Wire Type Multiband Strip Antenna for WiMAX /WLAN Operations

Md. Selim Hossain, A. N. M. Enamul Kabir, Debabrata Kumar Karmokar

Abstract*—This paper presents a wire type multiband strip antenna for WiMAX and WLAN operations by means of numerical simulations. The dimension of the antenna is 39×30 mm^2 and provides an impedance bandwidth of 300 MHz (2350-2650 MHz) and 130 MHz (5490-5620 MHz) at lower and upper frequency band respectively, which fully covers the 2.4, 2.5 and partially covers the 2.3, 5.5 GHz bands. The antenna contains very high peak gains of 8.25, 8.43, 8.46 and 6.43 dBi at 2.3, 2.4, 2.5 and 5.5 GHz band respectively with less than 0.2, 0.1, 0.3 and 1.5 dBi gain variations within the 10 dB return loss bandwidth. The VSWR of the antenna varies between 1.20~1.80 and 1.06~1.83 at the lower and upper resonant frequency bands respectively and the peak values of the return loss are -20.85 and -30.71dB. The antenna has good omnidirectional radiation characteristics at E-plane and H-plane.

***Index Terms*—Strip Antenna, Multiband Antenna, Numerical Electromagnetic Code (NEC), WiMAX, WLAN.**

I. INTRODUCTION

At present the demand of wireless local area networks (WLANs) and worldwide interoperability for microwave access (WiMAX) are increasing numerously worldwide for commercial communication because WLAN provides high speed connectivity and easy access to networks without wiring and WiMAX can provide a long operating range with a high data rate for mobile broadband wireless access, faultless internet access for wireless users becomes more popular. Also in recent times the function of various portable devices is increasing, so the antenna designer's encountered difficulty in designing antennas that could provide multiband operations with high gain in each operating band. The fast growing WLAN protocols operating bands are IEEE 802.11 b/a/g at 2.4 GHz (2400–2484 MHz), 5.2 GHz (5150–5350 MHz) and 5.8 GHz (5725–5825 MHz), the operating bands of WiMAX is 2.5/3.5/5-GHz (2500–2690/3400–3600/ 5250–5850 MHz) bands [1-4].

A dual wideband printed monopole antenna for WLAN/WiMAX applications [1], a multiband flat-plate Inverted-F antenna for Wi-Fi/WiMAX operation [2], a T-shaped monopole antenna with shorted L-shaped strip-sleeves for WLAN 2.4/5.8-GHz operation [3], an internal PIFA's for UMTS/WLAN/WiMAX multi-network operation for a USB dongle [4], a CPW-fed triangle-shaped monopole antenna for 2.4/5 GHz WLAN and 3.4 GHz WiMAX applications [5], a capacitively fed hybrid monopole/slot chip antenna has been proposed for 2.5/3.5/5.5 GHz WiMAX operation in the mobile phone [6], a printed antenna with a quasi-self-complementary structure for 5.2/5.8 GHz WLAN operation [7], a compact monopole antenna has been proposed for dual ISM band (2.4 and 5.8 GHz) operation [8], a printed antenna which is working in 2.4 GHz Bluetooth, 3.5 and 5.8 GHz WiMAX, 2.4–2.5 and 5.0–5.8 GHz Wi-Fi, 2.4–2.84 GHz, 5.15–5.35 and 5.72–5.83 GHz WLAN operation [9], a broadband low-profile printed T-shaped monopole antenna for 5 GHz WLAN application [10] and a compact PIFA for Bluetooth, S-DMB, WiBro, WiMAX and WLAN applications [11], have been proposed.

To provide the rising demand and cover up the widespread applications of WiMAX and WLAN an antenna with high gain, satisfactory bandwidth and less gain variation within the antenna bandwidth are desired. To meet up most of mentioned requirements multiband strip antenna is one of the superior candidates within the micro-strip printed antennas.

II. ANTENNA DESIGN

In designing strip antenna for WiMAX and WLAN operation, we examine the possibility of increasing antenna gain and number of operating bands. Using MoM's in Numerical Electromagnetic Code (NEC) [12], we conducted parameter studies to ascertain the effect of different loading on the antenna performance to find out the optimal design. In our analysis we assume the copper conductor and 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. Fig. 1 represents the basic geometry of the IFA (structure 1). Here one leg of IFA directly connected to the feeding 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. In the analysis the dimensions of the ground plane considered as 60 mm × 60 mm. Fig. 2 and 3 represents the loaded IFA, called the double branch inverted-F antenna (DBIFA) (structure 2) and triple branch inverted-F antenna (TBIFA) (structure 3) respectively. Fig. 4 represents the proposed strip antenna. Fig. 5 and 6 represents the modified strip antenna (structure 5 and 6).

