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A Multiband Printed Antenna Suitable for Wireless Applications

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Abstract

This study deals with a new research work on a low cost multiband printed antenna which can be used for three operating frequency bands GSM900/PCS/WIFI/Bluetooth. The achieved antenna is mounted on an FR-4 substrate. In this study, the solts technique is used to obtain the multiband behavior. The different solts are inserted in the radiator face and the back face that is the ground. The whole circuit is optimized taking into account the good matching of the input impedance in the operating frequency bands with a stable radiation pattern. In order to optimize the proposed antenna structure we have used CST-MW and to compare the obtained simulation results we have conducted another electromagnetic simulation by using HFSS solver. The final circuit validated into simulation has been fabricated and tested which permits to validate the proposed multiband antenna.

Keywords: *multiband antenna, patch, microstrip antenna,* ARDUINO

1. Introduction

Patch antennas are suitable for mobile wireless applications and can be achieved for multi frequency bands for example 2G/GSM900/PCS, 3G/UMTS/HSDPA/WiFi/ Bluetooth and 4G/LTE [1-4].The demand for multisystem handset equipments has recently increased rapidly. For easy integration and to miniature the mobile communication devices, we can use a multiple frequency band antenna into a mobile handset. Since each communication protocol may operates in distinctive frequency bands, instead of using several antennas, it is highly useful to have one multiband antenna to meet the need of multiple communication systems [5].

Several efforts have been devoted to develop multiband planar antennas during the last years, such as planar inverted-F antennas (PIFA) [5-6], inverted-F antennas (IFA) [7-8]. Microstrip patch Antennas have become popular in most handsets and devices for mobile phone applications. This is mainly due to their miniature size, easy fabrication, and low cost. To achieve a multiband planar antenna, many configurations and techniques can be used [9-13].

In this paper, a planar multiband antenna is proposed for Wireless applications in various communication services with a microstrip design. The multiband antenna covers following frequency bands: GSM900 (880-960 MHz), PCS (1850-1990 MHz), WiFi (2400-2480 MHz), Bluetooth (2400-2480 MHz). This design is fully planar, fairly compact, and low cost by using an Epoxy substrate.The next sections will present the different steps followed to achieve, to optimize and to validate into simulation and measurement the proposed antenna.

2. Antenna Design Procedures

The first step was to design a patch antenna (Figure 1) at 2.45 GHz and after that by introducing solts technique we can pass from an antenna having one operating frequency band to a multiband antenna. The dimensions of the patch are calculated by using the following equations [14]:

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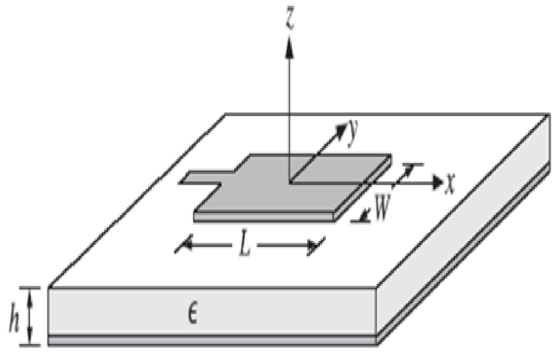


Figure 1. The patch antenna

The Width of the rectangular patch is given from:

$$W = \frac{1}{2 f_r \sqrt{\mu_0 \varepsilon_0}} \sqrt{\frac{2}{\varepsilon_r + 1}} = \frac{c}{2 f_r} \sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1}$$

The expression of the effective length constant is given from:

The length extension is given from:

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left[1 + 12 \frac{h}{W} \right]^{-\frac{1}{2}} \tag{2}$$

