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Research Article

Multi-Band Microstrip Antenna Design for Wireless Energy Harvesting

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Abstract

The purpose of this work is to propose an efficient microstrip rectenna operating on 900/1800 MHz GSM bands and the 2.4 GHz ISM band. The receiving antenna with presented joint feeding line implemented in a multilayer substrate. The reflection coefficient at the input of the optimized multi-Band microstrip patch antenna is below -10dB over the every frequency band. The measurement results are in excellent contract with the CST STUDIO SUITE 2011 simulation results.

Keywords: Rectennas; Rectifying Antennas; RF to DC conversion; Wireless Energy Transfer; Microstrip Antenna

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1. Introduction

The modern science has made everything almost impossible to possible. By the art of technology every system is upgrading. At this era power transmission is now carried out without any wires or conductor materials. It’s been done by the radio frequencies. This technology is known as so called wireless power transmission. We all know that now different radio frequencies are broadcasted from billions of radio transmitters globally. Different satellite stations such as radio, television broadcast stations, mobile base stations uses different frequencies to transmit their signals. These signals can be used for having wireless energy. The ability to harvest radio frequency energy from any surrounding or dedicated sources, enables wireless charging of low-power devices and has resulting benefits to product design, usability, and reliability. As low power is consumed so cellular phones always comes first in every one’s mind to harvest this small energy received from these radio frequencies. Cellular phone receives different radio frequency bands which can be used to charge the phone. By the technique of wireless energy transmission and wireless energy harvesting we can get rid of this regular scheduled charging battery.

A rectifying antenna or rectenna which can convert radio frequency energy to DC power plays an important role in wireless energy harvesting. The rectenna basically consists of four elements: antenna, low pass filter (LPF), diodes, and DC pass capacitor [1-3]. At rectenna starting development its focuses on directivity and efficiency for great power reception and conversion, then large array [4]was adopted for microwave power reception. Afterward, many functions were added to improve the performance of the rectenna array, such as arbitrary polarization[5], dual-polarization[6], CP[7] and dual band[8]. By using a rectifying antenna mobile batteries can be charged itself, and won’t have to charge the battery regular way with this technique.

In this paper, a microstriprectenna designed to cover the 900/1800 MHz GSM bands and the 2.4 GHz ISM band. The theoretical simulations are performed using CST STUDIO SUITE 2011 software.

2. Microstrip Antenna Technology

A basic microstrip patch antenna is a resonant-type radiator so one of its dimensions must be nearly $\lambda g/2$, where λg is the guided wavelength. The properties of the substrate namely, dielectric constant (εr) and height play a fundamental role in the performance of the printed antenna. The size of an antenna based even on a quarter wavelength line is physically too large to be used at 900MHz, especially when designed on low permittivity substrates to enhance bandwidth and efficiency.

A microstrip antenna is built by a dielectric substrate between two metal layers, one layer is the antenna and the other is the ground. There are many types of substrate with dielectric constant values usually in the range of $2.2<\varepsilon r <12$. Thick substrates with low dielectric constants are desired because they have higher bandwidth efficiency at the cost of a larger antenna size. Most of the performance and complexity of the design of a microstrip antenna depends on how the antenna patch will be fed. As the aim is to devise a reconfigurable microstrip antenna having high tuning ranges, with single feed, the original passive antenna design is vital. The design must ensure good matching below-10dB for resonant modes, even when the frequencies are shifted a great extent by applying the reverse DC voltage.

3. Antenna design

The antenna geometry shows in Figure 1. First, a microstrip patch antenna is designed based on the standard design method to determine the length (L) and width (W). A substrate with dielectric permittivity of 4.3 and thickness of 4.5mm is selected to obtain a compact radiation structure that at the same time meets the demanding bandwidth specification.