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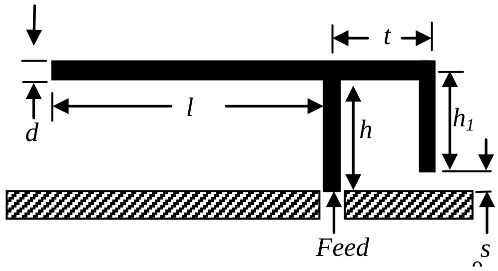


Fig. 1. Inverted-F antenna (IFA) (Structure 1)

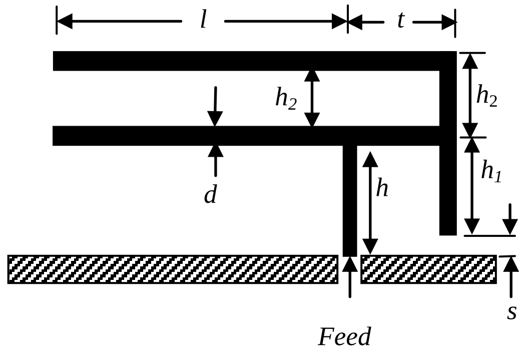


Fig. 2. Double branch IFA (DBIFA) (Structure 2)

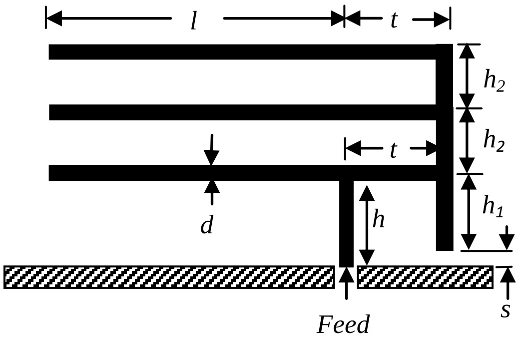


Fig. 3. Triple branch IFA (TBIFA) (Structure 3)

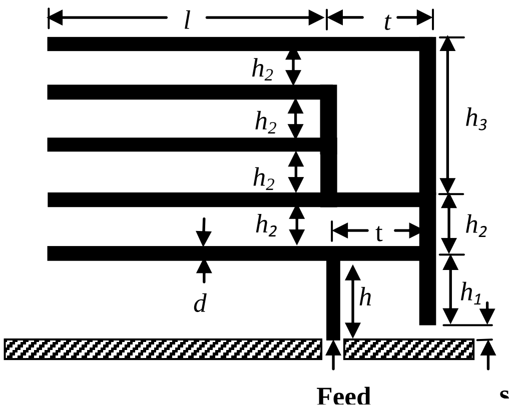


Fig. 4 Strip antennas (Structure 4) (Proposed)

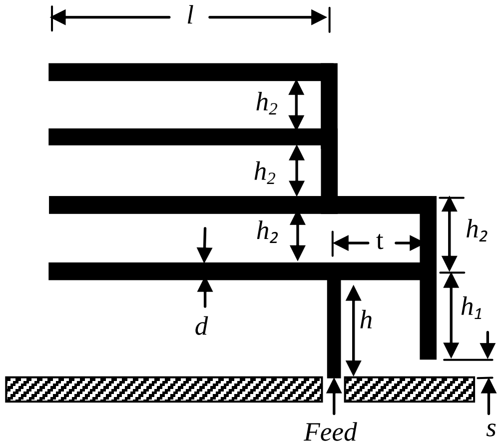


Fig. 5. Modified strip antennas (Structure 5)

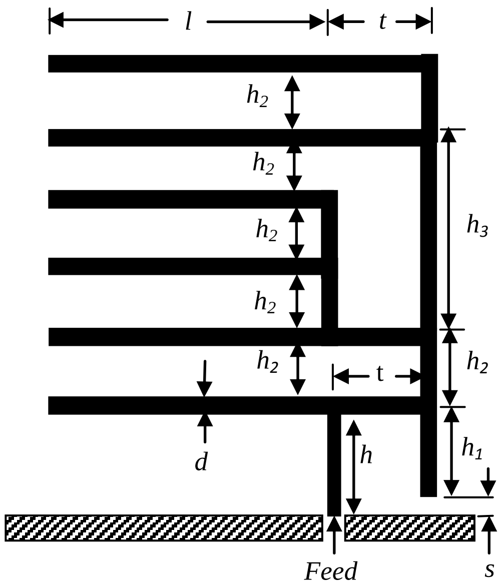


Fig. 6. Modified strip antennas (Structure 6)

