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# An Innovative Conception of a Compact Quadruple Frequency Microstrip Patch Antenna for Wireless and Mobile Communication

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**Abstract**
In this article, we present a simulated conception and study of an original compact quadruple frequency microstrip patch antenna that covers the wireless mobile frequencies at 900MHz, 1800MHz, 2100MHz and 2600MHz. This innovative conception provides the bandwidth required for mobile phone standards including GSM, DCS, PCS, UMTS, LTE and IEEE Wireless Local Area Network (WLAN) standard: 802.11ah (Wi-Fi). The benefits of this design are demonstrated as: low weight, small congestion, low manufacturing cost, multiband antennas feature and simple configuration. In our work, we present all outcomes of the following specifications: resonant frequency, frequency bandwidth, returns loss, VSWR, radiation patterns and fields distributions. The numerical simulations results were completed by means of Ansoft HFSS software.

**Keywords:** Microstrip Patch Antenna, Multiband Antenna, Mobile Communication.

## Introduction

The antennas highly demanded by wireless communication systems must generally ensure conditions of several qualities: low profile, low weight, reduced volume, simplicity of structures, low manufacturing cost with easy production in large quantities, conformability and possibility to integrate the microwave circuits to antennas. These conditions make it possible to achieve an environment characterized by high requirements of reliability, mobility, effectiveness and success. The great evolution experienced by mobile communication systems worldwide has led scientists to develop new generations of antennas for base and mobile stations. This phenomenal increasing of users number and services needs has generated the strong requirement and has strongly called to utilization of the most advanced technologies for prospective radio systems [1].

Consequently, communications solutions dedicated to unoccupied areas and places based on the use of antennas represent multiple added values. These technologies must guarantee the conditions for mobility and accessibility according to the targeted frequency, and ensuring a better level of coverage without using any amplification. The proper antenna selection process takes into account several criteria based on the existence and confirmation of the conditions of good service.

Finally, the great evolution experienced by wireless communications systems, generated a huge need in the use of microstrip antennas. Among the internationally known systems there is GSM (Global System for Mobile communication) (880MHz-960MHz), DCS (Digital Cellular System) (1710-1880MHz) in Europe, PCS (Personal Communications Services/System) (1850-1990MHz) in USA, UMTS (Universal Mobile Telecommunications System) (1920-2170MHz) and LTE (Long Term Evolution) (800MHz/1800MHz/2100MHz/2600MHz) [2]. Microstrip antennas have experienced in the last decade a great use and expansion throughout the world.

In addition, in the industrial, patch antennas manufacturing is realized following a very reduced machining process cost thanks to their structure very simple, therefore, a production with a huge amount of units. In addition, this type of antenna is simple and applicable to different situations to integrate wide variety of forms it can take. However, the patch antenna has remarkable disadvantages. First, its bandwidth is narrow due to the surface wave losses. Second, its gain is relatively low and finally the presence of a large patch size to achieve better performances [3].

So, multiband antennas are increasingly solicited in the fields of industries for the most advanced technologies, in order to minimize the number of integrated antennas providing the combination of a number of features on a single antenna. To overcome this demand, several processes and technological methods are followed by the international scientific community.

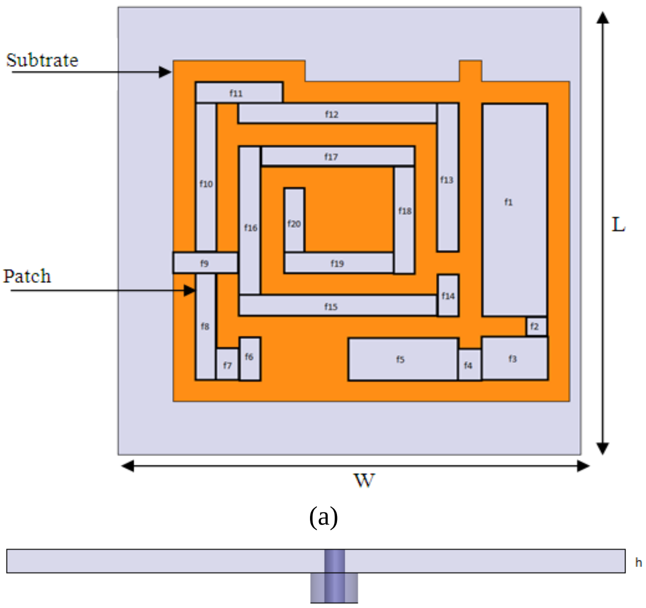
These techniques involve the following methods using: frequency selective surface [4], thicker profile for folded shorted patch antennas [5], slots, thicker substrate [6], square-shaped [7] and U- shaped [8], patch antenna with compatible feeding and feeding techniques like L-probe feed [9]. These methods are used to enhance bandwidth of microstrip patch antenna. The size of feeding patch and thickness of dielectric ought to be chosen neatly.

