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Design, simulation and analysis of a Penta Band Microstrip Patch Antenna with a Circular Slot

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***Abstract*—This paper is based on design, simulation and analysis of a penta-band microstrip patch antenna with a circular slot. Roger 4350 has been chosen as the substrate material for the proposed antenna which has electrical permittivity of 3.48. A circular slot has been created within a 30 x 30 square patch. The dimensions of the slot, patch as well as that of the edge for probe feed have been optimized for obtaining desired results.**

***Index Terms*—Microstrip Patch Antenna, Penta-band, circular slot**

I. INTRODUCTION

Microstrip Patch Antennas are popular for low-profile applications at frequencies above 100 MHz (λo < 3 m). They commonly consist of a rectangular or square metal patch on a thin layer of dielectric (called the substrate) on a ground plane. The assembly is usually contained inside a plastic radome which protects the antenna structure from damage. Patch antennas are simple to fabricate and easy to modify and customize. Patches may be photo-etched making them adaptive for low-cost, mass production. Microstrip or patch antennas are becoming increasingly useful because they can be printed directly onto a circuit board. Microstrip antennas are becoming very widespread within the mobile phone market. Patch antennas are low cost, have a low profile and are easily fabricated. The recent trend in this field is to design a cost effective multiband-patch which is suitable to be operated in multiple microwave frequency bands for application in various microwave technologies. [1], [2]

II. DESIGN

A 30 x 30 mm patch is designed in IE3D environment. A circular slot is created at the centre of the patch. The optimized radius of the slot is taken as 6.5 mm. The objective of the design is to obtain five resonant peaks in the S_{11} vs Frequency graph. The knowledge of resonant peaks is extremely important while designing a multiband patch antenna. In previous works it has been observed how the number of resonant peaks as well as dips changes with the change in the patch dimensions. [8]

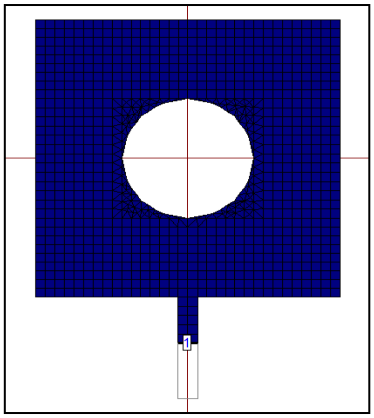

Fig. 1 *Square patch with a circular slot*

III. SIMULATION RESULTS

The average current distribution on the antenna surface is displayed in Fig. 2

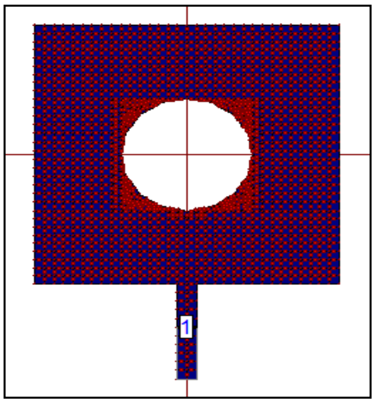

Fig. 2 *Average current distribution*

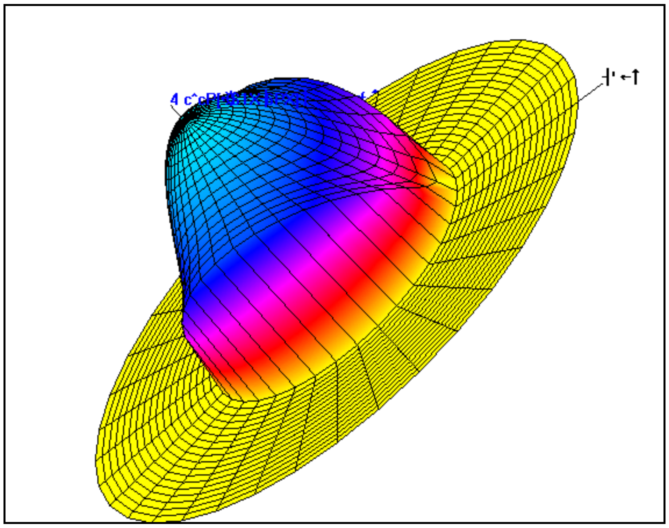

Fig. 3 *Radiation Pattern*

A **radiation pattern** defines the variation of the power radiated by an antenna as a function of the direction away from the antenna. This power variation as a function of the arrival angle is observed in the antenna's far field. Fig. 3 shows the 3D radiation pattern of the simulated structure. The radiation pattern is a plot which allows us to visualize where the antenna transmits or receives power.

