

Slots were made in the patch antenna of (Gupta *et al.*, 2016).Flame Retardant (FR4) dielectric material was used in the substrate of this antenna. A BW of 4.7GHz was accomplished in C-Band for Satellite Communication. The shape of the patch was hexagonal in (Suresh *et al.*, 2015) and one slot was also made in this patch for

1 Department of Electrical Engineering, UET Peshawar, Pakistan,
2 Vice Chancellor, UET Taxila, Pakistan

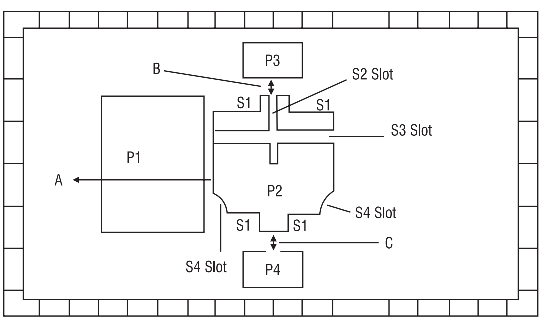
Ku-band satellite communication systems. The change in the parameters of the slot has obtained linear as well as circular polarization.

Slots were created in the patch of (Basra *et al.*, 2014) and this patch was rectangular. The area of the patch was 41.4×49.4mm2 .The material of the Substrate was Taconic TLY-5. The height of the substrate was 1.6mm and its relative permittivity was 2.2. The BW of the antenna was improved in this work.

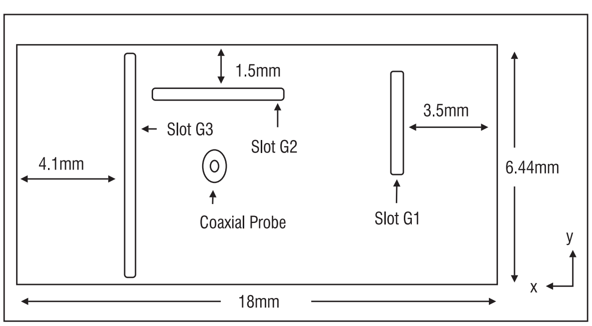
ANTENNA DESIGN METHODOLOGY

Slots were created in the main Patch P_2 and the defected ground structure (DGS) technique was implemented in the 1st microstrip patch antenna of Fig. 1. It is evident from the Fig. that some slices have been removed from the patch. Four equal slices S_1 were removed from the main patch P_2. The vertical rectangular slot S_2 and the horizontal rectangular slot S_3 have also been made on the main patch. Two slots each represented by S_4 of equal radius R_1 were made on the lower sides of the main patch after the elimination of S_1.

This antenna is 18mm long and 6.4mm wide as elaborated in the following Fig.



(a)



(b)

Fig. 1: First Structure (a) Patch Side (b) Ground Side

Antenna was excited by a 50 Ω coaxial cable and dimensions of this 1st structure are demonstrated in Table 1. Area of all the patches in this table is represented by L×W mm^2. Where, W and L stand for width and length respectively. Three slices namely G_1, G_2 and G_3 were engraved in the ground. Substrate's dielectric material was Preperm L-450. Dielectric constant of this mentioned material was 4.4 and its height or thickness was 1.64mm. Copper material was used in the construction of all five patches and ground of the structure and thickness of this copper was 0.035mm. Centers of the main patch, ground plane and substrate were located at *x=0 and y=0.* Location of coaxial cable was 1.6mm along x-axis. First antenna's specifications and dimensions are elaborated in Table 1 and Table 2. Size of the central radiating patch P1 given in the table was considered before the elimination of all slices.