The use of the method of the coaxial feed with the grouping of all these technologies provides an excellent general idea of the antenna physical functioning, that enabled us to acquire an antenna able to comply with the standards : GSM,DCS, PCS, UMTS, LTE and WLAN applications namely in ISM band used by system Wi-Fi (0.9 GHz for 802.11 ah).

In this article, an inner multi-band antenna with low profile is shown schematically using several techniques, with respect to those previously indicated. This paper presents the original conception and its effects and impacts. The functioning bands are assessed by using of Ansoft HFSS with the return loss test |S11| more than 6 dB. Radiation simulation models on whole frequency bands are satisfactory.

## The original antenna design

The 3D perspective of top and side views of the original antenna is represented in figure 1. The antenna is simulated on an FR4_epoxy substrate (L=45 mm, W= 42 mm) with a dielectric constant $\varepsilon_r$=4.4. The substrate thickness is h=1.6 mm. A rectangular patch including technical slots represented with different dimensions in table 1. The $\varepsilon_r$ value is selected such that it provides better efficiency and larger bandwidth. The antenna is fed by a coaxial feed in order to enhance the bandwidth and gain.




(a)

(b)

**Fig.1. Geometry of the proposed antenna with (a) Top view (b) Side view**

**TABLE.1. Simulation Parameters**

| Slot | Length | Width |
|---|---|---|
| f1 | 20 mm | 6 mm |
| f2 | 2 mm | 2 mm |
| f3 | 6 mm | 4 mm |
| f4 | 3 mm | 2 mm |
| f5 | 10 mm | 4 mm |
| f6 | 4 mm | 2 mm |
| f7 | 3 mm | 2 mm |
| f8 | 10 mm | 2 mm |
| f9 | 8 mm | 2 mm |
| f10 | 14 mm | 2 mm |
| f11 | 8 mm | 2 mm |
| f12 | 18 mm | 2 mm |
| f13 | 14 mm | 2 mm |
| f14 | 4 mm | 2 mm |
| f15 | 18 mm | 2 mm |
| f16 | 14 mm | 2 mm |
| f17 | 16 mm | 2 mm |
| f18 | 10 mm | 2 mm |
| f19 | 10 mm | 2 mm |
| f20 | 6 mm | 2 mm |

## Results and discussions

### *A. Return Loss*

The dielectric constant of substrate material represents a significant parameter in the patch antenna conception. A substrate with an elevated dielectric constant value minimizes the size of the antenna although it has as well an impact on the antenna performances. Consequently, a trade-off exists between patch antenna dimensions and performances. In addition, in communication systems field the microstrip patch antenna must be not voluminous. Therefore, the dielectric substrate height ought to be fewer. As an easy way, an approximate relation needs to be memorized: reflection coefficient -6dB approximately equals VSWR 3:1. An antenna with -6 dB reflection coefficient is still a good one [10].

For our antenna, we have studied the impact of dielectric constant and the thickness of the substrate on the resonance frequency and the return loss test |S11|. We have tested three values of dielectric constant with three different materials: the first is $\varepsilon_r$=2.2 that concerns the Rogers RT/ Duroid 5880 (tm), the second is $\varepsilon_r$=4.4 with FR4_epoxy and the third is $\varepsilon_r$ = 6.15 with Rogers RT/Duroid 6006 (tm). Each dielectric constant is studied according to three cases of substrate thickness. Figure 2 represents the return loss test |S11| for the three cases of dielectric constant. We notice that the only case which the antenna has a resonance for the four frequency 900MHz, 1800MHz, 2100MHz and 2600MHz with return loss test |S11| more than 6 dB is the case of dielectric constant $\varepsilon_r$ =4.4 and substrate thickness h=1.6 mm.