For IFA of Fig. 1, the resonant frequency related to *d* given as [13]

$$f_1 = \frac{c}{4(l+t+h_1)} \tag{1}$$

Where *c* is the speed of light. The effective length of the current is $l+t+h_1+d$. Under this case the resonant condition can be expressed as

$$l+t+h_1+d = \frac{\lambda_0}{4} \tag{2}$$

The other resonant frequency that is a part of linear combination with the case $0<d<(1+t)$ and is expressed as

$$f_2 = \frac{c}{4(l+t+h_1-d)} \tag{3}$$

The resonant frequency (f_r) is a linear combination of resonant frequency associated with the limiting case. For the antenna geometry of Fig. 1, f_r can be written from equation (1) and (2) as [14]

$$f_r = r.f_1 + (1-r) f_2 \tag{4}$$

Where $r=d/(l+t)$.

Fig. 7 shows the return loss variation with frequency of IFA, DBIFA, TBIFA and strip antenna. It represent that the return loss of IFA is like dual band shape but both band stay above the required 10 dB level. As the performance of IFA is not satisfactory for the multiband operation then we apply a small suitable structured load on the horizontal branch of the IFA named double branch IFA (DBIFA) as shown in Fig. 2.

From Fig. 7 we observe that when we apply that load then the antenna performance improves significantly but the performance of the lower frequency band is not till satisfactory. So we further modify the applied load (as shown if Fig. 3) and observe that the antenna has achievable return loss characteristic for both operating band.

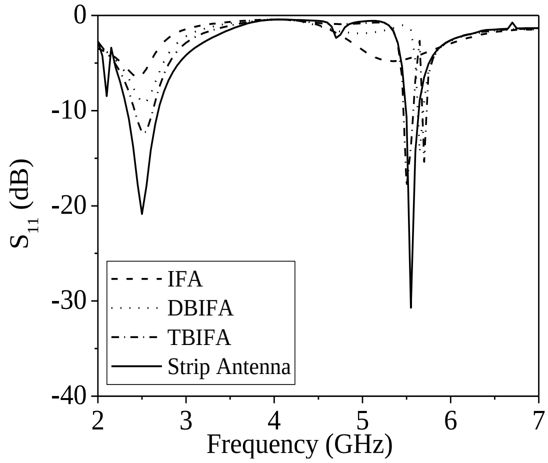


Fig. 7. Variations of return loss for different types of antennas.

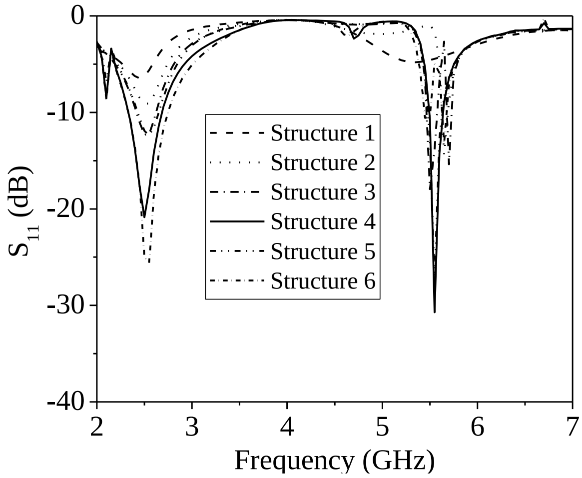
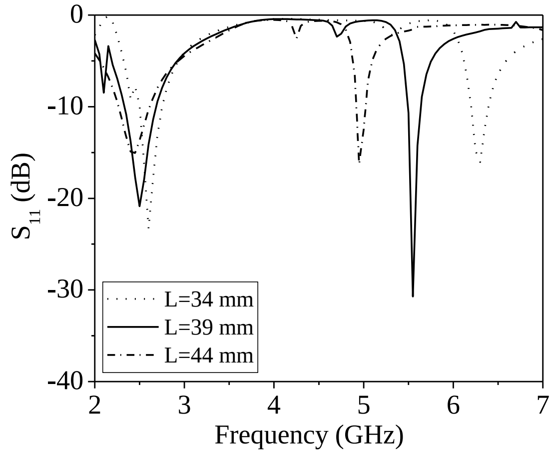
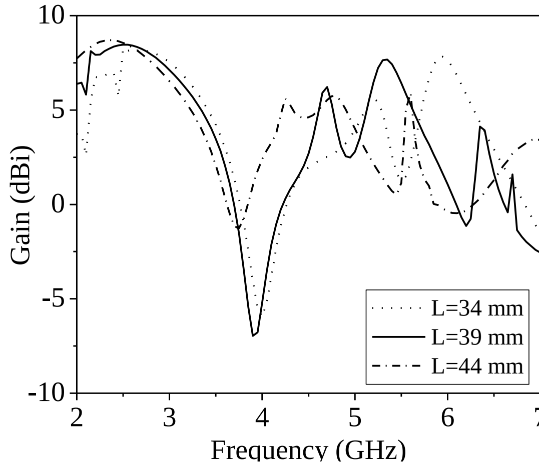


