International Journal of Electronic and Electrical Engineering.
ISSN 0974-2174 Volume 4, Number 3 (2011), pp. 267-274

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A Low-Cost Wire Type Strip Antenna for Dual ISM-Bands (2.4 and 5.8 GHz) Operation

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Abstract

This paper presents a low-cost wire type strip antenna for dual ISM-bands (2.4 and 5.8 GHz) operation by means of numerical simulation. The antenna has very high peak gain of 8.35 and 7.28 dBi with less than 0.5 and 2.0 dBi gain variation within the 10 dB return loss bandwidth at 2.4 and 5.8 GHz ISM-bands respectively. Moreover the proposed antenna can provide a bandwidth of 680 MHz (2350–3030MHz) and 125 MHz (5795–5920 MHz) at lower and upper frequency bands respectively and the size of the antenna is 34×37 mm2. In addition, the proposed antenna has achievable return loss and radiation characteristics.

Keywords: Strip antenna, ISM band, RFID, WLAN, Bluetooth.

Introduction
In recent times the industrial, scientific and medical (ISM) bands (frequency range: 2.4 to 2.485 GHz and 5.725 to 5.875 GHz) are significant means of wireless communication. Wireless local-area networks (WLANs), Bluetooth and wireless sensor networks all uses ISM band (IEEE 802.11b and IEEE 802.11b/g standard). The fast growing WLAN protocals operating bands are IEEE 802.11 b/a/g at 2.4 GHz (frequency ranges 2400–2485 MHz), 5.2 GHz (frequency ranges 5150–5350 MHz) and 5.8 GHz (frequency ranges 5725–5825 MHz). The frequency band used for the RFID system is 125 kHz; 13.56, 869 and 914 MHz; 2.45 and 5.8 GHz band [1-6]. There is a trend all over the world for the advance of compact, low-profile, multi-function antenna with the ability to support various commercial protocols.

An inverted-F antenna (IFA) printed on a PCMCIA card for the 2.4 GHz ISM band [1], T-shaped monopole antenna with shorted L-shaped strip-sleeves for 2.4/5.8-GHz WLAN operation [3], CPW-fed triangle-shaped monopole antenna for wireless applications [4], low-profile IFA and wideband loaded IFA's for 5 GHz WLAN applications [5], CPW-fed shorted F-shaped monopole antenna for 5.8-GHz RFID application [6], compact monopole antenna for dual ISM-bands (2.4 and 5.8 GHz) operation [7], dual wideband printed monopole antenna for WLAN/WiMAX applications [8] and surface-mount monopole antenna for 2.4/5.2/5.8-GHz band operation [9] have been proposed.

To provide the increasing demand and cover up the widespread applications of WLAN, Bluetooth and RFID a low profile multiband antenna with high gain properties in all bands is desired. To meet up most of mentioned requirements, the proposed wire type strip antenna is one of the good candidates within the micro-strip printed antennas.

Antenna Design

In designing the antenna for dual ISM-bands operation, using method of moments (MoM's) in Numerical Electromagnetic Code (NEC) [10], we conducted parameter studies to ascertain the effect of different loading on the monopole antenna to find out the optimal design.

