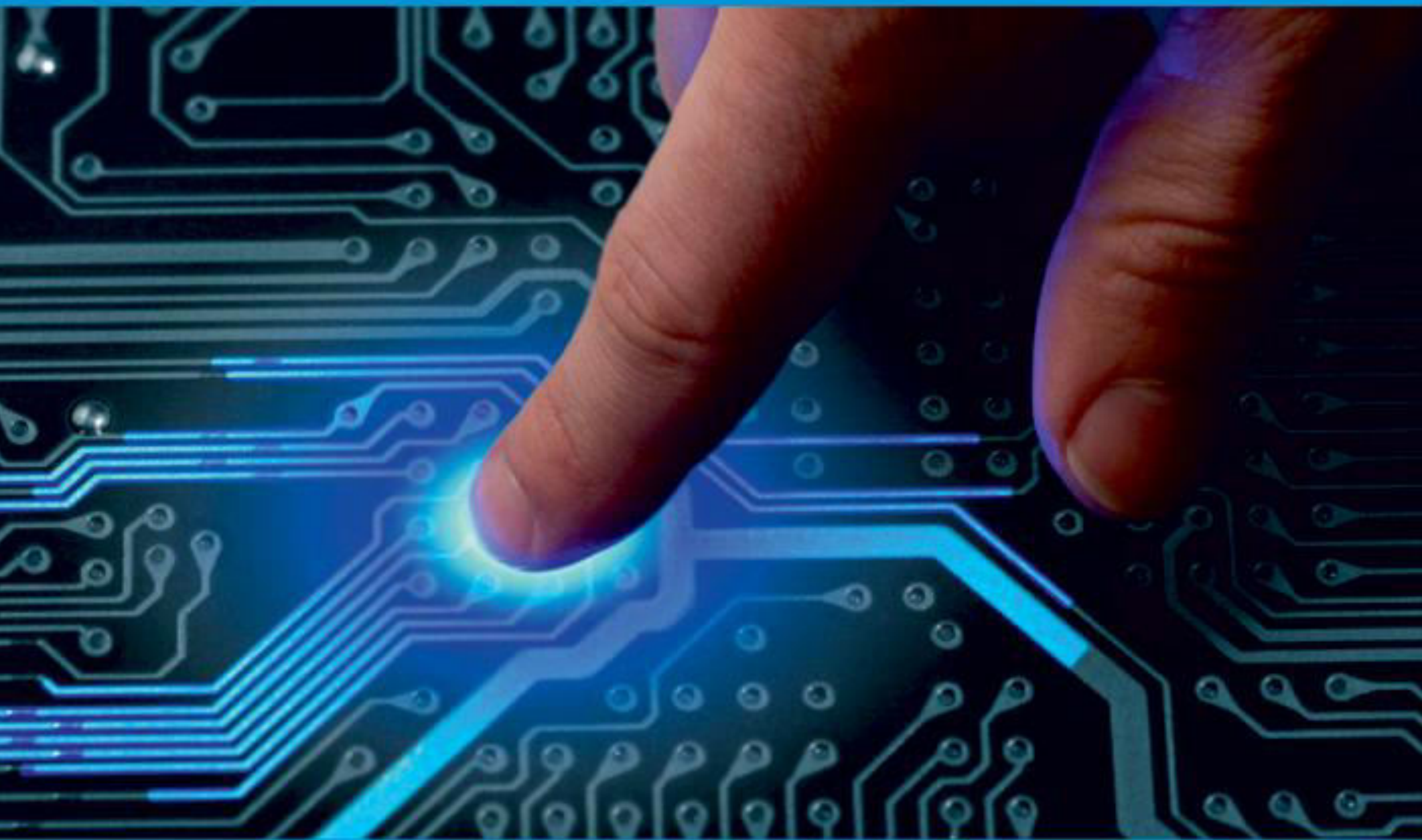
IJIRCCE

e-ISSN: 2320-9801 | p-ISSN: 2320-9798



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN COMPUTER & COMMUNICATION ENGINEERING

Volume 11, Issue 5, May 2023

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 8.379

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.379 || A Monthly Peer Reviewed & Referred Journal |

|| Volume 11, Issue 5, May 2023 ||

| DOI: 10.15680/IJIRCCE.2023.1105364 |

Performance Comparison of Microstrip Antennas with Diverse Substrates at Multiple Frequencies

