

Comparison of CPW Fed Microstrip Patch Antennas with Varied Ground Structures for Fixed Satellite Applications

Deepanshu Kaushal, T. Shanmuganatham

Abstract—This paper draws a comparison between two microstrip patch antennas having different ground structures. The designs utilize 45 mm x 40 mm x 1.6 mm FR4 epoxy substrate (relative permittivity of 4.4 and dielectric loss tangent of 0.02) and CPW feeding technique. The design 1 uses conducting partial ground plates along the two sides of the radiating X'mas tree shaped patch. The design 2 utilizes an X'mas tree shaped slotted ground structure that features a circular radiating patch. A comparative analysis of results of both designs has been carried. The two designs are intended to serve the fixed satellite applications in X and Ku band respectively.

Keywords—CPW feed, partial ground structures, slotted ground structures, fixed satellite applications.

I. INTRODUCTION

OVER the recent years, a wide research interest has been witnessed in the field of satellite communication technology. Today, the entire world seems to be interconnected by the satellite communication networks. Based on the revised FCC regulations, the range of frequencies covering 11.28 GHz and those around 12.52 GHz may be utilized for fixed satellite ((space to earth) and (earth to space)) applications. The microstrip patch antennas have extremely thin profile, light weight and they occupy less volume of the satellites on which they get mounted. Their planar structure accounts for their conformability to the satellite structure. These antennas (single element/array) may be fabricated together with the feeding network using simple etching technique thus making the fabrication economical. Also, the microstrip patch antennas may be integrated with the active components and circuits into one module and it is easy to realize circular polarization, dual-frequency, and dual polarization operations for them.

Several existing literatures related to the works over the microstrip patch antennas have been referred. In [1], the swastik shaped patch antenna that was proposed by Shanmuganatham for fixed satellite applications achieved a reflection coefficient of -11.6 dB and a gain of 3.3 dBi. The microstrip danger shaped patch antenna proposed by Kaushal [2] offered a gain of 4.9 dBi with a bandwidth of 4.61 MHz.

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The wideband circularly polarized antenna proposed by Wu et al. [3] that used a metasurface superstrate for C- band satellite communication application achieved an average gain of 5.8 dBi. The compact antenna proposed by Islam [4] for small satellite applications achieved a gain of 7.2 dBi and a bandwidth of 13 MHz. The compact high gain antenna for small satellite applications proposed by Arneri [5] achieved a bandwidth of 80 MHz. The design 1 proposed in this paper achieves a reflection coefficient of -19.1 dB at 12.52 GHz with a peak gain of 9.45 dBi and a bandwidth of 780 MHz while the design 2 attains a reflection coefficient of -15.8 dB at 11.28 GHz with a peak gain of 8.68 dBi and a bandwidth of 1.38 GHz. Both designs may be used for fixed satellite applications [6] in X and Ku bands respectively. Section I briefly describes the microstrip patch antennas and their suitability for satellite applications. The two proposed antenna designs are described in Section II. Section III gives the parametric study of the two designs. The results for the two designs have been given and compared in Section IV.

II. ANTENNA DESIGNS

A. Design 1

The design 1 shown in Fig. 1 uses a X'mas tree shaped patch (green) over a 45 mm x 40 mm x 1.6 mm FR4 epoxy substrate [7] (blue). The CPW feeding technique [8] has been utilized. The conducting plates on either side of the patch constitute a partial ground (brown). The specifications of the antenna design 1 have been listed in Table I.

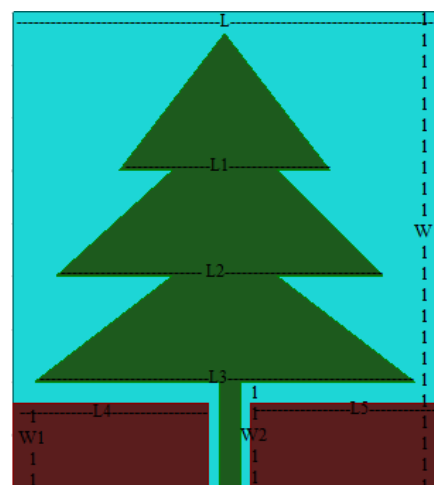


Fig. 1 Geometry of the Proposed Design 1

TABLE I
 GEOMETRIC SPECIFICATIONS OF PROPOSED DESIGN 1

Parameter	Value (mm)
L	40
W	45
L1	20
L2	30
L3	35
L4	18.5
L5	17.5
W1	8
W2	10

B. Design 2

The design 2 uses a ground plane (brown) that has been slotted in the form of a X'mas tree. The slotted ground features a circular conducting patch (green). The feeding technique used is again CPW feed. The design is shown in Fig. 2 and the geometrical specifications are listed in Table II.

