IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735.Volume 11, Issue 3, Ver. I (May-Jun .2016), PP 53-57
www.iosrjournals.org

Triple Band Microstrip Patch Antenna with I Slot For Radar Altimeter Applications

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Abstract: *A triband I slot microstrip patch antenna is designed and simulated in this paper. The designed antenna resonates at three bands (4.4-4.7GHz), (5-5.18GHz) and (7.3-15.9GHz).this antenna can be used as a basic element for radar altimeter antenna. The performance of the presented antenna is explained in terms of return loss, resonance frequency, radiation pattern and gain. Design and simulations of the antenna are implemented using High Frequency Structure Simulator Software (HFSS).*

Keywords: *patch antenna, Radar altimeter, microstrip line feed, enhanced bandwidth, HFSS*

I. Introduction

Microstrip patch antenna is a type of radio antenna with low profile, which can be mounted on a flat surface. Microstrip antennas are inexpensive to manufacture and design because of their simple geometry. Narrow bandwidth is one of the disadvantages that patch antenna suffer from [1]. The bandwidth of patch antenna can be enhanced by adding slots to the patch [2-5].the enhanced bandwidth microstrip antenna is fascinating for many applications such as Radar, Satellite communication, biomedical application, Remote sensing etc [5]. The application considered in this paper is radar altimeter. A radar altimeter, radio altimeter (RA) used on aircraft to measure the distance above the ground presently beneath an aircraft by timing how long it takes abeam of radio waves to reflect from the ground and return to the plane. The working band of radar altimeter in navigation applications lies in C-band [6].Radar altimeter find applications in many fields like navigation applications, civil and military applications, and weather applications [6]. All these applications depend on distance measurement which relates to the bandwidth of the altimeter antenna and hence larger bandwidth enable measuring higher altitudes [6]. Radar altimeter is apart of radar. Radar is an object-detection system that uses radio wave to determine the range, the angle, or velocity of objects. For aircraft, radar transmits radio waves to ground or sea level and receives an echo signal after time duration. Speed of vehicle and height between aircraft and ground specify the value of time [6]. Now a days communication and Radar systems development requires development of inexpensive, low profile and light weight antennas to be able to achieve high performance over a wide band of frequencies [7]. Narrow bandwidth can be enhanced by several methods, for example, slotted patch antenna [2-5], increasing the substrate thickness, use of various impedance matching and feeding techniques [8-9]. In this paper, a microstrip antenna with I slot is presented to be the basic element for radar altimeter applications. The antenna is designed at 4.5GHz. I slot is added to enhance the bandwidth. Through this paper, the performance of the antenna is examined using HFSS,and MATLAB program.

II. Antenna Structure And Design

The structure of the designed antenna consists of ground plane, dielectric substrate, and rectangular patch feeding by a microstrip line. Dimensions of rectangular patch antenna are length (L) and width (W). The antenna is designed to resonate at 4.5GHz. The parameters chosen to meet the design requirements are based on transmission line model equations [1] as shown below. The designed parameters are shown in table 1.The dielectric material used for the design is RT-Duroid which has a dielectric constant of 2.2. The thickness of the dielectric substrate is 3.2mm.
The width of the patch antenna is given by:

$$w = \frac{1}{2 f_r \sqrt{\mu_o \varepsilon_o}} \sqrt{\frac{2}{\varepsilon_r + 1}}$$

Effective dielectric constant can be calculated as:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + \frac{12h}{w}\right]^{-\frac{1}{2}}$$

Length extension (ΔL):

The actual length of the

$$\Delta l = 0.412h \frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{w}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{w}{h} + 0.8\right)}$$

patch is:

$$l = \frac{1}{\sqrt{\varepsilon_{reff}}\sqrt{\mu_o \varepsilon_o}} - 2\Delta l$$

I slot is added to enhance the bandwidth. The dimensions of the added slot are l1&w1, slot length and width respectively. "Fig. 1," shows I slot patch antenna. The length and width of the slot is determined using parametric study, the optimum values obtained are 15mm and 2mm.

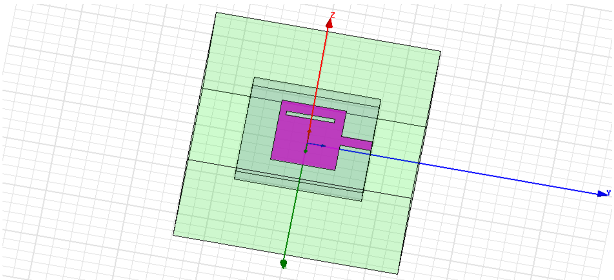

Fig.1: Rectangular patch antenna with I slot

Table 1: Parameters of Rectangular Patch Antenna

PARAMETERS	DIMENSIONS
Patch length(L)	20mm
Patch width(W)	33mm
Substrate length	39.2mm
Substrate width	52.2mm
Substrate thickness	3.2mm
Substrate dielectric constant	2.2mm

III. Parametric Study Of Effect Of Variation Of Slot Width And Position

Effect of variation of slot width is shown in table 2 and "Fig.2," and Effect of variation of slot position is shown in table 3 and "Fig.3".