Prof. Dr.Prateek Mishra

Department of Electronics and Communication Engineering, Baderia Global Institute of Engineering and Management, Jabalpur, (M.P.), India

ABSTRACT: Microstrip antennas are widely used in modern communication systems due to their compact size, low cost, and ease of integration with printed circuit boards. This paper presents a detailed performance comparison of microstrip antennas utilizing various substrate materials across multiple frequency ranges. The study investigates the impact of different substrate materials—such as FR4, Rogers RT/Duroid, and Teflon—on key performance metrics including return loss, bandwidth, gain, and radiation pattern. The antennas are designed and simulated using a range of frequencies to evaluate their performance under different conditions. The results reveal significant variations in antenna characteristics based on substrate material and frequency, providing insights into the trade-offs between material properties and antenna performance. By analyzing these variations, the study aims to guide the selection of appropriate substrate materials for specific applications and frequency ranges. The findings offer valuable information for optimizing microstrip antenna designs to meet the requirements of various communication systems, from wireless networks to satellite communications.

KEYWORDS: FR4, DUROID-6006, HFSS, patch.

I. INTRODUCTION

Microstrip antennas, also known as patch antennas, are an integral component in modern wireless communication systems due to their compact size, lightweight structure, and ease of integration with planar circuit designs. These antennas are widely employed in various applications, including mobile phones, satellite communications, and wireless networks. The performance of a microstrip antenna is significantly influenced by the choice of substrate material, which affects its electrical properties and, consequently, its operational characteristics.The substrate material plays a crucial role in determining the impedance matching, bandwidth, and overall efficiency of the antenna. Commonly used substrates such as FR4, Rogers RT/Duroid, and Teflon exhibit distinct electrical properties, including dielectric constant and loss tangent, which impact the antenna's performance metrics. The dielectric constant of the substrate affects the effective permittivity of the antenna, influencing parameters such as resonant frequency, bandwidth, and gain. Similarly, the loss tangent of the substrate determines the dielectric losses, which can affect the efficiency and radiation pattern of the antenna.This paper aims to provide a comprehensive performance comparison of microstrip antennas fabricated with different substrate materials across multiple frequency ranges. By evaluating antennas with substrates like FR4, Rogers RT/Duroid, and Teflon, we seek to understand how variations in substrate properties influence key performance metrics such as return loss, bandwidth, gain, and radiation pattern. The study employs both simulation and experimental methodologies to analyze the antennas' behavior in diverse operational environments.The motivation behind this comparative study is to offer insights into how substrate material selection impacts the overall performance of microstrip antennas. This information is crucial for designing antennas tailored to specific application requirements, whether for high-frequency applications requiring low-loss materials or cost-effective solutions where broader bandwidth is necessary. By systematically exploring the relationship between substrate materials and antenna performance, this paper aims to provide valuable guidelines for optimizing microstrip antenna designs and advancing the development of efficient communication systems.

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.379 || A Monthly Peer Reviewed & Referred Journal |

|| Volume 11, Issue 5, May 2023 ||

| DOI: 10.15680/IJIRCCE.2023.1105364 |

II. BASIC STRUCTURE

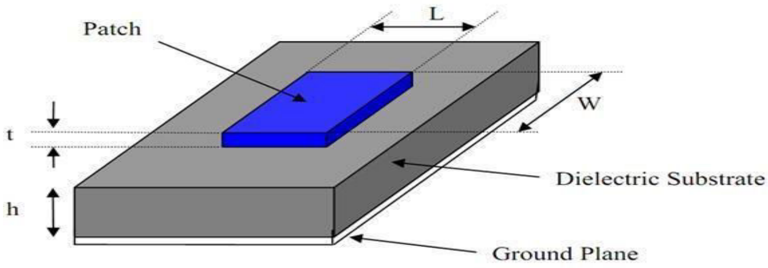


Fig1. Structure of Microstrip Antenna

In its most basic form, a Microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which also has a ground plane on the other side as shown in Figure 1. The patch
[2] is generally made of conducting materials such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate.