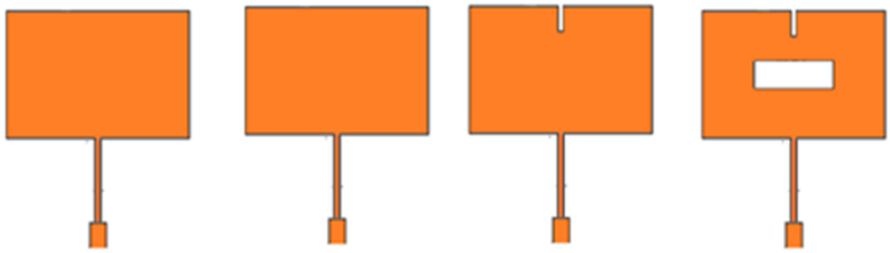
$$\Delta L = 0.412 * h * \frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264 \right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8 \right)} \tag{3}$$

The length of rectangular patch is given from:

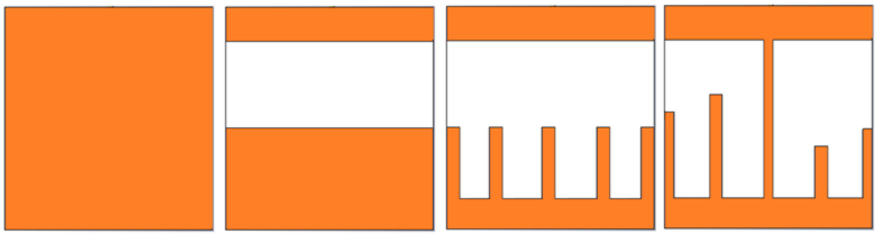
$$L = L_{eff} - 2\Delta L = \frac{c}{2 f_r \sqrt{\varepsilon_{eff}}} - 2\Delta L \tag{4}$$

Where: c is the free space velocity of light, εr is the relative permittivity of substrate, L is the length of patch, W is the width of the patch, h is the height of the substrate, εeff is the effective relative permittivity of patch, Leff is the effective length of the patch and fr is the resonant frequency.

After the validation of the recangular patch antenna at 2.45 GHz, we have conducted many series of optimization by introducing solts in order to obtain a multiband behavior. The methods of optimization used are integrated in the electromagnetic solver CST-MW Studio. The different steps followed to optimize and to design the proposed antenna are presented in Figure 2, the validation of the patch antenna with multi frequency operation capabilities is due to the multiple frequency bands introduced by the combination optimization of the geometry antenna, cutting notched and slot shaped on the radiator patch and ground faces.



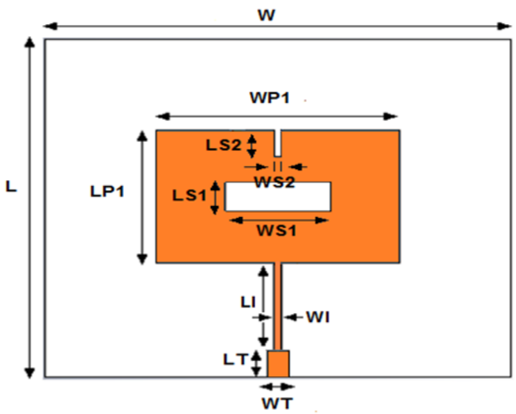
(a) Top face

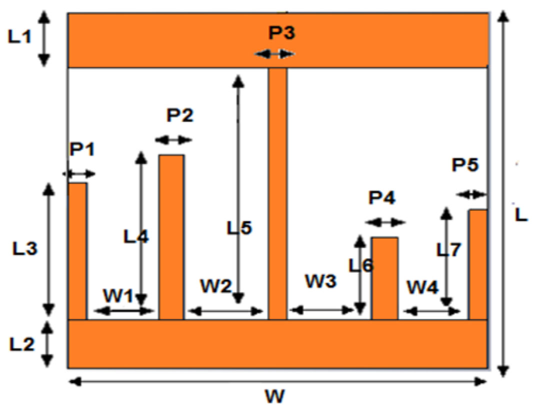


(b) Back face

Figure 2. Design evolution of the proposed antenna

The final microstrip antenna is presented in Figure 3, where we have the top and the Back faces of the final circuit. The proposed antenna is a planar microstrip patch with dimensions of 65x67x1.6 mm^3 mounted on an substrate, having thickness of 1.6 mm with a relative dielectric permittivity of 4.4 and 0.025 for loss tangent. This antenna is fed by 50Ω microstrip line, the ground plane of the proposed antenna is modified and optimized to reach the multiband behavior for the suitable frequency bands.





