A 2.45 GHz DGS Based Harmonic Rejection Antenna For Rectenna Application

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Abstract— **This paper presents a circular shaped ground slot harmonic rejection antenna for wireless power transfer at 2.45 GHz. Defected ground structure (DGS) has been used to remove higher order harmonics from the antenna response. In the proposed work the antenna has been simulated and measurement up to 10 GHz which establishes removal of up to fourth harmonics. This makes it suitable for the proposed application.**

***Keywords*— Patch antenna, Harmonic suppression, defected ground structure, rectenna.**

I. INTRODUCTION

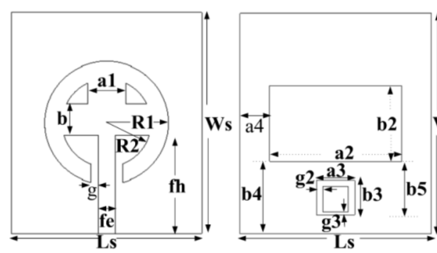
Wireless power transmission (WPT) systems widely use rectenna for receiving incoming RF wave and rectifying it to DC. A conventional rectenna system consists of a receiving antenna, bandpass filter (BPF), matching circuit, rectifier circuit, post rectification low pass filter (LPF) and resistive load [1]. The concept is that the antenna receives a time varying signal that is converted to DC by the rectifier. The matching circuit is used to match the antenna impedance with the rectifier impedance. The diodes, used in the rectifier circuit, are non-linear devices and generate a large number of harmonics. The BPF and LPF are used to prevent these harmonics to reach the antenna terminal or load and hence to increase the system efficiency.

To reduce the size of the rectenna and simultaneously increase its efficiency, researchers have proposed the use of harmonic rejection antenna. Since these antennas are void of harmonic response, they neither radiate the harmonics generated by the diodes nor can receive signals with frequencies equal to harmonics of the design frequency. Such antennas therefore enable the designer to remove the BPF from the rectenna circuit, making the system compact and efficient. To suppress the harmonics in antenna response, different techniques have been proposed, such as, defected ground structure (DGS), photonic band-gap structure (PBG), hybrid PBG [2], right angle embedded slits [3], slot antenna [4-5] etc.

In this paper a circular shaped ground slot antenna has been presented for wireless power transfer using the 2.45 GHz band. The structure has been simulated up to 10 GHz, which reveals the capability of the antenna to reject at least up to fourth harmonics. To validate the simulation, proposed antenna has been fabricated and measured. The measured result shows good agreement with the simulated result.

II. ANTENNA GEOMETRY

The front and back views of the proposed antenna are shown in Fig.1. Design and optimization of the antenna has been carried out using CST Microwave Studio (Version 14.0). Final optimized dimensions are tabulated in Table I. FR4 substrate (ε_r = 4.4, 1.6 mm height, and tangential loss of 0.02) has been considered as the substrate material for the design of the antenna.



(a) (b)

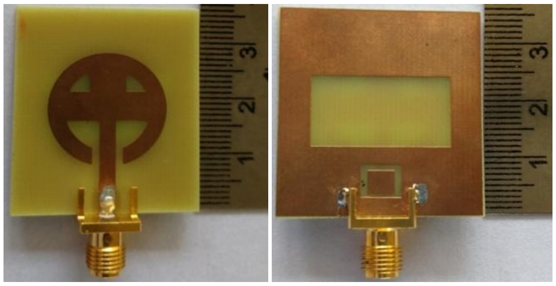
Figure 1. Antenna geometry (a) Top view and (b) Bottom view

TABLE I. PARAMETER VALUES OF THE PROPOSED ANTENNA

All dimensions are in mm								
Ls	Ws	R_1	R_2	a_1	b	f_e	f_h	G
30	35	9.75	7	6	4	2.63	15.5	1.19
a_2	b_2	a_3	b_3	g_2	g_3	a_4	b_4	b_5
20.66	12	6	5.5	1	0.5	4.67	11.50	8.50

III RESULTS AND DISCUSSION

The measured reflection coefficient of the fabricated antenna has been plotted and compared with the simulated result in Fig. 3. The frequency response of a conventional antenna (with out harmonic rejection) also has been ploted in the same figure for comparison. The frequency response of a conventional antenna (with out harmonic rejection) also has been ploted in the same figure for comparison. Fig. 3 reveals a very narrow 10 dB return loss bandwidth around 2.45 GHz with harmonic rejection at least up to fourth harmonics, which is suitable for wireless power transfer. The measured return losses of the fabricated antenna at the second, third and fourth harmonics are 2.64 dB, 1.32 dB and 3.33 dB, respectively. The figure also reveals that the measured result is in good agreement with the simulated result, which validates the simulation.