Table 1: First Antenna's Dimensions

Sign	Explanation	Dimensions
L×W	Size of the ground / substrate	6.4×18 mm^2
L1× W1	Size of the main patch P2 before the elimination of the slots	3.2×4.2 mm^2
L1× W2	Size of the unexcited patch P1	3.2×3.5 mm^2
L2× W3	Size of the patch P3 and the patch P4	0.8×2.0 mm^2
S1	Dimensions of all four S1	1.6×0.4 mm^2
A	Partition between patches P1 and P2	0.3 mm
B	Separation between patches P2 & P3	0.45 mm
C	Separation between patches P2 & P4	0.5 mm

Table 2: First Antenna's Specifications

S. No	Explanation	Value
1	Specifications of Slice S2	0.2×1.6 mm^2
2	Specifications of Slice S3	4.1×0.3 mm^2
3	Specifications of Slice G3	0.4×6 mm^2
4	Specifications of Slice G2	5×0.25 mm^2
5	Specifications of Slice G1	0.5×2.8 mm^2
6	Curvature of circular slice S4	0.5 mm

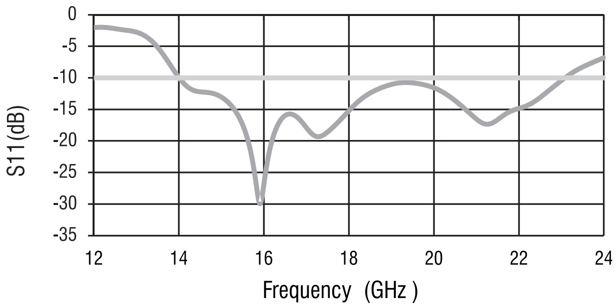


Fig. 2: Reflection Coefficient of First Antenna

Bandwidth of this 1st antenna is demonstrated in Fig. 2.

Bandwidth (BW) of this first Antenna was 9.07GHz; lower frequency of this BW was in Ku band while the higher frequency was in K band. A reflection coefficient of -30dB was recorded at 15.91GHz. Ratio of maximum to minimum voltage was well below 2 and gain of this antenna is explained in Fig. 3. Minimum value of gain in the entire bandwidth was 4.5dBi and its maximum value was 6.5dBi.

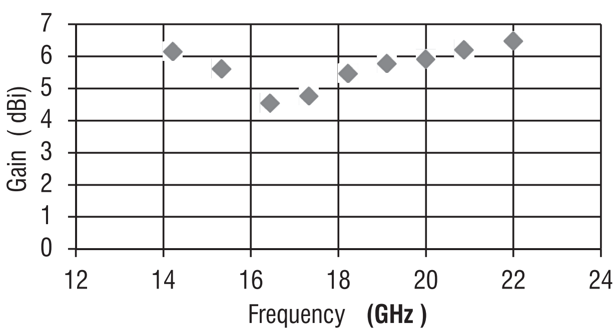


Fig. 3: First Antenna's Gain

Bandwidth Augmentation

BW of this structure was augmented by making changes in slices G_1, G_2 and by etching fourth slice from the ground. Modified form of this antenna will be known as second antenna in this article for further explanation. Specifications of all ground slices are specified in Table 3 and are shown in Fig. 4.

Due to modification in DGS, bandwidth of this antenna was augmented to 10.25GHz as explained in Fig. 5. Lower frequency occurred in Ku band while higher frequency was in K band. Center frequency of the mentioned bandwidth was 20.54GHz.

Table 3: Specifications of Ground Slices

S. No	Explanation	Value (mm^2)
1	Specifications of Slice G1	0.5×3.1
2	Specifications of Slice G2	0.4×6
3	Specifications of Slice G4	4×0.5
4	Specifications of Slice G3	5×0.25

