DOI: 10.21917/ijct.2015.0173

COMPACT DUAL-BAND INVERTED L SHAPED MONOPOLE ANTENNA FOR WLAN APPLICATIONS

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Abstract
A highly compact and an optimized design of an Inverted L shaped printed monopole antenna with a simple compact ground plane is proposed. To make the designed antenna suitable for implantation it is embedded in FR-4 substrate and is presented. The antenna is designed for dual-band operation at 2.4GHz and 5.2GHz. It is suitable for Wireless Local Area Network (WLAN) applications with return loss (S_{11}) < -10dB. The antenna has two different resonant current paths that support two resonances at 2.44GHz and 5.18GHz (forming an F-shaped structure). The size of the antenna is 32.5mm × 19.6mm × 1.6mm. The antenna design is simulated using the tool Advanced Design System (ADS) 2014. This antenna design has good return loss and radiation characteristics in both the required frequency bands. The radiation pattern obtained from the proposed antenna is an Omni directional radiation pattern in the E and H plane over the frequency ranges 2.4GHz and 5.2GHz.

Keywords:
Monopole Antenna, WLAN, ADS Software, FR4 Substrate

1. INTRODUCTION

The blistering development of the modern wireless communication systems for personal communication and in portable devices leads to an excessive demand for novel, compact, and multi band antennas. With a growing interest in this field and a keenness to design devices that provide multiple services, there is a need for miniaturized multipurpose antenna in modern communication system [1]. Multi-band antennas should support multi-frequency operations with suitable radiation characteristics for the desired frequencies of different applications [2]. In the course of recent years, there have been hasty developments in the applications of wireless local area network (WLAN). The 2.4GHz, 5.2GHz and 5.8GHz bands are on demand in practical WLAN applications [3]. The requirement for WLANs is increasing rapidly worldwide as they provide high speed connectivity and easy access to networks without the need of wired connections [4]. Today, the most widely used WLAN protocols are IEEE 802.11b/g, which operates at 2.4GHz ISM band (2.4-2.485GHz), and IEEE 802.11a which operates at 5GHz U-NII band and ISM band (5.15-5.825GHz). For system flexibility and feasibility, antennas should have the capability to operate in both the specified operating frequencies are highly desired.

Therefore in order to fulfil the IEEE 802.11 standard specifications and antenna requirements, dual band printed monopole antennas are required. They can transmit and receive signals simultaneously in these two bands. In circumstances, where devices like laptops, mobile phones move from one cell to another with different operating frequency band, a dual band antenna can be very useful. Thus it avoids using two antennas for transmission of video, voice and data information. In addition, the restricted equipment space of WLAN devices, the necessities for antenna with low profile, light weight, easy incorporation with system circuit as well as high performance are addressed. It makes the research and design of dual band antennas a new trend. The printed monopole antennas have become very popular because of its low cost factor and fabrication simplicity. Printed monopole antenna can be easily integrated in communication systems and can be fabricated on printed circuit boards (e.g. fabricated on laptops for WLAN applications) and avoids the use of two separate antennas for transmission of video, voice and data. The Radiation pattern of a monopole antenna is Omni directional which can cover large area.

2. RELATED WORKS

A Rectangular Microstrip Antenna is realized by two different single-slotted single-band rectangular microstrip antennas with a slotted ground plane. The length and position of each open-ended slot is varied in order for the antenna to operate in a suitable resonant band at 5.15-5.35GHz and 5.725-5.825GHz of WLAN IEEE 802.11a [1].

An F-shaped monopole antenna comprises a vertical metal line and two (one upper and other one lower) horizontal metal lines of different lengths are proposed [2]. Antenna has two separate radiating strips, one driven strip and one parasitic shorted strip. The driven strip controls the excitation of upper band at 5GHz and the parasitic strip controls the lower band at 2.4GHz for WLAN operation [3].

A microstrip fed T-shaped element and an F-shaped element have been used to achieve a dual band operation based on coupled-feeding between F and T [4] [5]. The antenna comprises of a central arm and two side arm monopoles of different sizes, which are modified to generate two separate resonant modes for the desired dual-band operations [6]. By using U-shaped slot patch geometry, dual band operation has been obtained [7].