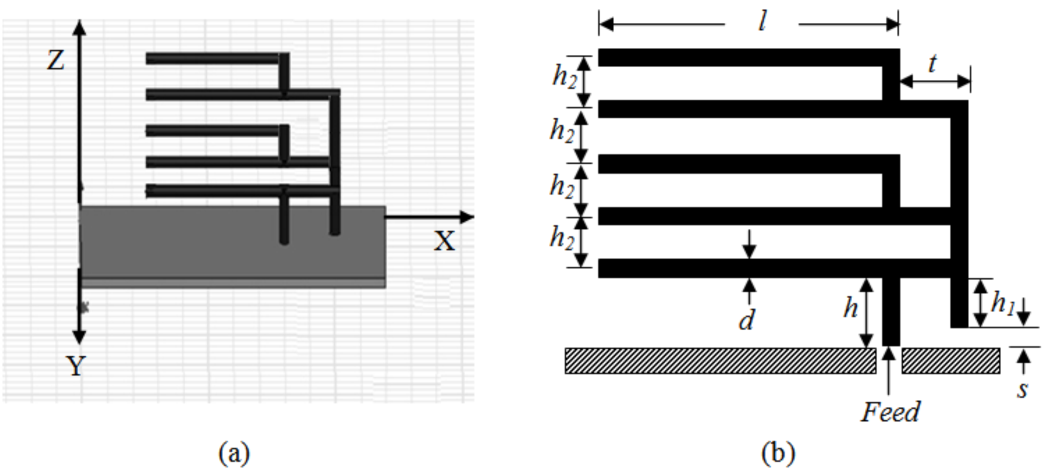


Figure 1: Proposed wire type strip antenna (a) 3-D view and (b) 2-D geometry.

For the analysis of the accuracy optimum segmentation of each geometrical parameter are used in NEC. Figure 1 represents the geometry of the strip antenna. Here one leg of the antenna directly connected to the feeding point and another leg spaced *s* from the ground plane. For the simulation we consider printed circuit board (PCB) with permittivity of $\varepsilon_r = 2.2$ and substrate thickness of *1.58 mm*. The antenna is assumed to feed by 50 Ω coaxial connector, with its central conductor connected to the feeding point and its outer conductor connected to the ground plane just across the feeding point. In the analysis the dimensions of the ground plane considered as $60 \times 60\ mm^2$. The dimensions of the proposed strip antenna are given are Table 1.

Table 1: Dimensions of the proposed wire type strip antenna.

Antenna Name	Antenna Parameters	Values (mm)	Dimension (mm^2)
Wire type strip Antenna	l	31	34×37
	t	6	
	h	14	
	h_1	13	
	h_2	5	
	d	3	
	s	1	

Simulation Results

The proposed antenna is constructed and numerically analyzed using MoM's in NEC. The numerical simulation analysis of the proposed strip antenna to realize the operation for the dual ISM-bands is presented below. Figure 2 shows the voltage standing wave ratio (VSWR) variation and Figure 3 represents the return loss of strip antenna. The value of VSWR varies form 1.30 to 1.62 and 1.32 to 2.2 at lower and upper ISM bands respectively.

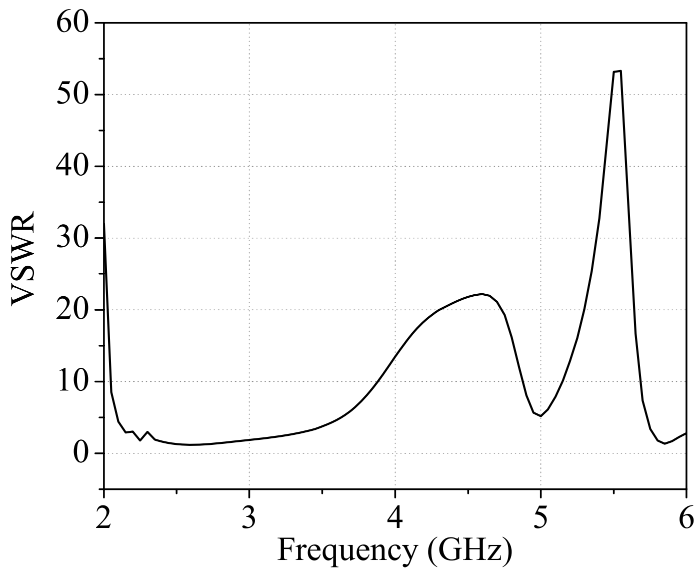


Figure 2**:** VSWR variation of proposed antenna with frequency.

