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Wireless Mobile Charging Using Rectenna

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Abstract
The purpose of this work is to build a system for mobile to wirelessly charge it using microwaves. The main component used for conversion of message signals, in the form of microwaves, to electrical signals is rectenna. The rectenna is a microstrip antenna, which operates at GSM frequency (1.8GHz) having low S11 parameter, followed by a rectifier circuit having a bridge topology, consisting of schottky diodes. The designed antenna shows bandwidth of 50MHz, having return loss -21dB and efficiency 45%. There are some additions in mobile phone to apply this technique as a sensor and a filter. With this technique the need for separate chargers for mobile phones is eliminated and makes charging universal. Thus the more you talk, the more is your mobile phone gets charged.

Keywords-Wireless mobile charging, Rectenna, Rectifying circuit, Patch antenna, bandwidth, gain, directivity.

I. INTRODUCTION

In the modern era mobile phones are basic need of every person as these are the fastest and the easiest medium of communication. The charging of mobile phone batteries has always been a problem. Battery lifetime is dependent of the manufacturer Company and also price of phone. To overcome this problem wireless charging of mobile phones using microwaves is a very important and useful technique. With this technique you can use your mobile phone without thinking about the battery stand by. This technique works on microwaves. The microwaves are used to send the messages. There are some additions in mobile phone to apply this technique as a sensor, a rectenna circuit and a filter. With this technique the need for separate chargers for mobile phones is eliminated and makes charging universal. Thus the more you talk, the more is your mobile phone gets charged.

Rectifying antenna (rectenna) which converts RF energy to DC power plays an important role in free space wireless power transmission. The typical rectenna in the prior literatures basically consists of four elements: antenna, low pass filter (LPF), diodes, and DC pass capacitor. The initial development of rectenna focuses on its directivity and efficiency for great power reception and conversion.

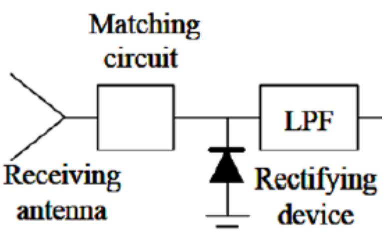

Figure 1-Basic rectenna schematic

Microstrip antennas are getting popular for modern communication system due to their features which includes compact size, low cost and ease of fabrication. An extensive work on simple microstrip geometries including rectangular, circular and triangular shaped structures has been reported. Bandwidth and efficiency of a Microstrip antenna depends upon many factors for eg. Patch size, shape, substrate thickness, dielectric constant of substrate, feed point type and its location, etc. For good antenna performance, a thick dielectric substrate having a low dielectric constant is desirable for higher bandwidth, better efficiency and better radiation.

The rectangular patch antenna is approximately a one-half wavelength long section of rectangular Microstrip transmission line. When air is the antenna substrate, the length of the rectangular Microstrip antenna is approximately one-half of a free-space wavelength. As the antenna is loaded with a dielectric as its substrate, the length of the antenna decreases as the relative dielectric constant of the substrate increases. The antenna has become a necessity for many applications in recent wireless communication such as radar, microwave and space communication. The specifications for the design purpose of the structure are as follows-

[i] Type of antenna: Rectangular Microstrip Patch antenna
[ii] Resonance frequency: 1.8GHz
[iii] Input impedance: 50 Ω
[iv] Feeding method: Microstrip Line Feed

II. DESIGN SPECIFICATION

The length and width of rectangular patch antenna are calculated from below equations. Where c is the velocity of light, εr is the dielectric constant of substrate[1].