TABLE I:

Return Loss, S11, VSWR and Reflection Loss [4]

Return Loss (dB)	S_{11}	VSWR	Reflection Loss (dB)
3.0	-3.0	5.85	3
6.0	-6.0	3.0	1.26
7.0	-7.0	2.6	0.97
8.0	-8.0	2.3	0.75
9.0	-9.0	2.1	0.58
10.0	-10.0	1.9	0.46
11.0	-11.0	1.8	0.36
12.0	-12.0	1.7	0.28
13.0	-13.0	1.6	0.22
14.0	-14.0	1.5	0.18
15.0	-15.0	1.4	0.14
16.0	-16.0	1.4	0.11
17.0	-17.0	1.3	0.09
18.0	-18.0	1.3	0.07
19.0	-19.0	1.3	0.06
20.0	-20.0	1.2	0.04

S_{11} is a measure of how much power is reflected back at the antenna port due to mismatch from the transmission line. A VSWR of 1 is ideal; this indicates that there is no reflected power at the antenna port. When the antenna and transmission line are not perfectly matched, reflections at the antenna port travel back towards the source and cause a standing wave to form. A VSWR ≤ 2 is acceptable for an antenna. So, values of $S_{11} \leq 10$ are considered as the margin for resonant peaks- TABLE I.

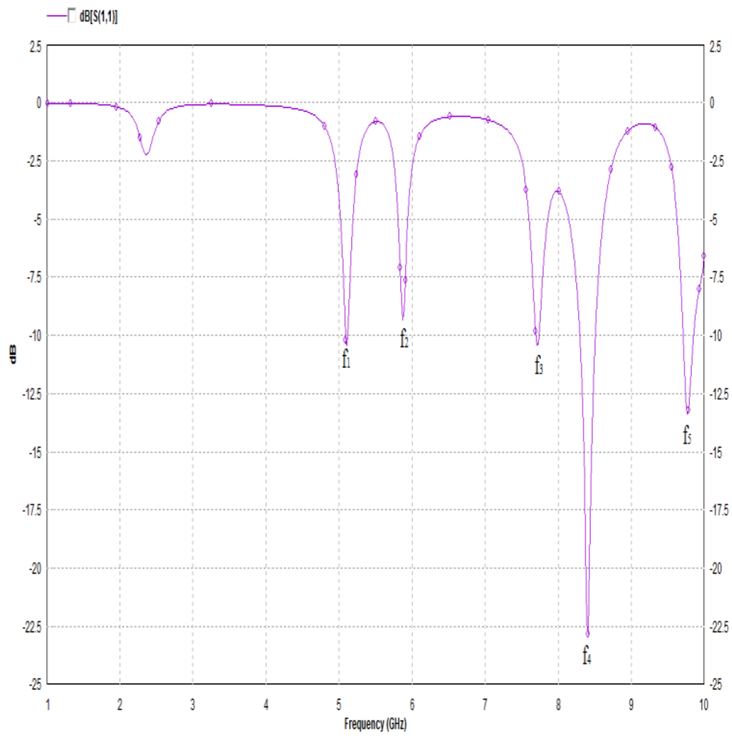

Fig. 4 *S_{11} vs Frequency*

Fig. 4 shows the *S_{11} vs Frequency* curve of the proposed penta-band antenna. Five resonant peaks namely f_1, f_2, f_3, f_4 and f_5 have been observed from the graph.