Table 2: Parametric Study of Effect of Variation in Slot Width

Slot width (mm)	Slot length (mm)	Resonance frequency (GHz)	Return loss (dB)	Bandwidth (GHz)
1.5	15	4.52 5.08 10.68	-29.3861 -15.4509 -28.71	0.28 0.18 8.5
1.8	15	4.52 5.08 10.54	-23.2246 -15.8247 -37.4294	0.29 0.18 8.55
2	15	4.52 5.08 10.68	-25.572 -12.884 -47.158	0.3 0.18 8.6
2.5	15	4.52 10.68	-23.24 -45.8083	0.31 8.61
3	15	4.52 10.82	-21.07 -36.629	0.25 8.6
4	15	4.52 10.82	-18.7056 -40.6874	0.25 5.2

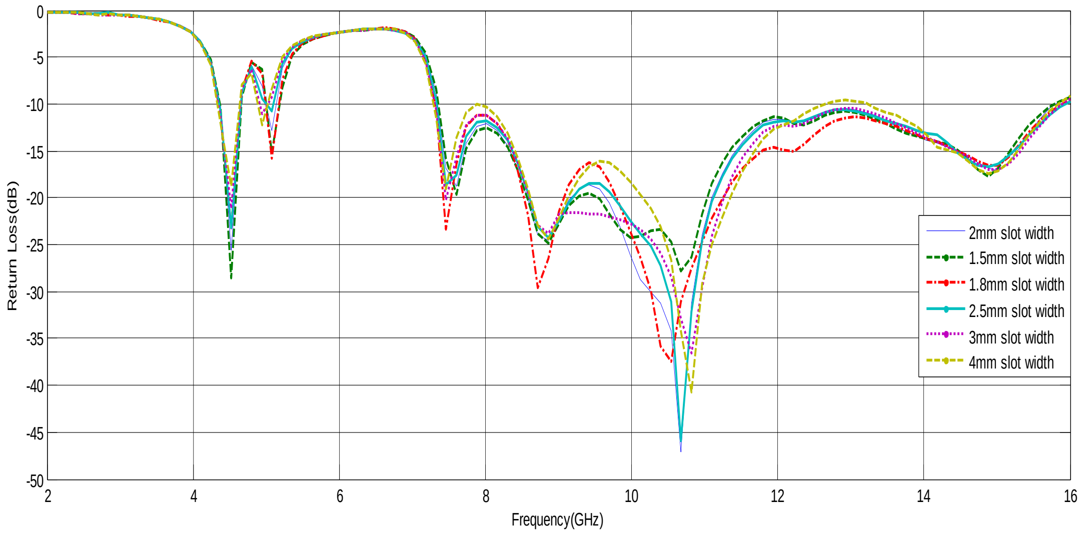

Fig.2: Return Loss with Variation in Slot Width

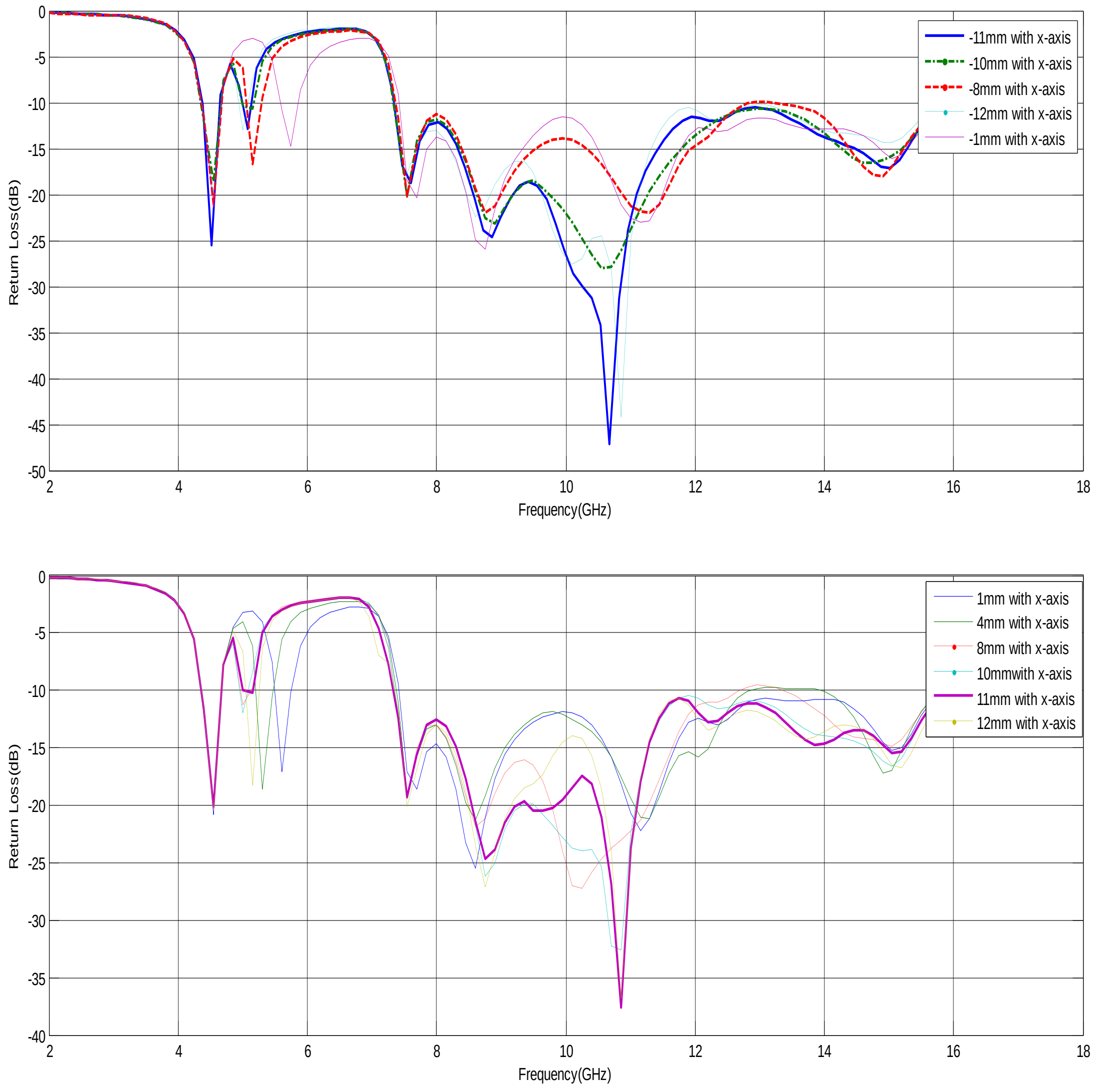

Fig.3: Return Loss with Variation in Slot Position

Table 3: Parametric study of effect of variation of slot position

Slot Width and Length(mm)	Position of Slot with X axis(mm)	Return Loss(dB)	Operating Band(GHz)	Bandwidth (GHz)
2 x 15	-1	-21.3665 -14.7589 -22.8948	4.4-4.7 5.6-5.9 7.3-16.1	0.3 0.3 8.8
2 x 15	1	-20.8621 -17.0656 -25.5579	4.4-4.7 5.5-5.75 7.4-16	0.3 0.25 8.6
2 x 15	-4	-30.8493 -20.0595 -24	4.4-4.7 5.4-5.7 7.3-15.9	0.3 0.3 8.6
2 x 15	4	-19.6565 -18.5802 -21.3061 -16.9625	4.4-4.7 5.2-5.5 7.4-12.8 14-15.8	0.3 0.3 5.4 1.8