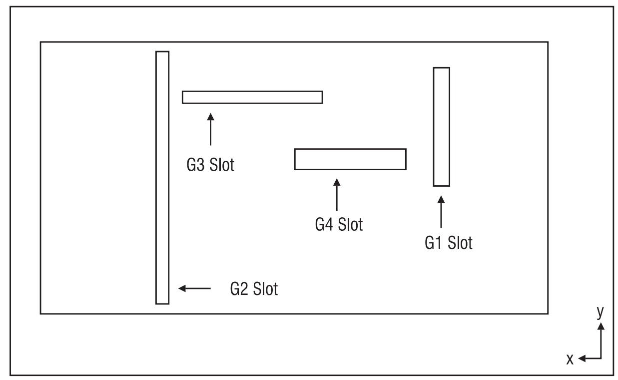


Fig. 4: Ground of the 2nd Antenna

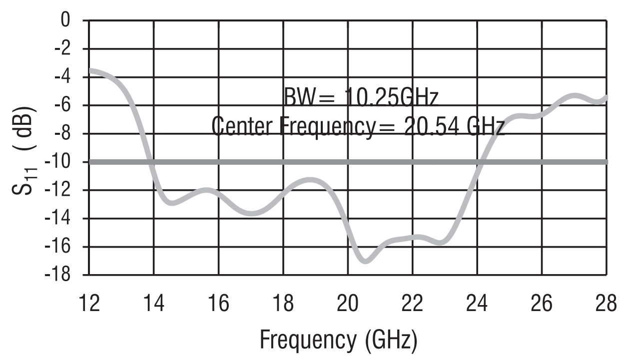


Fig. 5: S11 of the second Antenna

VSWR and Efficiency

The subject cited ratio was less than 2 and is demonstrated in Fig. 6.

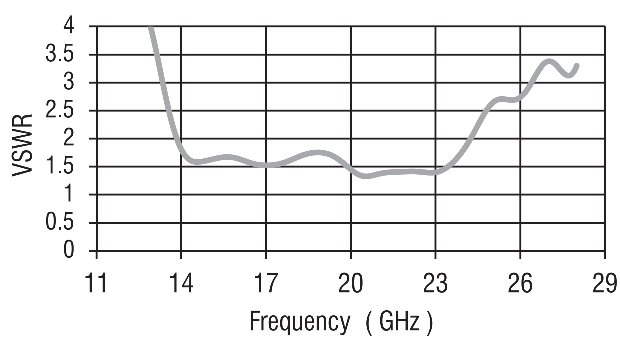


Fig. 6: Second Antenna's VSWR

Efficiency of this second antenna is depicted in Fig. 7. Total efficiency was in between 90% and 96.6%. Radiation efficiency was in between 98% and 99.3%.

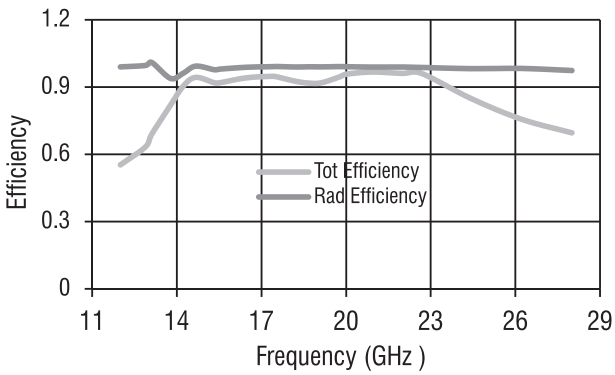


Fig. 7: Efficiencies of the Second Structure

For Further improvement in the bandwidth, the length of this second antenna was increased, the ground structure was adjusted and the new dimensions of the DGS can be noted from Table 4. This antenna was 18mm long and 9mm wide.

Table 4: Changes in Ground Structure

S. No	Explanation	Worth (mm2)
1	Size of G1	0.4×3.1
2	Size of G2	0.2×6.4
3	Size of G3	6.3×0.7
4	Size of G4	5.5×0.6

Explanation of Outcomes

The above mentioned modification enhanced the bandwidth from 10.25GHz to 12.65GHz. The center frequency was 20.68GHz and the reflection coefficient was less than -10dB in the above mentioned BW as depicted in Fig. 8. VSWR which is due to standing wave phenomenon was less than 2 as demonstrated in Fig. 9.