1st resonant peak - f_1 :
(a) Frequency: 5.11 GHz (b) S_{11}: -10.43 dB (c) VSWR: 1.86

2nd resonant peak - f_2 :
(a) Frequency: 5.87 GHz (b) S_{11}: -09.35 dB (c) VSWR: 2.03

3rd resonant peak - f_3 :
(a) Frequency: 7.70 GHz (b) S_{11}: -10.44 dB (c) VSWR: 1.86

4th resonant peak - f_4 :
(a) Frequency: 8.41 GHz (b) S_{11}: -22.83 dB (c) VSWR: 1.15

5th resonant peak - f_5 :
(a) Frequency: 9.76 GHz (b) S_{11}: -13.39 dB (c) VSWR: 1.54

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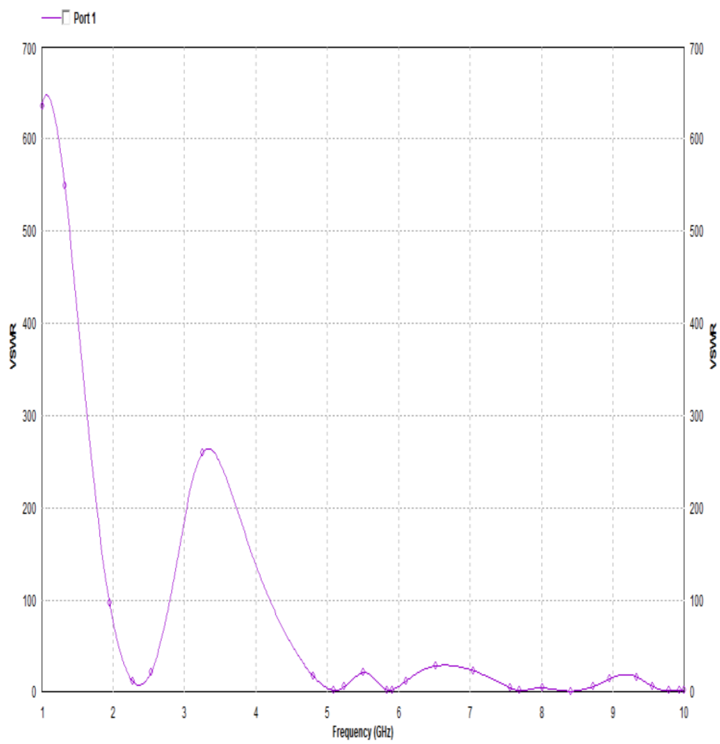

Fig. 5 *VSWR vs Frequency*

Antenna gain is usually defined as the ratio of the power produced by the antenna from a far-field source on the antenna's beam axis to the power produced by a hypothetical lossless isotropic antenna, which is equally sensitive to signals from all directions. Usually this ratio is expressed in decibels, and these units are referred to as "decibels-isotropic" (dBi). Power gain (or simply gain) is a unitless measure that combines an antenna's efficiency $E_{antenna}$ and directivity D,

$$G = E_{antenna} . D \quad (1)$$

Fig. 6 shows that the proposed antenna has the maximum gain at a frequency of 7.70 GHz.

Directivity of an antenna is a measure of how 'directional' an antenna's radiation pattern is. An antenna that radiates equally in all directions would have effectively zero directionality, and the directivity of this type of antenna would be 1 (or 0 dB). It measures the power density the antenna radiates in the direction of its strongest emission, versus the power density radiated by an ideal isotropic radiator (which emits uniformly in all directions) radiating the same total power. Fig. 7 shows the *Total Field Directivity vs Frequency* curve of the proposed patch.

