Research Article

Microstrip patch antenna for x-band medical-stereotactic radio surgery applications with coaxial fed

Supriya Jana[1*], Sudeshna Dey[2]

[1]ECE Department, Seacom Engineering College under WBUT, Howrah, West Bengal, INDIA.
[2]ECE Department, Ideal Institute of Engineering under WBUT; Kalyani, Nadia, West Bengal, INDIA.
Email: supriyajana9734@yahoo.co.in, sudesna.ece@gmail.com

Abstract

The Microstrip Patch Antenna for X-Band is one of the most preferred antenna structures for low cost and compact design for wireless system and microwave application. Multiband antenna is a relative interest since they can support multiple communication system. In this paper we represent the design of a compact size, single feed, single layer and dual frequency microstrip patch antenna for X-Band Medical Stereotactic Radio Surgery applications. A novel design of small sized, low profile coaxial fed patch antenna with unequal slots with wang edges is proposed for the frequency of X-Band application with the substrate. With the introduction of slots at the edges of the microstrip patch antenna has been reduced to 53.26%. The characteristics of the designed structure are investigated by using method of moment based EM simulation software IED. The simple configuration and low profile nature of the proposed antenna parameters such as return loss, bandwidth, gain, directivity, VSWR are calculated and leads to easy fabrication and multi frequency operation makes it suitable for the applications in X-band wireless communication systems.
Keywords: Printed Antenna, Resonant frequency, Gain, Slot, Substrate, Bandwidth.

***Address for Correspondence:**
Dr. Supriya Jana, ECE Department, Seacom Engineering College under WBUT, Howrah, West Bengal, INDIA.
Email: supriyajana9734@yahoo.co.in
Received Date: 12/11/2014 Revised Date: 17/12/2014 Accepted Date: 20/01/2015

Access this article online	
Quick Response Code:	Website: www.statperson.com
	Volume 5 Issue 1

INTRODUCTION

Microstrip patch antennas play a very significant role in today's world of wireless communication systems. Microstrip antennas have at interest due to their small size, light weight, low cost on mass production, low profile and easy integration with other components in microwave and wireless communication applications[1-3]. A Microstrip patch antenna is very simple in the construction using a conventional Microstrip fabrication technique. The most commonly used Microstrip patch antennas are rectangular, triangular and circular patch antennas. These patch antennas are used as simple and for the widest and most demanding applications. Dual characteristics, circular polarizations, dual frequency operation, frequency agility, broad band width, feed line flexibility, beam scanning can be easily obtained from these patch antennas[6-8]. This paper describes the design compact unequal slotted rectangular patch antenna. In comparison to more size reduction is achieved with simpler structure. The size of the antenna may be effectively reduced by cutting unequal arrow based slots on printed antennas. The X band defined by an IEEE standard for radio waves and radar engineering with frequencies that ranges from 8.0 to 12.0 GHz[4-5] respectively. The X band is used for short range tracking, missile guidance, marine, radar and air bone intercept[10-15]. Especially it is used for X-band medical applications ranges roughly from 9.2 GHz to 9.5GHz. The application for the X-band technology is stereotactic radio surgery. Accuracy Oncology has developed the Cyber Knife[16]. This machine uses an image-guided robotic system to precisely deliver an X-ray beam to focal lesions. It integrates treatment planning, imaging, and delivery components, all of which are controlled by a Workstation.

How to site this article: Supriya Jana, Sudeshna Dey. Microstrip patch antenna for x-band medical-stereotactic radio surgery applications with coaxial fed. *International Journal of Recent Trends in Science and Technology* January to March 2015; 5(1): 36-41
http://www.statperson.com

The Cyber Knife uses a compact X-band 6MeV Linac operating at 9.3 GHz approximately and weighing 285 lbs. The relatively lightweight Linac makes it possible for the robotic arm carrying it to be accurately positioned. The Cyber Knife is a frameless robotic radio surgery system used for treating benign tumors, malignant tumors and other medical conditions. This system is a method of delivering radiotherapy, with the intention of targeting treatment more accurately than standard radiotherapy. The two main elements of the Cyber Knife are radiation produced from a small liner particle accelerator and robotic arm which allows the energy to be directed at any part of the body from any direction.