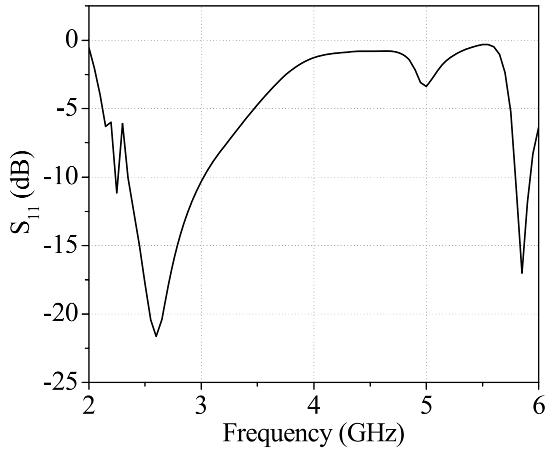


Figure 3: Return loss variation of proposed antenna with frequency.

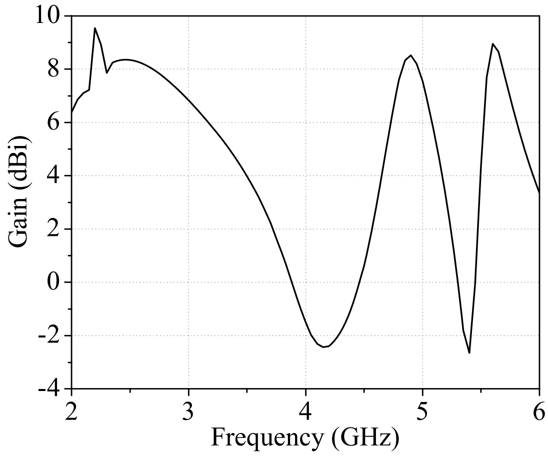


Figure 4: Total gain variation of proposed antenna with frequency.

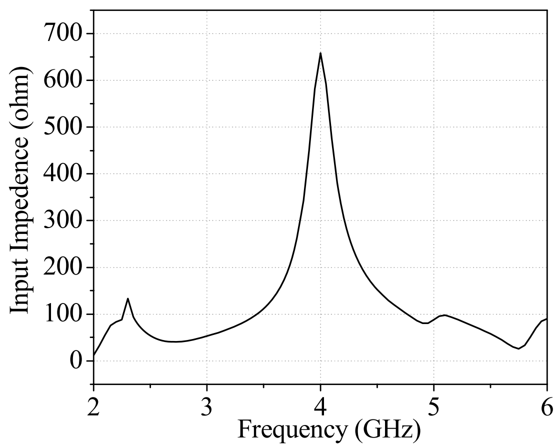


Figure 5: Input impedance variation of proposed antenna with frequency.

Two separate resonant modes at about 2.60 GHz and 5.85 GHz are obtained were excited with good impedance matching. The lower mode has a wider impedance bandwidth of 680 MHz (2350–3030MHz) and the upper mode has a impedance bandwidth of 125 MHz (5795–5920 MHz). The obtained impedance bandwidths fully cover the 2.4 GHz and partially cover the 5.8 GHz ISM band. Figure 4 shows the gain of strip antenna. The peak gain of the antenna is 8.35 and 7.28 dBi with less than 0.5 and 2.0 dBi gain variation within the 10 dB return loss bandwidth at lower and upper ISM bands respectively, which indicates that the antenna has high gain within the operating band. Figure 5 represents the antenna input impedance variation and Figure 6 represents the antenna phase shift causes due the impedance mismatch as a function of frequency. The input impedance of the antenna is 62.2252 and 50.7772 Ω at 2.45 and 5.85 GHz respectively. Phase shift of the antenna is about 15^0 in 2.4 GHz whereas it is closer to 20^0 at 5.8 GHz band.