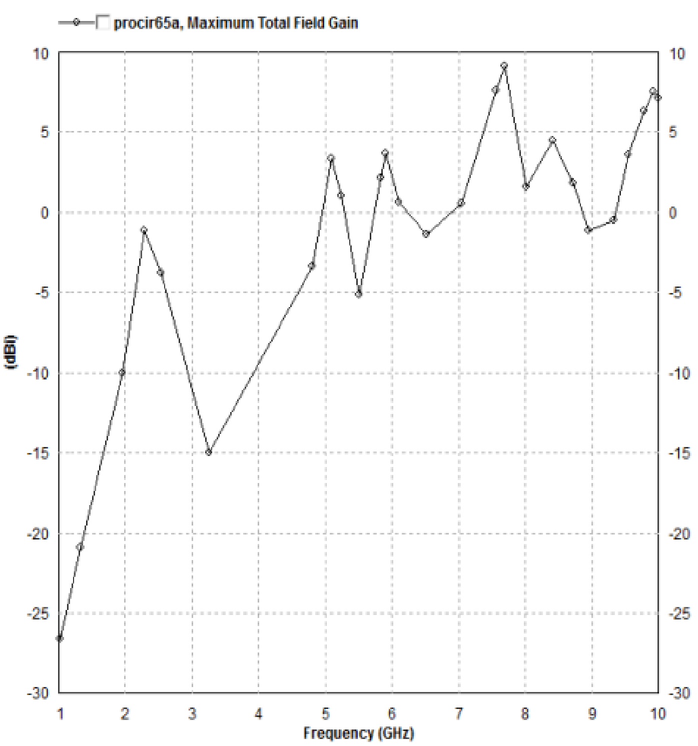

Fig. 6 *Maximum Total Field Gain vs Frequency*

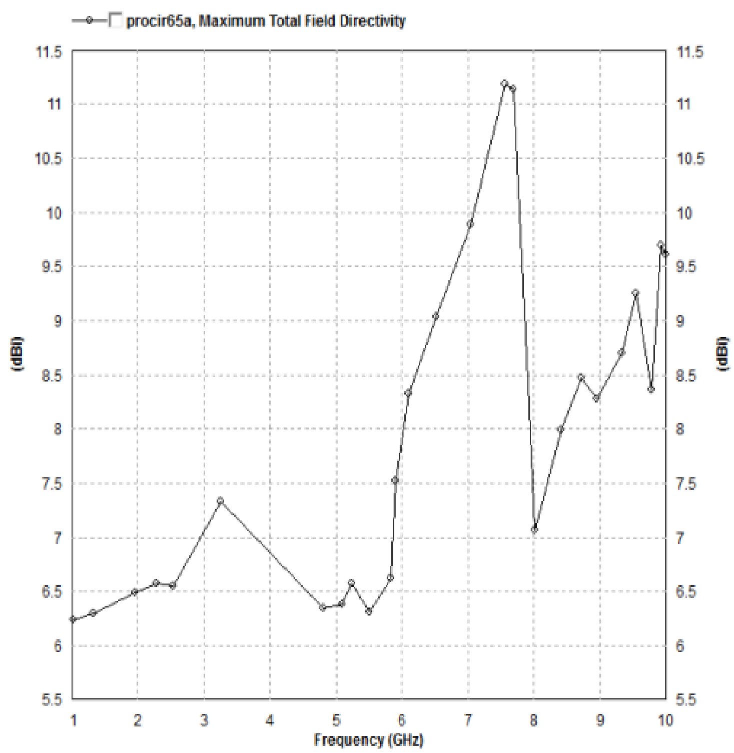

Fig. 7 *Maximum Total Field Directivity vs Frequency*

In antenna theory, **Antenna efficiency** is a loose term usually meaning radiation efficiency, often abbreviated to efficiency. It is a measure of the efficiency with which a radio antenna converts the radio-frequency power accepted at its terminals into radiated power.

The efficiency of an antenna relates the power delivered to the antenna and the power radiated or dissipated within the antenna. A high efficiency antenna has most of the power present at the antenna's input radiated away. A low efficiency antenna has most of the power absorbed as losses within the antenna, or reflected away due to impedance mismatch. Efficiency is very often quoted in terms of a percentage; for example, an efficiency of 0.5 is the same as 50%.

Fig. 8 shows the *Efficiency vs Frequency* curve of the proposed patch.