So, our original compact quadruple frequency microstrip patch antenna should be designed with dielectric constant $\varepsilon_r$ =4.4 and with substrate thickness h=1.6 mm.

Figure 3 represents the designed microstrip patch antenna reflection coefficient, resulted from the simulation based on the HFSS software using and demonstrating that the antenna is functioning at four resonance frequencies: 0.91GHz, 1.83GHz, 2.12GHz and 2.59GHz.

About our designed antenna: the first band permits us to cover the standard GSM, WLAN (802.11ah) and ISM 902 frequency bands. The second permits us to cover DCS and PCS and third band for UMTS and fourth for LTE.

Table 2 presents the resonance frequencies of the proposed designed antenna. The antennas simulated bandwidths were 37 MHz for the first band, 67 MHz for the second, 20 MHz for the third and 17 MHz for the fourth band. In all cases, the antenna offers selective bandwidths to cover some particular European wireless systems.

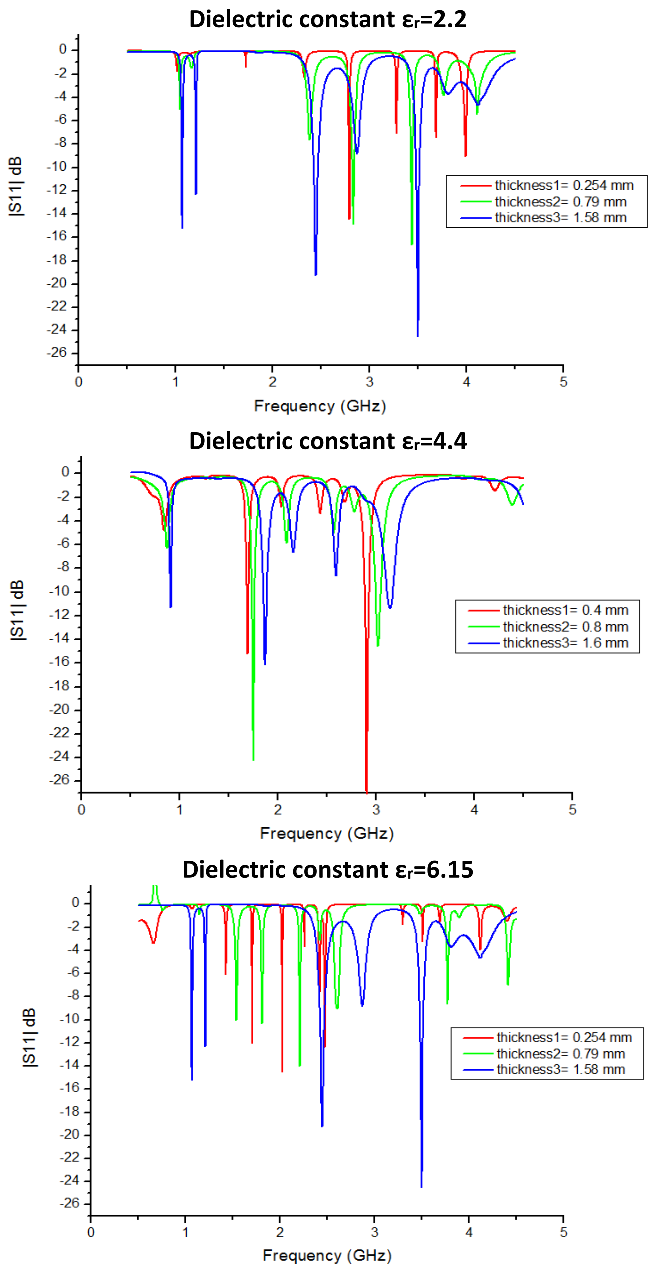



**Fig.2. The study of return loss test |S11| according to dielectric constant $\varepsilon_r$ and substrate thickness h**