MATHEMATICAL ANALYSIS

The configuration of the conventional printed antenna is shown with L=6 mm, W=10 mm, substrate (PTFE) thickness h = 1.6 mm, dielectric constant $\varepsilon_r = 4.4$. Coaxial probe-feed (radius=0.5mm) is located at W/2 and L/3. Assuming practical microstrip patch antenna width W= 10 mm for efficient radiation and using the equation [6],

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

And Width of the patch (w): $w = \dfrac{c}{2f_0\sqrt{\frac{(1+\varepsilon_r)}{2}}}$

Where, c = velocity of light in free space. Using the following equation [9] we determined the practical length L (=6mm).

$$L = L_{eff} - 2\Delta L$$

Where, the extended length of antenna $\Delta L = \left[0.412h \times \frac{(\varepsilon_{reff}+0.3)\times(W/h+0.264)}{(\varepsilon_{reff}-0.258)\times(W/h+0.8)}\right]$

Effective dielectric constant of antenna (ε_{reff}): $\varepsilon_{reff} = \left[\left(\frac{\varepsilon_r+1}{2}\right) + \frac{\varepsilon_r-1}{\left(2\times\sqrt{\left(1+12\times\frac{h}{W}\right)}\right)}\right]$[9]

And Effective dielectric length of antenna (L_{eff}): $L_{eff} = \left[\frac{c}{2\times f_r \times \sqrt{\epsilon_{eff}}}\right]$

Where, L_{eff} = Effective length of the patch, $\Delta L/h$ =Normalized extension of the patch length, ε_{reff} = Effective dielectric constant.

Voltage Standing Wave Ratio (VSWR): VSWR= $\frac{Vmax}{Vmin} = \frac{1+|\tau|}{1-|\tau|}$

As the reflection coefficient ranges from 0 to 1, the VSWR ranges from 1 to ∞

ANTENNA DESIGN

The conventional printed antenna is shown in fig. 1 with length and width respectively 6 mm, 10 mm. The proposed microstrip patch antenna shown in fig. 2 with the following dimensions: length =6.8964 mm, width= 9.7048 mm for 9.40635 GHz and length=4.59049 mm, width= 6.86132 mm for 13.3046 GHz.

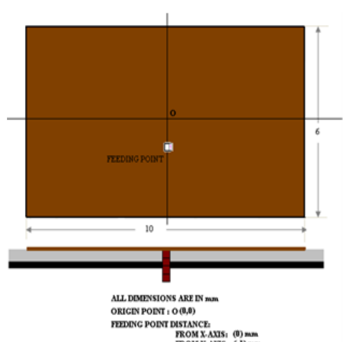

Figure 1: Conventional Antenna configuration

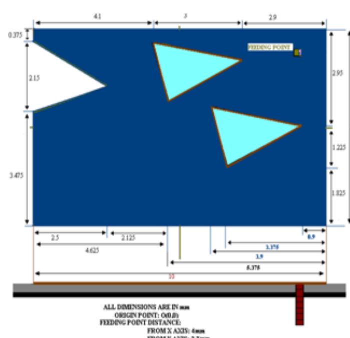

Figure 2: Simulated Antenna configuration

Figure 2 shows the configuration of simulated printed antenna designed with similar PTFE substrate. The upper right point triangular shaped the location of coaxial probe-feed (radius=0.5 mm) are shown in the figure 2.

Table 1: Optimised Antenna Parameters

Antenna parameters	Values
Resonant Frequency	9.40635 GHz
Dielectric Constant	4.4
Length	6.8964 mm
Width	9.7048 mm
Thickness	1.6mm

The proposed antenna simulated using IE3D[17] software is best operated at X band frequencies for medical applications[16].

RESULT AND DISCCUSION

Simulated (using IE3D[17]) results of return loss in conventional and simulated antenna structures are shown in Figure 3-4. A significant improvement of frequency reduction is achieved in simulated antenna with respect to the conventional antenna structure.

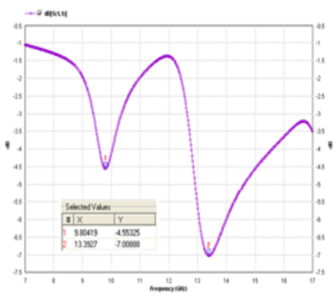

Figure 3: Return Loss vs. Frequency (Conventional Antenna)

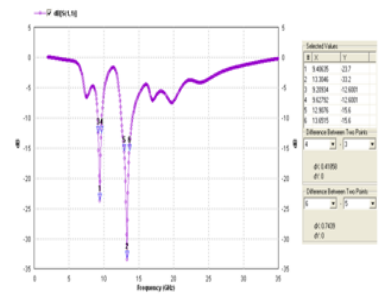

Figure 4: Return Loss vs. Frequency (Slotted Antenna)