Fig. 8. Variation of return loss (dB) for different structure with frequency

We continue advanced analysis on the loaded IFA for achieving best performance from the antenna structure (shown in Fig. 4 called strip antenna). We further analysis different structure of IFA, strip antenna and other strip antenna called modified strip antenna. Fig. 8 shows the return loss variation for different structure with frequency. From this analysis we observe that the structure 4 (called strip antenna) show the best performance.



(a)



(b)

Fig. 9. Variation of (a) return loss and (b) gain for different values of L of strip antenna

TABLE I. DIMENSION OF THE PROPOSED ANTENNA OF FIG. 4

Antenna name	Antenna parameters	Values (mm)	Dimension (mm^2)
Strip antenna	l	33	39×30
	t	6	
	$L=l+t$	39	
	h_1	13.4	
	h_2	4	
	h_3	12	
	h	14	
	d	2	
	s	0.6	

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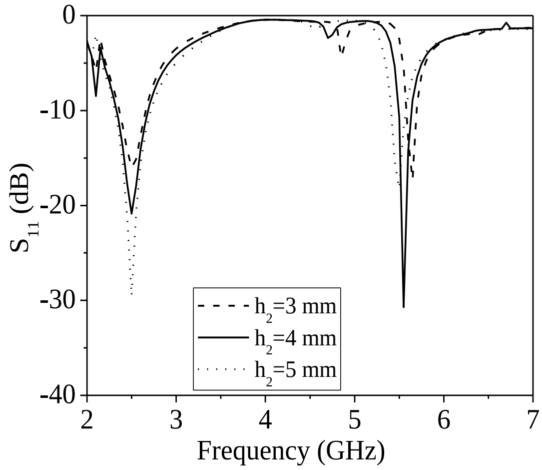
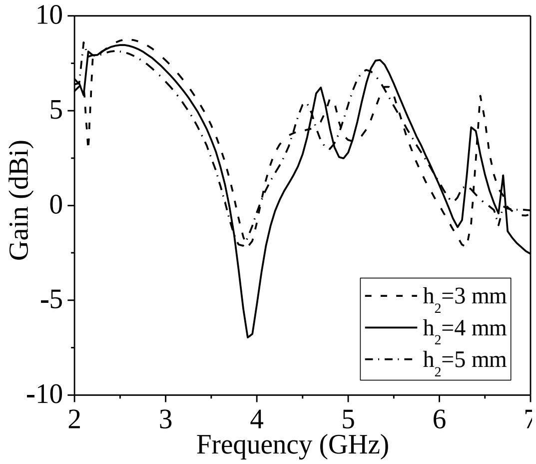
Fig. 9, 10 and 11 show the effects of L, h_2 and t on the performance of strip antenna (antenna structure of Fig. 4). Table I represents the optimized dimensions of the proposed antenna of Fig. 4. The dimension of the proposed wire type strip antenna is 39×30 mm^2.