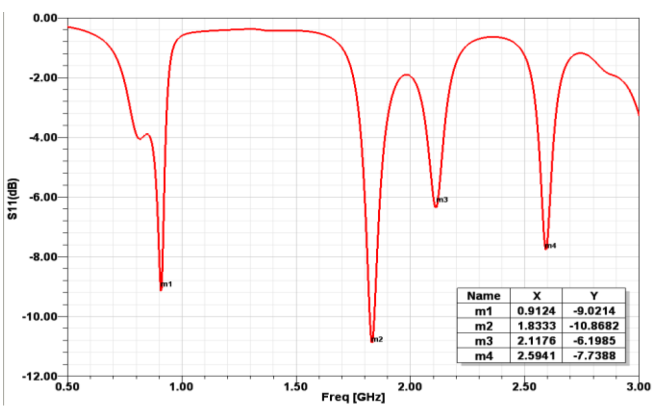



**Fig.3. Reflection coefficient of the proposed antenna**

**TABLE.2. Frequency and bandwidth of the proposed antenna**

| Frequency Resonance (MHz) | Bandwidth (MHz) | Width (MHz) | $\lvert S_{11}\rvert$ (dB) | Standards |
|---|---|---|---|---|
| 912 | 888 - 925 | 37 | 9.02 | GSM, WLAN (802.11ah) and ISM 902 frequency bands |
| 1833 | 1800 - 1867 | 67 | 10.87 | DSC, PCS |
| 2118 | 2100 - 2120 | 20 | 6.20 | UMTS |
| 2594 | 2596 - 2613 | 17 | 7.74 | LTE |

### *B. VSWR*

The proposed antenna can cover the following standards: GSM, DCS, PCS, UMTS, LTE, WLAN (802.11ah) and ISM 902 frequency bands with constraint of VSWR ≤ 3 as shown in figure 4.

Figure 4 shows the variation of voltage standing wave ratio of the antenna according to the frequency. We observe that the value of VSWR in the band is less than the value 3, which is sufficient to cover the band allocated by the mobile phone standards.

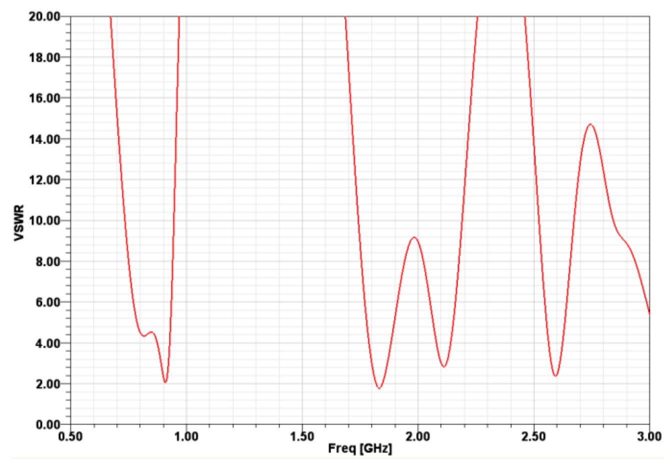
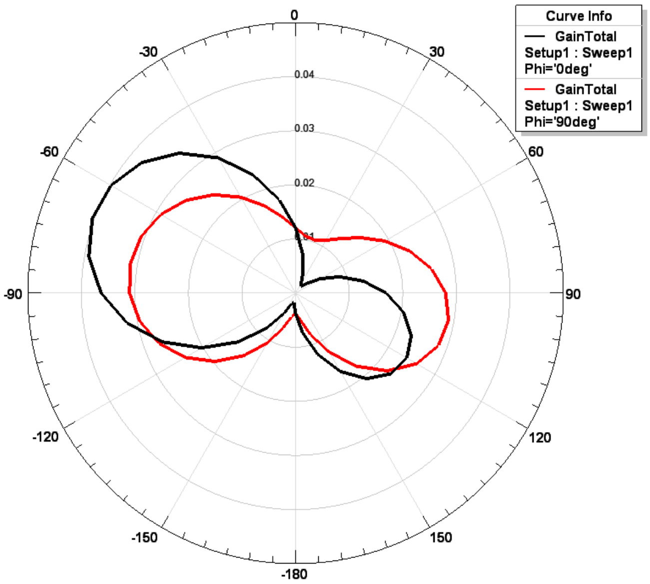