The modified T-shaped planar monopole antenna with two asymmetric horizontal strips is used to provide two broadband dual-resonance modes [8]. Two rectangular monopole elements are stacked at the top of each other, with a ground plane at the back of the substrate produces Dual Band response [9]. A hexagonal patch fed by a two-step Coplanar Waveguide (CPW) feed is used to excite the asymmetrical slot [10].

3. ANTENNA GEOMETRY

In this paper, a compact structure having a dual band nature at 2.4GHz and 5.2GHz to be used for WLAN applications is proposed. The shape of the radiating patch is designed to be an inverted L shape as shown in Fig.1 and having the length and width of each branch as specified in Table.1.

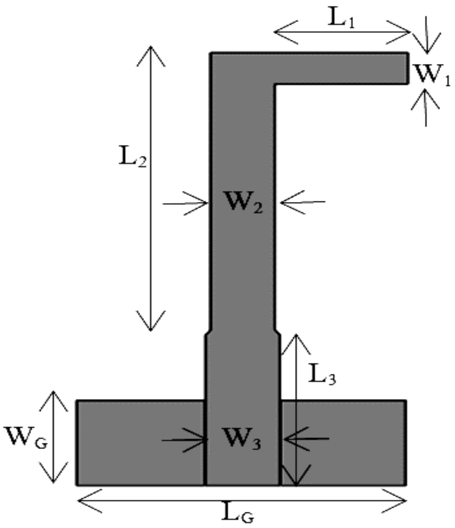


Fig.1. Layout of the Inverted L shaped Monopole Antenna

Various dimensions of the radiating patch as well as the ground plane are specified in the following Table.1.

Table.1. Dimensions of the Inverted L shaped Monopole Antenna

Dimension	**Value (mm)**
L_1	8
L_2	20
L_3	12
L_G	19.8
W_1	2.5
W_2	3.9
W_3	4.5
W_G	6.8

4. SIMULATION SETUP

The basic antenna structure consists of a rectangular radiating patch, a feed line, and a ground plane and thus forms the monopole antenna. The entire structure is designed and simulated using the tool Advanced Design System (ADS) 2014.The substrate used here is FR4 with specifications as given below.

Table.2. Substrate specifications

Dielectric Constant	ε_r	4.4
Tangent Loss	$\tan\delta$	0.001
Substrate Thickness	h	1.6mm
Conductor Layer Thickness	t	0.052mm

5. RESULTS & DISCUSSION

5.1 RETURN LOSS

The return loss characteristic of the above structure is shown in Fig.2. It displays the dual band performance of the proposed antenna structure covering both 2.4GHz band and 5.2GHz band.

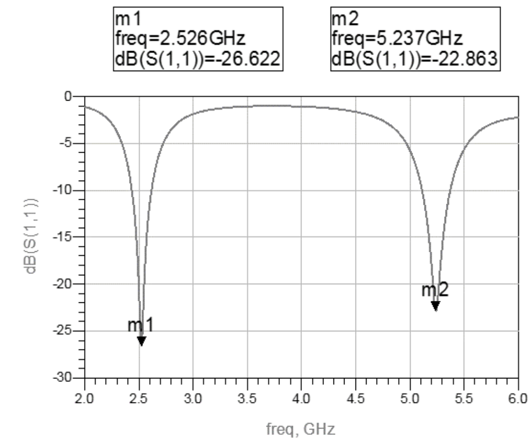


Fig.2. Return Loss characteristics of the dual band monopole antenna

5.2 SMITH CHART

The Fig.3 and Fig.4 shows the Smith chart of the proposed monopole antenna at both the frequencies 2.4GHz and 5.2GHz. In both plots, the impedance locus lies in the VSWR circle, indicating that the input signal is coupled properly.

