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Design of irregular Diamond Shape Microstrip Patch Antenna with U slot to Enhance bandwidth for S band applications

Satyendra Kumar Swarnkar [1], Dr.Anand kumar Tripathi[2],Dr.Zakir Ali[3]

[1](Research Scholar in Electronics and communication Department, P.K. University Thanara ,Shivpuri, India)
[2](Professor in P.K. University Thanara ,Shivpuri, (M.P.) India)
[3](Associate Professor in Electronics and communication Department, Bundelkhand University, Jhansi India)

Abstract

Now a day's developing wireless communication systems (WCS), mobile communications, direct broad banding technique (DBT), wireless local area networks (WLANs) suggest that demand for Microstrip antennas and array will increase even further. In this paper the bandwidth of microstrip patch antenna is enhanced by using U slot technique and chooses a dielectric layer which is covered by copper material. Here two patches, one is radiating patch and second is ground are used to enhance the bandwidth and whole Geometry resonates at their operating frequency (6 $GH_{z.}$) which is in the S band. Glass Epoxy material is used as dielectric between radiating patch and ground plane. The dimension of radiating element is adjusted to achieve desired resonant frequency. The coaxial probe feeding technique is used for its simplicity. Zeland IE3D simulation software used for antenna simulation and effects of physical parameters are investigated. These works obtains the efficiency, bandwidth directivity, and gain of microstrip antenna and can be increased by some changes in structure with cutting slot. The bandwidth is found as 57.85% and the return loss as -19.5dB which is higher as compare to conventional patch antenna.

Keywords: Bandwidths, Return loss, U slot Microstip patch Antenna, Efficiency, VSWR.

1. Introduction

The S band is covering frequencies from 2 to 6 GHz. Thus it crosses the conventional boundary between the UHF and SHF bands at 3.0 GHz. This frequency band is used by airport surveillance radar , weather radar, surface ship radar, and some satellites. The mini radar short-band ranges from 1.55 to 5.2 GHz. The S band also contains widely used for low power microwave devices such as wireless headphones, cordless phones, (Wi Fi), and microwave ovens (typically at 2.495 GHz). Printed microstrip patch antennas [1] are getting popular for modern communication system due to their features which includes small size, low cost and ease of fabrication. An extensive work on simple microstrip geometries including rectangular, circular and triangular shaped structures have been reported [2]. The advantages of patch antennas are that they radiate with moderately high gain in a direction perpendicular to the substrate and can be fabricated in a low cost material. Efficiency and Bandwidth of a Microstrip radiator depends upon many factors for as size, shape, substrate thickness, dielectric constant of substrate, feeding techniques and its location, etc. For good performance, a thick dielectric substrate having a low dielectric constant is desirable for higher bandwidth, better efficiency and better radiation [3-5]. Rectangular microstrip patch has been modified for some applications to other shapes. Irregular Diamond shape microstrip antenna has smaller size compared to the square for the high frequency range .At high frequency range, antenna size will very reduce. The small size is an important requirement for portable communication equipments [6-9]. Coaxial probe feed is used to feed the antenna. Thick substrate properties are used for improvement of proposed antenna. Zeland IE3d simulation software is used for output characteristics. IE3D simulation software used for electromagnetic analysis and design in the high frequency range.

2. Antenna designing and geometry

2.1 Resonance Frequency of Antenna

The resonance frequency f_{mn} depends on the patch size, cavity dimension, and the filling dielectric constant, as follows [9][10]:

$$f_{mn} = \frac{k_{mn} c}{2\pi\sqrt{\varepsilon_r}} \quad (1)$$

Where m = 0, 1, 2, and n = 0, 1, 2…, k_{mn} = wave number at m, n mode, **c** is the velocity of light, ε_r is the dielectric constant of substrate, and

$$k_{mn} = \sqrt{\left(\frac{m\pi}{W}\right)^2 + \left(\frac{n\pi}{L}\right)^2} \quad (2)$$