II. LITERATURE REVIEW

Deschamps first proposed the concept of the MSA in 1953. However, practical antennas were developed by Munson and Howell in the 1970s **[1,2,3]**. The numerous advantages of MSA, such as its low weight, small volume and ease of fabrication using printed-circuit technology, led to the design of several configurations for various applications. With increasing requirements for personal and mobile communications, the demand for smaller and low-profile antennas has brought the MSA to the forefront **[1]**.

Goyal R et al.[7] put forward the bow shape microstrip antenna having Benzocyclobuten as a substrate material. It was a rectangular patch antenna but the size was reduced upto 40% that of conventional rectangular patch antenna. Resonent frequency was found 4.35 GHz when tested experimentally. Antenna with Benzocyclobuten material shows good results for return loss and radiation pattern.

Awan,Munir et al. [8] exploited this feature and worked on three different types of materials viz. FR4, GML 1000 and RT/Duroid 5880. Antenna was designed for 2.5GHz and simulated with those materials. Simulation software HFSS has been used. Design of 8 element microstrip patch array for 10GHz shows good experimental results as compare to the desirable results. 10GHz X-Band antenna is useful in small countries where the small area is required to cover by emission of microwave beams through satellite. This patch antenna with narrow beam-width of approximately 20 deg to 365 deg are required to complete the satellite communication coverage.

Rathi V et al. [9] has worked on effects of substrate thickness on antenna parameters. The designed frequency was 2.4 GHz. They have studied different properties by making changes in substrate parameters.

Chen,W et al [10]. has made an attempt to answer questions like i) how does the impedance of antenna changes with change in substrate thickness. ii) how does the impedance bandwidth of antenna changes with change in substrate thickness. iii) what is the effect of feed location on impedance bandwidth. Numerical results are presented to show the clear effects of each parameter.

Singh and Tripathi V. L et al.[11] worked on two layer conventional substrate with different permeability and different height. The designed frequency is 2.4GHz. The slot antenna fabricated on reactive impedance substrate (RIS). The final optimized structure exhibits an axial-ratio bandwidth of about 15% and impedance bandwidth better than 10%.

Antenna Design
In order to identify and verify the improvement for rectangular structure in microstrip antenna, the conventional Microstrip antenna design method is used [1].
Design Steps:
Designing the patch antenna is to employ the following formulas as an outline for the design procedures.

i. Width (W)

$$W = \frac{c}{} \tag{1}$$

Where

c - free space velocity of light, 3 x 10^8 m/s f_r - frequency of operation

ε_r - dielectric constant

ii. Effective Dielectric constant (εreff)

$\varepsilon_{reff} =$ +

Where;

ε_r - dielectric constant

h - Height of dielectric substrate W - Width of the patch

iii. Effective Length (Leff)

$$L_{eff} = \frac{\varepsilon_r+1}{2} \quad \frac{\varepsilon_r-1}{2} \quad \left[1 \quad \frac{h}{w}\right]^{\frac{-1}{2}} \tag{2}$$

$$\frac{c}{} \quad 3)$$

Where;

c - Free space velocity of light, 3 x 108 m/s f_r - frequency of operation

ε_{reff} - effective dielectric constant

iv. Patch Length Extension (Δl)

$$\Delta L = 0.412h \frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)(\frac{W}{h}+0.8)}$$

v. Actual Length of Patch (L)

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

(4)

(5)

III. ANTENNA MODELING

In this paper, rectangular patch antenna have been designed using HFSS. The substrate materials are FR4 and DURIOD. Antenns are designed for different frequencies viz. 2.4GHz, 3GHz, 3.5GHz, 4GHZ. To calculate antenna dimensions by conventional method we need to provide some data like substrate height, its dielectric constant etc. Table No.1 Shows modeling of antenna for different frequencies using two substrate materials. FR4 has dielectric constant of 4.4 where as the DUROID- 6006 has dielectric constant of 6.

