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Novel Microstrip Antenna Design

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Abstract

A simple, small, compact, low cost, and practical antenna for 2.4 GHz applications is proposed in this paper. A detailed investigation on miniaturized microstrip planar antenna design using a combination of proposed shorted patch and meandering method are presented. All design and simulations are done using Computer Simulation Studio (CST) software. For accuracy reasons, verification has been done, all the designs were fabricated, and measurements on return loss and impedance bandwidth were implemented by using RF Analyzer.

Keywords: *Antenna, microstrip, RF analyzer*

1. Introduction

Wireless feature implementations have rapidly evolved over the past decades. Driven by this rapid progress, requirement for smaller and cheaper antenna design becomes an integral factor in the deployment of wireless enabled products. It is evident that the wireless feature has become an important aspect in an introduction of any new products nowadays, regardless it being mobile or not. Manufacturers nowadays are pushing for a cheaper, smaller, simpler and more integrated way to implement wireless features [1]. One key element in wireless feature is the antenna design. Choosing the appropriate antenna design is crucial in order to optimize the wireless coverage and robustness of the transmission. The selection will also reflect to the material cost, implementation simplicity and manufacturability of the product. The size of the antenna is an important factor. Small sized is typically desirable since it is generally cheaper and flexible to be used in small products. Nevertheless the limitation of antenna size is still bounded to its relation the wavelength of the transmission [1]. Thus reductions of antenna generally will have a negative impact to the performance. In most cases, trade-off needs to be done in order to get good balance between all of these factors [2]. Understanding in the standard requirements and a good knowledge on the variation of antenna design will greatly aid this trading off process. It is well known that the microstrip antennas have been widely used in the past decade for wireless enabled devices. This is mainly due to its attractive characteristics such as small size, low profile, low cost and good repeatability, among others. Although microstrip antennas is by conventions are physically small, the requirement to further shrinkage in size is still highly desired [3].

In this article, we implementing a combination of the proposed patch shorting and meandering technique for antenna size reduction. Target resonance frequency is set to 2.4 GHz. The shorted patch method realized by the theory that when an antenna is operating in the lowest mode, a virtual short circuit forms through a plane centered between the two radiating edges [4]. This is achieved by implementing either a shorting wall, shorting plate or

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shorting pin. The proposed method in this implementation is the Planar Inverted F-Antenna (PIFA). As for meandering technique, resonant frequency is lowered by lengthening surface current paths. This is achieved by introducing disruption on the resonant-length path causing the surface current to wonder according to a longer path. The proposed method in this implementation is the Meandered Line Antenna (MLA) and the Bowtie Antenna [4].

In ensuring this work is relevant to a practical implementation of a wireless module commonly used in the industry, a few limitations are set. The following describes these limitations and its reasoning:

- Microstrip-Fed Antenna: This feeding method is more practical especially for integrated antenna wireless module since RF circuit and antenna will be on the same side of the Printed Circuit Board (PCB).
- Low Cost PCB material: Due to economy of scale, FR4 PCB material is significantly cheaper than others. 2 layer FR4 PCB is chosen in this work.
- Full ground plane backed: To minimize internal interference from the product itself to the wireless transmission, a full grounded antenna structure is maintained.
- 2-D structure: To simplify manufacturability and repeatability of the antenna a 2D antenna structure is proposed. The antenna design and analysis in this work utilizes CST studio simulation software.

2. Design methods

A microstrip rectangular patch antenna is one the most basic antenna configuration used for practical application. A rectangular patch antenna can be represented as an array of two radiating narrow apertures, each of width, W and heights, h, separated by a distance, L [5], typically half wavelength of the intended resonance frequency as illustrated in Figure 1. Because the dimensions of the patch are finite along the length and width, the fields at the edges of the patch undergo fringing. Radiation will occur from this fringing field which extends the effective open circuit beyond the edge.