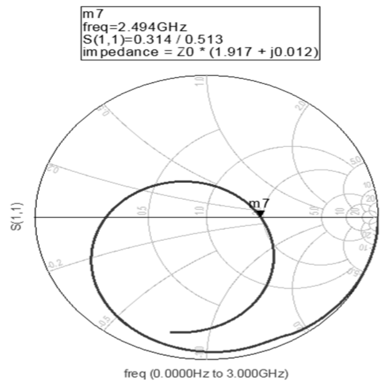


Fig.3. Smith chart of Dual band monopole antenna at 2.45GHz

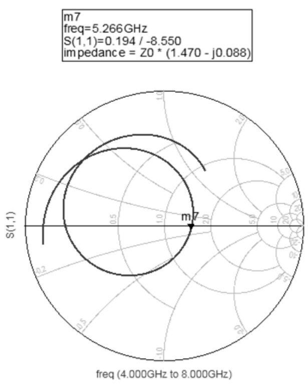


Fig.4. Smith chart of Dual band monopole antenna at 5.2GHz

5.3 RADIATION PATTERN

The radiation properties of the antenna as a function of space coordinates can be represented graphically to obtain the radiation pattern of the antenna. Radiation pattern of an antenna is basically three dimensional and thus it can be represented in spherical coordinate system as a function of (r, θ, Φ). The pattern provides the complete information regarding the characteristics of an antenna.

To represent the pattern in two dimensions, it is a common practice to cut the pattern either in XY plane or in XZ plane i.e., either azimuth or elevation. The electric field consists of θ and Φ components that are perpendicular to each other. Proper radiation is possible with a separation of $r \geq 2D2/\lambda$.

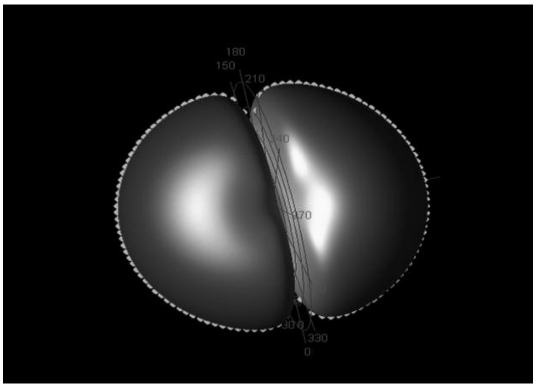


Fig.5. 3D Radiation pattern at 2.45GHz

The proposed antenna is capable of providing uniform distribution in its radiation plane, because monopole antennas are able to provide omni directional radiation pattern. The 3D radiation pattern of proposed antenna is shown in Fig.5 and Fig.6 respectively at 2.4GHz and 5.2GHz.

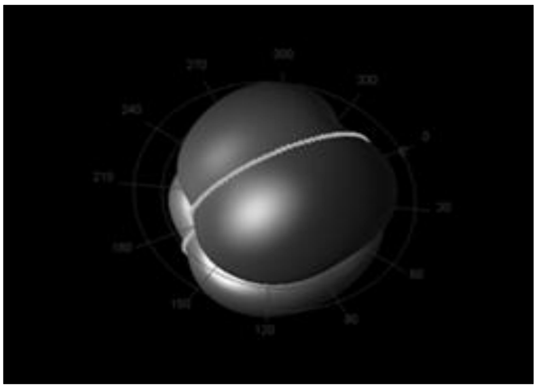
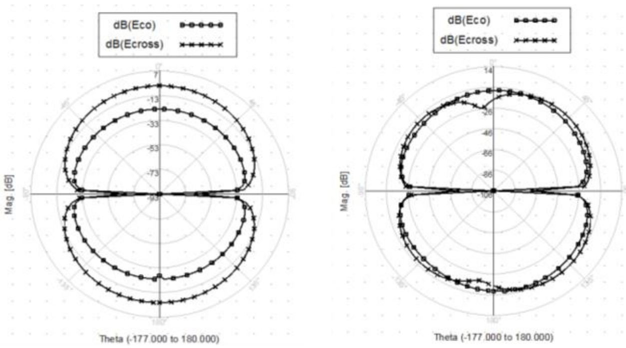


Fig.6. 3D Radiation pattern at 5.2GHz

The simulated far-field radiation pattern on the E-plane (x-z plane) and H-plane (y-z plane) at frequencies of 2.4GHz and 5.8GHz are plotted in Fig.7(a) and Fig.7(b). The antenna shows a stable omni directional pattern in the E-plane and H-Plane over the WLAN Spectrum.