Table1. Dimensions of an Antenna with Different Substrates

Substrate Material	Frequency	Dimensions	
		Width (W)	Length (L)
FR4	2.4 GHz	38.03 mm	29.46 mm
	3.0 GHz	30.42 mm	23.45 mm
	3.5 GHz	26.08 mm	20.02 mm
	4.0 GHz	22.82 mm	17.43 mm
DUROID-6006	2.4 GHz	33.40 mm	25.26 mm
	3.0 GHz	26.72 mm	20.11 mm

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.379 || A Monthly Peer Reviewed & Referred Journal |

|| Volume 11, Issue 5, May 2023 ||

| DOI: 10.15680/IJIRCCE.2023.1105364 |

	3.5 GHz	22.90 mm	17.15 mm
	4.0 GHz	20.04 mm	14.93m

IV. RESULT COMPARISON

Table2. Result comparison of Designed Frequency and Simulated Frequency.

Material	Designed Frequency	Simulated Frequency
FR4 (εr=4.4)	2.4 GHz	2.33 GHz
	3.0 GHz	2.91 GHz
	3.5 GHz	3.35 GHz
	4.0 GHz	3.83 GHz
DUROID-6006 (εr=6)	2.4 GHz	2.23 GHz
	3.0 GHz	2.89 GHz
	3.5 GHz	3.33 GHz
	4.0 GHz	3.80 GHz

After modeling of antenna, the structure is designed in HFSS software and results are obtained for return loss and radiation pattern.

TableNo.2 shows the designed frequency and the frequency obtained from HFSS simulator. Frequencies obtained by using FR4 material are closer to the designed frequency.

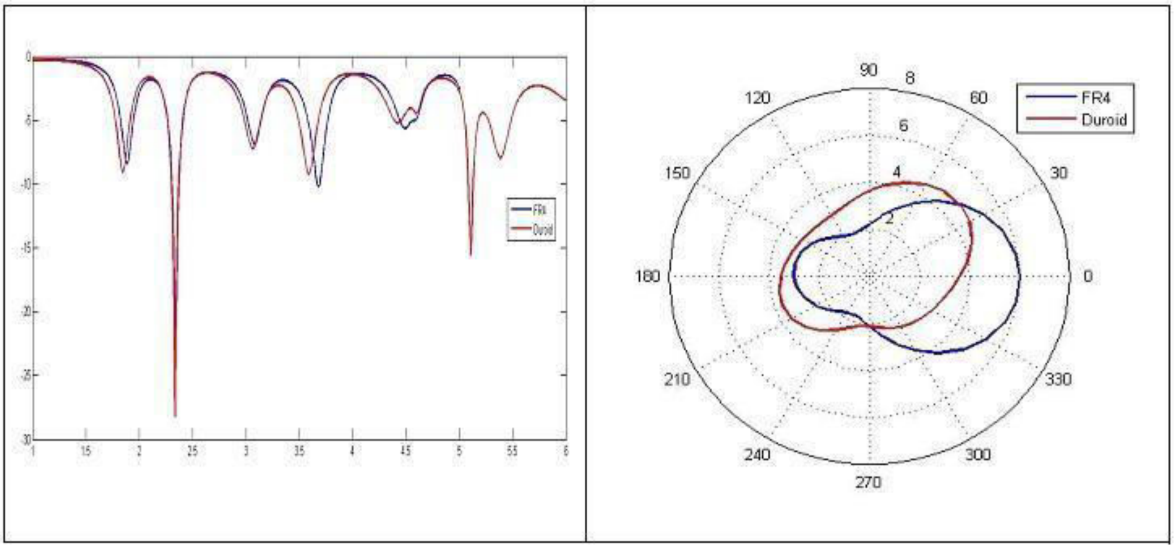


Fig2. Return Loss (S11) and Radiation Pattern at 2.4 GHz

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.379 || A Monthly Peer Reviewed & Referred Journal |