(a) Top view (b)bottom view

Figure 3. Geometry of the proposed antenna

After the optimization of the patch antenna by using CST-MW and HFSS, we have obtained the different optimized parameters listed in Table1.

Table 1.Parameters of the Validated Antenna (unit in mm)

Parameter	Value	Parameter	Value
L	65	W1=W4	11.5
W	67.05	W2=W3	13.625
WP1	35.11	P1=P5	3
LP1	25.6	P2=P4	4
WS1	15.11	P3	2.8
LS1	5.6	L1	10
WS2	1	L2	9
LS2	5	L3	25
LT	5	L4	30
WT	3	L5	46
LI	16.9	L6	15
WI	0.5	L7	20

The proposed antenna was fistly confirmed into simulation by using CST-MW solver and to verify the obtained results we have conducted an other simulation usingHFSS EM solver which permits to compare the both results as depicted in Figure 4.

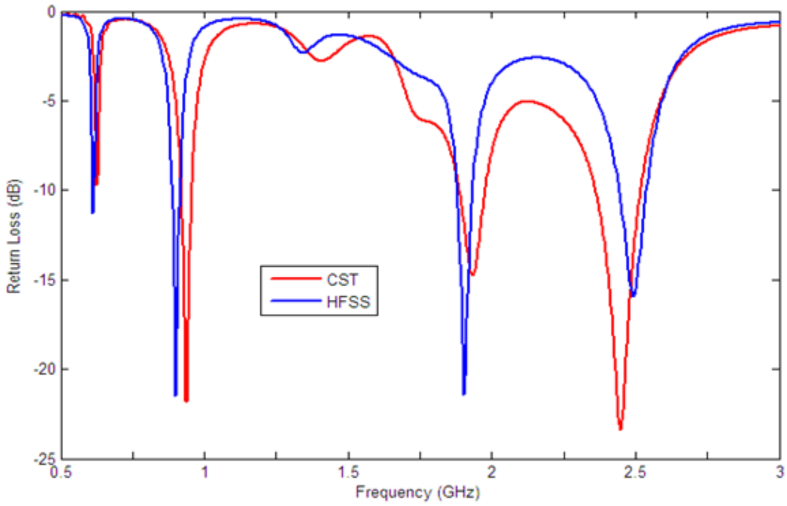


Figure 4. The reflection coefficient versus frequency obtained by HFSS and CST-MW

The simulation results ensure that the antenna covers multi-band frequencies for wireless applications. For a return loss less than 10 dB, we can deduce that the antenna operates in three frequency bands (883-915MHz), (1.87-1.94GHz) and (2.42-2.54GHz), which covers GSM900/PCS/WIFI/Bluetooth. The third frequency band is controlled by adjusting the dimensions of the planar antenna but the first and second one are controlled by the geometry and dimensions of the ground plane. To study the radiation of the proposed antenna, Figure5 shows the simulated (3D) radiation patterns of the proposed antenna at three resonant frequencies 0.9GHz, 1.9GHz and 2.45GHz. We can conclude that the proposed antenna has a bidirectional radiation patterns.