- **Calculation of the Width (*W*):** The width of the Microstrip patch antenna is given by equation as:

$$W = \frac{c}{2f_0}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

- **Calculation of Effective dielectric constant (**εreff **):** The following equation gives the effective dielectric constant as:

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

- **Calculation of the Effective length (**Leff **):** The following equation gives the effective length as:

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}}$$

- **Calculation of the length extension (**ΔL **):** The following equation gives the length extension as:

$$\Delta L = 0.412h\frac{\left[\varepsilon_{eff} + 0.3\right]}{\left[\varepsilon_{eff} + 0.258\right]}\frac{\left[\frac{w}{h} + 0.264\right]}{\left[\frac{w}{h} + 0.8\right]}$$

- **Calculation of actual length of patch (**L **):** The actual length is obtained by the following equation:

$$L = L_{eff} - \Delta L$$

III. DESIGN OF RECTANGULAR MICROSTRIP PATCH ANTENNA

The proposed antenna based on the Rectangular Microstrip Patch Antenna. The antenna is planar Rectangular Patch Antenna fed by Microstrip line, FR4 substrate with dielectric constant 4.4, loss tangent 0.02 and 2.2mm of thickness (h). This antenna is design at frequency 1.8 GHz, width of microstrip is 2 mm for match impedance with 50 ohms of transmission line. The Rectangular Microstrip Patch Antenna is shown figure 2. The Essential parameters of the design are shown in table 1

Table 1. Proposed antenna design Parameters:

Design of Micro strip patch antenna	Design
Name of Pattern	Rectangular shape
Frequency of Operation (GHz)	1.8GHz
Substrate used	FR4
Dielectric constant of substrate	4.4
Loss tangent	0.02
Height of the dielectric substrate (mm)	1.6
Feeding method (Microstrip feeding)	8.55(x-axis) ,10(y-axis) ,2.2(z-axis)
Length of the feed line	10
Width of the feed line	2
Width of the patch	38
Length of the patch	52
Width of the ground	53
Length of the ground	62

Proposed Antenna Design:

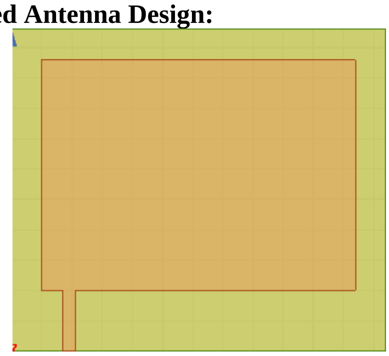

Figure 2- 1.8GHz rectangular patch antenna

IV. SIMULATED RESULTS OF ANTENNA

The performance parameters of the designed antenna like return loss, VSWR, radiation pattern and current distributions is measured and discussed here.

A. RETURN LOSS

The theory of maximum power transfer states that for the transfer of maximum power from a source with fixed internal impedance to the load, the impedance of the load must be the same of the source which is called Jacobi's law. Most microwave applications are designed with an input impedance of 50 ohms, so matching the antenna to 50 ohms is our desire. The impedance of the microstrip patch antenna does not depend on the substrate dielectric constant, εr or its height .The s-parameter graph and voltage standing wave ratio graph is unleashed for the impedance matching performance of the antenna.

Return loss is an important parameter when testing an antenna. It is related to impedance matching and the maximum transfer of power theory. It is also a measure of the effectiveness of an antenna to deliver of power from source to the antenna. The return loss (RL) is defined by the ratio of the incident power of the antenna Pin to the power reflected back from the antenna of the source P ref ; the mathematical expression is:

$$RL = 10 \log (Pin/ Pref) \text{ (dB)}$$

For good power transfer, the ratio Pin/Pref is high. Another definition of return loss we can get from this equation is the difference in dB between the power sent towards the antenna and the power reflected from it. It is always positive when the antenna is passive and negative when it is active.

