A Compact Slotted Microstrip Antenna for X- Band Application in Satellite Communication

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Abstract - ***The article presents the design of a rectangular shaped compact microstrip patch antenna for X- band application in satellite communication. The proposed antenna is fed using coplanar waveguide (CPW) feed. The proposed antenna is designed on RT/duriod 5880 substrate with thickness of 1.57 mm and relative permittivity of 2.2 having loss tangent 0.0009. The compact size of proposed antenna is 19.4 x 16 mm². Parametrical study is performed to optimize the different antenna parameters. The proposed antenna is able to obtain the frequency bandwidth from 7.24 GHz to 8.6 GHz suitable for uplink/downlink X-band used for satellite communication. The designed antenna has peak gain variation of 2.7 to 3.4 dBi within the operating band. Simulated radiation patterns are stable and omnidirectional over the desired frequency band.***

Keywords*: Coplanar waveguide, Compact Antenna, Irregular slot*

1. INTRODUCTION

Smaller size and wider bandwidth are key requirement for recent developments in communication system for designing a radiating element (antenna). In communication engineering, 7.0 to 11.2 GHz frequency band is set for X band application. IEEE set 8.0 to 12.0 GHz frequency range for radar engineering. The term X-band is stand for extended which is known as generally Extended AM broadcast band. X- Band Satellite Communication operates in the part of the X band or Super High Frequency (SHF) spectrum which is designated by the International Telecommunication Union (ITU) for satellite communication. The ITU designated the frequency band in the range 7.25 GHz to 7.75 GHz for downlink (Space to Earth) and 7.9 GHz to 8.4 GHz for uplink (Earth to Space) for government use. [1]. The X band frequencies has the advantage that it is less affected by rain fade i.e provide higher rain resilience compared to other higher frequency band like Ku or Ka used for satellite communication. This allows extremely high link availability. Microstrip circuits play a important role in designing a radiating element. Small size, low profile, simplicity of manufacturing, compatibility to planar and non-planar surfaces, ease of being integrated with circuits are some of the key advantages of a microstrip antenna.

Few papers have been published in open literature on X –band antenna [2-10]. A steering antenna with dual circular polarized covering the frequency from 7.25 GHz to 8.4 GHz for satellite communications in X band is presented in [2]. Design and implementation of broadband antenna operating in X-band is illustrated in [3]. A Sierpinski fractal shaped microstrip broadband antenna covering the frequency range from 8 GHz to 17 GHz is presented in [4]. A dielectric resonator based three elements dual segment antenna is reported in [5] for X-band application. A printed compact antenna of size 30 x 22 mm² with operating band 6.4 to 13.6 GHz is proposed in [6] using semielliptical shaped slots on ground plane. An X shape slotted rectangular patch antenna is presented for dual band operation for Ku band and K band applications [7]. An inverted S shaped probe feed antenna is presented for multi-frequency application [11]. A high-isolation printed antenna array for marine radar application is presented in [12].

In this work, a CPW fed compact square patch antenna with irregular plus shape slot is proposed. The total dimension of proposed antenna is 19.4 mm x 16 mm x 1.57 mm. The proposed antenna is covering the frequency band from 7.24 to 8.6 GHz suitable for X-band satellite communication.

2. DESIGN OF PROPOSED ANTENNA

The geometry of antenna with different dimensional parameters is shown in Fig-1. The proposed antenna is designed using RT/duriod 5880 substrate of 1.57 mm thick and dielectric constant of 2.2 having loss tangent 0.0009. The dimension of square patch is 10 x 10 mm² with irregular plus shape slotting done inside. The different dimensional parameters of square patch and ground plane (L_1, W_1, L_2 and W_2) and slot parameters (a, b, c, d, e and D) are optimized using Method of Moment based full wave Electromagnetic software simulator, IE3D.

The width w of CPW feed line is adjusted as 2.4 mm corresponding to 50Ω impedance. The other parameters which greatly affect the performance of proposed antenna are:

1. Spacing between ground plane and CPW feed line (parameter s).

2. Spacing between ground plane and square patch (parameter f).

All the dimensional parameters are optimized and finalized based on parametrical studies performed. Comparative performance graph for some of the dimensional parameters are presented in next section.