For TM_{01} mode, the length of non-radiating rectangular patch's edge at a certain resonance frequency and dielectric constant according to equation (1) becomes

$$L = \frac{c}{2 f_r \sqrt{\varepsilon_r}} \quad (3)$$

$$W = \frac{c}{f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad (4)$$

Where f_r = resonance frequency at which the rectangular microstrip antennas are to be designed. The radiating edge W, patch width, is usually chosen such that it lies within the range L<W>2L, for efficient radiation. The ratio W/L = 1.5 gives good performance according to the side lobe appearances. In practice[18] the fringing effect causes the effective distance between the radiating edges of the patch to be slightly greater than L. Therefore, the actual value of the resonant frequency is slightly less than f_r. Taking into account the effect of fringing field, the effective dielectric constant for TM_{01} mode is derived using [15,16]

By using above equation we can find the value of actual length of the patch as,

$$L = \frac{c}{2 f_r \sqrt{\varepsilon_{eff}}} - 2\Delta l \quad (5)$$

Where ε_{eff} = effective dielectric constant and Δl = line extension which is given as:

$$\varepsilon_{eff} = \frac{(\varepsilon_r + 1)}{2} + \frac{(\varepsilon_r + 1)}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \quad (6)$$

$$\frac{\Delta l}{h} = 0.412 \frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \quad (7)$$

2.2 Design of the Microstrip Antenna

A conventional microstrip antenna includes a ground plate, radiator unit and power unit. The substrate of L × W × h, the size of radiator slab L × W .The antenna dimensions calculated by microstrip theory [18]. Based on wireless communication standard, the band of the microstrip antenna should be lies between 3-6 GHz Simply taking the work frequency of the microstrip antenna as f = 6 GHz, we get the antenna length L_p = 11.32 mm, the antenna width W_p = 15.20 mm, by using Eq. (1-7) and conceder the finite ground length(L_p+6h), L_g = 20.92 mm and the ground width(W_p +6h), W_g = 24.80 mm, and the thickness of dielectric board h = 1.6 mm.

2.3 Simulation and Result Analysis

Now find the value of return loss on feeding point (10.46mm, 4.8mm) , the basic Geometry of proposed antenna shown in Fig.1 , and simulate the proposed antenna with EM simulator IE3D .All formulas taken by references, then run on operating frequency 6 GHz and evaluates maximum (return loss) reflection coefficient S_{11} with high bandwidth and also find VSWR which is less than 2.

After theoretical analysis we find the reflection coefficient -20.32 dB where simulated and measured result are -20.32dB and -22.75 dB at the resonance frequency 4.5 GHz, 4.5 GHz, respectively which shown in Fig.3 and fig 6., and the VSWR is less than 2 for all resonant frequency as shown in Fig.4 .

BW = f2-f1 / (f2+f1/2) = 7.8-4.3/6.05 = 57.85 %

Fig.5, Fig.7, Fig.8 indicate the Smith chart of proposed microstrip antenna, 3D radiation Pattern and 2D radiation pattern of the proposed geometry by software analysis respectively.Fig.9, Fig.10, Fig.11propesed the Gain (dBi) Vs Frequency, Directivity Vs Frequency and Efficiency (Antenna and Radiating) respectively.