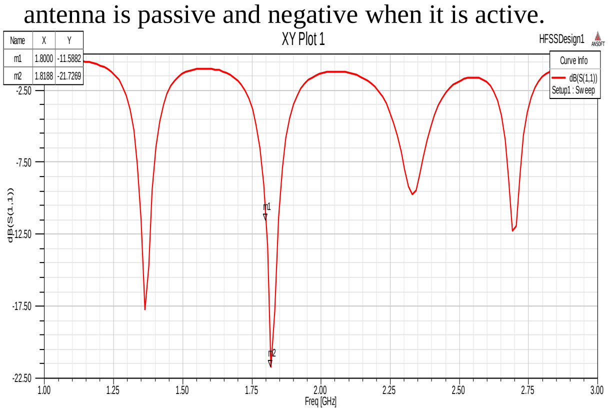

Figure 3- Simulated S11 parameter of the antenna

The return loss is obtained from the s-parameter graph as shown in figure 2. The designed antenna resonates at 1.805 GHz. The return loss at this frequency is -42.55dB which indicates that the designed antenna provides better impedance matching between the antenna and transmission line.

B. VOTAGE STANDING WAVE RATIO (VSWR):

It is defined as a measurement of the mismatch between the load and the transmission line. The VSWR plot for the antenna is shown in Figure 4.

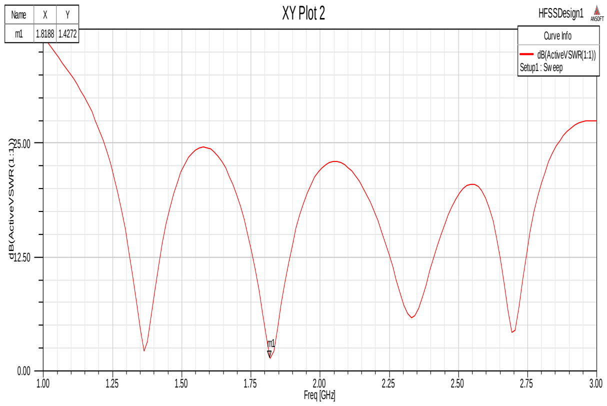

Figure 3- VSWR of the designed antenna

C. RADIATION PATTERN:

They are graphical representation of electromagnetic power distributions in free space, as shown in figure 5. Also, these patterns can be considered to be representative of the relative field strengths of the field radiated by the antenna. The designed antenna gives an omnidirectional radiation pattern. The polar plot at the resonant frequency for the designed antenna is shown in figure 6.

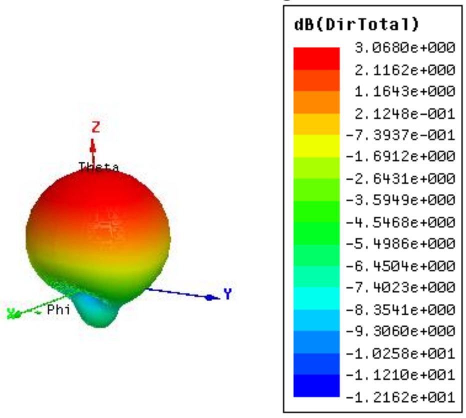

Figure 5- Radiation Pattern

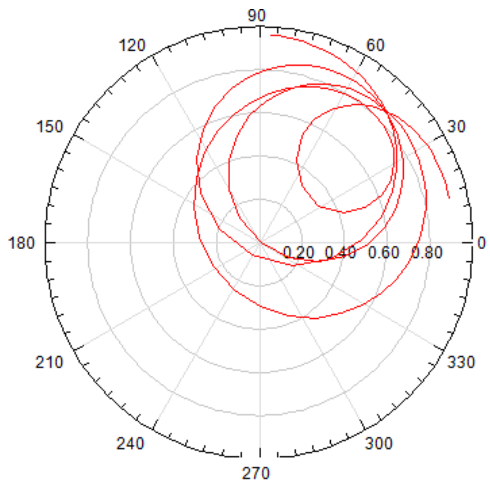

Figure 6- Polar plot

V. IMPEDANCE MATCHING

Impedance matching is the practice of designing the input impedance of an electrical load or the output impedance of its corresponding signal source to maximize the power transfer or minimize signal reflection from the load. Impedance matching is an essential part of antenna design. The input impedance of an antenna needs to be reasonably close to the rectifier impedance (e.g. 50 Ohm), otherwise the signal is reflected back. For maximum power transfer complex conjugate matching is used this is different from reflection less matching only when source or load has a reactive component.

$$Z_{load} = Z_{source}^{*}$$

Where * indicates complex conjugate.