3. SIMULATION RESULTS AND PARAMETRIC STUDY

Various antenna parameters are analyzed and investigated to improve the impedance bandwidth characteristics of proposed antenna. The analysis of each parameter is carried out by modifying only one antenna parameter at a time keeping the other parameters unchanged. The effect of parameter s, spacing (gap) between CPW feed line and ground plane is presented in Fig-2. It is seen that the impedance bandwidth decreases with increasing s. Better impedance bandwidth is observed for s = 0.2 mm. The effect parameter f, the spacing between square patch and ground plane is shown in Fig- 3. It is observed that both lower and upper -10 dB frequencies points are shifted to higher frequency band with increased value of parameter f. Better and desired frequency bandwidth is obtained for f = 0.3 mm.

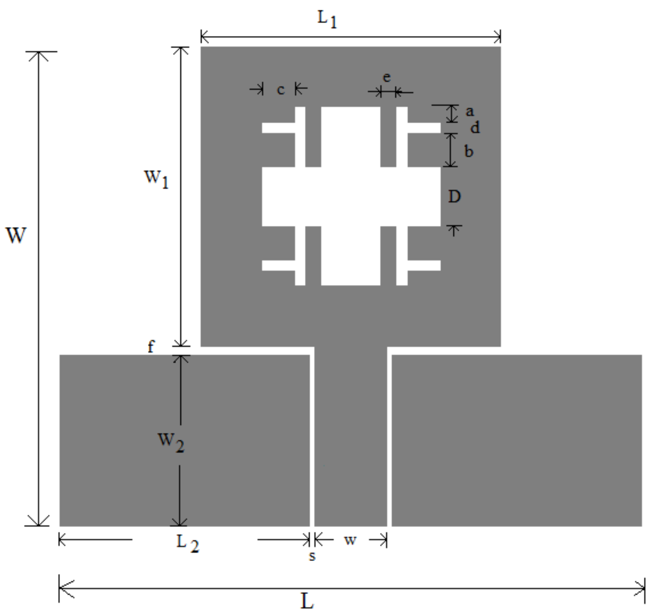


Fig-1. Geometry of proposed antenna

The width of CPW feed line is optimized to improve impedance matching. Better impedance bandwidth denotes the proper impedance matching. Comparative performance with parameter w is shown in Fig-4. It is observed that impedance bandwidth is increased with w up to w = 2.4 mm. Further increase in parameter w causes shift of lower -10dB frequency point towards right above 7.25 GHz, which does not meet the required operating band. Optimum value of w thus taken is 2.4 mm. Return loss performance with variation in length of ground plane parameter L_2 is depicted in Fig-5. The response is shifted toward left side with increased dimension of L_2 and for $L_2 < 8.3$ mm; the required frequency coverage is not achieved. The optimized value of length L_2 is 8.3 mm as larger value of L_2 unnecessary increases the overall dimension of circuit. Fig-6 represents the performance of proposed antenna with parameter W_2, width of ground plane. Noticeable effect is observed with increased dimension of parameter W_2. The lower and upper -10 Db frequencies are shifted towards left with increasing the parameter W_2, the width of ground plane. The required operating frequency band is not achieved for $W_2 < 5.7$ mm. The optimized value of W_2 is taken as 5.7 mm. For $W_2 = 5.7$ mm, the obtained frequency coverage is from 7.245 GHz to 8.63 GHz.