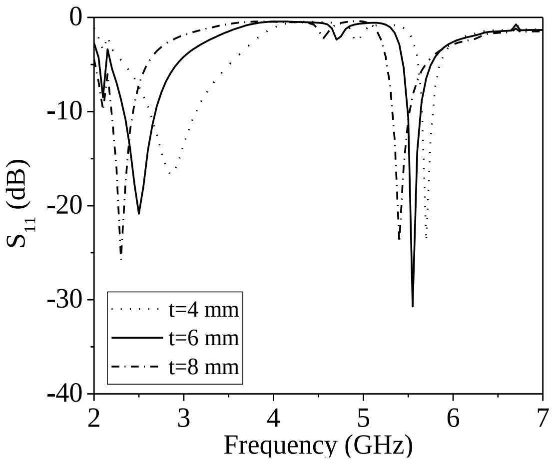


(a)

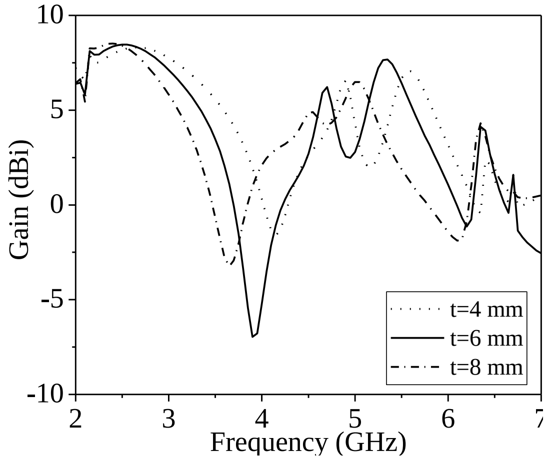


(b)

Fig. 10. Variation of (a) return loss and (b) gain for different values of h2 of strip antenna



(a)



(b)

Fig. 11. Variation of (a) return loss and (b) gain for different values of t of strip antenna

III. NUMERICAL SIMULATION RESULTS

The proposed antenna is constructed and numerically analyzed using MoM's. The numerical simulation result found from NEC software. The numerical results of the antenna are shown below. The proposed antenna have the return loss appreciable than the commonly required 10 dB level.

Fig. 12 represents the voltage standing wave ratio (VSWR) variation and Fig. 13 represents the return loss (dB) variation of strip antenna with frequency. The strip antenna provides a large impedance bandwidth of 300 MHz (2350-2650 MHz) and 130 MHz (5490-5620 MHz) which fully covers the 2.4, 2.5 GHz and partially covers the 2.3 and 5.5 GHz bands. The values of the VSWR of the antenna vary between 1.20~1.80 and 1.06~1.83 at the lower and upper frequency bands respectively (shown in Fig. 12) and the peak values of the return loss are -20.85 and -30.71 dB at lower and upper frequency band respectively (as in Fig.13).

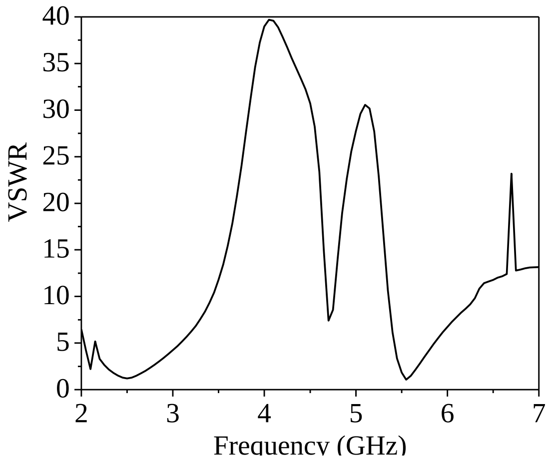


Fig. 12. VSWR variation of strip antenna with frequency

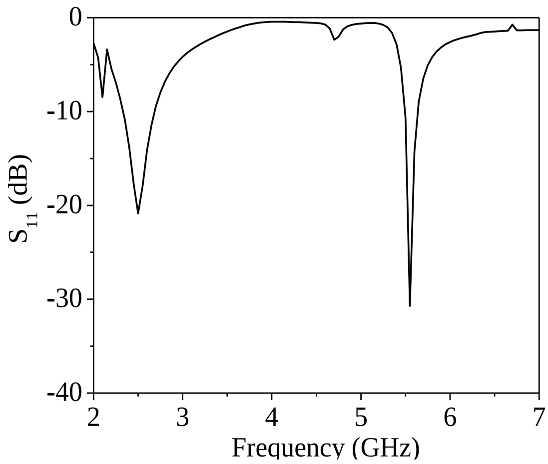


Fig. 13. Return loss variation of strip antenna with frequency.