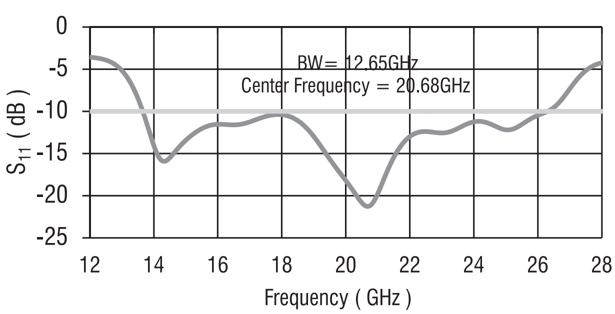


Fig. 8a: S11 of the Modified Design

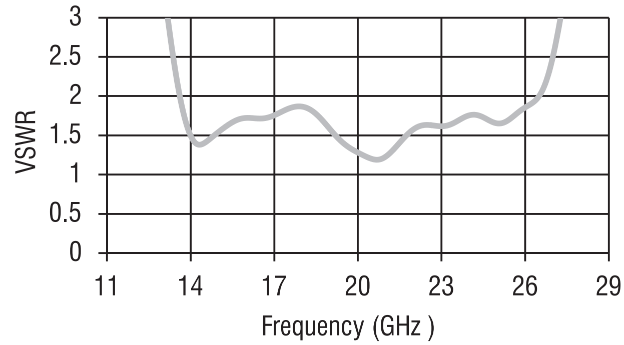


Fig. 8b: SWR of the 2nd Modified Design

Gain was varying from 5dBi to 7dBi as given in Fig. 9.

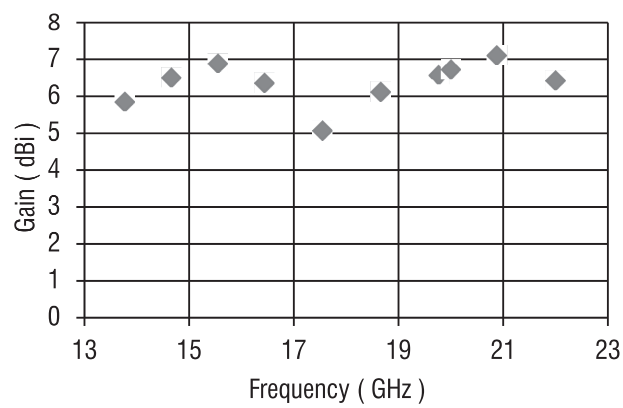


Fig. 9: Gain (dBi) of the 2nd Modified Structure

Design of the Final Structure

Further modification was made in the above mentioned design and a cavity was created at the center of the substrate which was 2mm long and 2mm wide. Views of this proposed design are explored in Fig. 10 & Fig. 11 and its details are listed in Table 5.

This last structure was 9mm long and 18mm wide. Coaxial cable was inserted at 1.6mm along x-axis.

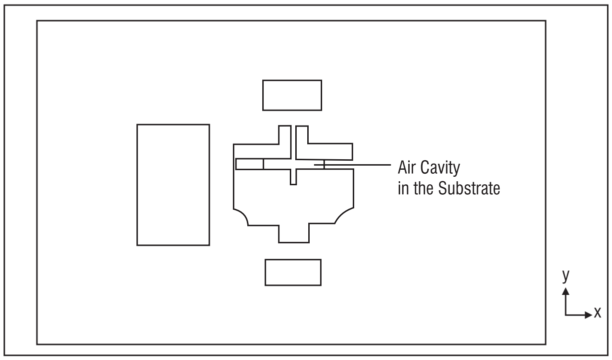


Fig. 10: Patch Side of the Final Structure

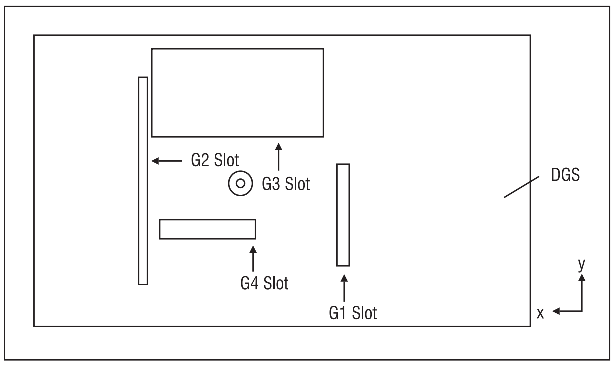


Fig. 11: Ground Side of the Final Structure

Table 5: Details of all the changes

S. No	Explanation	Worth (mm2)
1	Slice S2 Size	0.2×1.6
2	S3 Size	4.1×0.3
3	G1 Size	0.4×3
4	G2 Size	0.2×6.4
5	G3 Size	6.3×2.7
6	G4 Size	3.5×0.6

Explanation of the Final Outcomes

Reflection Coefficient

Reflection coefficient in dB was sketched and its minimum value was -45dB as exposed in Fig. 12. Bandwidth was expanded to 13GHz which started from 14.42GHz and went up to 27.55GHz. 15.36GHz is the frequency at which S11 got the above mentioned minimum value.

