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Slot Line Fed Uniplanar Antenna for 2.4/5.8 GHz WLAN Applications

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ABSTRACT

A compact dual band uniplanar antenna suitable for 2.4 and 5.8 GHz (IEEE 802.11 b/g and 802.11a) WLAN application is presented. The $0.28\lambda_0 \times 0.32\lambda_0$ structure comprises of a modified slot line as the radiating element. The ground plane size of proposed antenna has negligible effect on the radiation characteristics which enables easy integration of the antenna with MMIC circuits. Design equations of the antenna are developed and validated on different substrates. The simulation and experimental results show that the proposed antenna exhibits good impedance match, moderate gain and stable radiation patterns in both the frequency bands.

Key words: Slot line feed, uniplanar, multiband, WLAN

INTRODUCTION

A multiband uniplanar antenna with high gain and small size is a modern day communication requirement. Most of the portable devices have various wireless standards which require antennas operating in different bands. This makes the design of multi band antennas a hot research area. The existing antenna designs used for this purpose include dual loop antenna [1] and double T antennas [2]. Slot antennas are widely explored because of its good radiation characteristics and impedance band width [3]. Microstrip line is the widely used feed for slot antennas which has the inherent limitation of not being uniplanar [4]. Characteristics of slot line on a dielectric substrate have been studied by several researchers [5-6]. Use of slot line on low dielectric substrate as a transmission line is limited due to non confinement of field across the slot resulting in radiation. But the same can be used as an efficient radiator with an added advantage of having uniplanar nature. A slot line fed antenna on low permittivity substrate has been investigated which makes use of an open ended design that approximates it to a dipole [7].

In this communication, we present a simple uniplanar slot line fed antenna with moderate gain suitable for 2.4/5.8 GHz WLAN applications. The design consists of a slot line modified as a radiating element. The proposed antenna has a closed ended slot line without the use of balun which makes the design of the antenna simple. Also the ground plane of the antenna can be extended to integrate circuit components without affecting the radiation characteristics. Radiations in both the bands have the same polarization.

ANTENNA DESIGN AND CONFIGURATIONS

The antenna is fabricated on FR4 substrate (εr = 4.4, tan δ = 0.02 h = 1.6 mm). The gap g of the slot line feed is designed for 50Ω impedance. The proposed design is evolved from the basic closed ended slot line which is modified to form a rectangular slot with an arrow shaped transition to get resonances. The arrow shaped tapering from the rectangular slot to the slot line is included to reduce the antenna height and also to improve the impedance matching at higher resonances. The design is optimized using ANSOFT HFSS and the final geometry along with the evolution of the current design is shown in Fig. 1 and corresponding reflection characteristics is shown in Fig .2. Total length of the radiating slot is kept constant in all the 3 stages of evolution and it is seen that the impedance matching at both the resonances improves with the arrow based tapering.

Optimised design of the antenna and its evolution are as follows –
(Ls =31.5mm, g=0.5mm, Wg=36mmm, Lg=40mm, Ws=30mm, s=4.7mm, a=3mm, h=1.6mm)