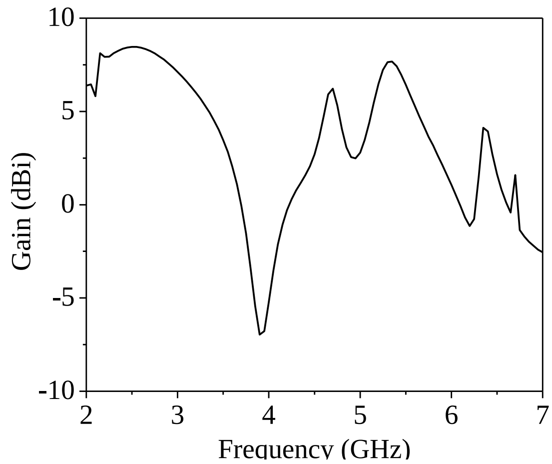


Fig. 14. Gain variation of strip antenna with frequency.

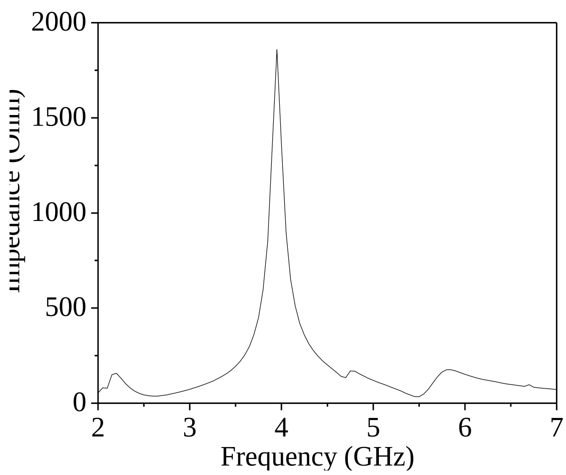


Fig. 15. Impedance variation of strip antenna with frequency

Fig. 14 shows the peak gains (dBi) of the proposed antenna. The peak gains of the antenna are 8.25, 8.43, 8.46 and 6.43 dBi at 2.3, 2.4, 2.5 and 5.5 GHz band respectively, with less than 0.2, 0.1, 0.3 and 1.5 dBi gain variations within the 10 dB return loss bandwidth.

Fig.15 represents the impedance (ohm) variation of frequency. From the simulated data, the proposed antenna is near about 50 Ω at operating frequency bands so extra impedance matching network is not essential for the operation of the antenna. Fig. 16 represents the antenna phase shift (degree) causes due to the impedance mismatch as a function of frequency. Also, from the simulation study, the antenna offers a phase shift of -14.484^0, -18.743^0, -7.066^0 and -25.277^0 at 2.3, 2.4, 2.5 and 5.5 GHz band respectively. So phase shift of strip antenna closer to 0^0 all over the antenna bandwidth. Fig. 17 and 18 show the normalized radiation patterns of strip antenna at 2.4 and 5.5 GHz bands respectively. Normalized radiation patterns for two resonant frequencies are shown as: total gain in H-plane (YZ/XZ plane) and E-plane (XY plane). The antenna's normalized total radiation in H and E-plane is almost omnidirectional at the 2.3/2.5/5.5 GHz WiMAX and 2.4 GHz WLAN operating frequency band.

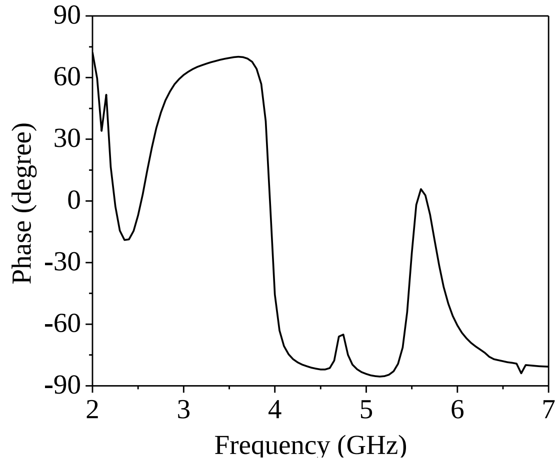
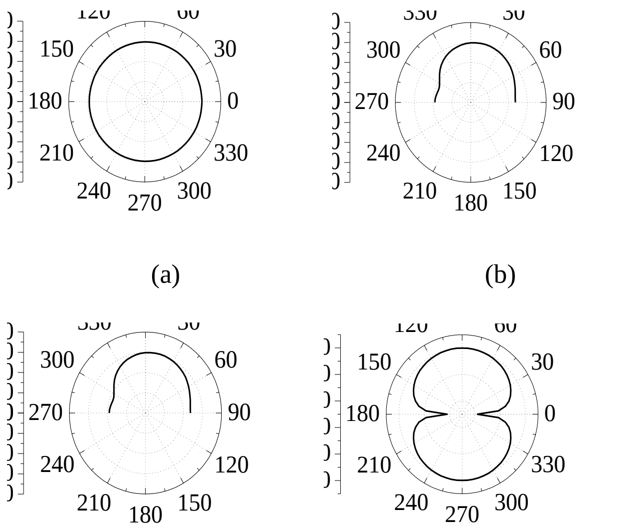