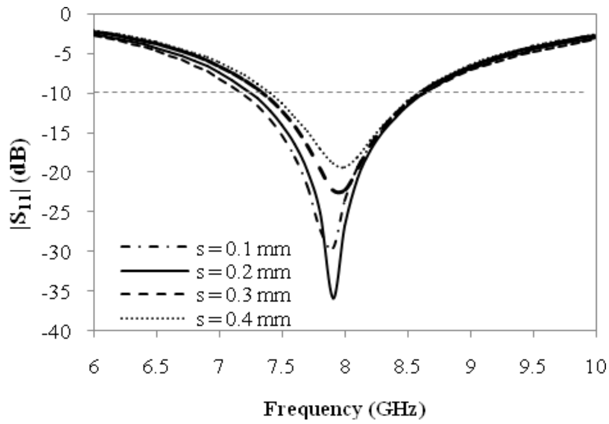


Fig-2. Effect of gap between feed line and ground plane

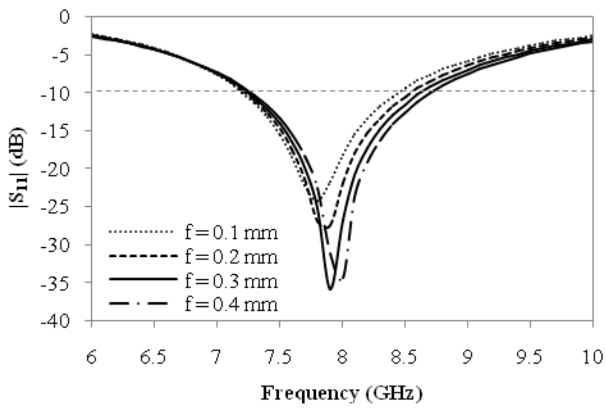


Fig-3. Effect of gap between patch and ground plane

Parametrical studies for all the other dimensional parameters such as square patch parameters L_1 and W_1 and slot parameters (a, b, c, d, e and D) are also performed and optimized values of different antenna parameters and slot parameters are summarized in Table 1.

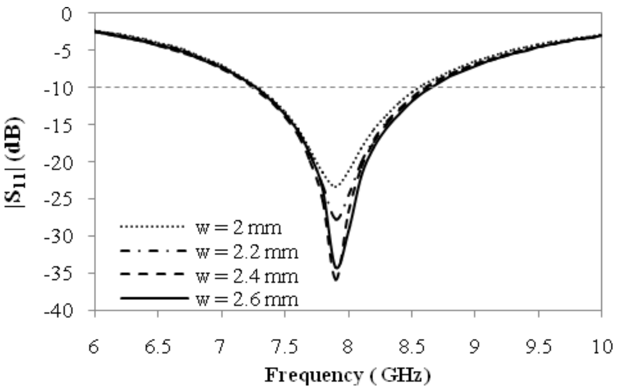


Fig-4. Effect of width of feed line on return loss

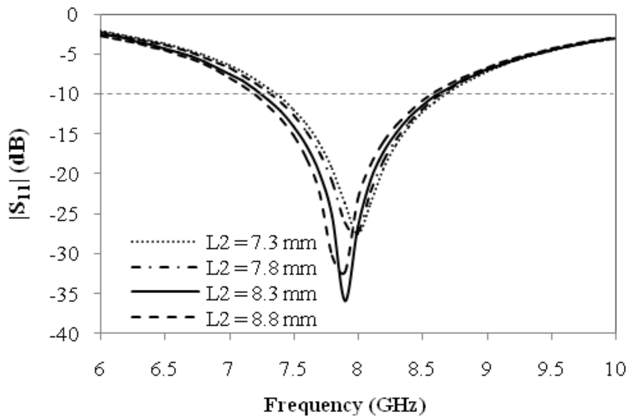


Fig-5. Effect of length of ground plane on return loss

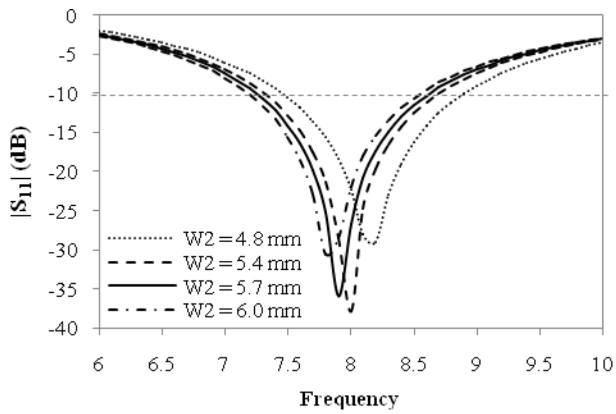


Fig-6. Effect of width of ground plane

Table-1: Optimized dimension of Antenna Parameters

Parameter	L	W	L_1	W_1	L_2	W_2	w	s
Dimension (mm)	19.4	16	10	10	8.3	5.6	2.4	0.2
Parameter	a	b	c	d	e	f	D	
Dimension (mm)	0.5	1.1	1.1	0.4	0.5	0.3	2	

Return loss performance of proposed antenna for optimized dimensional parameters is shown in Figure-7. The proposed antenna is able cover the frequency bandwidth ranging from 7.24- 8.6 GHz (7.25- 7.745 GHz for downlink and 7.9-8.395 GHz for uplink) allotted for X-band Military application used for satellite communication.