|| Volume 11, Issue 5, May 2023 ||

| DOI: 10.15680/IJIRCCE.2023.1105364 |

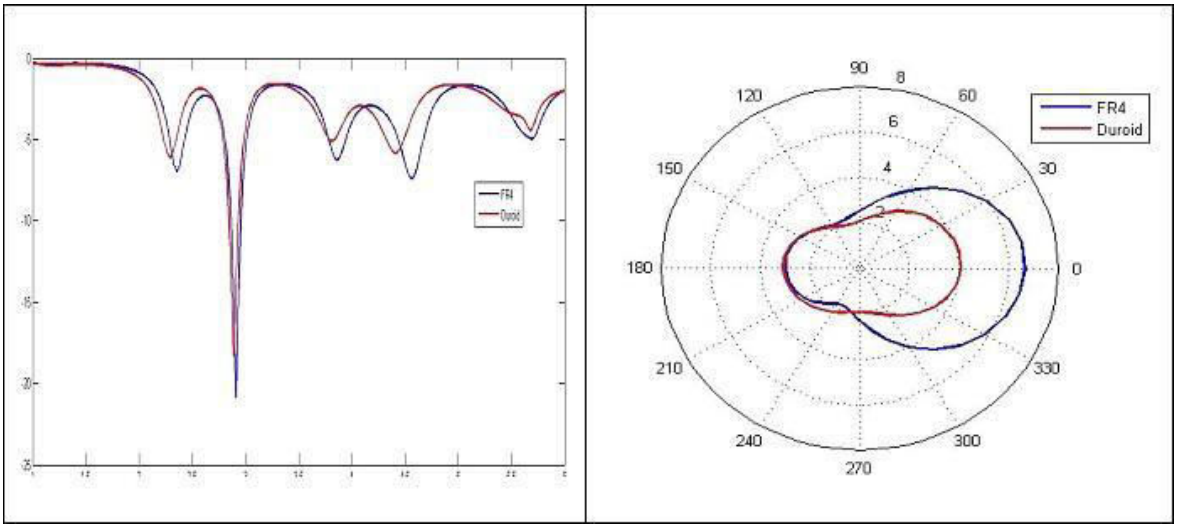


Fig3. Return Loss (S11) and Radiation Pattern at 3GHz

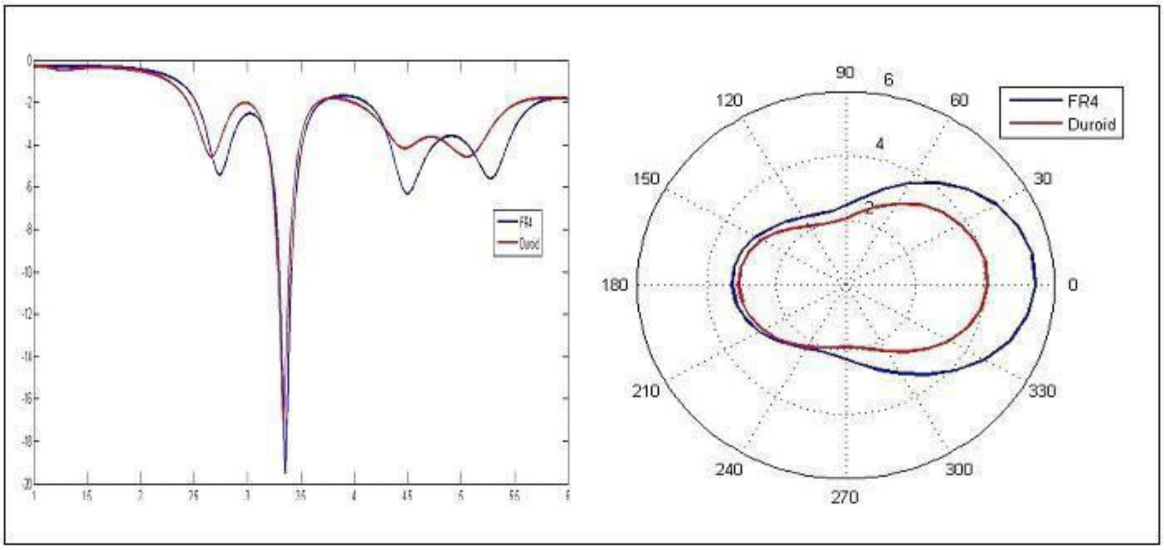


Fig4. Return Loss (S11) and Radiation Pattern at 3.5GHz

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.379 || A Monthly Peer Reviewed & Referred Journal |