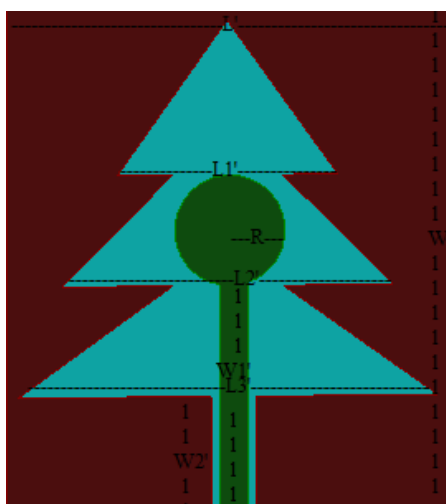


Fig. 2 Geometry of the Proposed Design 2

III. PARAMETRIC ANALYSIS

Both designs utilize FR4 epoxy substrate of relative permittivity [9] 4.4 and dielectric loss tangent of 0.02 [10]. The feeding technique used is CPW feed. The design 1 uses conducting partial ground plates on the either sides of a centrally placed X'mas tree shaped patch. The design 2 uses a ground plane that has X'mas tree shaped slot. The slotted

ground plane features a circular conducting patch. The designs have been simulated over HFSS v-15 [11]. The two designs have been analyzed for various plots including the reflection coefficient, bandwidth, radiation pattern, gain, directivity, VSWR and field patterns (E-field, H-field and surface current). Finally, the results are compared.

TABLE II
 GEOMETRIC SPECIFICATIONS OF PROPOSED DESIGN 2

Parameter	Value (mm)
L'	40
W	45
L1'	20
L2'	30
L3'	35
L4	18.5
W1'	20.1
W2'	10
R	5

IV. RESULTS

A. Design 1

1. Reflection Coefficient and Bandwidth

Fig. 3 shows that the proposed design 1 achieves a reflection coefficient [12] of -19.1 dB at 12.52 GHz with a bandwidth [13] of 780 MHz around it.

2. Radiation Pattern and Gain

Fig. 4 shows the radiation pattern [14] plot for the proposed design 1. A maximum gain [15] of 9.2 dBi achieved at 12.52 GHz was discussed.

3. Directivity

Fig. 5 shows that a peak directivity [16] of 5.7 dB is achieved at 12.52 GHz.

4. VSWR

Fig. 6 indicates that a VSWR [17] value of 1.25 is achieved at 12.52 GHz.

5. Distribution of Fields

Figs. 7-9 indicate the E-field [18], H-field [19] and the surface current distributions [20] for the proposed design 1 at 12.52 GHz.