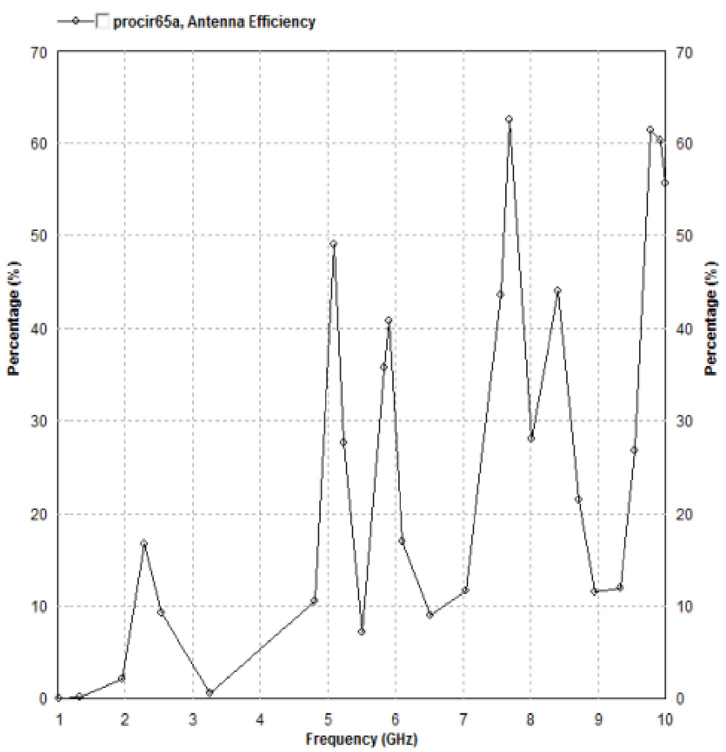

Fig. 8 *Efficiency vs Frequency*

The **Smith Chart** is a fantastic tool for visualizing the impedance of a transmission line and antenna system as a function of frequency. Smith Charts can be used to increase understanding of transmission lines and how they behave from an impedance viewpoint. Smith Charts are also extremely helpful for impedance matching.

Fig. 9 shows the Smith Chart of the proposed structure, which establishes the variation of Characteristic Impedance, Load Impedance, VSWR and the Reflection co-efficient for the prescribed set of frequencies from 1 GHz to 10 GHz.

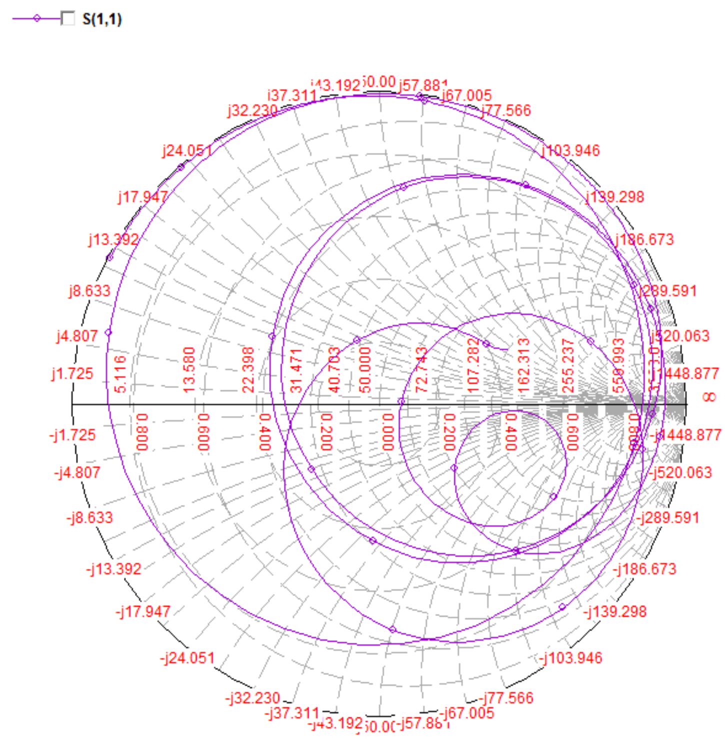

Fig. 9 *Smith Chart*

IV. CONCLUSION

The analysis of the different simulation results reveals that the proposed antenna is capable of producing effective type of responses in the multiple frequency bands. At the five different operating frequencies the S_{11} parameter is always kept less than or almost equal to -10 dB and the VSWR is kept less than or at least equal to 2 since a VSWR of less than or equal to 2 is acceptable for an antenna. Multiband patch antenna is extremely important for today's communication system. Multiband applications are possible by means of a single and portable radiating system. The future scope of this project is based on optimization of the patch dimensions for more effective type of responses.

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