As our system consist of antenna followed by rectifier circuit, for maximum power transfer a impedance matching circuit is designed with the help of AWR software.There needs to be a input impedance matching circuit between antenna and rectifier circuit as shown below. Figure 7 shows the rectifier circuit, figure 8 shows the matching circuit and figure 9 shows the graph of insertion loss and the return loss.

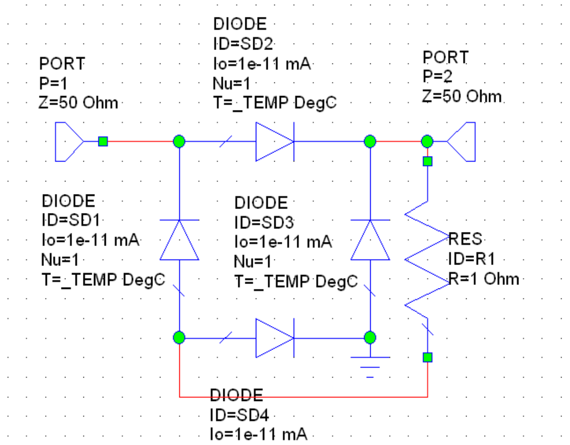

Figure 7- Rectifier circuit

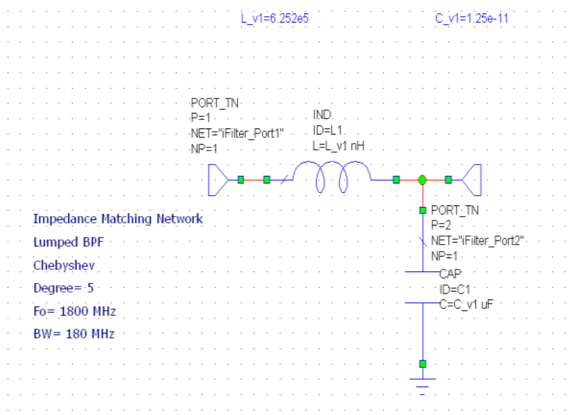

Figure 8- Matching Circuit

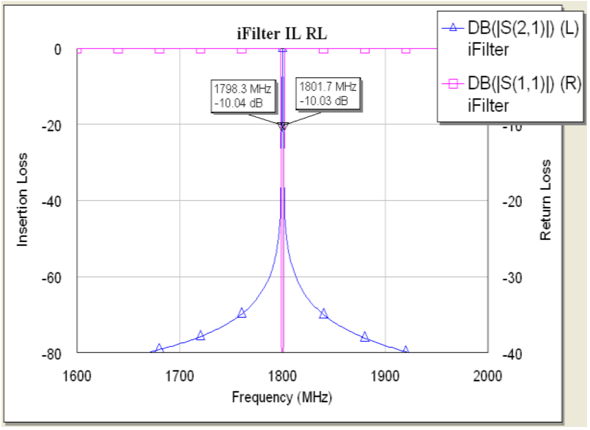

Figure 9- Insertion loss and return loss

VI. CONCLUSION

A narrowband rectangular microstrip patch antenna has been designed for wireless communication systems. The reflection coefficients −42.55 dB for 1800 MHz. The performance is meeting the bandwidth demand of 1750-1840 MHZ GSM frequency. At the same time, the antenna is thin and compact with patch dimension as 38(width) and 52(length). The dielectric used has a constant of 4.4. 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. The bandwidth can be easily enhanced by using techniques like increasing the width of the dielectric material. Excellent agreement between the measurement and simulation results is obtained.

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