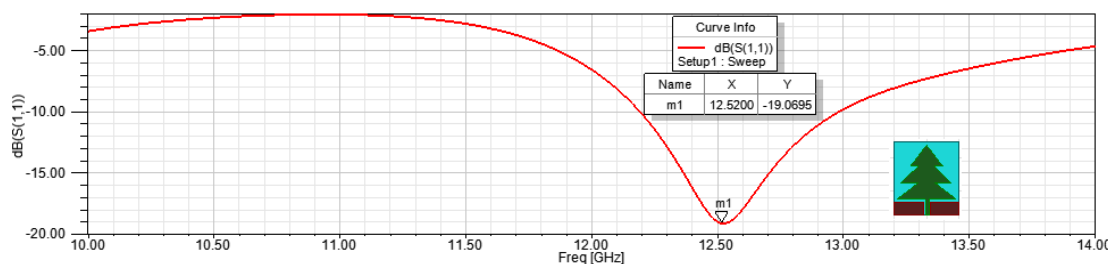


Fig. 3 Reflection Coefficient curve of the Proposed Design 1

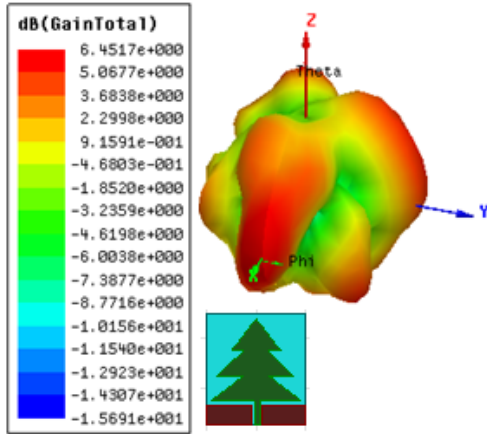


Fig. 4 Radiation Pattern Plot of the Proposed Design 1

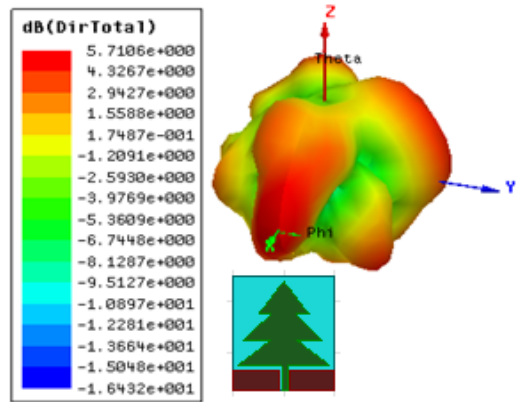


Fig. 5 Directivity Plot of the Proposed Design 1

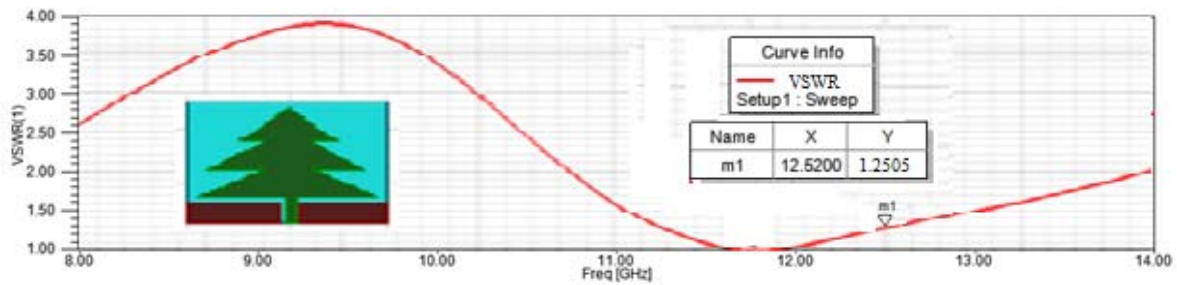


Fig. 6 VSWR Plot of the Proposed Design 1

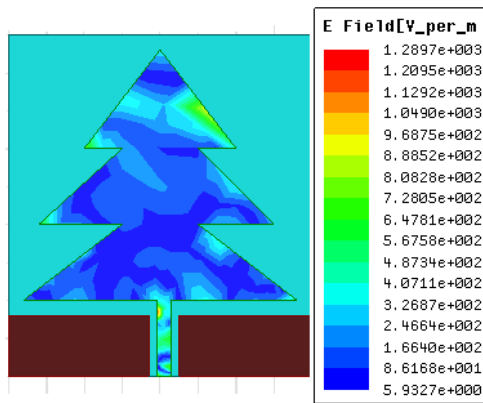


Fig. 7 E- field Distribution of the Proposed Design 1

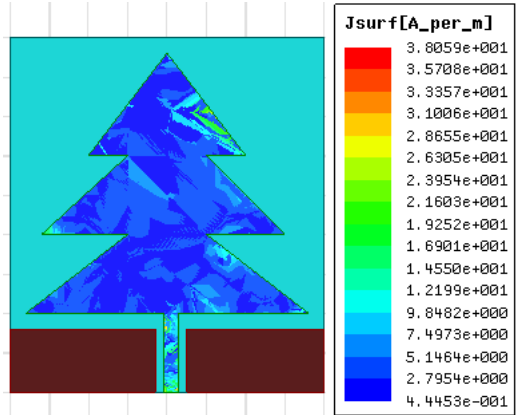


Fig. 9 Surface Current Distribution of the Proposed Design 1

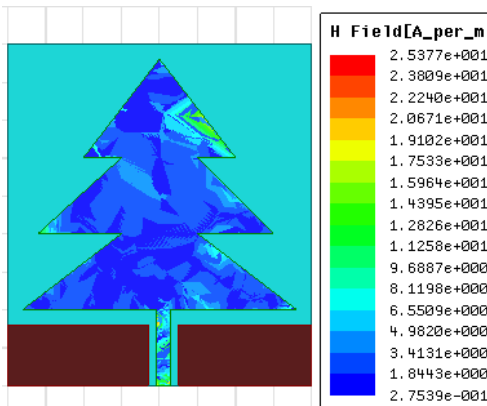


Fig. 8 H- field Distribution of the Proposed Design 1

B. Design 2

1. Reflection Coefficient and Bandwidth

Fig. 10 indicates that the proposed design [21] 2 achieves a reflection coefficient of -15.8 dB at 11.28 GHz.

