iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** IV **Month of publication:** April 2026

DOI: https://doi.org/10.22214/ijraset.2026.81343

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue IV Apr 2026- Available at www.ijraset.com

Design and Analysis of a Multiband Microstrip Antenna for Wireless Applications

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Abstract: The rapid evolution of wireless communication technologies has created a strong demand for compact, efficient, and multi-functional antennas. Microstrip patch antennas have gained significant popularity due to their low profile, ease of fabrication, and compatibility with printed circuit technology. However, conventional microstrip antennas suffer from limitations such as narrow bandwidth and low gain.S
This research presents the design and simulation of a dual-band microstrip patch antenna employing an inverted L-shaped radiating structure and a T-shaped Defected Ground Structure (DGS). The antenna is fabricated on an FR-4 substrate with a dielectric constant of 4.4 and thickness of 1.6 mm. The proposed design operates in two frequency bands: 3.05–3.40 GHz and 6.50–6.80 GHz, making it suitable for WLAN, WiMAX, MIMO, and IoT applications.
Simulation is carried out using ANSYS HFSS based on the Finite Element Method (FEM). The results demonstrate excellent performance with return loss below −10 dB, VSWR less than 2, gain up to 8 dB, and wide impedance bandwidth. The inclusion of DGS significantly enhances bandwidth and overall antenna performance. The proposed antenna is compact, cost-effective, and highly suitable for modern wireless communication systems.

I. INTRODUCTION

The rapid advancement of wireless communication technologies has significantly transformed modern society by enabling seamless connectivity across a wide range of applications, including mobile communication, satellite systems, wireless local area networks (WLAN), Internet of Things (IoT), and intelligent transportation systems. With the exponential growth in wireless devices and services, there is an increasing demand for compact, efficient, and multi-functional antennas capable of supporting multiple frequency bands within a single structure.

An antenna is a fundamental component of any wireless communication system, responsible for converting electrical signals into electromagnetic waves and vice versa. The overall performance of a communication system is highly dependent on the efficiency, bandwidth, gain, and radiation characteristics of the antenna. Therefore, the design of advanced antennas has become a critical area of research in modern communication engineering.

Among various antenna types, microstrip patch antennas have gained considerable attention due to their unique advantages such as low profile, lightweight structure, ease of fabrication, and compatibility with printed circuit board (PCB) technology. These features make them highly suitable for integration into compact and portable electronic devices. However, conventional microstrip antennas suffer from several limitations, including narrow bandwidth, low gain, surface wave losses, and single-band operation. These drawbacks restrict their applicability in modern multi-standard communication systems.

To overcome these limitations, researchers have introduced various techniques such as slot loading, stacked patches, use of low dielectric substrates, and modification of patch geometry. Among these, dual-band and multiband antenna designs have emerged as effective solutions, allowing a single antenna to operate at multiple frequency bands. This reduces system complexity, minimizes hardware requirements, and enhances overall performance.

Another significant technique for improving antenna performance is the use of Defected Ground Structure (DGS). DGS involves intentional modification of the ground plane by introducing slots or patterns, which alters the current distribution and electromagnetic characteristics of the antenna. This results in improved bandwidth, enhanced gain, better impedance matching, and reduced return loss. The combination of modified patch geometry and DGS has proven to be highly effective in achieving high-performance antenna designs.

In this research, a compact dual-band microstrip patch antenna is proposed using an inverted L-shaped radiating patch combined with a T-shaped Defected Ground Structure. The antenna is designed on an FR-4 substrate to maintain low fabrication cost while achieving satisfactory performance. The proposed antenna operates in two distinct frequency bands, making it suitable for applications such as WLAN, WiMAX, MIMO systems, and IoT-based communication networks.

The design and analysis of the antenna are carried out using ANSYS High Frequency Structure Simulator (HFSS), which is based on the Finite Element Method (FEM). Various performance parameters such as return loss, Voltage Standing Wave Ratio (VSWR), gain, radiation pattern, and bandwidth are evaluated to validate the effectiveness of the proposed design.