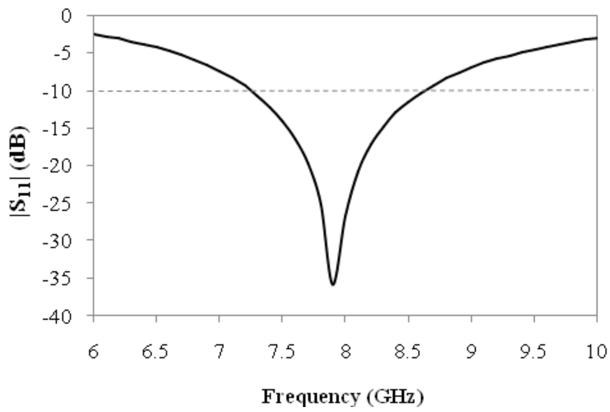


Fig-7. Return loss performance of proposed antenna

The peak antenna gain vs frequency plot of proposed antenna is presented in Figure-8. The maximum gain observed is 3.4 dBi at the frequency of 7.7 GHz with peak gain variation of 0.7 dBi (2.7- 3.4 dBi) within the operating band. the simulated radiation patterns at the resonance frequency 7.9 GHz is depicted in Figure-9. It is observed that the simulated E-plane pattern is bidirectional or like monopole pattern and H-plane pattern is nearly omnidirectional. Also the differences of more than 15 dBi between co polarized and cross polarized pattern both in E-plane and H-plane are observed.

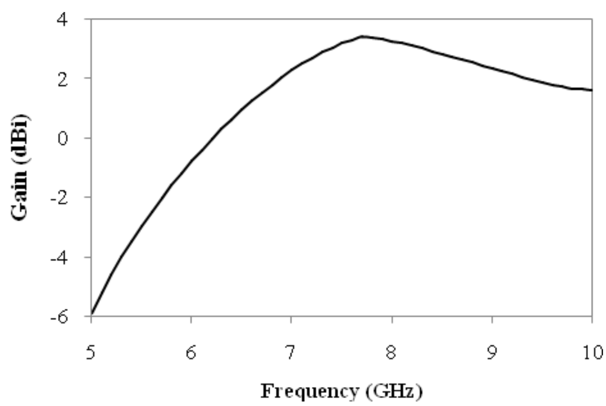
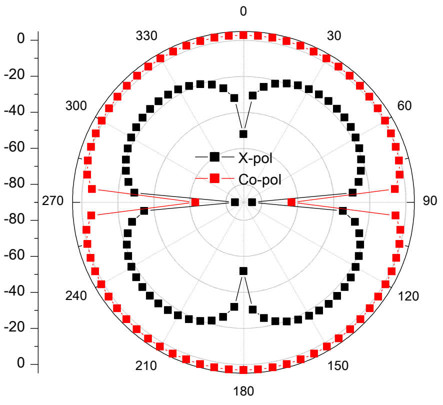
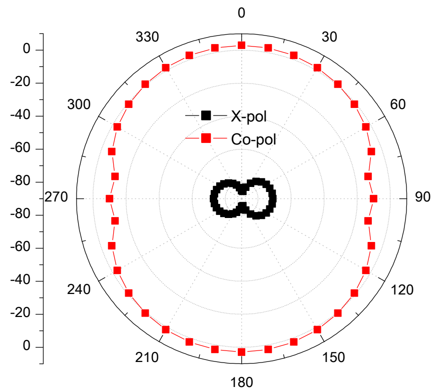


Fig. 8. Total field gain Vs frequency response



(a) E- Plane



(b) H- Plane

Fig. 9. Simulated radiation pattern

4. CONCLUSION

A monopole compact CPW fed slotted microstrip antenna is designed and presented. The proposed antenna is able to cover the entire X-band frequency ranging from 7.24-8.6 GHz allocated to Military uplink/downlink application for satellite communication. The proposed antenna has nearly stable and figure of eight radiation pattern in E-Plane and omnidirectional radiation pattern in H-Plane within the specified frequency band. The proposed antenna is very simple in design, can easily be fabricated and integrated into circuit.

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