In the conventional antenna return loss of about -7.01 dB is obtained at 13.39 GHz. Comparing fig.3 and fig.4 it may be observed that for the conventional antenna (fig.3), there is practically no resonant frequency at around 9.40635 GHz with a return loss of around -6 dB. For the simulated antenna there is a resonant frequency at around 9.40635 GHz, where the return loss is as high as -23.7dB and another frequency 13.3046 GHz with a return loss as high -33.2dB. Due to the presence of slots in simulated antenna resonant frequency operation is obtained with large values of frequency ratio. The first and second resonant frequency is obtained at f_1 = 9.40635 GHz with return loss of about -23.7 dB and at f_2 = 13.3046 GHz with return losses -33.2 dB respectively. Corresponding 10dB band width obtained for Antenna 2 at f1, f2 are 418.58 MHz and 748.9MHz respectively. The simulated E plane and H-plane radiation patterns are shown in Figure 5-8 and 11-12. The simulated E plane radiation pattern of simulated antenna for 9.40635 GHz is shown in figure 5.

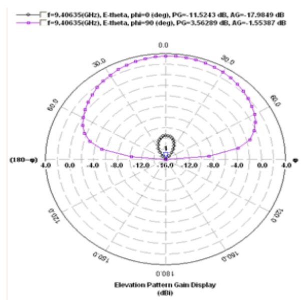

Figure 5: E-Plane Radiation Pattern for Slotted Antenna at 9.40 GHz

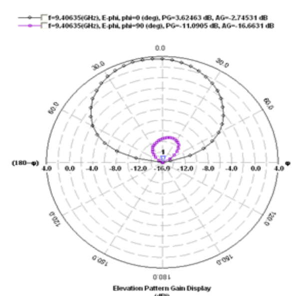

Figure 6: H-Plane Radiation Pattern for slotted Antenna at 9.40 GHz

The simulated H plane radiation pattern of simulated antenna for 9.40635 GHz is shown in figure 6. The simulated E plane and H-plane radiation pattern (3D) of simulated antenna for 9.40635 GHz is shown in figure 7 and figure 8.

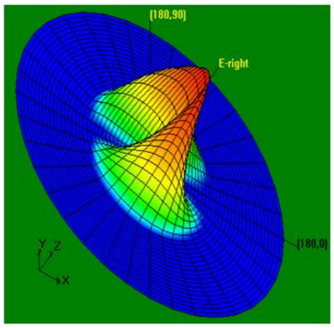

Figure 7: E-Plane Radiation Pattern (3D) for slotted antenna at 9.40 GHz

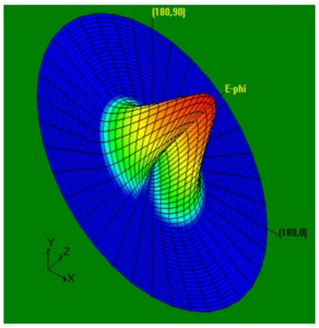

Figure 8: H-Plane Radiation Pattern (3D) for slotted antenna at 9.40 GHz

The simulated smith chart and VSWR of simulated antenna shown in figure 9 and figure 10.

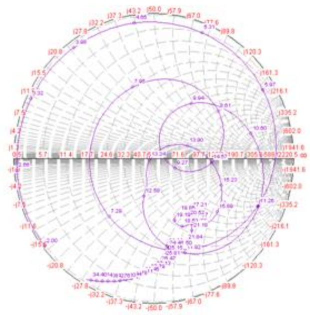

Figure 9: Simulated Smith Chart for slotted antenna

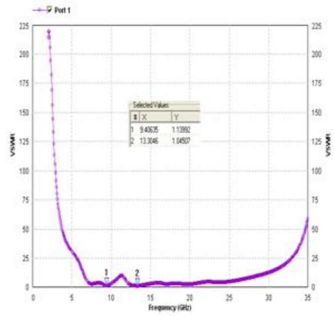

Figure 10: Simulated VSWR for slotted antenna

The simulated Cartesian E -plane and H-plane radiation pattern (2D) of simulated antenna for 9.40635 GHz is shown in figure 11 and figure 12.

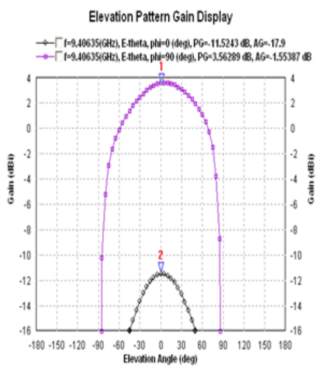

Figure 11: E-Plane Radiation Pattern (2D) for slotted antenna at 9.40 GHz

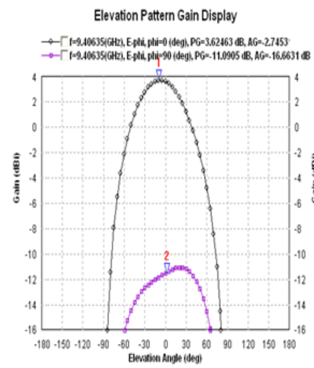

Figure 12: H-Plane Radiation Pattern (2D) for slotted antenna at 9.40 GHz

The simulated current distribution and total substrate for slotted antenna shown in figure 13 and figure 14.