SWR of the Final Design

The value of SWR was kept below 2 as plotted in Fig.

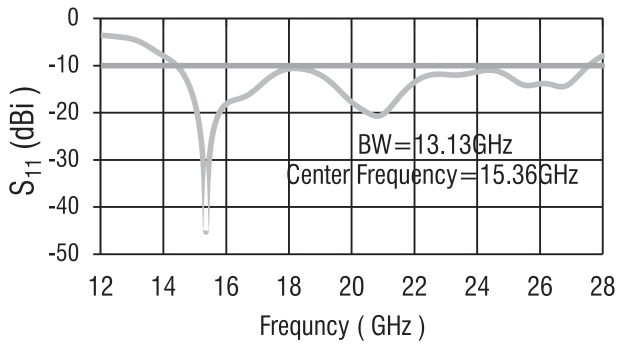


Fig. 12: S11 in Decibels

13 and it approximately touched the minimum possible value of 1 at 15.36GHz.

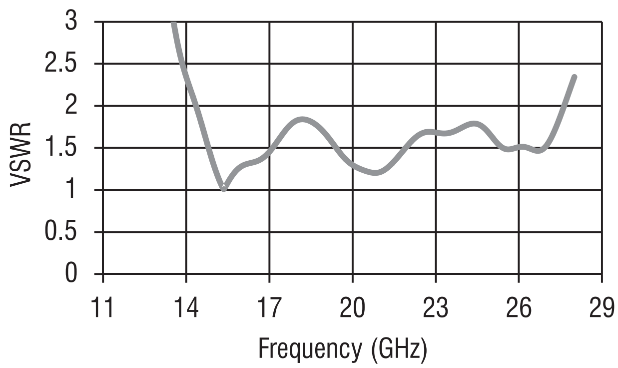


Fig. 13: Final Structure's SWR

Final Structure's Efficiency

Fig. 14 displays efficiency and it was slightly varying from 0.90 to 0.99, while radiation efficiency was larger than 0.99.

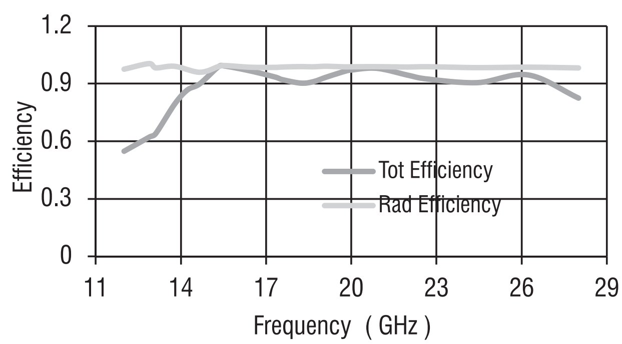


Fig. 14: Final Structure's Efficiencies

Final Structure's Gain

Variation in Gain which was observed during simulation of this design was from 5dBi to 7dBi and it can

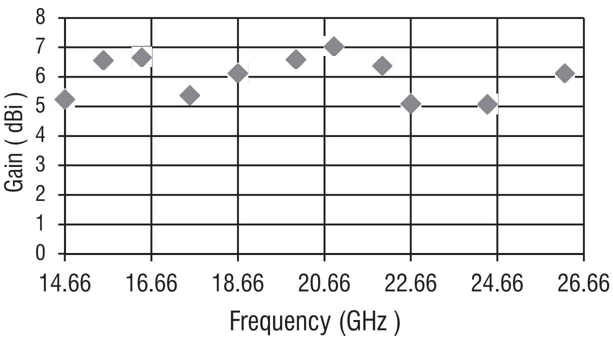


Fig. 15: Gain

be confirmed from Fig. 15 as well.

2D Radiation Patterns

The mentioned pattern at the random frequency of 14.66GHz is displayed in Fig. 16a. The antenna has broadside radiation pattern with magnitude of 5.23dBi and an angular width of 94^0.

