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A Novel Printed Multiband Low Cost Antenna for WLAN and WiMAX Applications

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***Abstract*-In this paper, a star-shaped microstrip patch antenna with modified ground structure consisting of an F-shaped slot printed in the ground is presented. The purpose of this design is to achieve and validate this microstrip multiband antenna. The entire area of the proposed antenna is 50x50mm^2 and is printed on an FR-4 substrate and fed by a 50 Ohm microstrip line. This antenna has been analyzed and simulated for the WLAN and WiMAX applications. Simulation results show that the antenna has a good matching input impedance bandwidths for, S11<=-10 dB, covering the WLAN at 2.4/5.2 GHz and WiMAX at 3.5 GHz. Simulation has been done by using three different electromagnetic solvers for comparison CST-MW, Ansoft's HFSS and ADS. After the realization, we have tested and validated this antenna. The measurement results of the antenna present a good agreement with the numerical results.**

***Index Terms*- Multiband antenna, WLAN band, WiMAX band, CST-MW, Ansoft's HFSS, ADS.**

I. INTRODUCTION

In recent years, there has been a growing demand for microwave and wireless communication systems in various applications. This has resulted in an interest to improve antenna performances that can operate with multiband frequencies such as Global System for Mobile Communications (GSM) [1], Digital Communication system (DCS) [2], Global Positioning systems (GPS) [3], Wireless Local Area Networks (WLAN) which has made rapid progress and several IEEE standards are available namely 802.11a/b/g/j[4], Universal mobile Telecommunications System (UMTS) [5] and the Worldwide Interoperability for Microwave Access (WiMAX) [6]. For such applications, microstrip patch antennas have attractive characteristics such as low profile, light weight, low cost and easy to be integrated with radio frequency devices [7-9].

Different techniques have been developed to obtain multi-band antennas with compact size. We can find fractal antennas with different geometries (Sierpinski gasket, Sierpinski carpet and Koch curves) [10-12] and PIFA [13-14]. In addition, we can find another method based on the use of modified ground structure to miniaturize and improve the bandwidth and reflection coefficient for multiband antennas [15-18]. The aim of this study is to use a simple microstrip patch antenna with modified ground structure to obtain multiband behavior.

In this paper, a simple structure composed from a star-shaped microstrip patch antenna with a modified ground structure consisting of an F-shaped slot printed in the ground is designed for multi operation frequency that covers the WLAN 802.11 a/b/g and WiMAX applications. All parameters of the proposed antenna have been optimized and analyzed with the finite integration time domains (FITD) introduced in CST Microwave Studio software to obtain the desired performances. A prototype antenna has been constructed and the simulation and measurement results have been compared.

II. ANTENNA DESIGN

To design an antenna with multiband behavior, we have used the optimization techniques

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integrated in CST Microwave Studio. The final structure is validated into simulation following many steps. Firstly, a rectangular microstrip patch antenna and a feed-line are printed on the top layer of a substrate FR-4 epoxy with the following characteristics:

- Substrate thickness: h=1.6mm.
- Relative dielectric permittivity $\varepsilon r=4.4$.
- Dielectric loss: $\tan(\delta)=0.025$.
- Metallic thickness: t=35µm.

The patch antenna presented in Fig.1. is validated at 3.5GHz.

Fig.1. Rectangular microstrip patch antenna

Secondly, in order to obtain the multiband behavior, we have used the modified ground structure technique with a change of the structure of the initial rectangular microstrip patch antenna as shown in Fig.2. The modified ground structure will take the shape of an F-shaped slot composed from three different arms (L1, L2 and L3), and it is inserted in the ground. Total volume of the proposed antenna is (50x50x1.6) mm^3, and dimensions of the proposed antenna are shown in Table.1.