The main objective of this work is to develop a compact, cost-effective, and high-performance dual-band antenna that meets the requirements of modern wireless communication systems while maintaining simplicity in design and fabrication.

II. LITERATURE REVIEW

The design and development of microstrip patch antennas have been extensively explored over the past few decades due to their significant role in modern wireless communication systems. With the increasing demand for compact, lightweight, and multi-functional devices, researchers have focused on improving antenna performance in terms of bandwidth, gain, efficiency, and multiband capability.

A. Overview of Microstrip Patch Antennas

Microstrip patch antennas are planar antennas consisting of a radiating patch printed on one side of a dielectric substrate and a ground plane on the other side. Due to their low profile, ease of fabrication, and compatibility with integrated circuits, they are widely used in applications such as satellite communication, mobile devices, and wireless networks.

Despite these advantages, conventional microstrip antennas inherently suffer from several limitations such as narrow bandwidth, low gain, and surface wave losses. These drawbacks limit their effectiveness in modern communication systems that require wideband and multiband performance.

B. Limitations of Conventional Antenna Designs

Traditional antenna designs are typically optimized for a single frequency band, which makes them unsuitable for current wireless systems that operate across multiple frequency ranges. The key limitations include:

- Narrow Bandwidth: Typically limited to 2–5%, which restricts wideband applications
- Low Gain: Reduces communication range and signal strength
- Surface Wave Losses: Decrease radiation efficiency
- Single-Band Operation: Requires multiple antennas for different applications

These challenges have motivated researchers to explore innovative techniques for performance enhancement.

C. Techniques for Bandwidth Enhancement

Several approaches have been proposed in literature to improve the bandwidth of microstrip antennas:

1) Substrate Modification: Increasing substrate thickness enhances bandwidth by strengthening fringing fields. However, it also introduces higher surface wave losses and reduces efficiency.
2) Low Dielectric Constant Materials: Using substrates with lower dielectric constants improves radiation efficiency and bandwidth but increases the physical size of the antenna.
3) Slot Loading Techniques: Introducing slots (U-slot, E-slot, H-slot) in the patch modifies current paths, enabling multiband operation and bandwidth enhancement. Although effective, slot design requires precise optimization.
4) Stacked Patch Structures: Stacking multiple patches vertically increases bandwidth significantly but leads to increased complexity and fabrication cost.

D. Dual-Band and Multiband Antenna Designs

Modern wireless systems demand antennas capable of operating at multiple frequency bands. Dual-band and multiband antennas address this requirement effectively.

- Dual-band antennas operate at two distinct frequencies
- Multiband antennas support more than two frequency bands

Common techniques used include:

- Multi-resonant structures

- Fractal geometries
- Slot-based designs
- Patch shape modifications

These designs reduce the need for multiple antennas, saving space and improving system efficiency.

E. Patch Geometry Modification Techniques

Modifying the geometry of the radiating patch is one of the most effective methods for achieving multiband operation.

1) U-Shaped and E-Shaped Patches: These shapes provide improved bandwidth and dual-band characteristics but increase design complexity.
2) H-Shaped Patches: Offer good impedance matching but are difficult to fabricate accurately.
3) L-Shaped and Inverted L-Shaped Patches

Widely used due to:

- Compact size
- Simple design
- Multiple current paths
- Efficient dual-band operation

The inverted L-shaped geometry is particularly effective in generating multiple resonant frequencies, making it suitable for compact antenna designs.

F. Defected Ground Structure (DGS)

Defected Ground Structure is a powerful technique used to enhance antenna performance by introducing intentional defects in the ground plane.

2.6.1 Working Principle: DGS modifies current distribution and introduces additional inductance and capacitance, which affects electromagnetic behaviour.

2.6.2 Advantages of DGS

- Bandwidth enhancement
- Gain improvement
- Reduced return loss
- Improved impedance matching
- Harmonic suppression

2.6.3 Types of DGS

- Dumbbell-shaped
- Circular
- Rectangular
- Spiral
- T-shaped

Among these, the **T-shaped DGS** is particularly effective for dual-band antennas due to its ability to enhance upper-band performance.