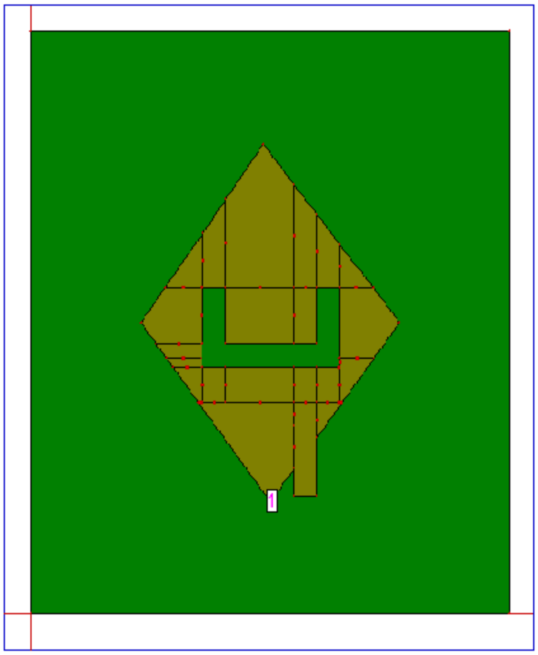

Fig. 1: Proposed Geometry of irregular Diamond slotted antenna on IE3D

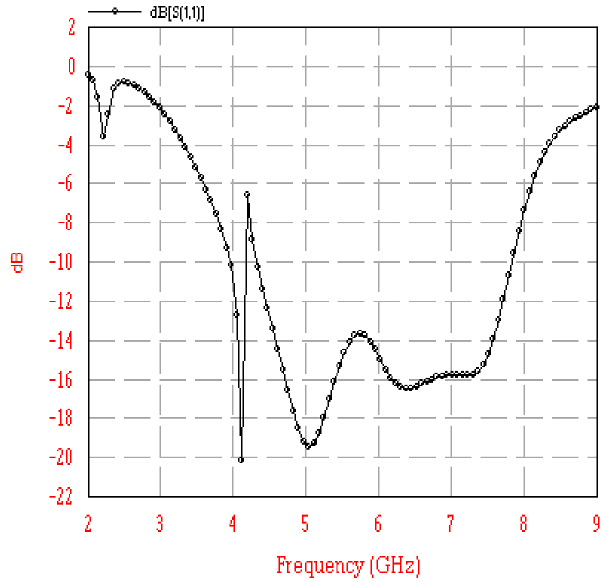

Fig. 3: S_{11} (Return Loss) Vs frequency of microstrip antenna

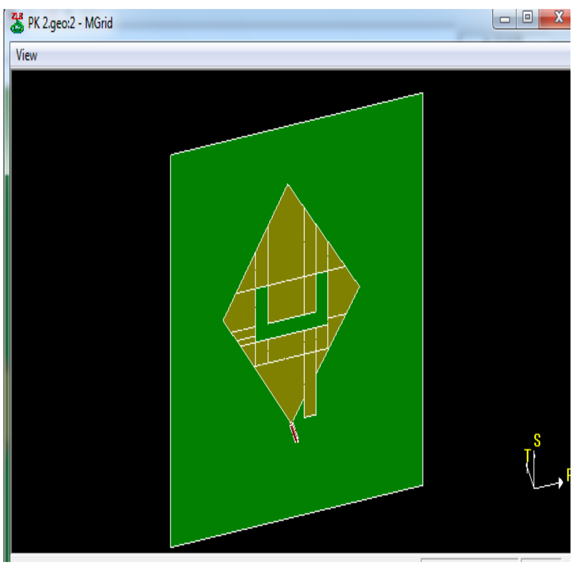

Fig. 2: 3D Geometry of irregular Diamond slotted antenna on IE3D

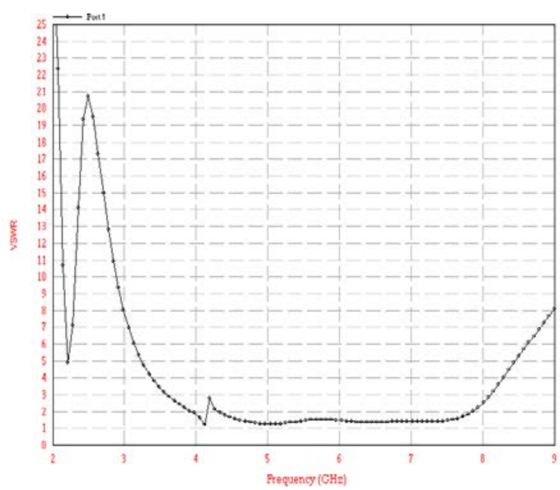