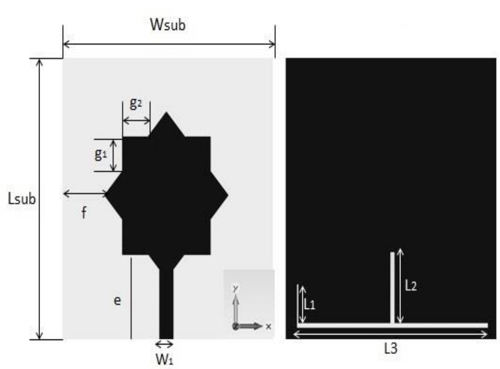

Fig.2. Geometry of the proposed antenna

Table 1: Dimensions of the proposed antenna (Unit: in mm)

Parameter	Value	Parameter	Value
Wsub	50	L3	44
Lsub	50	e	15
W1	3	f	10.85786
L1	7.5	g1	5.857864
L2	12	g2	5.857864

Fig.3. presents the different steps followed to reach the final structure, with the variation of the return loss for each antenna structure.

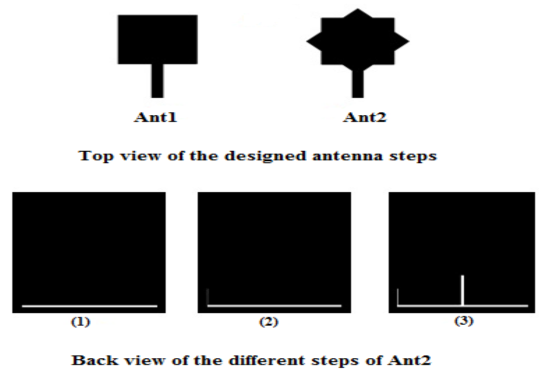

Fig.3. The followed steps to develop the proposed antenna

The simulations of the proposed antenna are realized by using CST-Microwave studios which permit to obtain the different reflection coefficients corresponding to each antenna 1 and 2 as shown in Fig.4.

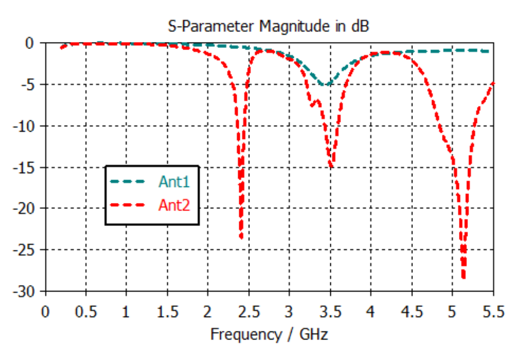

Fig.4. Different return losses |S11| obtained for each antenna

After many series of optimization, we conclude that the L1 and L2 parameters influence the frequency band. Fig.5. shows the simulated reflection coefficient of the antenna as a function of frequency for the different values of L1 while other parameters are fixed. It can be seen from the Fig.5. that the length of L1 has a clear effect on the position of the third and the first resonant frequency. When increasing the length of L1, we notice that the third resonant frequency gets higher with a shift of the first resonant frequency. Fig.6. shows that the simulated reflection coefficient versus various length of L2. It can be seen from the same figure that the length of L2 has an effect on the first and the third resonant frequencies. When increasing the length of L2, we see that the first and the third resonant frequencies get higher.

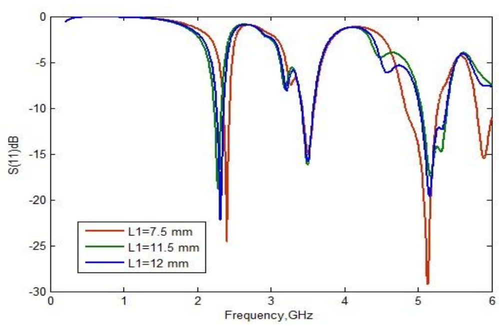

Fig.5. Return loss |S11| for different lengths of (L1) parameter versus frequency with other parameters fixed

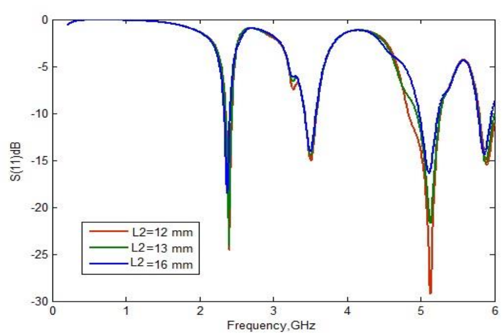

Fig.6. Return loss |S11| for different lengths of (L2) parameter versus frequency with other parameters fixed

Table 2. presents a synthesis of the return loss results for the three frequency bands.