2 x 15	-8	-21.1447 -16.6927 -21.9857 -17.9494	4.4-4.7 5.1-5.3 7.3-12.8 13.3-16	0.3 0.2 5.5 2.7
2 x 15	8	-19.7517 -11.2 -27.1828 -14.8222	4.4-4.7 5.1-5.2 7.3-12.6 13.5-15.8	0.3 0.1 5.3 2.3
2 x 15	-10	-18.5668 -27.9068	4.4-4.7 7.3-16	0.3 8.7
2 x 15	10	-20.2227 -32.5764	4.4-4.7 7.35-15.9	0.3 8.55
2 x 15	-11	-25.572 -12.884 -47.7595	4.4-4.7 5-5.18 7.3-15.9	0.3 0.18 8.6
2 x 15	11	-20.0614 -37.565	4.4-4.7 7.3-16	0.3 8.7
2 x 15	-12	-19.7389 -44.2132	4.4-4.7 7.3-15.7	0.3 8.4

It is observed from table 2 and "Fig.2" that the best value of the width of the slot is 2mm, and it is shown that from table 3 and "Fig.3" that the optimum value of the position of the slot with x-axis is -11mm.

IV. results and simulation

The results of the proposed antenna are shown in figures 4, 5, and 6. The results include return loss, gain, and VSWR. There is three bands centered at 4.52G,5.08G,and 10.68GHz with return loss of -25.572dB,-12.884dB, and -47.158dB respectively. The bandwidth of the three bands as follow 300MHz, 180MHz, and 8.6GHz. This antenna be able to work in three bands of radar (C-band,X-band,and ku-band) with minimum loss.