2. Radiation Pattern and Gain

Fig. 11 shows the radiation pattern of the proposed design 2 and indicates a maximum gain of 9.9 dBi achieved at 11.28 GHz.

3. Directivity

As shown in Fig. 12, the maximum directivity achieved in case of the proposed design 2 at 11.28 GHz is 6.7 dB.

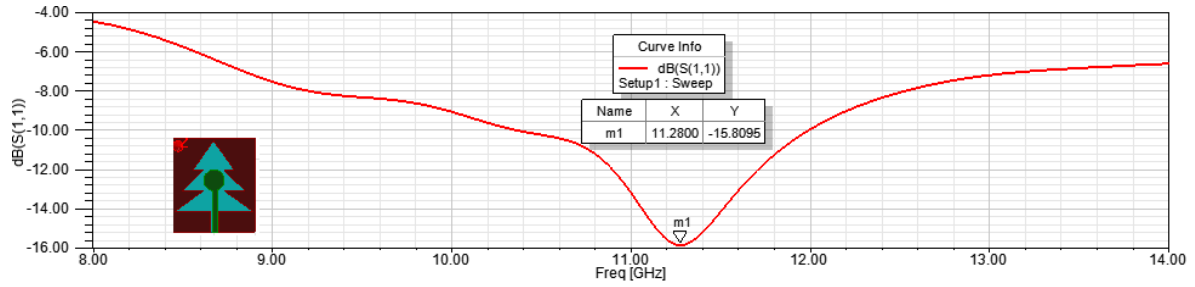


Fig. 10 Reflection Coefficient curve of the Proposed Design 2

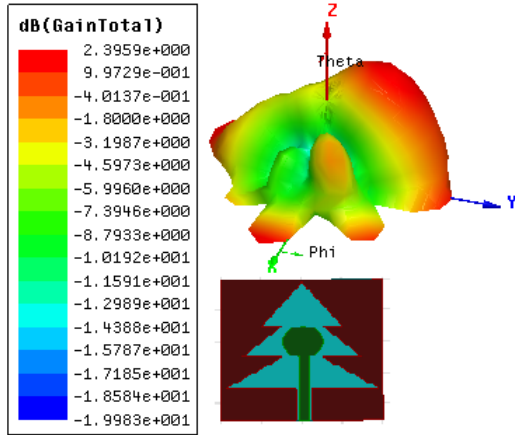


Fig. 11 Radiation Pattern Plot of the Proposed Design 2

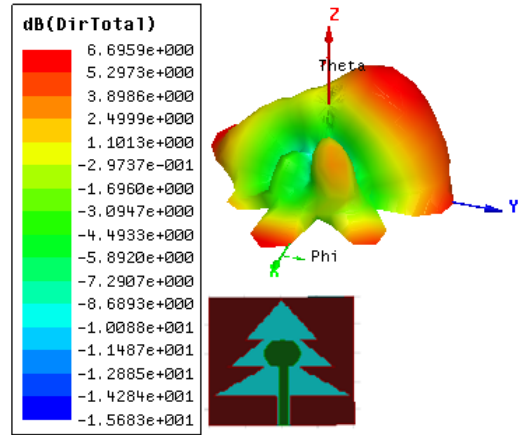


Fig. 12 Directivity Plot of the Proposed Design 2

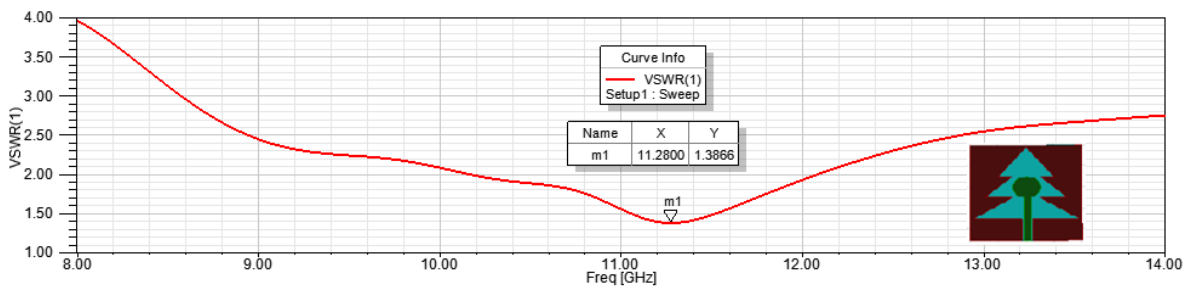


Fig. 13 VSWR Plot of the Proposed Design 2

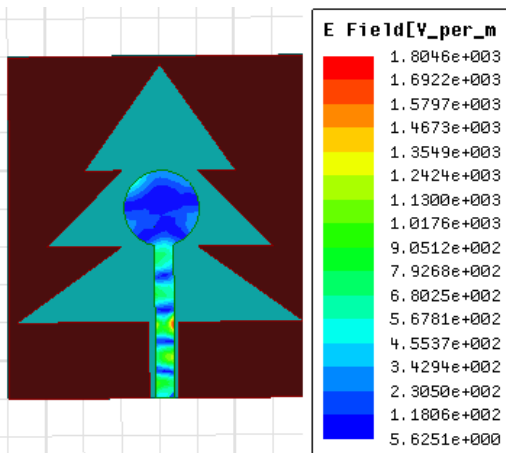


Fig. 14 E- field Distribution of the Proposed Design 2

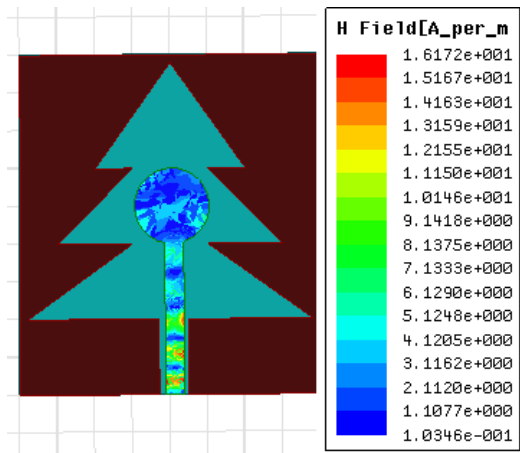


Fig. 15 H- field Distribution of the Proposed Design 2

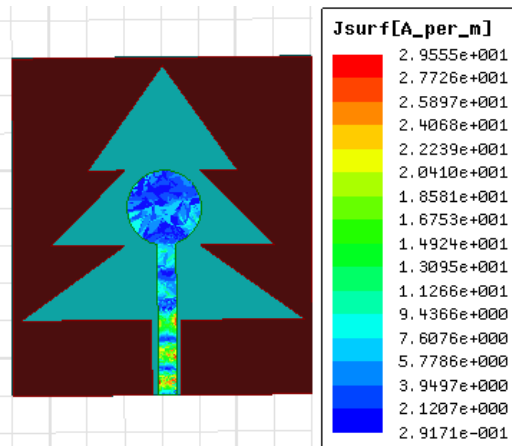


Fig. 16 Surface Current Distribution of the Proposed Design 2

TABLE III
COMPARATIVE ANALYSIS OF THE RESULTS

Parameter	Proposed Design 1	Proposed Design 2
Number of Bands	Single (1)	Single (1)
Operating Frequency (GHz)	12.52	11.28
Reflection Coefficient (dB)	-19.1	-15.8
Gain (dBi)	9.15	9.972
Directivity (dB)	5.7	6.7
VSWR	1.25	1.38
Applications	Fixed Satellite	Fixed Satellite

3. VSWR

Fig. 13 indicates that the proposed design 2 achieves a VSWR value of 1.38 at 11.28 GHz.

4. Distribution of Fields

The distribution of different fields including the E- field, H- field and the surface current for the proposed design 2 are indicated in Figs. 14-16.

Table III draws a comparison of the significant characteristics of the two proposed designs.

V.CONCLUSION

The design of two CPW fed microstrip patch antennas with varied ground structures is proposed. Both designs utilize FR4 epoxy substrate of relative permittivity 4.4 and dielectric loss tangent 0.02. Design 1 utilizes partially conducting ground plates along the two sides of a radiating X'mas tree shaped patch and achieves a reflection coefficient of -19.1 dB, peak gain of 9.15 dBi, peak directivity of 5.7 dB and VSWR of 1.25. Design 2, on the other hand, uses an X'mas tree shape slotted ground plane featuring a conducting circular patch. Design 2 achieves a reflection coefficient of -15.8 dB, peak gain of 9.97 dBi, peak directivity of 6.7 dB and a VSWR of 1.38. The two designs may be used for fixed satellite ((earth-space) and (space-earth)) applications.

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