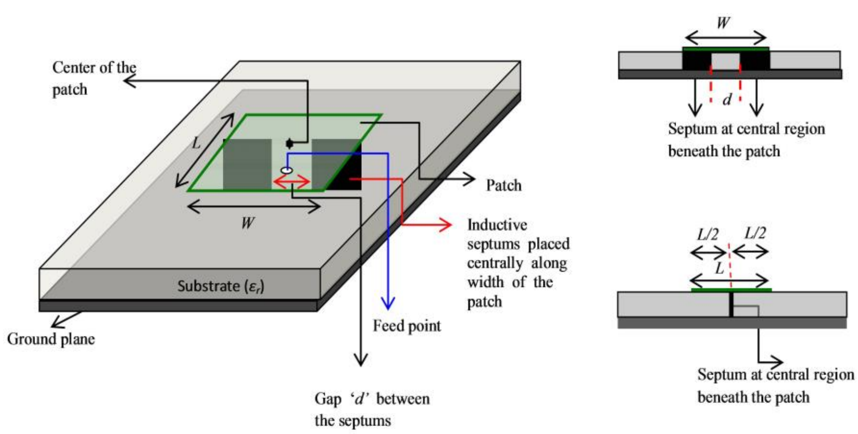

Figure 1. Antenna Structure

Due to the fringing field, the patch is electrically slightly larger than its actual physical length. This difference between electrical and physical length is dependent on the height and dielectric constant of the PCB. This deviation is given by formula below.

$$\Delta L = \frac{0.412(h)(\varepsilon_{eff}(\mathrm{W}) + 0.3)(\frac{W}{h} + 0.26)}{(\varepsilon_{eff}(W) - 0.25)(\frac{W}{h} + 0.8)} \quad (1)$$

The effective dielectric constant, ε_{eff} can be further reduced to:

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

ε_r is the substrate dielectric constant.
Since the length of the patch has been extended by ΔL on each side the effective length, $L_{eff}$of the patch is now (L=λ/2 for dominant T<010 mode with no fringing).

$$L_{eff} = L + 2\Delta L \quad (3)$$

For the dominant TM010 mode, the resonant frequency, f_{res} is dependent on the length of the antenna itself, which is written as:

$$f_{res} = \frac{1}{2L_{eff}\sqrt{\varepsilon_{eff}}\sqrt{\varepsilon_0\mu_0}} = \frac{c}{2L\sqrt{\varepsilon_{eff}}} \quad (4)$$

Where μo, ε_o, and c are the free space permeability, permittivity and speed of light, respectively. This gives the equation of patch physical length in relation of resonant frequency. For a design of an efficient radiator, the following equation solves an optimized width, *W* that provides good radiation efficiency, [5].

$$W = \frac{c}{2f_{res}}\sqrt{\frac{2}{\varepsilon_e + 1}} \quad (5)$$

3. Simulation, Analysis and Fabrication

In this work, a conventional rectangular patch antenna with inset feed is designed by using transmission-line model and simulation. This is aimed to be a benchmark for antenna miniaturization study in terms of size and radiation properties. Consistency of PCB parameters in simulation and material in fabrication is maintained for accurate comparison. The dimensions are realized in the theory [5, 6]. By solving the equation discussed is section 2, a conventional rectangular patch was designed as performance benchmark in this study. The target resonance frequency, f_{res} is 2.45GHz with center frequency of 2.4GHz ISM band. Figure 2(a) illustrates the dimension of the conventional antenna. To confirm the actual performance of the designed and simulated antenna, the design is fabricated by using actual mass producer of PCB as in Figure 2(b).

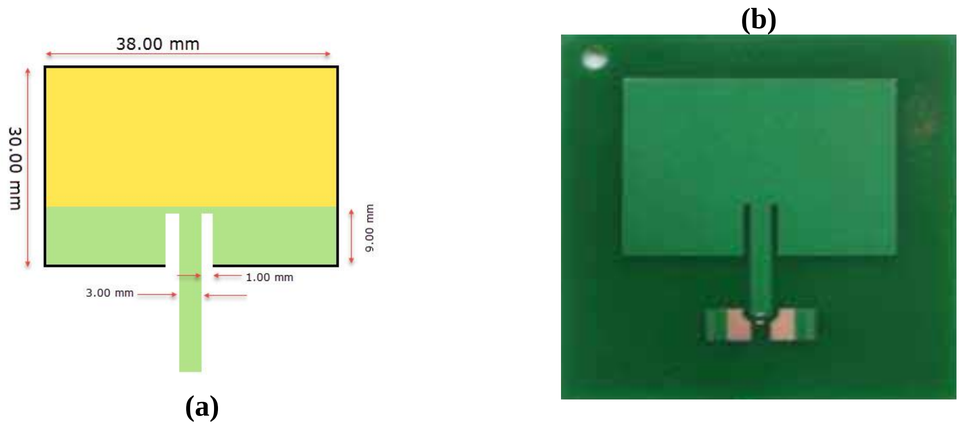

Figure 2. Proposed Antenna, (a) Measures (b) Fabrication

Table 1. Simulation Parameters

Parameter	Value
Size	1111 mm^2
Resonance frequency	2.4 GHz
10dB bandwidth	2.14%
Return loss	-35 dB
Gain	2.4 dBi
Directivity	7 dBi