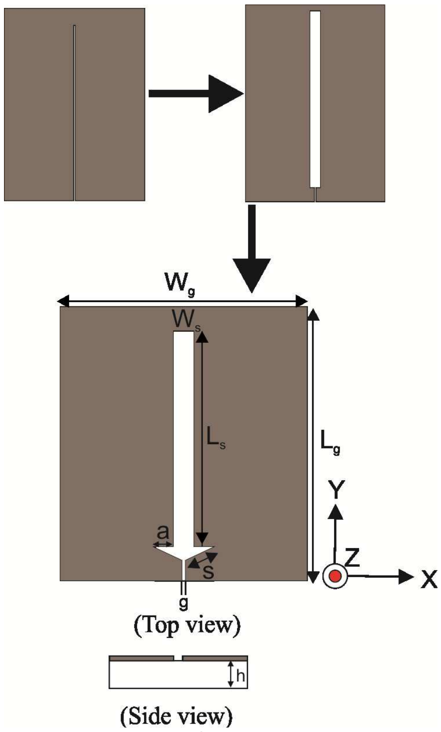

Fig. 1 Optimised design of the antenna and its evolution

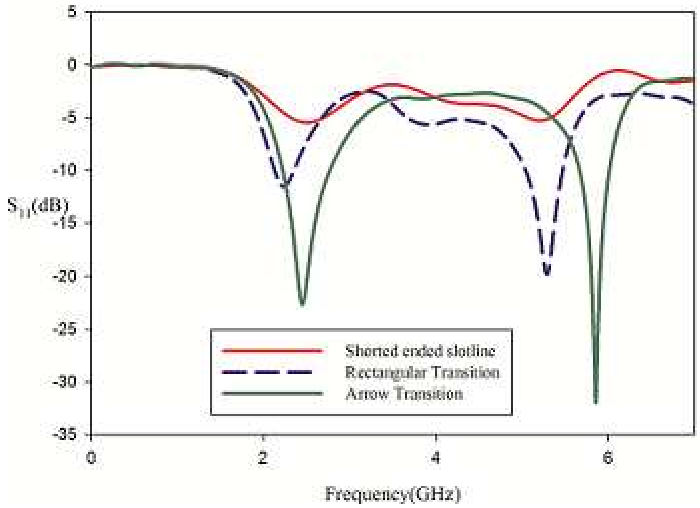

Fig. 2 Reflection Characteristics

RESULTS AND DISCUSSION

Based on the optimized parameters, the prototype antenna is fabricated and its characteristics are studied using the vector network analyzer HP8510C. Fig. 3 plots the simulated and measured antenna reflection characteristics which confirm the dual band operation of the antenna covering 2.4 GHz WLAN band and the 5.8GHz WLAN bands. Slight variation in the S_{11} from the simulation is due to the fabrication inaccuracy. The dependency of the resonances on the various parameters of the antenna is investigated. From Fig.4, it is clear that as the slot length (L_s) is increased both the resonances are shifted to a lower value as expected. The studies for different slot width W_s is shown in Fig.5 show that as W_s increases both resonant frequencies increase. But the variation for the higher resonance is more predominant than the lower. This is because the decrease in the lumped capacitance is predominant at the higher frequencies.

Variation in ground length (L_g) and width (W_g) have no noticeable effect in the resonances which is shown in Fig.5 and 6. Hence the integration of the circuit elements may not cause changes in radiation characteristics. The variation of the parameter 'a' is shown in the Fig.7. As the width of the arrow is increased both the resonance are coming to a lower value which in turn reduces the slot length and the size of the antenna.

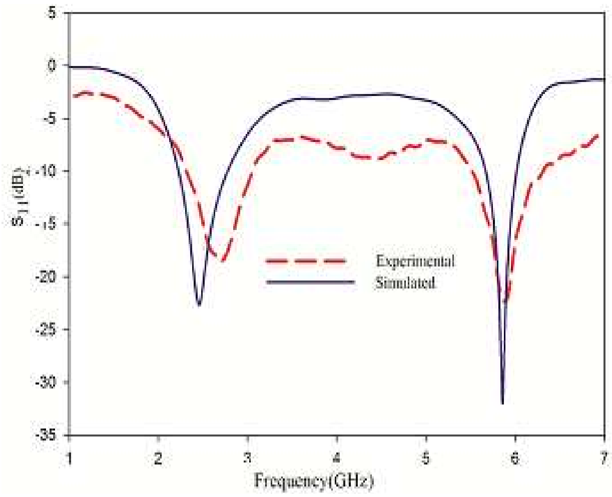

Fig. 3 Reflection characteristics of the fabricated prototype

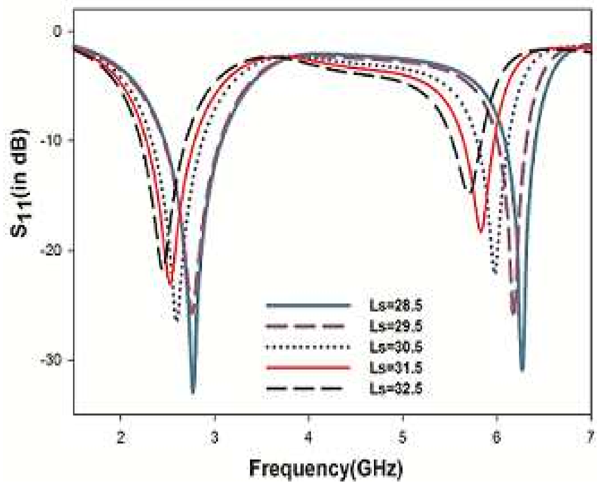

Fig. 4 Variation studies on 'Ls'