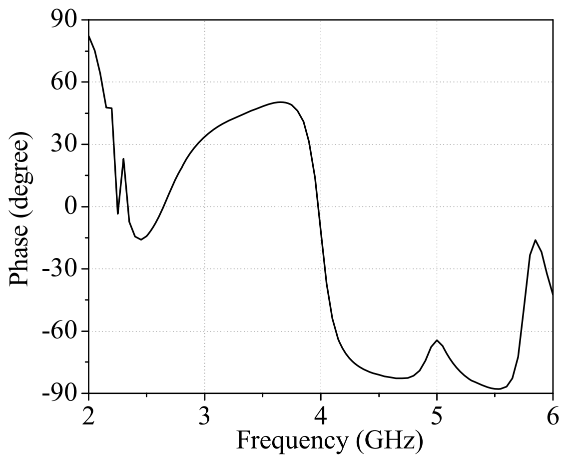
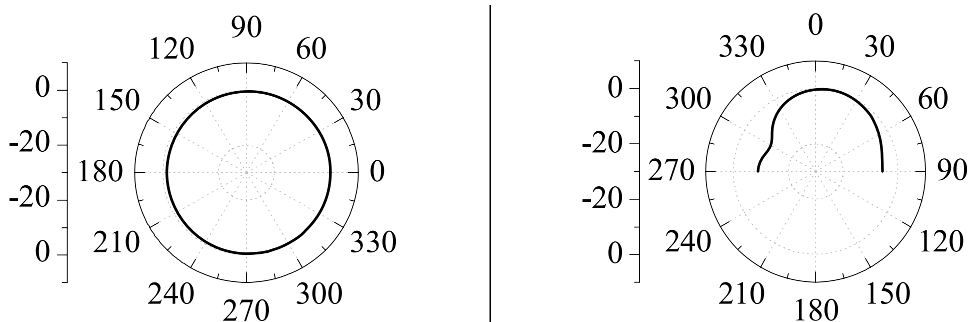


Figure 6: Phase variation of proposed antenna with frequency.



(a) (b)

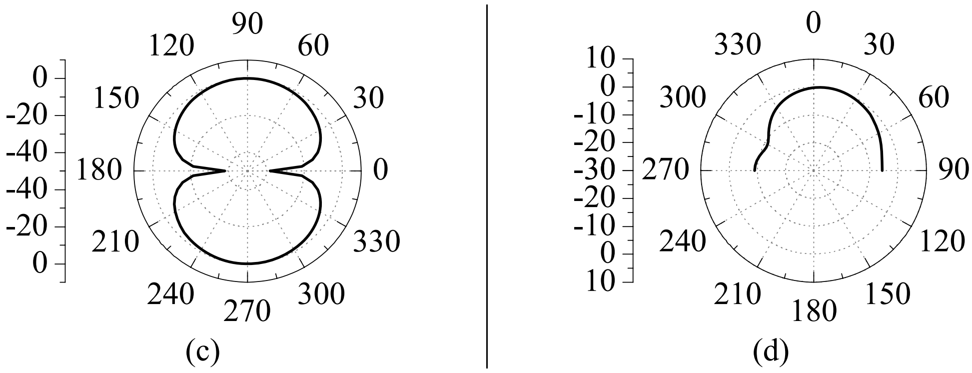
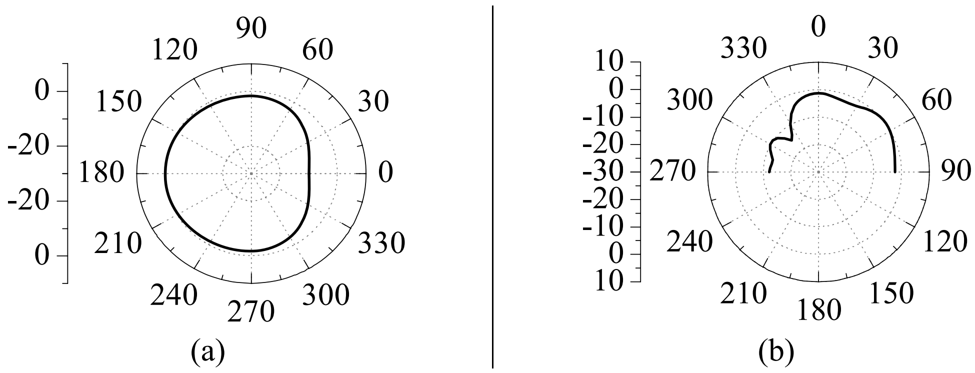
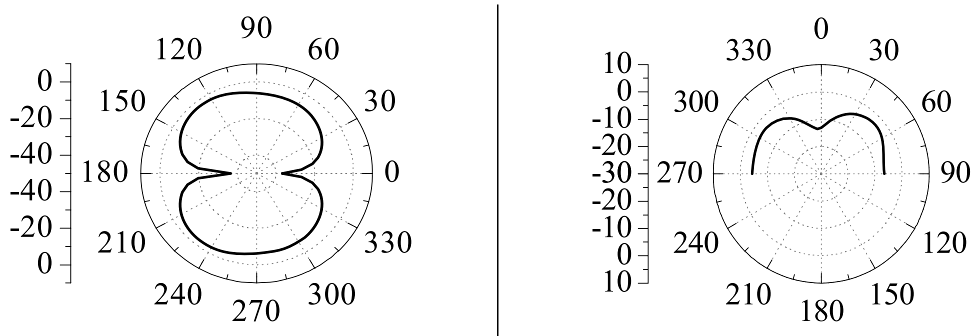