G. Review of Previous Research

Several studies have contributed to the advancement of dual-band microstrip antennas:

- Slot-Based Antennas: Achieved dual-band operation but with limited bandwidth
- E-Shaped Patch Antennas: Improved bandwidth but increased fabrication complexity
- Fractal Antennas: Provided multiband operation but were difficult to design and manufacture
- DGS-Based Designs: Showed significant improvement in bandwidth and gain
- Inverted L-Shaped Antennas: Offered simple design with effective dual-band performance

These studies highlight the importance of combining multiple techniques to achieve optimal antenna performance.

H. Comparative Analysis

Technique	Advantages	Limitations
Slot Loading	Dual-band capability	Limited bandwidth
E-Shaped Patch	Wide bandwidth	Complex design
Fractal Design	Multiband operation	Difficult fabrication
DGS	High performance	Requires optimization
L-Shaped Patch	Compact and simple	Needs tuning

I. Research Gap

From the analysis of existing literature, the following gaps are identified:

- Lack of compact dual-band antenna designs
- Limited bandwidth in existing solutions
- Trade-off between complexity and performance
- Need for cost-effective and easy-to-fabricate antennas

III. METHODOLOGY

A. Antenna Design Approach

The proposed antenna consists of:

- FR-4 substrate
- Inverted L-shaped patch
- Microstrip feed line
- T-shaped DGS

B. Substrate Selection

FR-4 is selected due to:

- Low cost
- Easy availability
- Good mechanical strength

Parameters:

- Dielectric constant (εr): 4.4
- Thickness: 1.6 mm

C. Antenna Geometry

- Substrate size: 70 mm × 60 mm
- Compact structure suitable for portable devices

D. Inverted L-Shaped Patch

This geometry provides:

- Dual current paths
- Dual resonance frequencies
- Improved impedance matching

E. Defected Ground Structure

A T-shaped DGS is used to:

- Increase bandwidth
- Improve gain
- Reduce return loss

F. Feeding Technique

Microstrip line feed is used because:

- Simple design
- Low cost
- Good impedance matching

G. Design Equations

Key equations used:

Width of Patch (W)

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

- c = speed of light ($3 \times 10^8\ m/s$)
- f_r = resonant frequency
- ε_r = dielectric constant of substrate

Effective Dielectric Constant (ε_eff)

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

- Accounts for fringing fields
- h = substrate height

Effective Length (L_eff)

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{eff}}}$$

This is the electrical length of the patch

Length Extension (ΔL)

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

Due to fringing fields at patch edges

Actual Patch Length (L)

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

IV. SIMULATION AND IMPLEMENTATION

Simulation is performed using ANSYS HFSS.

A. Setup Parameters

- Frequency range: 3–7 GHz
- Boundary: Radiation
- Excitation: Wave port
- Mesh: Adaptive tetrahedral

B. Model Steps

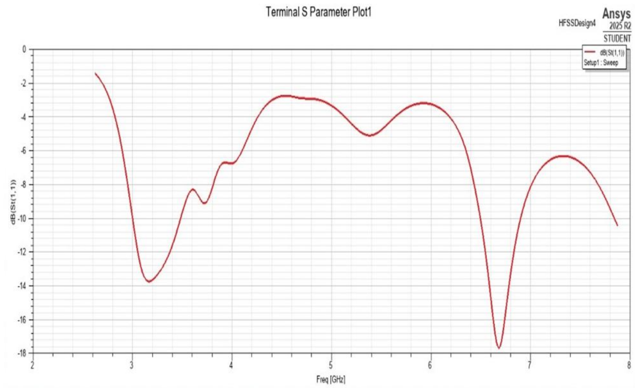
- Substrate creation
- Patch design
- Ground plane with DGS
- Feed line connection