4. Results and Discussion

A few miniaturized antenna designs were attempted in this work to observe the working principle of proposed shorted patch and meandering. The first design is based on shorting wall concept where a series of vias are added in the middle of the patch where current is set maximum and voltage is zero. The quantity and positioning were tuned to optimize the size and reduce inductive effects. The size of antenna is half of conventional patch where $L \approx \lambda/4$ as [7]. Figure 3 shows the results of surface analysis for the proposed antenna.

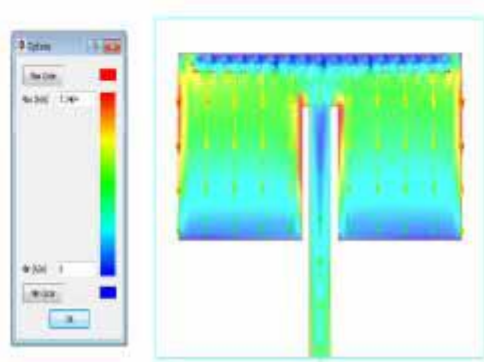

Figure 3. Schematic of the LNA to be Improved [3]

As shown in Figure 4, in this design we obtained return loss of -30.4dB and an accurate desired resonance frequency at 2.45 GHz is achieved. This is true as long as impedance of the pin shorting remains low. With high impedance shorting path the antenna will detune and causes the resonance frequency to be shifted as [7]. It is also observed that the impedance bandwidth of the antenna at10dB is 1.7% which is a little reduced compared to a full patch. This reduction also causes the radiation pattern to behave differently compared to a full patch antenna. As seen in Figure 6, the radiation spreads equally above the ground plane. This result a lowers the directivity compared to a full patch antenna. The simulated directivity of this antenna is 4.61 dB. The efficiency remains the same at 45%.

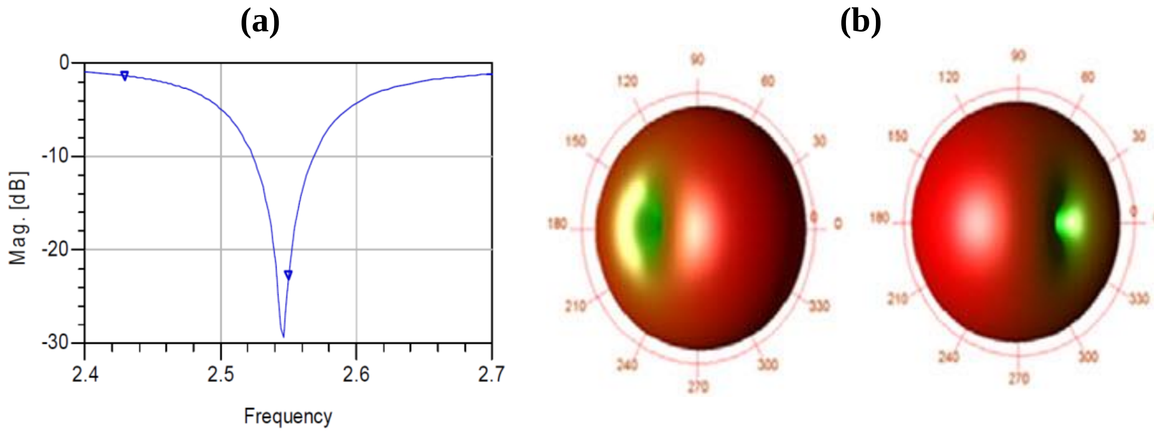

Figure 4. Simulation Results (a) Return Loss, (b) Radiation Pattern

5. Conclusions

Novel, compact and low cost suspended plate antenna miniaturization design for 2.4GHz application has been presented. It is observed that significant size reduction from a conventional rectangular patch antenna can be achieved by implementing these proposed techniques. For this, the radiation properties such as impedance band width, return loss, gain, directivity, efficiency, radiation pattern and surface current was discussed and analyzed. Improvements were also made based on best efforts to minimize the degradation.

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