(a) (b)

Fig.7. Radiation Patterns of Co-polarization and Cross-polarization in X-Z plane (a) at 2.4GHz (b) at 5.2GHz

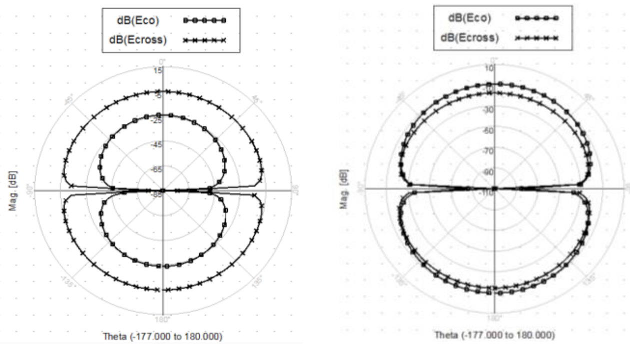


Fig.8. Radiation Patterns of Co-polarization and Cross-polarization in Y-Z plane (a) at 2.4GHz (b) at 5.2GHz

5.4 CURRENT DISTRIBUTION

The surface current distributions of the proposed antenna over the drift frequencies are shown in Fig.9. It can be observed that the surface current distribution is close to the feed line. The current gets uniformly distributed over the patch at the resonant frequencies.

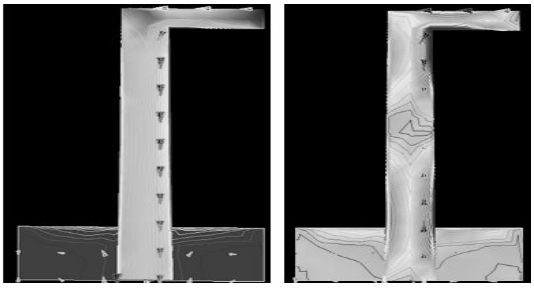


Fig.9. Surface Current Distributions at 2.4GHz and 5.2GHz

5.5 VSWR

The measured and simulated voltage standing wave ratio (VSWR) for the proposed antenna is shown in Fig.10. It can be seen that, lower VSWR which is smaller than 2 is achieved over the resonant frequency bands at 2.4GHz and 5.8GHz.

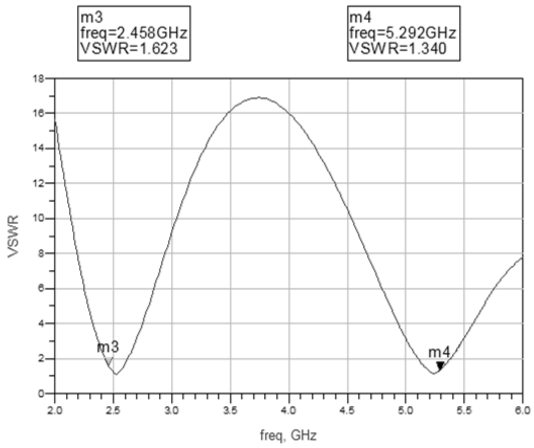


Fig.10. Simulated VSWR

5.6 ANTENNA GAIN

The Fig.11 depicts the simulated gain of the proposed antenna over the different values of theta. Additionally, the radiation efficiency of this proposed antenna is 100%.

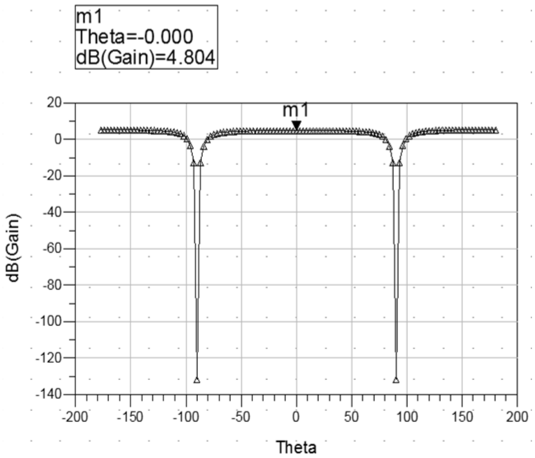


Fig.11. Theta vs. Gain at 2.4GHz

Power radiated (Watts)		0.00213493
Effective angle (Steradians)		3.63904
Directivity(dBi)		5.38223
Gain (dBi)		5.01064
Maximim intensity (Watts/Steradian)		0.000586674
Angle of U Max (theta, phi)	144	95
E(theta) max (mag,phase)	0.558962	94.7349
E(phi) max (mag,phase)	0.359996	33.8985
E(x) max (mag,phase)	0.34116	-151.891
E(y) max (mag,phase)	0.466584	-88.6315
E(z) max (mag,phase)	0.32855	-85.2651