Fig. 16. Phase shift variation of strip antenna with frequency.



(a) (b)

(c) (d)

Fig. 17. Normalized radiation pattern (a) total gain in E-plane (b) total gain in H-plane, (c) vertical gain in H-plane and (d) horizontal gain in E-plane of strip antenna at 2.4 GHz

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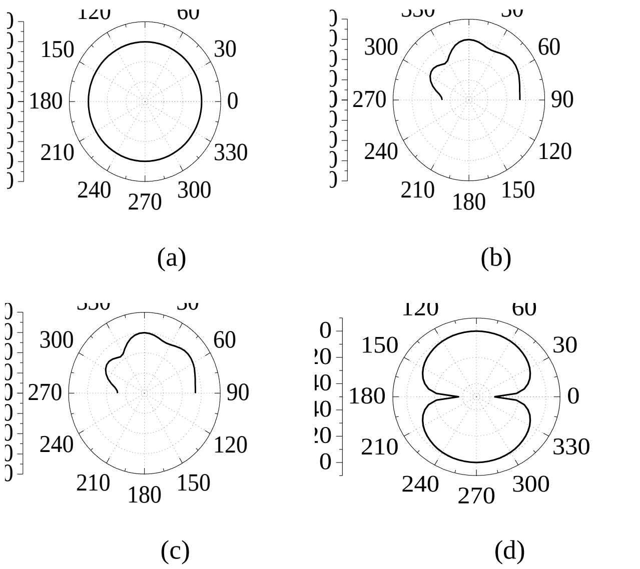

Fig. 18. Normalized radiation pattern (a) total gain in E-plane (b) total gain in H-plane, (c) vertical gain in H-plane and (d) horizontal gain in E-plane of strip antenna at 5.5 GHz

Printed monopole antenna [1], flat-plate Inverted-F antenna [2], T-shaped monopole antenna with shorted L-shaped strip-sleeves [3], internal PIFAs [4] CPW-fed triangle-shaped monopole antenna [5], capacitively fed hybrid monopole/slot chip antenna [6], printed quasi-self-complementary antenna [7], compact monopole antenna [8], printed antenna [9] suffer from the gain limitations for required applications.But the gain of the proposed antenna is much better with stable gain variation within the antenna bandwidth than the antennas proposed earlier. In overall considerations, the performance of the proposed strip antenna is much better than all other antennas.

TABLE II
GAIN COMPARISON WITH REFERENCES

Antenna	Peak Gain	
	2.4 GHz WLAN	5.5 GHz WiMAX
Strip antenna (Proposed)	8.43	6.43
Printed monopole antenna [1]	-	4.0
T-shaped monopole with shorted L-shaped strip sleeves antenna [3]	3.4	1.0
CPW-fed triangular shaped monopole antenna [5]	2.14	-
Capacitively fed hybrid monopole/slot chip antenna [6]	-	2.7-3.8
Compact monopole antenna [8]	1.354	-
Printed antenna [9]	-2.06	3.07
Printed T-shaped monopole antenna [10]	-	3.5

IV. CONCLUSION

A wire type multiband strip antenna has been proposed and investigated by means of numerical simulations using method of moments in NEC. The antenna occupies a very small area of 39×30 mm^2 with bandwidths of 300 MHz (2350-2650 MHz) and 130 MHz (5490-5620 MHz) at lower and upper frequency band respectively. Moreover the gain of the antenna is very high and the gain variation of the antenna is very low at the operating bands. The simulated pattern, return loss and radiation characteristics indicates the suitability of the antenna for WiMAX /WLAN operations. As the antenna occupies small area, so it is promising to be embedded within the different portable devices employing WiMAX /WLAN applications.

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