A Low Cost Multiband Microstrip Antenna for Wireless Applications

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Abstract
This paper presents a new study on a low cost multiband microstrip antenna suitable for three operating frequency bands GSM900/PCS/WIFI/Bluetooth. The proposed antenna is mounted on an FR-4 substrate; the technique used to obtain the multiband behavior is based on the use of the solts inserted in the top face which is the radiator and the back face that is the ground. The use of this technique has taken into account to have at the end an antenna having good matching input impedance in the operating frequency bands with good performances concerning radiation. To validate such antenna, we have used two electromagnetic solvers, the first one was used for the optimization of the proposed antenna and the second one is used to confirm the simulation results. After the validation into simulation, the final circuit was fabricated and tested which permits to validate the proposed antenna.

Keywords: multiband planar antennas, PCS, Bluetooth, wifi, ARDUINO

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1. Introduction
Multiband antennas are widely being considered for future wireless communication applications 2G/GSM900/PCS, 3G/UMTS/HSDPA/WIFI/ Bluetooth and 4G/LTE [1-4]. The demand for multiband handset equipments has recently increased rapidly. Modern mobile communication devices tend to integrate multiple communication systems into a mobile handset. Since each communication protocol may operate 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 FR-4 substrate material. 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 (Figure1) 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 rectangular patch antenna are calculated from the following equations [14]:

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The Width of the rectangular patch is given from:

\[ W = \frac{1}{2 f_r \sqrt{\mu_0 \varepsilon_0}} \sqrt{\frac{2}{\varepsilon_r + 1}} = \frac{c}{2 f_r \sqrt{\varepsilon_r + 1}} \]  

(1)

The expression of the effective length constant is given from:

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

(2)

The length extension is given from:

\[ \Delta L = 0.412 \times h \times \left( \frac{\varepsilon_{eff} + 0.3}{\varepsilon_{eff} - 0.258} \right) \left( \frac{W}{h} + 0.264 \right) \]  

\[ \left( \frac{W}{h} + 0.8 \right) \]  

(3)

The length of rectangular patch is given from:

\[ L = L_{eff} - 2\Delta L = \frac{c}{2 f_r \sqrt{\varepsilon_{eff}}} - 2\Delta L \]  

(4)

Where: \( c \) is the free space velocity of light, \( \varepsilon_r \) 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, \( \varepsilon_{eff} \) is the effective relative permittivity of patch, \( L_{eff} \) is the effective length of the patch and \( f_r \) is the resonant frequency.

After the validation of the rectangular patch antenna at 2.45 GHz, we have conducted many series of optimization by introducing solts on the top and back faces of the antenna in order to obtain a multiband behavior. The methods of optimization used are integrated in the electromagnetic solver CST-MW Studio. The design evolution of the proposed antenna is presented in Figure 2, the validation of the patch antenna with multi frequency operation capabilities is due to the multiple resonances introduced by the combination optimization of the geometry antenna, cutting notched and slot shaped on the radiator patch and ground faces.
The proposed 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 mm³ mounted on an FR-4 substrate, having 1.6 mm as thickness 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.

After many series of optimization by using CST-MW and HFSS, we have obtained the different optimized parameters listed in Table 1.
Table 1. Parameters of the proposed 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 firstly validated into simulation by using CST-MW studio and to verify the obtained results we have conducted an other simulation using HFSS 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 total 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, Figure 5 shows the simulated three-dimensional (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 pattern at all the operating frequency bands.
The simulated surface current of the proposed antenna, it's presented in Figure 6. It is observed that the surface currents are highly concentrated around the stubs for all frequency bands.

3. Fabrication and Test
The performance of the multi-band planar antenna has been examined during detail parametric studies by employing HFSS EM and CST-MW solvers. After that the proposed antenna with optimized parametric dimensions has been fabricated as shown in Figure 7. The performance of the antenna prototype has been measured by using a Vector Network Analyzer E8362C, range up to 20.0 GHz and a 3.5 mm calibration kit from Agilent technologies.
The measured and simulated values of reflection coefficients (S11) versus frequency of the proposed 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. Therefore 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 paper, a new monopole multiband microstrip antenna structure for mobile phone and wireless 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 makes it suitable for use in mobile phone and other wireless applications. The different steps followed in this study can be used to match this antenna 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 network.

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