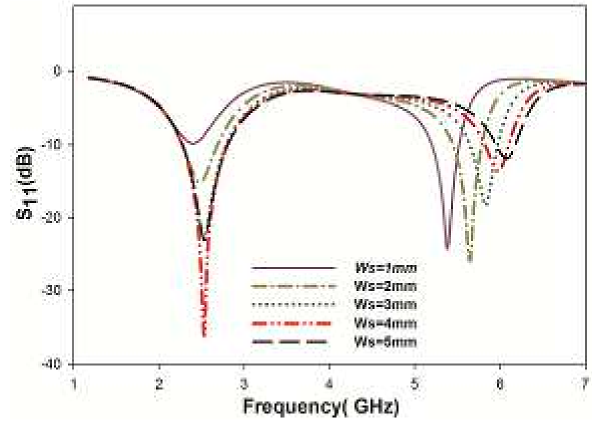

Fig. 5 Variation studies on 'Ws'

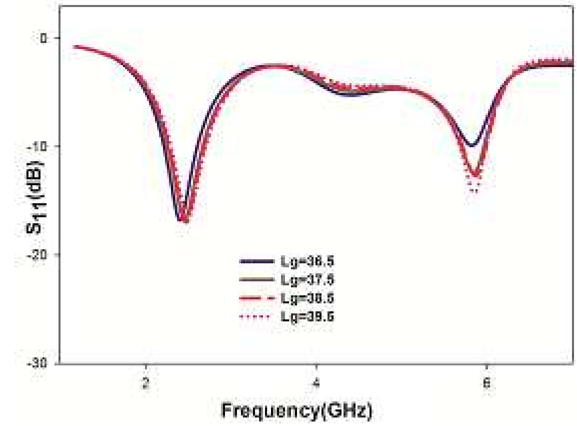

Fig. 6 Variation studies on 'Lg'

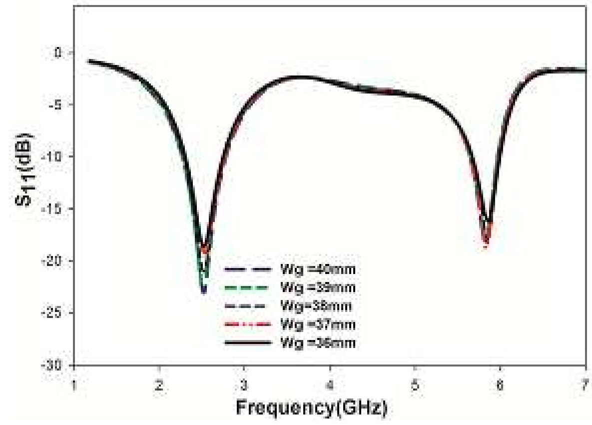

Fig. 7 Variation studies on 'Wg'

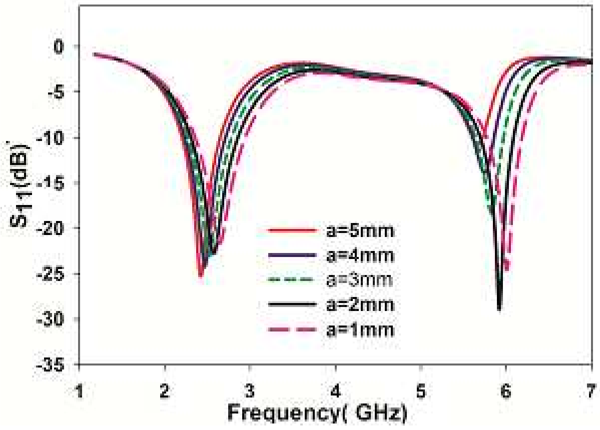

Fig. 8 Variation studies on parameter 'a'

For better understanding the resonance mechanism of the proposed antenna, the surface current distribution at 2.4GHz and 5.8GHz is obtained from Ansoft HFSS and is plotted in Fig. 9. The distribution at 2.4GHz shows a half wave variation along the length of the slot. From fig.9 (a) the maximum surface current density can be seen at point A, B, and minimum at point B. The minimum is approximately at the center of the slot. Surface current distribution at 5.8GHz is depicted in Fig.9 (b), which is found to be the higher order mode of the first resonance. The current distributions at the center of the slot along 'C' to 'B' on both sides are equal in magnitude and opposite in direction which get cancelled out at the Fairfield. From the parametric analysis the design equations of the antenna is formulated as,