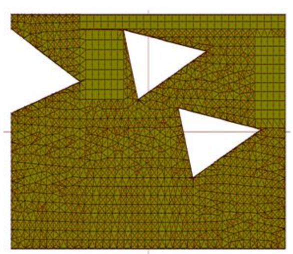

Figure 13: Current Distribution for slotted antenna

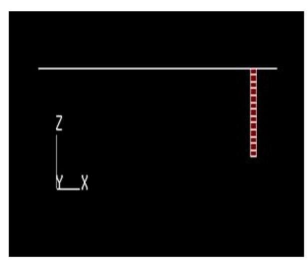

Figure 14: Total Substrate for slotted antenna

All the simulated results are summarized in the following Table1 and Table2.

Table 1: Simulated results for antenna 1 and 2 w.r.t return loss

Antenna structure	Resonant frequency (ghz)	Return loss (db)	10 db bandwidth (ghz)
Conventional	f_1= 9.80	-4.55	NA
	f_2= 13.39	-7.01	NA
	f_1= 9.40635	-23.7	0.41858
Slotted	f_2 = 13.3046	-33.2	0.7489

Table 2: Simulated results for antenna 1 and 2 w.r.t radiation pattern

Antenna structure	Resonant frequency (ghz)	3db beamwidth (^{0})	Absolute gain *(dbi)*
Conventional	f_1= 9.80	NA	NA
	f_2= 13.39	NA	NA
	f_1= 9.40635	136.189	3.73214
Slotted	f_2 =13.3046	131.27	0.330357

Frequency Ratio for Conventional Antenna	$f_2 / f_1 = 1.366$
Frequency Ratio for Slotted Antenna	$f_2 / f_1 = 1.414$

CONCLUSION

This paper focused on the simulated design on differentially-driven microstrip antennas. Simulation studies of an unequal arrow based printed antenna have been carried out using Method of Moment based software IE3D[17]. The main drawback of printed antenna was impedance bandwidth. Introducing slots at the edge of the patch size reduction of about 53.26% has been achieved. The 3dB beam-width of the radiation patterns are 136.189^0 (for f_1), 131.27^0(for f_2) which is sufficiently broad beam for the applications for which it is intended. The resonant frequency of slotted antenna, presented in the paper, designed for a particular location of feed point (4 mm, 2.3 mm) considering the centre as the origin. Alteration of the location of the feed point results in narrower 10dB bandwidth and less sharp resonances. The experimental result shows that this design is ideally practical for X-band medical applications[16].