Table 2: Synthesis of simulation results using CST-MW

Operating frequency band		Resonant frequency (GHz)	Return loss (dB)	Bandwith (GHz)
Simulated results by CST-MW	First resonant	2.404	-24.449	2.359-2.441
	Second resonant	3.511	-14.989	3.421-3.596
	Third resonant	5.135	-29.183	4.828-5.2813

To compare the simulation results obtained in CST-MW, we have conducted the same study by using two electromagnetic solvers HFSS and ADS. As depicted in Fig. 7, we can conclude that we have an agreement between the three solvers with a small difference which is due to the different numerical methods used in these electromagnetic solvers [19].

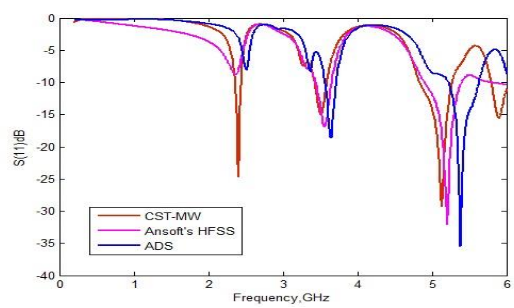

Fig.7. Comparison of return loss |S11| between CST-MW, Ansoft's HFSS and ADS

The current distributions of the proposed antenna for the three resonant frequency bands are illustrated in Fig.8.

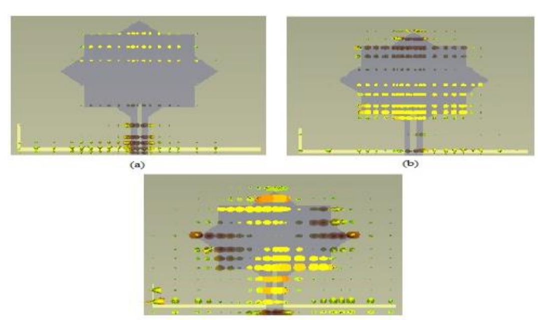

Fig.8. Current distributions of the proposed antenna at: a: @ 2.404GHz b: @ 3.511 GHz c: @ 5.135 GHz.

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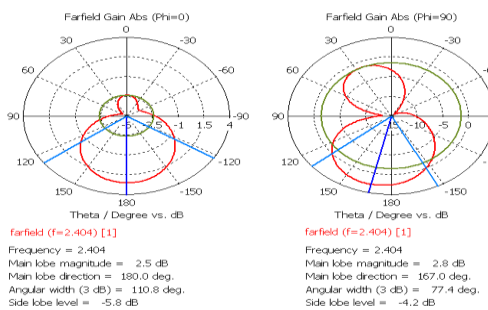
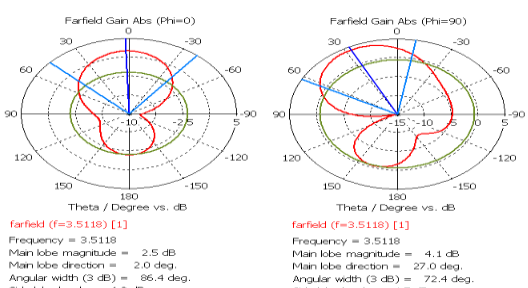
For the current distribution, as presented in Fig. 8 it affects different parts of the patch depending on the frequency level. When it reaches 2.404GHz, the current distribution is concentrated above the patch microstrip antenna, in the middle along the feed line and throughout the F-shaped slot in the ground plane. When the frequency reaches 3.511GHz, the density of the current distribution is in the lower part of the microstrip patch antenna and along the F-shaped slot in the ground plane. At the frequency of 5.135 GHz, the current distribution is concentrated on the edges of the patch antenna and in the middle particularly along the transmission line and along the F-shaped slot in the ground plane.