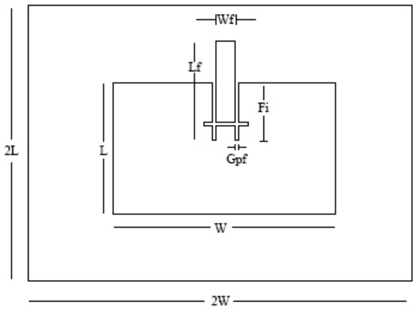

Figure 1 Proposed antenna

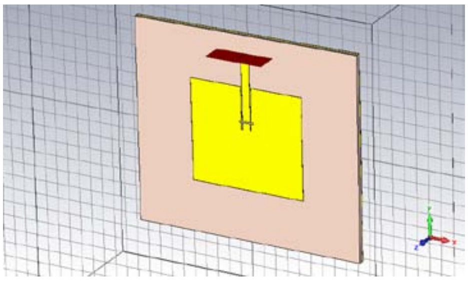

Figure 2 Microstrip Antenna designed in CST

For the stage of physical design and simulation, the CST STUDIO SUITE 2011 software hadbeen used. In order to generate an electromagnetic field solution, CST STUDIO SUITE 2011 employs the finite element method our design, such as, solids, sheets, and planes (Figure 2).

The length and width of the patch are 72mm and 94mm respectively, which are dimensioned to resonate at 900, 1800 MHz and 2.4 GHz frequency. The results of the simulations and parametric studies will be shown and analyzed.

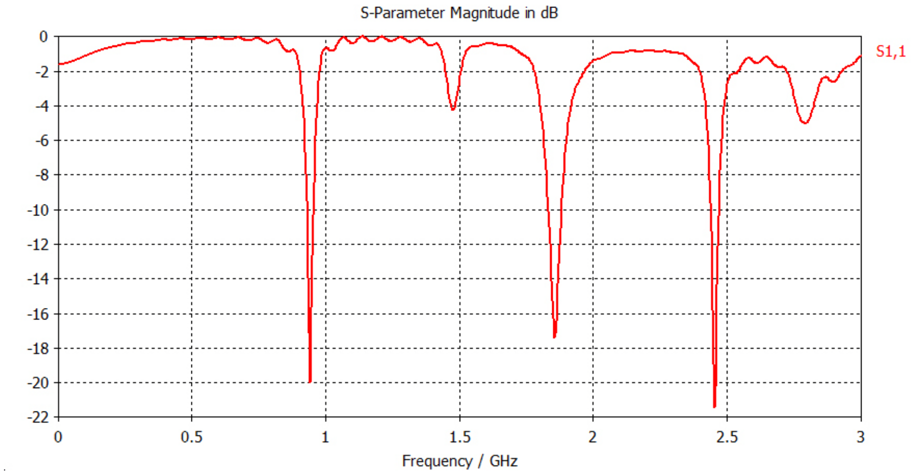

Figure 3 Voltage in different frequencies

This line graph (Figure 3) demonstrates the S-parameter magnitude in dB from 900 MHz to 2.4 GHz. dB values decreases to an average of -18dB at 900 MHz, 1.8GHz and 2.4 GHz. It also went down -4dB at 1.5 GHz and 2.7 GHz. Normally, the impedance matching between receiver antenna and rectification circuit is done using the 50 Ohm standard in order to simplify testing. With such a classical design (50 Ohm input impedance for the antenna) and with a global optimization of the rectifying circuit, we obtain a simulated voltage level of 350 mV on a 1MOhm load (representative of a high impedance connected sub-circuit) and for an input power level of -15dBm. RF do DC conversion efficiency reaches 25 % when supplying a 3kOhm resistive load. Far-field directivity at different frequency simulations shown us ensure good matching below-10dB for each frequency. If the rectifying circuit has been optimized at frequency for an input power of 10dBm. The rectenna exhibits a measured efficiency of 74 % at 0.3mW/cm² power density and an output DC voltage of 2.9 V.

This 2D view illustrated the current distribution each frequency (Figure 5).