Fig. 4: Voltage standing wave ratio (vswr) Vs frequency

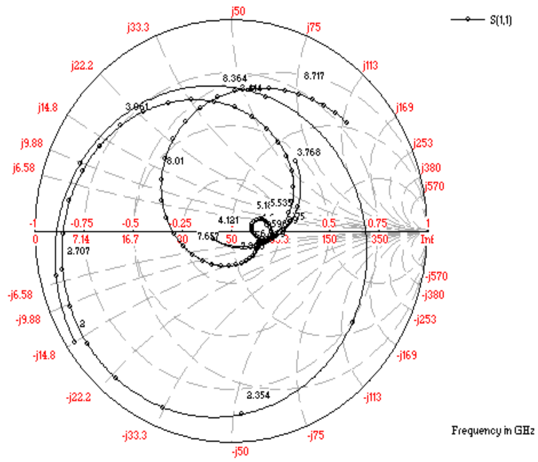

Fig. 5: Smith chart of proposed microstrip antenna

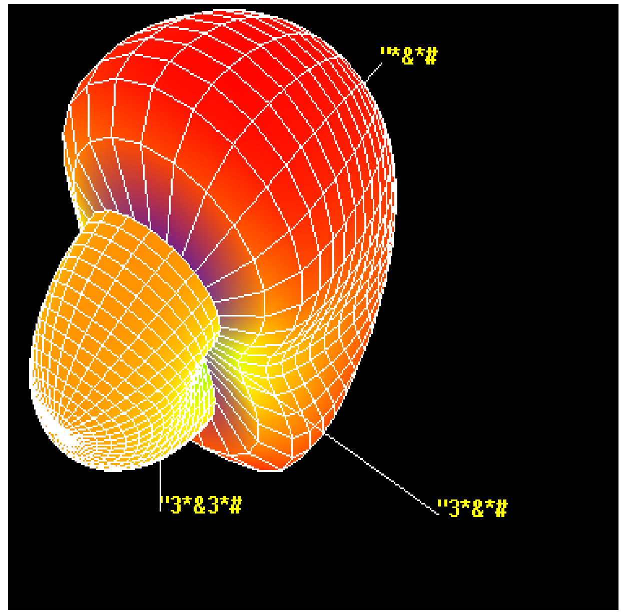

Fig. 7: 3D radiation Pattern containing main lobe and back lobe of antenna

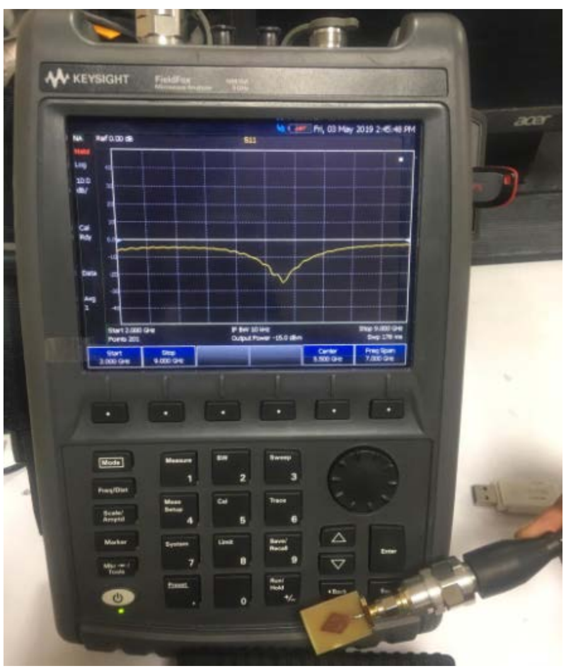

Fig. 6: S_{11} (Return Loss) Vs frequency of microstrip antenna on Vector analyzer