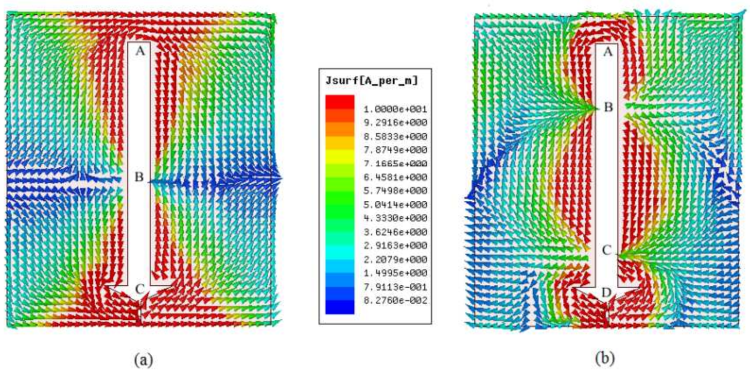

Fig. 9 Surface current distributions (a) 2.4GHz (b) 5.8GHz

$$L_s+a+s+g/2= 0.5\,\lambda_{gn} \quad (1)$$

Here λ_{gn} is the wavelength in the dielectric which is computed from the free space wavelength λ_0 as,

$$\lambda_{gn} = \lambda_0 \;/\sqrt{\varepsilon_{re}} \quad (2)$$

ε_{re} is the effective permittivity of the substrate. These design equations are validated on different substrates keeping the values of 's', 'a' and 'g' constant i.e., 4.7mm, 0.5mm and 3mm respectively. Thus the antenna can be designed on various substrates by changing the parameter L_s only. The geometrical parameters obtained for antennas on different substrates as shown in table 1. The reflection characteristics of the antennas on different substrates based on the design equation is shown in Fig.10.

Table - 1 Parameters Computed from Design Equations

Substrate	Parameters of the antennas					
	h	ε_r	***a***	***g***	***s***	L_S
ROGERS5880	1.57	2.2	3	.5	4.7	41.71
FR4(optimized)	**1.6**	**4.4**	**3**	**.5**	**4.7**	**31.5**
ROGERS RO3006	1.28	6.15	3	.5	4.7	25.355
ROGERS6010LM	.635	10.2	3	.5	4.7	18.711

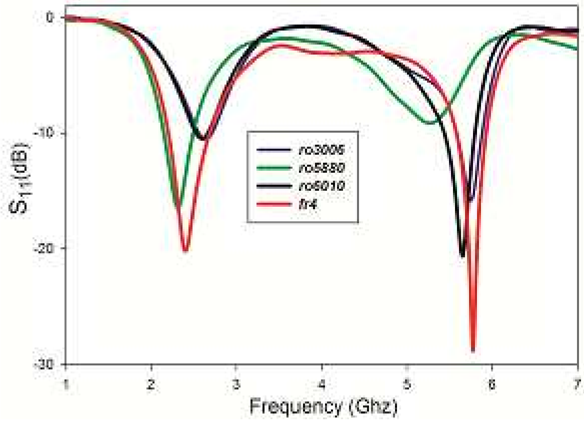

Fig. 10 Reflection Characteristics on different substrates

In all the cases the antennas are operating in 2.4 GHz and 5.8 GHz WLAN bands. The responses are similar which validates the design equations. E-plane and H-plain patterns of the antenna for 2.4GHz and 5.8GHz are shown in Fig.11 and Fig.12, which shows nearly Omni directional characteristics. The measured peak gains of the proposed antenna in the lower and higher resonances are 2.79dBi and 4.74dBi respectively. The simulated radiation efficiency of the antenna for the lower and higher resonances is 99.23% and 98.47% respectively. The gain and efficiency of the antenna with respect to frequency is shown in Fig.13. The arrow shaped transitions adds to the efficiency of the antenna compared to rectangular transitions. Antenna is horizontally polarized in both the bands.