**Fig.4. The VSWR of the studied antenna.**

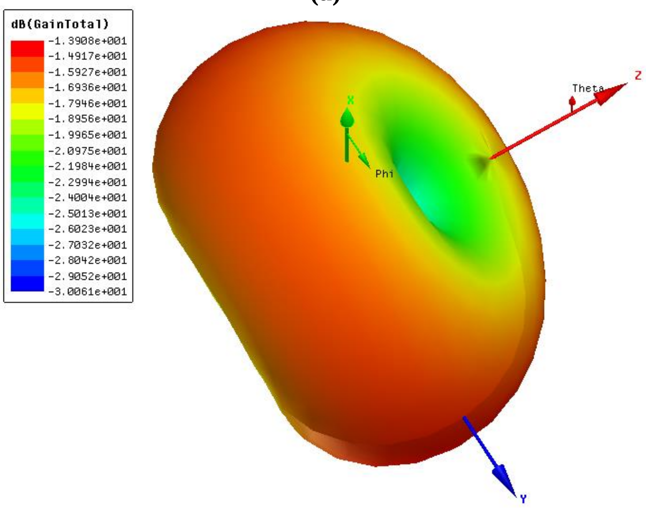
### *C. Radiation pattern*

The term radiation pattern refers to the directional (angular) dependence of the strength of the radio waves from the antenna or other source. Since a microstrip patch antenna radiates normally to its patch surface. The elevation pattern for φ=0°and φ=90°would be important. Figures 5, 6, 7 and 8 present the radiation pattern for the proposed patch antenna.

The proposed antenna displays a good omnidirectional radiation pattern even at lower and higher frequencies, which is required to receive information signals from all directions.

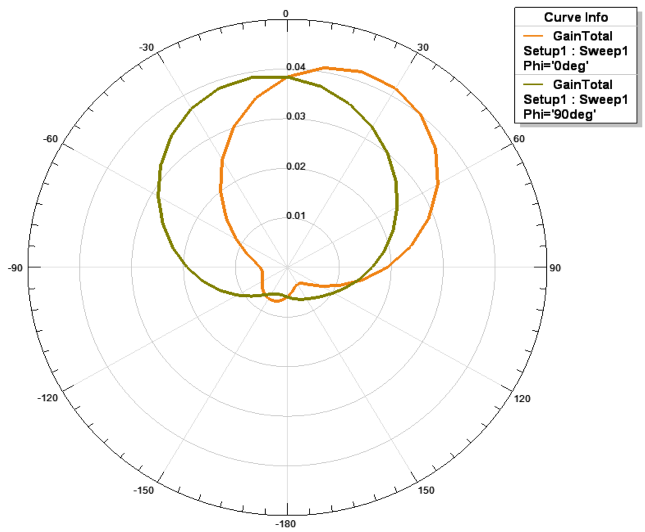



**(a)**




**(b)**

**Fig.5. (a) 2D Radiation Pattern for 900 MHz frequency (b) 3D Radiation Pattern for 900 MHz frequency**

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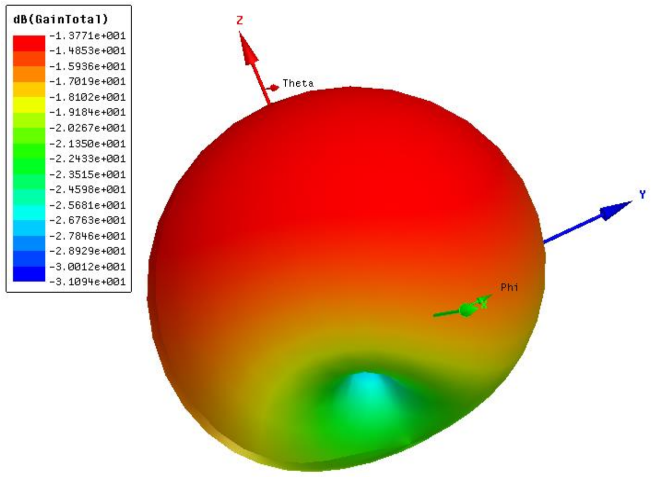