Figure 7: Radiation pattern (normalized) (a) total gain in E-plane (b) total gain H-plane (c) horizontal gain in E-plane and (d) vertical gain in H-plane at 2.4 GHz.

Figures 7 and 8 show the normalized radiation patterns at 2.4 and 5.8 GHz respectively. The antenna's normalized total radiation in E and H-plane is almost omnidirectional. For the better analysis of the antenna, for two resonant frequencies antenna's normalized radiation patterns are shown as: total gain in E-plane, total gain in H-plane, horizontal gain in E-plane and vertical gain in H-plane.

The IFA printed on a PCMCIA [1], T-shaped monopole antenna [3], CPW-fed triangle-shaped monopole antenna [4], low-profile IFA and wideband loaded IFA's [5], CPW-fed shorted F-shaped monopole antenna [6], compact monopole antenna [7], printed monopole antenna [8] and surface-mount monopole antenna [9] suffers from the gain limitations. But the gain in both operating band of the proposed strip antenna is much better than the antennas proposed earlier as listed in Table 2.





(c) (d)

Figure 8: Radiation pattern (normalized) (a) total gain in E-plane (b) total gain H-plane (c) horizontal gain in E-plane and (d) vertical gain in H-plane at 5.8 GHz.

Table 2: Comparison between the proposed and referance antennas.

Antenna Name	Peak Gain (dBi) at lower ISM band	Peak Gain (dBi) at upper ISM band
Wire type strip antenna (Proposed)	8.35	7.28
IFA [1]	2.64	–
T-Shaped Monopole [3]	3.5	1.0
CPW-Fed Triangle-Shaped Monopole [4]	2.14	3.05
Wideband LIFA [5]	–	7.0
CPW-Fed Shorted F-Shaped Monopole [6]	–	4.3
Compact Monopole [7]	1.354	2.105
Printed Monopole [8]	2.4	4.2
Surface-Mount Monopole [9]	3.6	5.5

Conclusion

A wire type strip antenna for dual ISM–bands operation is proposed by means of numerical simulations. The antenna occupies a small area of 34×37 mm^2 with bandwidths of 680 MHz (2350–3030MHz) and 125 MHz (5795–5920 MHz). Moreover the antenna can provide high gain in the both operating bands. From the analysis on antenna radiation patterns, return loss, input impedance and radiation are desirable for the specified applications. Due to the compactness of the antenna, it is promising to be embedded within the different multi–function mobile devices employing ISM-bands operation.

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