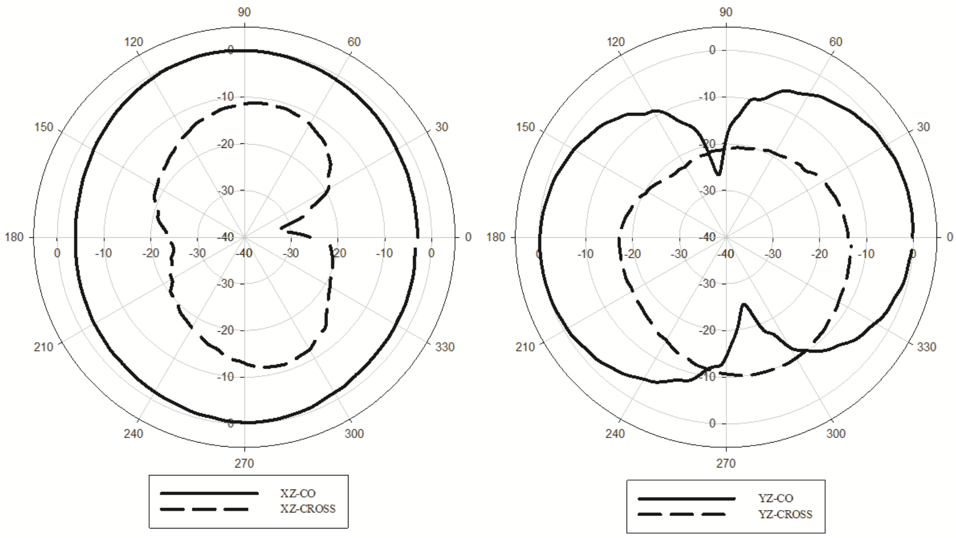

Fig. 11 Radiation pattern at 2.4GHz

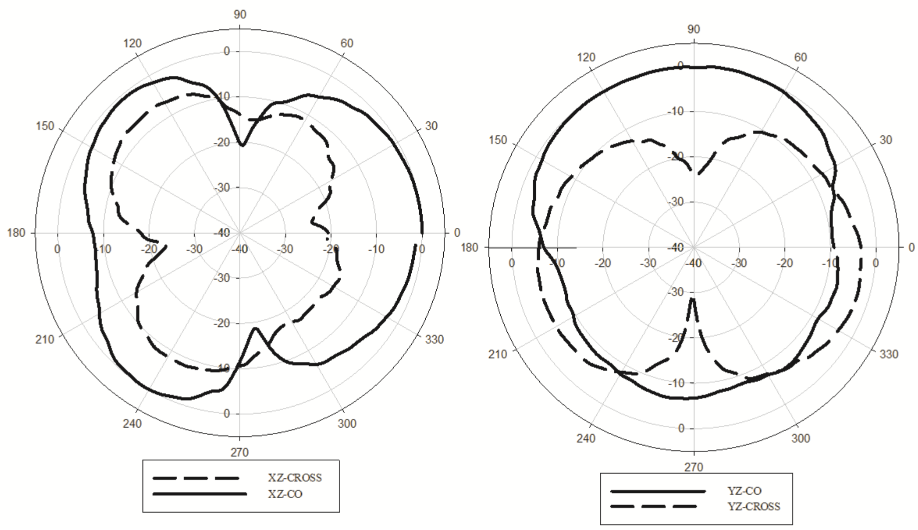

Fig. 12 Radiation Pattern at 5.8GHz

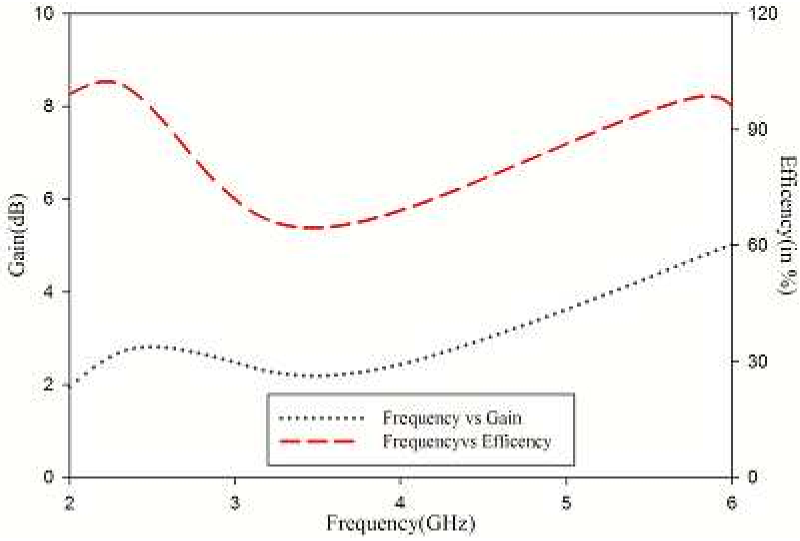

Fig. 13 Variation of Gain and Efficiency vs Frequency

CONCLUSION

A simple closed slot line fed dual band antenna for 2.4/5.8 GHz WLAN is presented. The antenna is simple in structure and exhibits stable radiation patterns and relatively good gain and efficiency compared to previously reported designs. The antenna has less geometrical parameters which make it easier to realize using the proposed design guidelines.

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