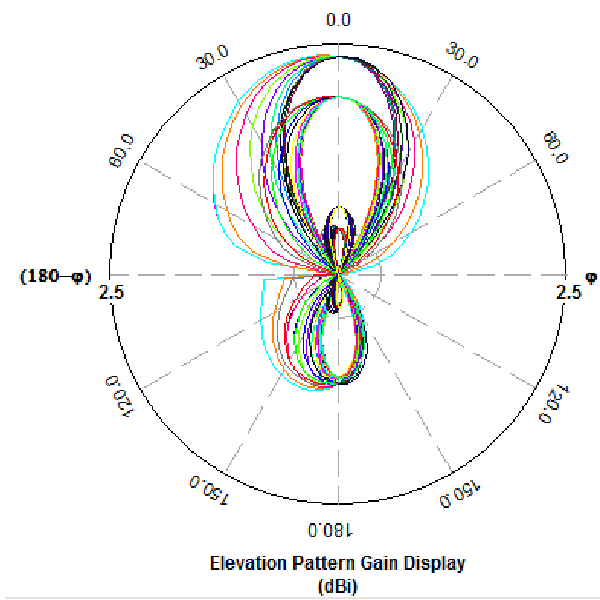

Fig. 8: 2D radiation pattern indicate greater main lobe in z direction

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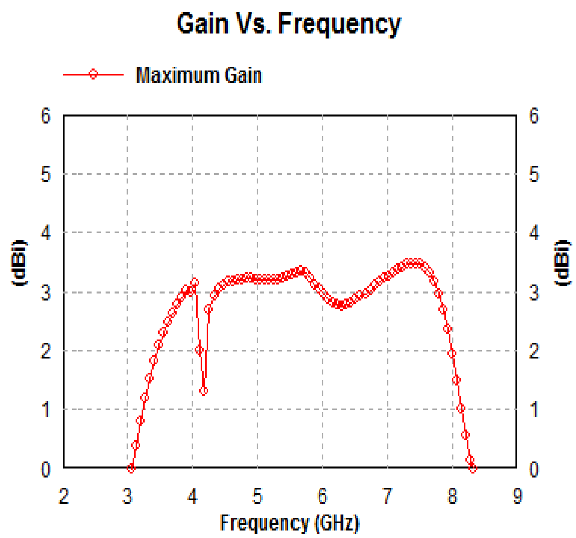

Fig. 9: Gain (dBi) Vs Frequency of microstrip patch radiator

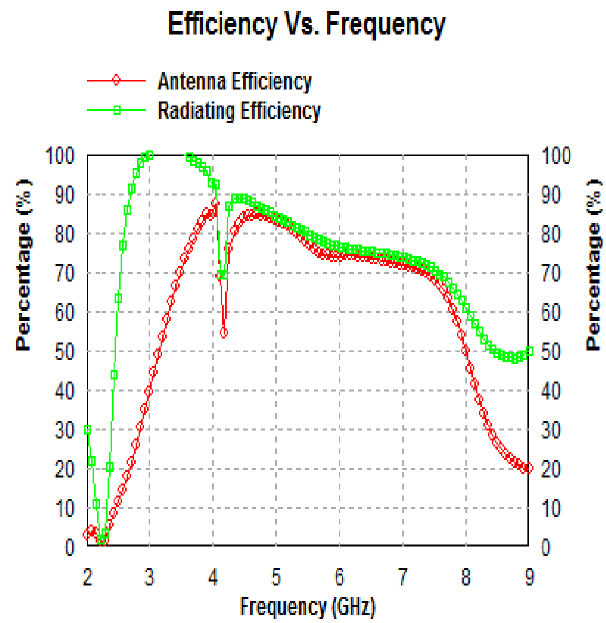

Fig. 11: Efficiency (Antenna and Radiating) Vs Frequency of microstrip patch radiator