|| Volume 11, Issue 5, May 2023 ||

| DOI: 10.15680/IJIRCCE.2023.1105364 |

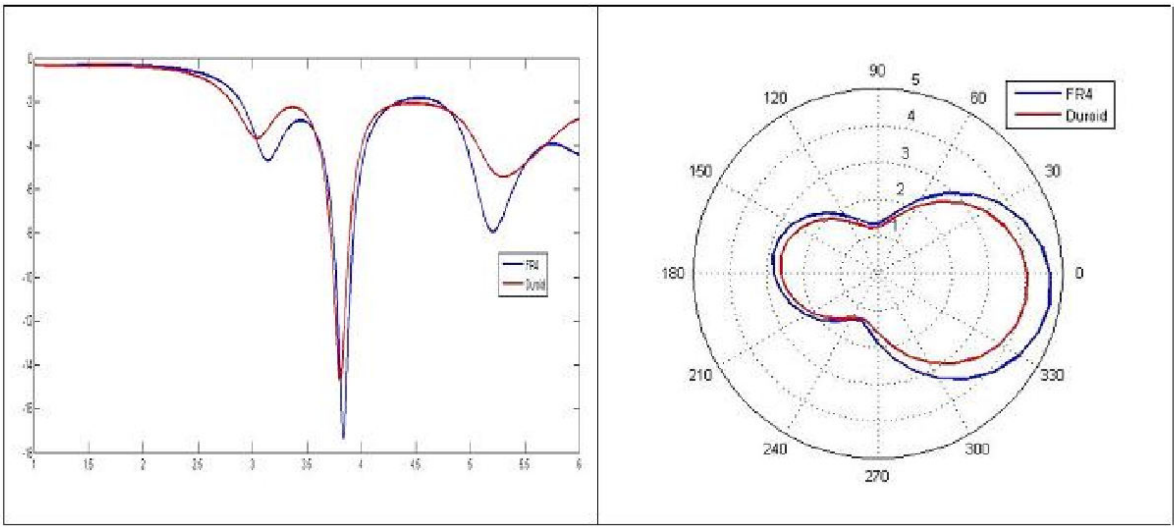


Fig5. Return Loss (S11) and Radiation Pattern at 4GHz

V. CONCLUSION

The performance of microstrip Antenna is mainly depend on its structure and dimensions but the substrate material shows significant role in performance parameters such as Return Loss (S11). The rectangular patch antenna is designed for 4 different frequencies with two FR4 and DUROID-6006. The result shows that FR4 material is quite suitable for frequencies up to 4GHz. The reflection at the source and axial directivity of the antennas designed by FR4 is better than antennas designed by using DUROID-6006.

REFERENCES

1. Constantine A. Balanis, “Antenna Theory Analysis and Design”.
2. Ramesh Garg, Prakash Bhartia, Inder Bahl,Apisak ittipiboon, “Microstrip Antenna Design Handbook,” Second Edition, 1998.
3. Bharat Bhushan Agrawal, Vibha Rani Gupta, “Improvement of Impedance Matching of a Rectangular Printed Monopole Antenna”, Microwave Review, September, 2008.
4. D. Orban and G.J.K. Moernaut “The Basics of Patch Antennas”-www.antennatheory.com.
5. D. Orban and G.J.K. Moernaut “Fundamental Dimension Limits of Antennas”-www.antennatheory.com.
6. Ahmed A. Kishk, “Fundamentals Of Antennas”, Center of Electromagnetic System Research (CEDAR).
7. Goyal R, Jain Y. K , “Compact Bow shape Microstrip Antenna with Different Substrates”, IEEE Conf. Information and Communication Technologies(ICT), 11-12 April 2013, Jeju Island, ISBN No-978-1-4673-5759-3, Pg.No-64-69.
8. Awan A H,Muneer B, Ull Islam Q, “Design, Substrate Comparison and Fabrication of 8-Element high gain Microstrip Patch Antenna”, IEEE Conf. Advances in Space Technologies(ICAST), 29- 30 November 2008, Islamabad, ISBN No-978-1-4244-3299-8, Pg.No-12-17.
9. Rathi V, Rawat S, Pokhariya H S, “Study the Effects of Substrate Thickness and Permittivity on Patch Antenna”, IEEE Conf. Signal Processing, Communication and Computing (ICSPCC), 14- 16 Septeber 2011, Xi’an, ISBN No-978-4577-0893-0, Pg.No-1-4.
10. Chen W, Lee K F, Lee R Q, “Effect of Substrate Thickness on Input Impedance of Coaxially-fed Rectangular Patch Antenna”, IEEE Symposium, Antenna snd Propagation Society International Symposium, June 28, 1993 – July 2, 1993, Ann Arbor,MI, USA, ISBN No-0-7803-1246-5, Vol- 1, Pg.No-1200-1203.
11. Singh I,Tripathi V S, Tiwari S, “Compact Circularly Polarised Microstrip Patch Antennna on Reactive Impedance Substrates”, IEEE Conf, Computer and Devices for Communication (CODEC), 17-19 December 2012, Kolkatta India, ISBN No-978-1-4673-2619-3 Pg.No-1-4.
12. Faiji, D, Pagel N, Ngo V L, Seidel, H, “Effect of Substrate on reliability and antenna indicator parameters” IEEE Conf. 1-4 Nov 2010. Kona HI, ISBN-978-1-4244-8170-5. Pg No-1342-1345.