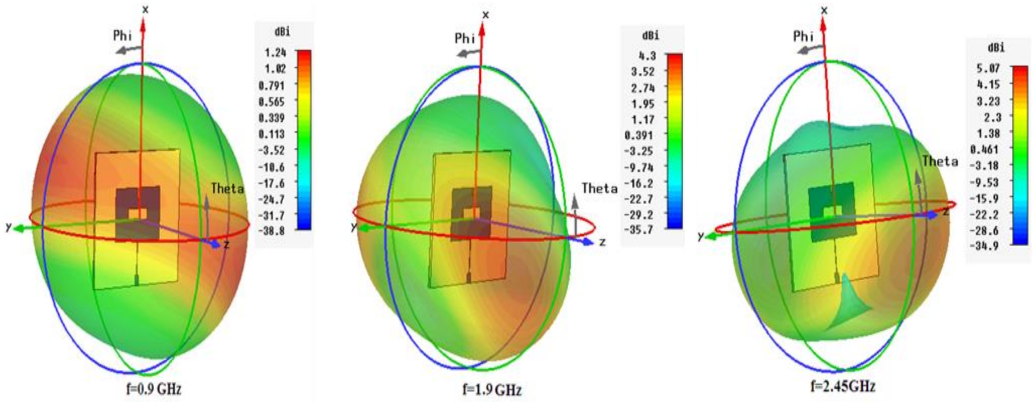


Figure 5. The simulated radiation patterns of the proposed antenna at different resonant frequencies

The simulated current density is presented in Figure 6. It is observed that the surface currents are highly concentrated around the stubs for all frequency bands.

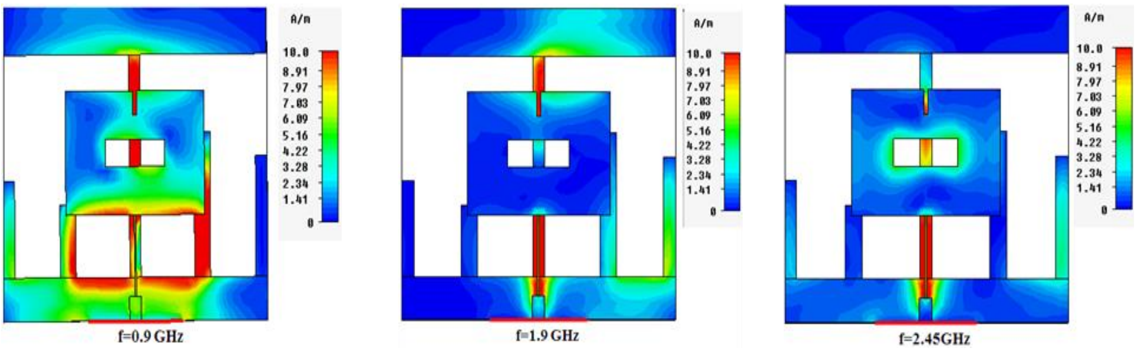


Figure 6. Simulated surface current of the proposed antenna at different resonant frequencies

3. Fabrication and Test

After the validation of the optimized antenna, the final circuit has been fabricated as shown in Figure 7. The performance of the antenna prototype has been measured by using a Vector Network Analyzer, range up to 20.0 GHz and a 3.5 mm calibration kit.

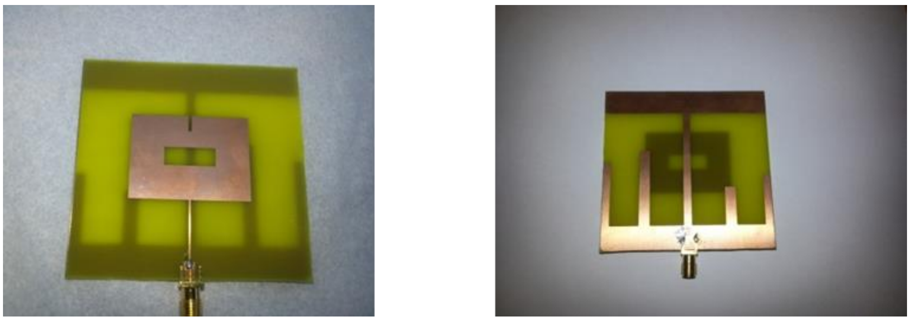


Figure 7. Photograph of the proposed antenna

The measured and simulated values of (S11) versus frequency of the achieved antenna are given in Figure 8. The obtained results present an agreement between simulation and measurement. The proposed antenna is validated to function in [883-915MHz], in [1.87-1.94GHz] and in [2.42-2.54GHz], it can be concluded that the proposed antennais suitable to cover the typical bandwidth requirement for GSM900/PCS/WIFI/Bluetooth. The small difference between simulation and measurement can be due to conditions and precision of fabrication and also to the substrate which has a permittivity depending on frequency but in the electromagnetic solver we have the possibility to specify just a constant value.