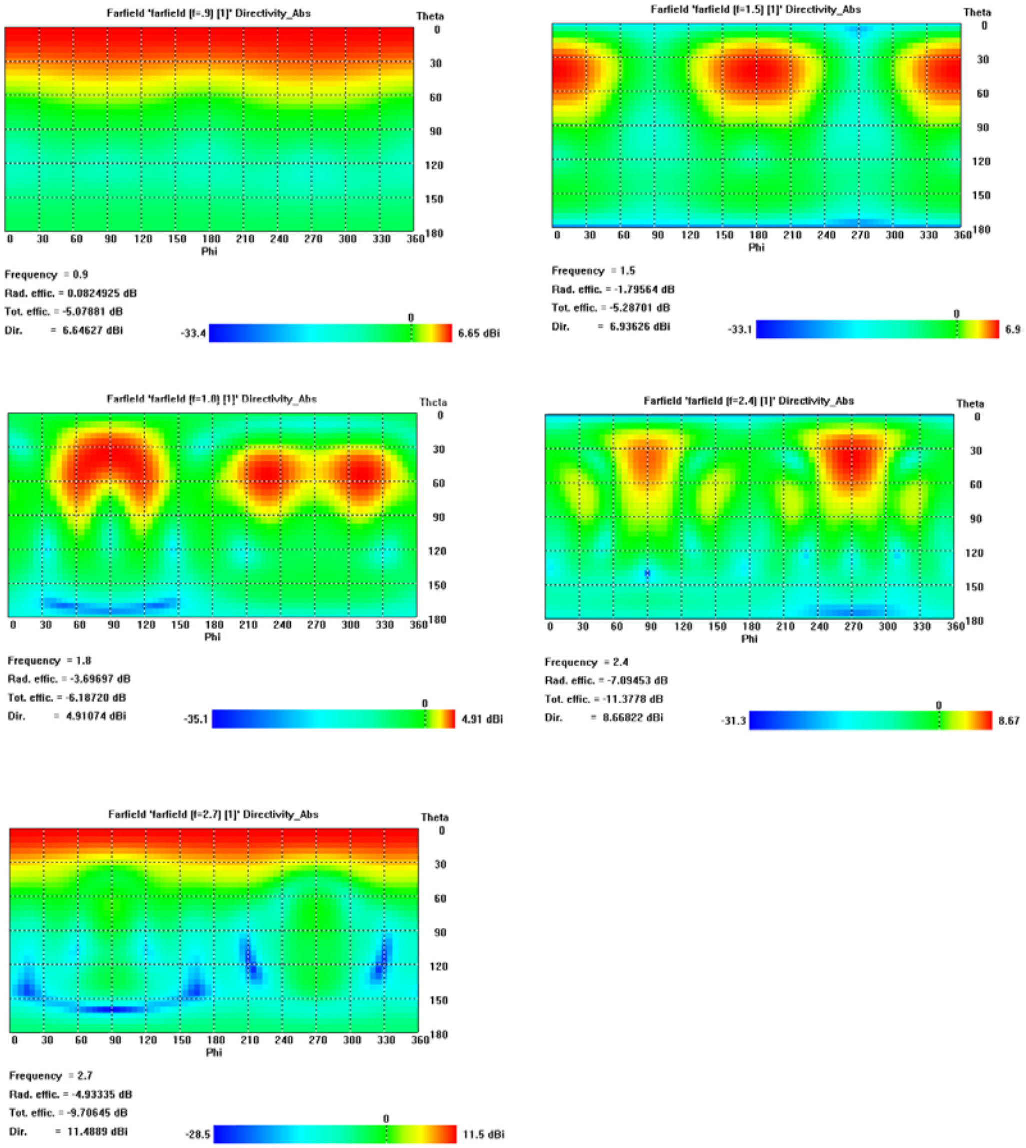

Figure 4 Field distribution (V/m) at 900 MHz,1.8 GHz,2.4 GHz and 2.7 GHz.

4. Conclusion

In a rectenna design, antenna has an important role. The reflection coefficient is below -10dB for 900/1800 MHz and 2.4 GHz. The performance is more than meeting the demanding bandwidth specification to cover the GSM bands and ISM frequency band. At the same time, the antenna is thin, compact and it use of low dielectric constant substrate material. These features are very useful for worldwide portability of wireless communication equipment. The parametric study provides a good insight on the effects of various dimensional parameters. Excellent agreement between the measurement and simulation results is obtained. In future research the rectifying circuit can be added with this antenna to make an even more effective rectenna.

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