| e-ISSN: 2320-9801, p-ISSN: 2320-9798| www.ijircce.com | |Impact Factor: 8.379 || A Monthly Peer Reviewed & Referred Journal |

|| Volume 11, Issue 5, May 2023 ||

| DOI: 10.15680/IJIRCCE.2023.1105364 |

13. D.rakesh, P.rakesh kumar, Prof. Habibulla khan k ch sri kavya, “performance evaluation of microstrip square Patch antenna on different substrate Materials”, Journal of Theoretical and applied Information Technology, 30th April 2011, Vol-26, No-2, ISBN No-1992-8645, Pg.No- 97-106.
14. A. K. Verma and Nasimuddin, “Analysis of Circular Antenna on Thick Substrate”, Journal of Microwaves and Optoelectronics, Vol. 2, N.o 5, July 2002. ISSN 1516-7399.
15. Anzar Khan, Rajesh Nema, “Analysis of Five Different Dielectric Substrates on Microstrip Patch Antenna”, International Journal of Computer Applications, Volume 55– No.18, October 2012, Page No- 0975 – 8887.
16. Bilal Ahmed, Ilyas Saleem, H. Zahra, Hunaina Khurshid and S. Muzahir Abbas, “Analytical Study on Effects of Substrate Properties on the Performance of Microstrip Patch Antenna”, International Journal of Future Generation Communication and Networking, Vol. 5, No. 4, December, 2012.
17. Hossein Mosallaei, Senior Member, IEEE, and Kamal Sarabandi, Fellow, IEEE, “Antenna Miniaturization and Bandwidth Enhancement Using a Reactive Impedance Substrate”, IEEE Transactions on Antennas And Propagation, Vol. 52, No. 9, September 2004.
18. K. Sarat Kumar, B.T.P.Madhav, T. S. R. Prasad, “Characterization of Substrate Material Effects on Circularly Polarized Triangular Microstrip Antenna with Spur lines” International Journal Of Advances In Engineering, Science And Technology (IJAEST), Vol. 2 No. 2 May-July 2012, ISSN : 2249-913X.
19. Sohaib Abbas Zaidi and M.R. Tripathy, “Design and Simulation Based Study of Microstrip E– Shaped Patch Antenna Using Different Substrate Materials”, Advance in Electronic and Electric Engineering, ISSN 2231-1297, Volume 4, Number 6 (2014), pp. 611-616.
20. Suvadeep Choudhury, “Effect of Dielectric Permittivity and Height on a Microstrip-Fed Rectangular Patch Antenna”, IJECT Vol. 5, Issue Spl-2, Jan - March 2014, ISSN : 2230-7109 (Online) | ISSN : 2230-9543 (Print).
21. Asok De, N.S. Raghava, Sagar Malhotra, Pushkar Arora, Rishik Bazaz, “Effect of different substrates on Compact stacked square Microstrip Antenna”, Journal Of Telecommunications, Volume 1, Issue 1, February 2010.
22. Halim Boutayeb, Member, IEEE, and Tayeb A. Denidni, Senior Member, IEEE, “Gain Enhancement of a Microstrip Patch Antenna Using a Cylindrical Electromagnetic Crystal Substrate”, Ieee Transactions On Antennas And Propagation, Vol. 55, No. 11, November 2007.

INNO SPACE
SJIF Scientific Journal Impact Factor
Impact Factor: 8.379

doi crossref

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

निस्केयर
NISCAIR

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN COMPUTER & COMMUNICATION ENGINEERING