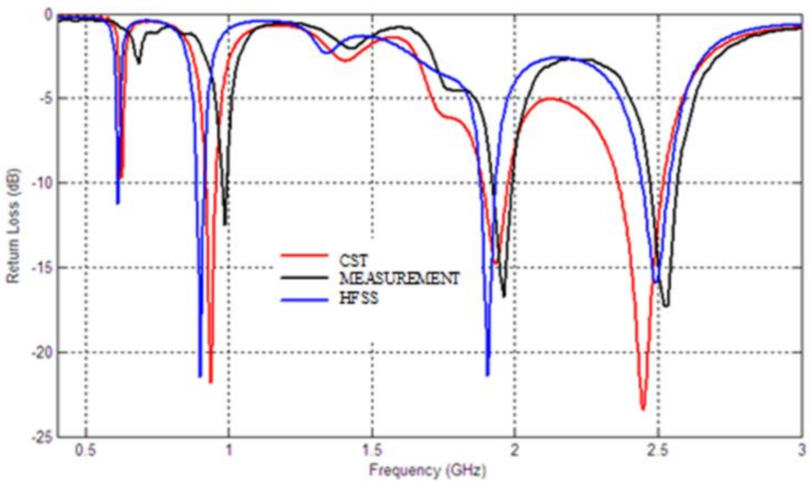


Figure 8. Comparaison between simulation and measurement of the reflection coefficient

In order to test the ability of the validated antenna to transmit a signal in the GSM band we have associated the final circuit with a GSM Shield that is based on SIM900 ARDUINO card from SIMCOM. The GSM Shield permits to communicate using the GSM cell phone network. The shield allows to send SMS, MMS by using a SIM card. Therfore we have done an application by using this atenna which permits to send an SMS using GSM Ntework and in the same time validates the microstrip antenna for GSM band.

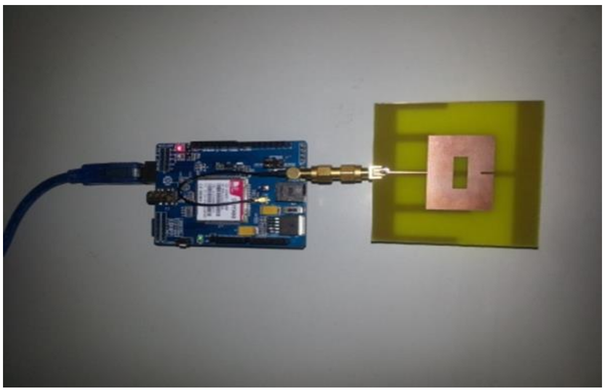


Figure 9. The ARDUINO card associated to the proposed antenna

4. Conclusion

In this work, a new printed multiband microstrip antenna for mobile applications is proposed and validated by using two electromagnetic solvers. The simulation results show that this antenna can be suitable for three frequency bands (883-915MHz, 1.87-1.94GHz and 2.4-

2.54GHz), which covers GSM900/PCS/WIFI/Bluetooth for mobile phone applications. The proposed antenna can radiate bi-directional patterns at all the operating frequency bands which is suitable for use in mobile phone and other wireless applications. The different steps followed in this study can be used to match this circuit for others frequency bands. At the end we have done a radiation test of the proposed antenna by associating it to an ARDUINO card which permits to send messages for a long distance using GSM ntework.

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