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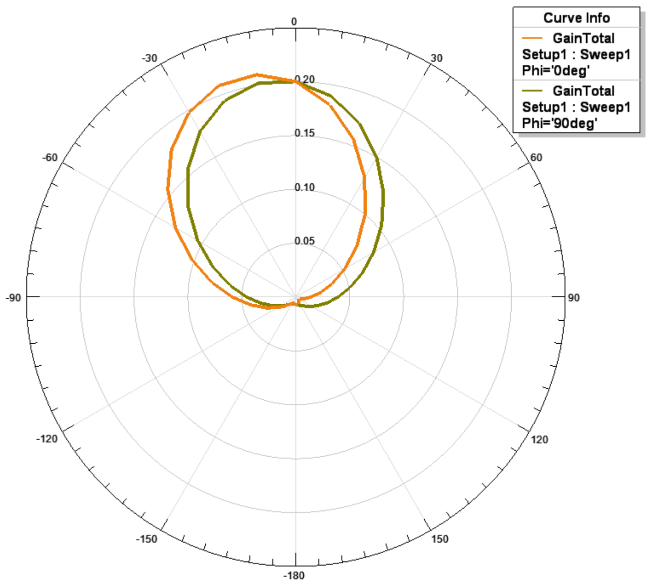
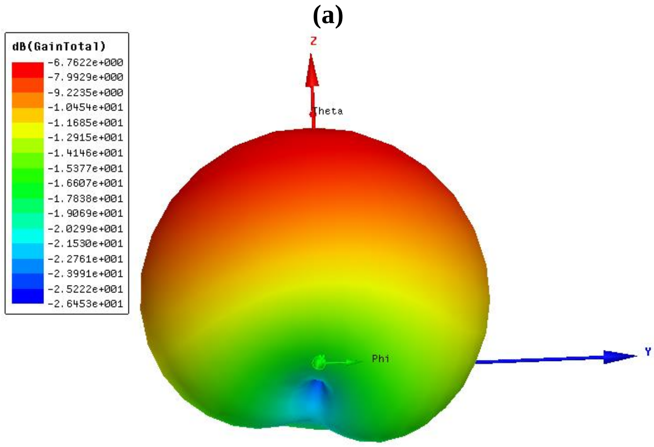
**Fig.6. (a) 2D Radiation Pattern for 1800 MHz frequency (b) 3D Radiation Pattern for 1800 MHz frequency**