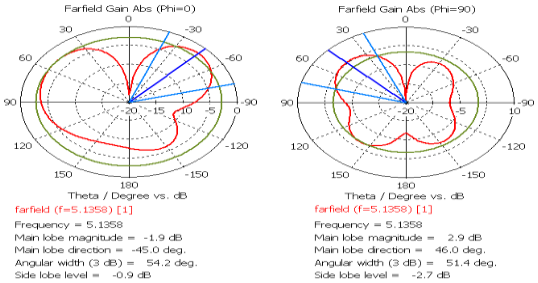
The simulated Far-field radiation patterns in CST-MW for the three resonant frequencies are depicted in Fig.9. It can be seen that the antenna presents a stable radiation for each resonant frequency.



(a)



(b)



(c)

Fig.9. Radiation pattern of the proposed antenna in CST: a: @ 2.404GHz b: @ 3.511 GHz c: @ 5.135 GHz

Fig.10. presents the variation of the gain versus frequency. After the simulation, we have obtained the gain 1.347 dB at 2.404 GHz, 3.996 dB at 3.511 GHz and 3.162 dB at 5.135 GHz.

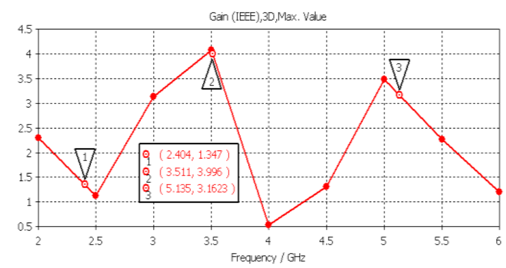


Fig.10. Gain vs frequency

Table 3 presents a comparison of the proposed antenna with bibliography regarding antenna size, resonance frequency and antenna purpose. As we can see from the same table that the proposed antenna is smaller in terms of size and suitable for tri-band applications.

Table 3: Comparison of proposed antenna performance with other compact antennas

Published literature versus proposed work	Antenna Size (mm^2)	Resonance frequency (GHz)	Antenna purpose
Ref[20]	75x75	2.4/5.2	Dual-band
Ref[21]	50x75	2.4/5.2	Dual-band
Ref[22]	68x40	2.4/5.8	Dual-band
Ref[23]	100x45	2.4/3.5/5.2	Tri-band
Proposed work	50x50	2.4/3.5/5.2	Tri-band

III. EXPERIMENTAL RESULTS AND DISCUSSION

After the comparison of simulation results on different solvers, CST-MW, ADS and HFSS, we have achieved the structure antenna by using the LPKF machine. Fig.11. shows pictures of the simple fabricated structure of the multiband antenna.

Fig.11. Photo of the fabricated antenna structure

After testing the achieved antenna, we have conducted comparison between simulation by CST-MW and measurement results as shown in Fig.12. The measurement is performed with a Vector Network Analyzer (VNA) from Rohde & Schwarz. The calibration Kit used is 3.5 mm from Agilent technologies. We notice that there is an agreement between simulation and measurement results of the reflection coefficient of the proposed antenna. The difference between the measured and simulated results is due to the fabrication constraints, uncertainties in the dielectric constant and substrate thickness and soldering effects.

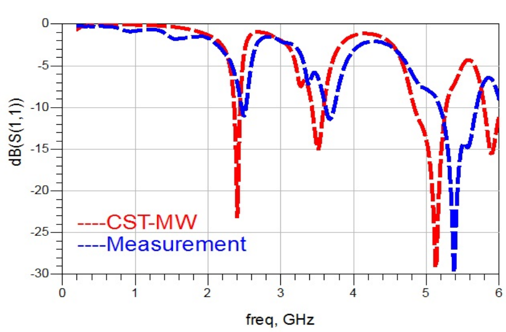


Fig.12. Comparison of simulated and measured return loss

The results presented in Fig.12 show that the proposed antenna can be suitable for WLAN 2.4/5.2 GHz and WiMAX 3.5 GHz applications.

VI. CONCLUSION

In this study, a new low cost compact antenna has been analyzed and validated for multiband applications. The size of proposed antenna is $50x50mm^2$. As described in this paper, optimization and simulation results are performed by using three electromagnetic solvers. Using a modified ground structure permits us to improve the multiband behavior of the antenna. The achieved and tested planar antenna presents a good agreement between simulation and measurement results. These results validate the antenna structure for particular microwave applications band, WLAN 802.11 a/b/g and WiMAX applications.

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