REFERENCE

1. I.Sarkar, P.P.Sarkar, S.K.Chowdhury "A New Compact Printed Antenna for Mobile Communication", 2009 Loughborough Antennasand Propagation Conference, 16-17 November 2009, pp 109-112.
2. S. Chatterjee, U. Chakraborty, I.Sarkar, S. K. Chowdhury, and P.P.Sarkar, "A Compact Microstrip Antenna for Mobile Communication", IEEE annual conference. Paper ID: 510
3. J.-W. Wu, H.-M. Hsiao, J.-H. Lu and S.-H. Chang, "Dual broadband design of rectangular slot antenna for 2.4 and 5 GHz wireless communication", IEE Electron. Lett. Vol. 40 No. 23, 11th November 2004.
4. U. Chakraborty, S. Chatterjee, S. K. Chowdhury, and P. P. Sarkar, "A comact microstrip patch antenna for wireless communication," Progress In Electromagnetics Research C, Vol. 18, 211-220, 2011 http://www.jpier.org/pierc/pier.php?paper=10101205
5. Rohit K. Raj, Monoj Joseph, C.K. Anandan, K. Vasudevan, P. Mohanan, " A New Compact Microstrip-Fed Dual-Band Coplaner Antenna for WLAN Applications", IEEE Trans. Antennas Propag., Vol. 54, No. 12, December 2006, pp 3755-3762.
6. Zhijun Zhang, Magdy F. Iskander, Jean-Christophe Langer, and Jim Mathews, "Dual-Band WLAN Dipole Antenna Using an Internal Matching Circuit", IEEE Trans. Antennas and Propag.,VOL. 53, NO. 5, May 2005, pp 1813-1818.
7. J. -Y. Jan and L. -C. Tseng, " Small planar monopole Antenna with a shorted parasitic inverted-L wire for Wireless communications in the 2.4, 5.2 and 5.8 GHz. bands" , IEEE Trans. Antennas and Propag., VOL. 52, NO. 7, July 2004, pp -1903-1905.
8. Samiran Chatterjee, Joydeep Paul, Kalyanbrata Ghosh, P. P. Sarkar and S. K. Chowdhury "A Printed Patch Antenna for Mobile Communication", Convergence of Optics and Electronics conference, 2011, Paper ID: 15, pp 102-107.
9. C. A. Balanis, "Advanced Engineering Electromagnetics", John Wiley and Sons., New York, 1989.
10. Supriya Jana and Moumita Mukherjee "Microstrip Patch Antenna for Microwave Communication: Microstrip Antenna Theory: Modeling and Development", LAP LAMBERT Academic Publishing (December 25, 2012)-Germany, ISBN: 978-3-659-31336-3.
11. Supriya Jana , Bipadtaran Sinhamahapatra, Sudeshna Dey, Samiran Chatterjee, Arnab Das , Bipa Datta, Moumita Mukherjee, Santosh Kumar Chowdhury, "Single Layer Monopole Hexagonal Microstrip Patch Antenna for Microwave Communication", International Refereed Journal of Engineering and Science (IRJES), ISSN (Online) 2319-183X, (Print) 2319-1821 Volume 1, Issue 4(December 2012), PP.44-48.
12. Supriya Jana, Bipadtaran Sinhamahapatra, Sudeshna Dey, Arnab Das, Bipa Datta, Moumita Mukherjee, Santosh Kumar Chowdhury, Samiran Chatterjee, "Single Layer Monopole Hexagonal Microstrip Patch Antenna for Satellite Television", International Journal of Soft Computing and Engineering (IJSCE), ISSN: 2231-2307, Volume-2, Issue-6, January 2013, PP.321-324.
13. Bipadtaran Sinhamahapatra, Supriya Jana , Sudeshna Dey, Arnab Das , Bipa Datta, Moumita Mukherjee, Samiran Chatterjee, "Dual-Band Size Deducted Un-Equal Arm Y-Shaped Printed Antenna for Satellite Communication" International Journal of Engineering Research and Development (IJERD), e-ISSN: 2278-067X, p-ISSN : 2278-800X , Volume 5, Issue 9 (January 2013), PP. 36-40.
14. Supriya Jana, Bipadtaran Sinhamahapatra, Sudeshna Dey, Arnab Das, Bipa Datta, Moumita Mukherjee, Samiran Chatterjee, "Single Layer Monopole Hexagonal Microstrip Patch Antenna for Satellite Television", National Conference on Advancement of Computing in Engineering Research (ACER-13),Article No.-51,PP.19-20,March-2013;Co-sponsored by: IEEE Kolkata Section; Operational Research Society of India(ORSI) Kolkata Chapter; Rural Development Forum Institution of Engineers(India)[IEI]; Publication Partner: Academy and Industry Research Collaboration Center(AIRCC), (ISSN:2231-5403); (ISBN:978-1-921987-11-3);

DOI:10.5121/csit.2013.3234; CSandIT-CSCP2013; vol.3,No.2,2013; PP.369-375,March 2013.

15. Arnab Das, Bipa Datta, Samiran Chatterjee, Bipadtaran Sinhamahapatra, Supriya Jana, Moumita Mukherjee, Santosh Kumar Chowdhury, "A Compact Multi-resonant Microstrip Antenna", 13th Biennial National Symposium on Antennas and Propagation 2012 (APSYM 2012), Paper ID: 13102, 2012.Co-sponsored by: IEEE Student Branch, Cochin; UGC;Indian National Science Academy;AICTE;Department of Atomic Energy(Govt. Of India); Department of Science and Technology (Govt. Of India); CSIR (Govt. Of India); KSCSTE (Govt. Of India). Published by The Directorate of Relations and Publications; ISBN: 978-43-80095-40-0; PP.99-102, December 2012.
16. S. M. HANNA+, Siemens Medical Systems-OCS, Concord, CA "Applications of X-Band Technology in Medical Accelerators", Proceedings of the 1999 Particle Accelerator Conference, New York, 1999, pp 2016-2018
17. Zeland Software Inc. IE3D: MoM-Based EM Simulator. Web: http://www.zeland.com/

Source of Support: None Declared
Conflict of Interest: None Declared