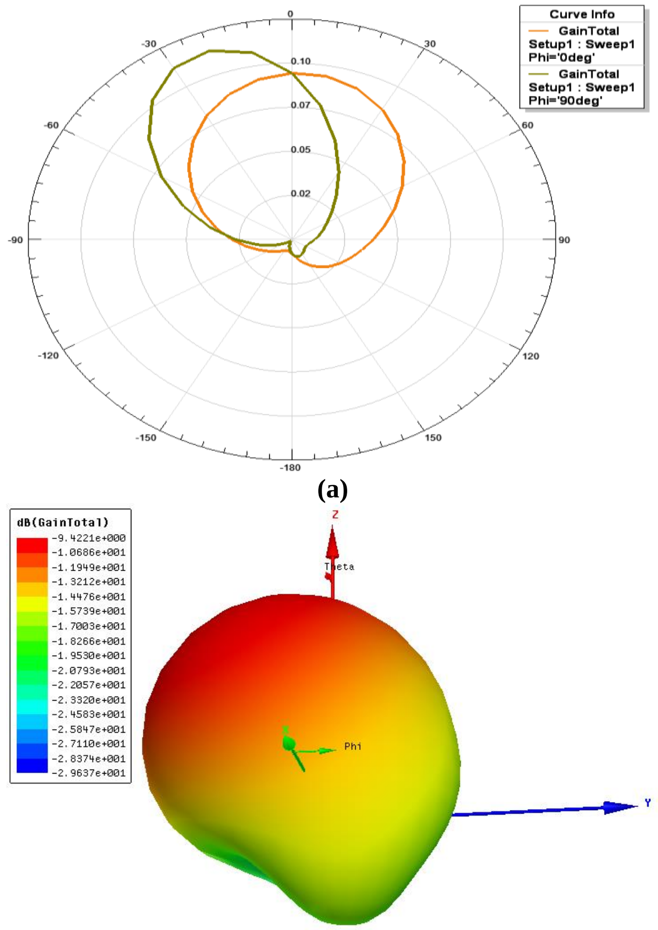



**(a)**




**(b)**

**Fig.7. (a) 2D Radiation Pattern for 2100 MHz frequency (b) 3D Radiation Pattern for 2100 MHz frequency**




**(a)**

**(b)**

**Fig.8. (a) 2D Radiation Pattern for 2600 MHz frequency (b) 3D Radiation Pattern for 2600 MHz frequency**

### *D. E-Field distributions*

E-field is an effect produced by an electric charge that exerts a force on charged objects in its vicinity. Electric fields themselves result directly from other electric charges or from the changing of magnetic fields. Figure 9 shows the electric field distribution. The maximum value of the E-field obtained is about 4.3 $10^3$ V/m.

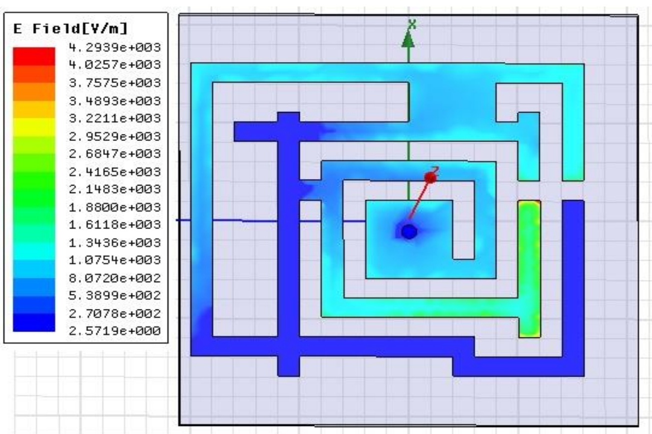



**Fig.9. E-field distribution**

### *E. H-Field distributions*

It is defined as the measured intensity of a magnetic field at a specific point. Usually it is expressed in amperes per meter.
The measured intensity of a magnetic field in the patch is shown in figure 10. The maximum value of the H-field obtained is 17.9 A/m.

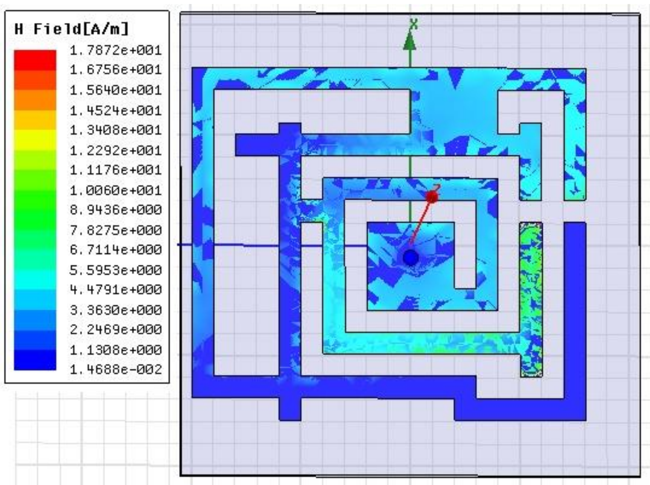



**Fig.10. H-field distribution**

## Conclusion

In this paper, the innovative analysis and conception of a novel compact quadruple frequency and miniature microstrip patch antenna for Wireless and Mobile Communication is presented. For this antenna, a selective bandwidth was achieved by utilizing various techniques. The designed microstrip antenna is optimized to cover the GSM, DCS, PCS, UMTS, LTE, WLAN (802.11ah) and ISM 902 frequency bands. The proposed antenna is very compact, very simple to produce, and is fed by coaxial cable which makes it very attractive for current and future cellular phones applications.

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