Fig.12. Antenna Parameters at 5GHz

The normalized elevation and azimuthal plane radiation patterns at 2.45GHz, and 5.25GHz are shown in Fig.13 to Fig.16.

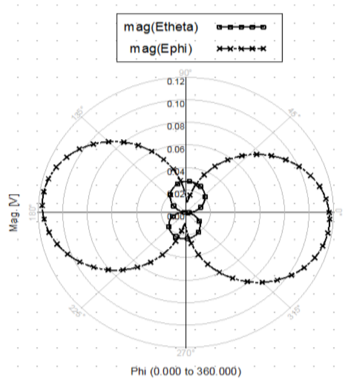


Fig.13. Azimuthal Radiation Pattern for 2.45GHz

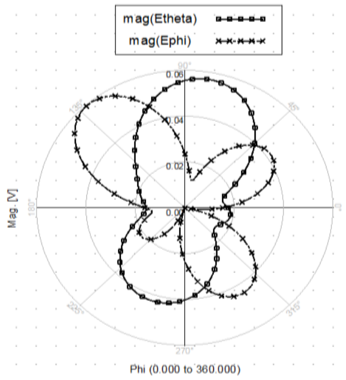


Fig.14. Azimuthal Radiation Patterns for 5.2GHz

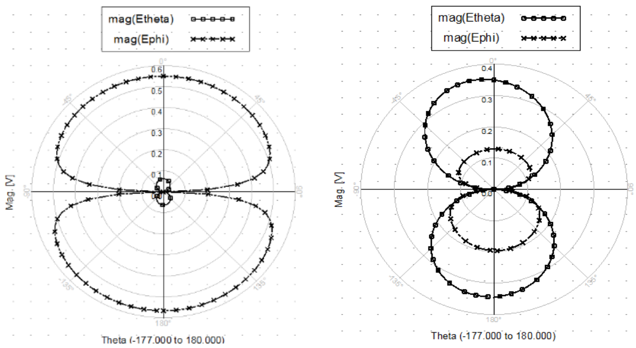


Fig.15. Elevation Patterns at Φ= 0˚ for 2.45 and 5.2GHz

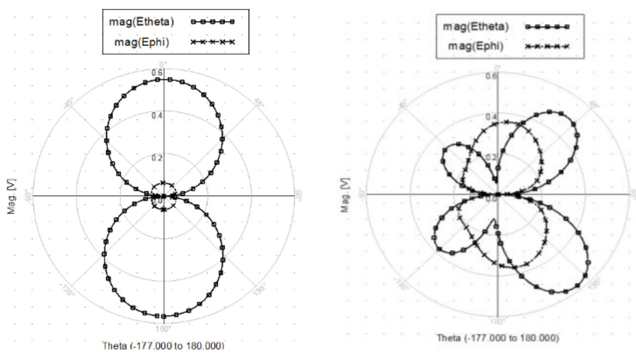


Fig.16. Elevation Patterns at Φ = 90˚ for 2.45GHz and 5.2GHz

6. CONCLUSION

A compact dual-band monopole antenna capable of operating at two frequency bands of WLAN (i.e. at 2.4GHz and 5.2GHz) has been proposed, designed and simulated. The antenna is particularly suited for the narrow frequency spacing of wireless devices, for example laptop computers. The antenna is formed by using two metal strips which is different from the conventional T shaped monopole antenna or PIFA. The two resonant modes of the antenna can be well-adjusted to cover the desired operating bands. It shows the good radiation characteristics over the 2.4GHz and 5.2GHz bands. It is perspective that the proposed antenna will become a promising compact dual band antenna for 2.4/5.2GHz WLAN operating devices.

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