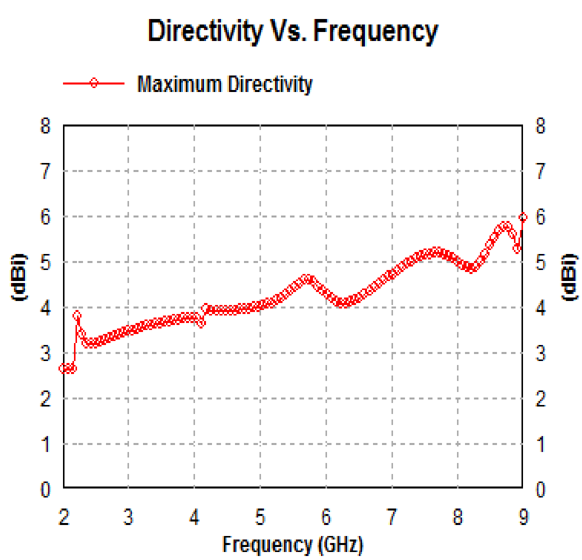

Fig. 10: Directivity Vs Frequency of microstrip antenna

Here the table contain reflection coefficient S_{11} (return loss) and bandwidth by simulated and hardware analysis as shown below in "table.1".

Table 1

Different parameter of the antenna on IE3D and Analyzer				
Parameter	**Operating frequency (GHz)**	**Resonance frequency (GHz)**	**Hardware**	**Simulated**
Return loss	6	4.5	-22.75 (dB)	-20.32 (dB)
Bandwidth	6	4.5	41.50%	57.85%

Conclusions

In this paper, the design of broadband irregular single U slotted microstrip radiator with operating frequency 6.0 GHz. The antenna has an output by using IE3D simulation software and verify with the hardware result. A glass epoxy substrate is used in the present proposed design, and impedance matching by coaxial connector with the irregular Diamond radiating patch. The software result shows the bandwidth is achieve 57.85% and 41.50% which is usable for the S Band applications, results shows that the proposed antenna is able to achieve VSWR less than 2 and the return loss is -22.75.db.

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Satyendra kumar swarnkar was born in Jhansi INDIA in 1973. He received the B.E. degree in electronics engineering from Jalgaon University, Jalgaon Maharashtra India in 1998 and the M.Tech. in electronicsengineering from Biet Jhansi, Abdul kalam technical university Lucknow ,India, in 2010 .
Since 2010, he has been with the Department of Electronic Engineering, S.R. Group of Institute Jhansi ,India, where he became a Assistant Professor in 2010. He has published many National and International level research papers in reputed journals and attended many workshops and seminars.

Anand Kumar Tripathi is presently working as Professor and Director (Academics) in **P.K.University, Shivpuri (MP)**He also served as Professor and Director in many Engineering colleges. In early days, he worked in many software development companies and then after he joined teaching as profession from Bundelkhand University, Jhansi (UP). In twenty five years of teaching journey, he taught many B.TECH, M.TECH, MCA, students of various engineering colleges of NCR region. He has published many National and International level research papers in reputed journals and attended many workshops. He has organized many International and National level Conferences / Workshops/Seminars/ Symposium etc. He has written a no. of books on **Software Development Techniques Operating System, DBMS, ‘C’ language** too. He has obtained Ph.D. degree in Computer Science from Bundelkhand University, Jhansi and PG degree from HBTI Kanpur and he is currently the Chairman of **Computer Society of India,** Jhansi Chapter, and the life time member of professional bodies like ISTE, ISCA, CSI, SSI, FIE. His Area of Interest is DBMS, Operating systems..

Zakir Ali was born in Jhansi India in 1984. He received the B. Tech. degree in electronics and communication engineering from Bundelkhand University Jhansi uttar Pradesh, India in 2006, and M.Tech. in electronics engineering from Biet Jhansi, UPTU Lucknow formally known as Abdul kalam technical university Lucknow ,India, in 2009 ,than Ph.D. Year of award 2013,presently working with Bundelkhand University in electronics and communication Department as a Associate professor . He is a Reviewer of International Association of Engineers.(UK), Global Journal of Researches in Engineering .(US), International Journal of Electronics (Taylor & Francis), International Journal of Computer Science & Network, International Journal of Engineering. IJE (IRAN) , and also Member of WASET Scientific and Technical Committee on Natural and Applied Sciences. (UK), Member of International Association of Engineers. (IAENG), USA - The IAENG Society of Computer Science.
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