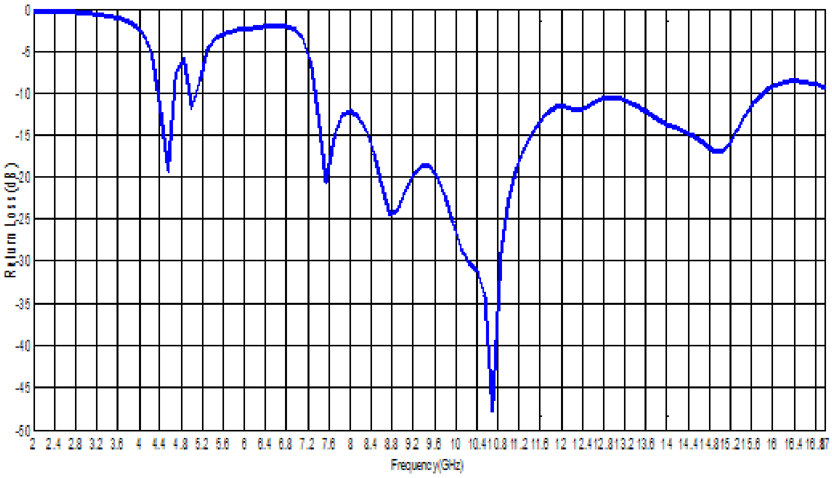

Fig.4: Return Loss for I slot patch antenna

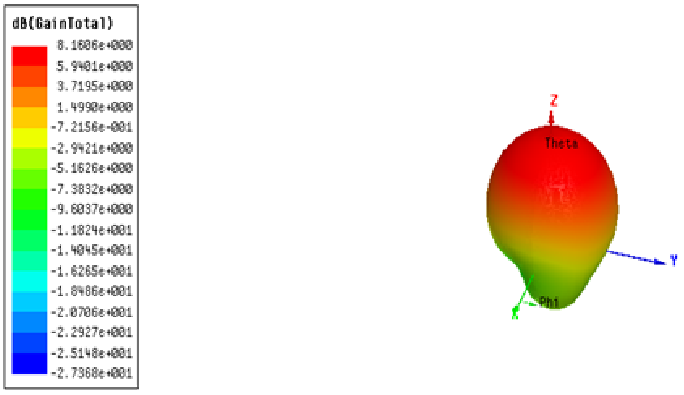

Fig.5: Gain Total for I slot patch antenna

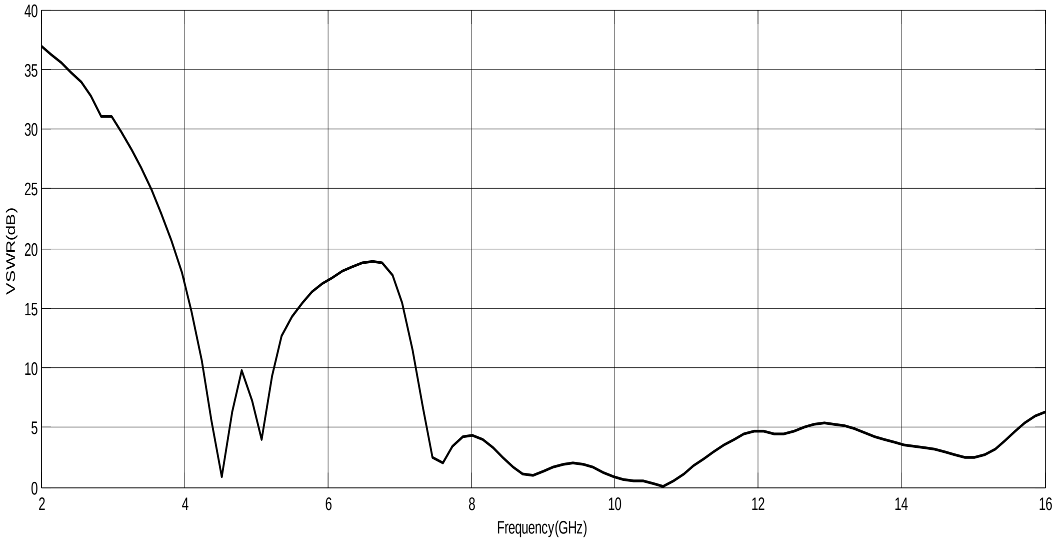

Fig.6: VSWR for I Slot patch antenna

V. Conclusion

In this paper, Microstrip patch antenna with I slot at 4.5GHz has been designed and simulated. From the results this antenna serves wide band applications and it can be used as a basic element for radar altimeter antenna. It is covered three bands of radar as explained. The effects of variation in slot width and slot position on bandwidth and return loss have been explained. The design of microstrip antenna has been done using ANSOFT HFSS, MATLAB Program.

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