V. RESULTS AND DISCUSSION

A. Return Loss

- 3.225 GHz: −13.8 dB
- 6.65 GHz: −17.8 dB

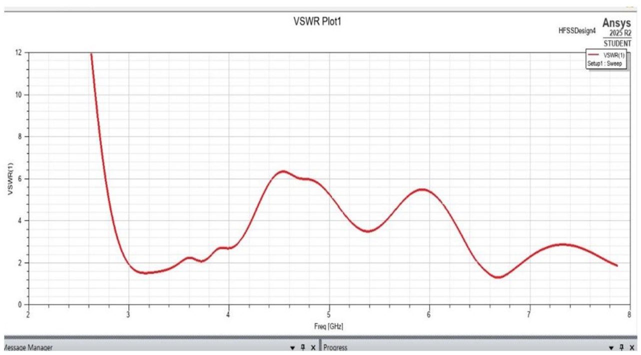
Indicates excellent impedance matching.



B. VSWR

- 3.225 GHz: 1.51
- 6.65 GHz: 1.29

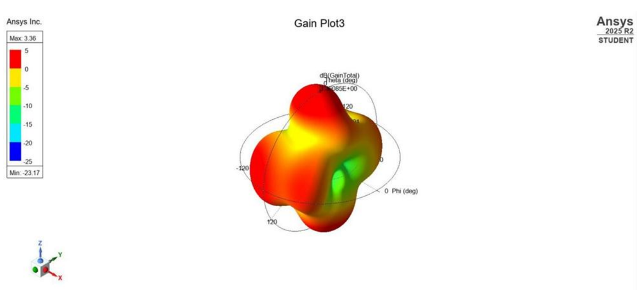
Values <2 confirm good performance.



C. Gain

- Lower band: 4.1 dB
- Upper band: 5.3 dB

Higher than many conventional designs.



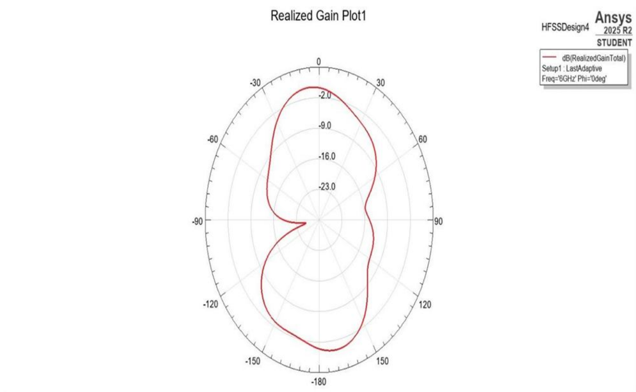
D. Bandwidth

- Lower band: 350 MHz
- Upper band: 300 MHz

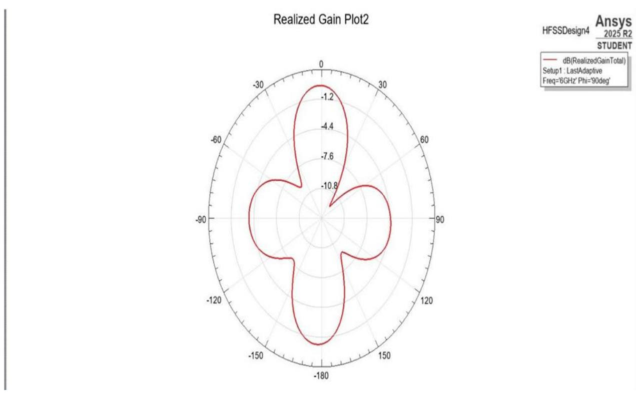
DGS significantly improves bandwidth.

E. Radiation Pattern

- E-plane: Directional



- H-plane: Omnidirectional



Suitable for practical wireless systems.

F. Key Observations

- Dual-band achieved successfully
- High gain and wide bandwidth
- Stable radiation patterns

VI. CONCLUSION

This research successfully presents a dual-band microstrip patch antenna using an inverted L-shaped structure and Defected Ground Structure.