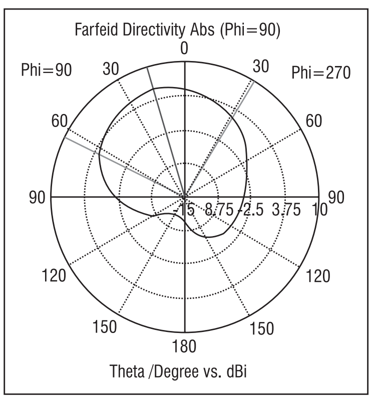


Fig. 16a: Radiation Pattern at 14.66GHz

This pattern at the random frequency of 19.77GHz is displayed in Fig. 16b, which was broadside with magnitude of 2.82dBi and an angular width of 97.3^0.

Similarly pattern at the random frequency of 22.66GHz is displayed in Fig. 16c, which is broadside radiation pattern with magnitude of 1.04dBi and an angular width of 117.2^0.

The pattern at 24.44GHz is depicted in Fig. 16d, with magnitude of 1.77dBi and an angular width of 111.3^0.

The current research work is compared with the previous research in Table 6 and in light of this comparison it is concluded that its efficiency is pretty high and its bandwidth is very large and can be declared a successful candidate for future applications.

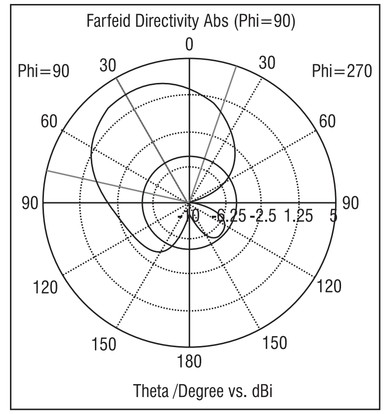


Fig. 16b: Radiation Pattern at 19.77GHz

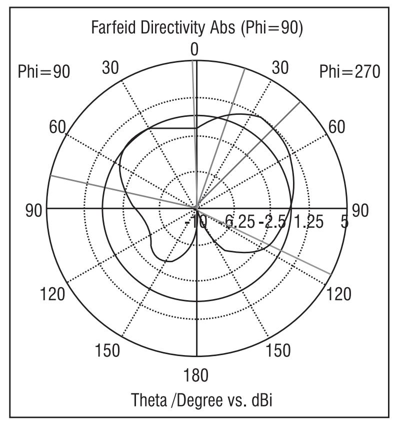


Fig. 16c: Radiation Pattern at 22.66GHz

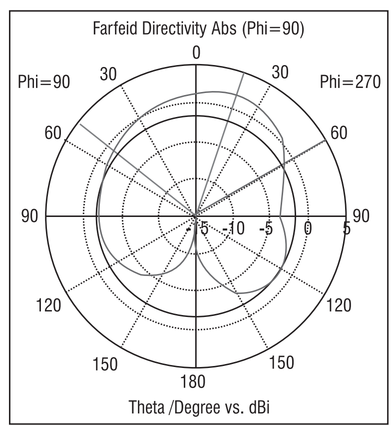


Fig. 16c: Radiation Pattern at 24.66GHz

CONCLUSION

The bandwidth of the initial antenna was 9.07GHz. Its lower frequency was in Ku band while its higher frequency was in K band. VSWR along the standing wave for this initial design was held below the desired level of 2 in the impedance *bandwidth*s of the first structure. Gain was varying from 4.5dBi to 6.5dBi. For further improvement in bandwidth, changes were incorporated in the initial design and thus the final structure of the proposed antenna was 18mm long & 9mm wide. Bandwidth was extended from 9.07GHz to 13GHz and a reflection coefficient of -45dB was recorded at 15.36GHz. The working frequency of the mentioned BW started from 14.42GHz and went up to 27.55GHz. SWR along the standing wave for this proposed design was held below the desired level of 2 in its impedance bandwidth and its Gain went up to 7dBi. Total efficiency was varying from 0.90 to 0.99. The area of the substrate / ground was 9×18mm^2.

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