Key Achievements

- Dual-band operation at 3.225 GHz and 6.65 GHz
- Wide bandwidth and high gain
- Low VSWR and excellent return loss
- Compact and low-cost design

The antenna is highly suitable for:

- WLAN
- WiMAX
- MIMO
- IoT systems

The DGS plays a crucial role in enhancing performance, making the design efficient and practical.

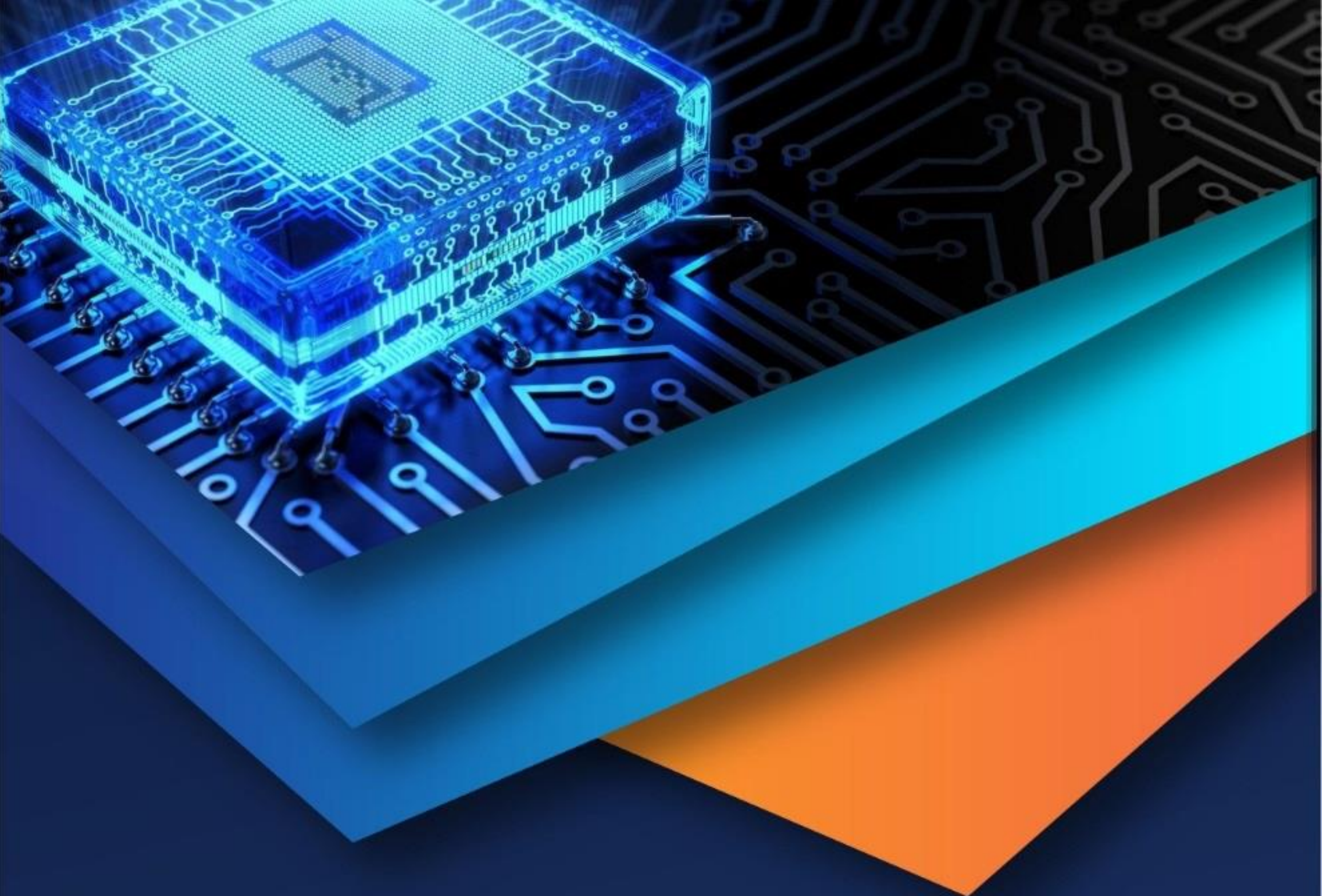
VII. FUTURE SCOPE

Future improvements include:

- Multiband antenna design
- 5G and milli meter-wave applications
- MIMO antenna arrays
- Reconfigurable antennas using switches
- AI-based optimization techniques

REFERENCES

[1] Y. Cao, C. Lu, and Y. Zhang, A compact dual band miniaturized antenna for WLAN operation, In: Proceedings of International Conference on Microwave and Millimeter Wave Technology, 2008, pp. 416–419.
[2] Q. He, B. Wang, and J. He, Wideband and dual-band design of a printed dipole antenna, IEEE Antennas Wireless Propag Lett 7 (2008), 1–4.
[3] M.J. Kim, C.S. Cho, and J. Kim, A dual band printed dipole antenna with spiral structure for WLAN application, IEEE Microwave Wireless Compon Lett 15 (2005), 910–912.
[4] R.K. Joshi and A.R. Harish, A modified bow-tie antenna for dual band applications, IEEE Antennas Wireless Propag Lett 6 (2007), 468–471.
[5] 5. B.S. Izquierdo and J.C. Batchelor, A dual band belt antenna, In: Proceedings of International Workshop on Antenna Technology: Small Antennas and Novel Metamaterials, 2008, pp. 374–377.
[6] C.I. Lin and K.L. Wong, Printed monopole slot antenna for internal multiband mobile phone antenna, IEEE Trans Antennas Propag 55 (2007), 3690–3697.
[7] B. Kelothu, K.R. Subhashini, and G. Lalitha Manohar, A compact high-gain microstrip patch antenna for dual band WLAN applications, In: Students Conference on Engineering and Systems, SCES, 2012.
[8] 8. M. Wong, A.R. Sebak, and T.A. Denidni, Analysis of a dual-band dual slot omnidirectional stripline antenna, IEEE Antennas Wireless Propag Lett 6 (2007), 199–202.
[9] K. Chung, S. Hong, and J. Choi, Ultrawide-band printed monopole antennas with band-notch filter, IET Microwave Antennas Propag 1 (2007), 518–522.
[10] J. Kaur and R. Khanna, Design of coaxial fed microstrip patch antenna for Wi-MAX/IMT applications, Res J Eng Technol 4 (2013), 40–44.
[11] K. Oh, B. Kim, and J. Choi, Design of dual and wideband aperture stacked patch antenna with double-sided notches, Electron Lett 40 (2004), 643–645.
[12] K.G. Thomas and M. Sreenivasan, Compact triple-band antenna for WLAN/WiMAXapplications, Electron Lett 45 (2009), 811–813.
[13] J. Kaur, M.V. Kartikeyan, and R. Khanna, Design of a multifrequency wideband microstrip patch antenna for 5.2/5.5/5.8 GHz wireless applications, In: Proceedings of National Conference on Recent Trends in Microwave, July 30–August 1, 2012.
[14] K. Lau, H. Wong, C. Mak, K. Luk, and K. Lee, A vertical patch antenna for dual-band operation, IEEE Antennas Wireless Propaga Lett 5 (2006), 95–97.
[15] A.A. Eldek, Analysis and Design of Wideband Slot and Printed Antennas for Phased Array Antenna Systems, PhD Thesis (Electrical Engineering), University of Messisippi, Messisippi, November 2004.
[16] R. Garg, P. Bhartia, I. Bahl, and A. Ittipiboon, Microstrip Antenna Design Handbook, Artech House, Norwood, MA, 1995.
[17] A. Asrokin, M.K.A. Rahim, and M.Z.A.A. Aziz, Dual band microstrip antenna for wireless LAN application, In: Asia-Pacific Conference on Applied Electromagnetics, APACE, 2005.



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