(a) (b)

Fig. 2. Fabricated antenna (a) Top view (b) Bottom view

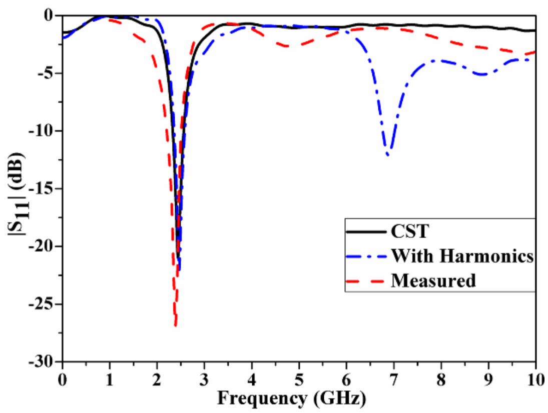


Fig. 3. Frequency response of $|S_{11}|$ of the proposed antenna.

The slight differences between the simulated and measured return losses are due to fabrication tolerances and losses in connectors.

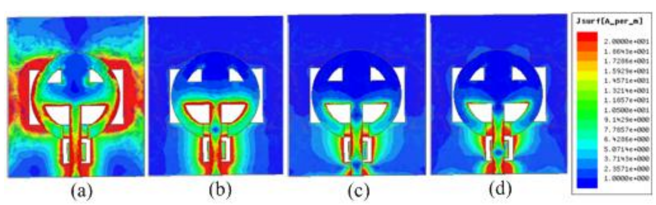


Fig. 4. Simulated current distribution on the radiating patch and ground plane of the proposed harmonic rejection antenna at (a) 2.45 GHz, (b) 4.9 GHz, (c) 7.35 GHz, and (d) 9.8 GHz

The surface current distributions on the radiating patch and on the ground plane of the proposed harmonic rejection antenna at the fundamental and up to fourth harmonics are shown in Fig. 4. The radiation efficiency of the proposed harmonic rejection antenna has been plotted with frequency in Fig. 5(a). The figure reveals that the proposed antenna has 78% radiation efficiency at the operating frequency. The measured and simulated gains of proposed antenna have been plotted in Fig. 5(b). The figure reveals that the measured gain of the proposed antenna is 2.7 dB in the operating band. The relatively low gain can be explained as follows. Etching rectangular slot in the ground plane increases the backward radiation leading to a decrease of the forward gain and the much lower front-to-back radiation ratio.

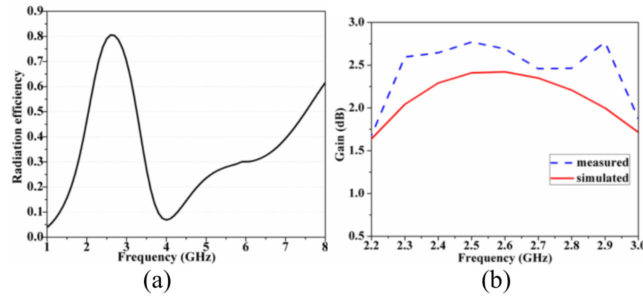


Fig. 5. (a) Simulated Radiation efficiency of the proposed antenna (b) Comparison of simulated and measured gain

The simulated and measured normalized co and cross polarized radiation patterns of the proposed antenna on both the orthogonal plane (*yz*-plane and *xz*-plane) at the resonant frequency 2.45 GHz are plotted in Fig. 6. It shows that the antenna has a bidirectional radiation pattern in *yz*-plane and omni-directional radiation pattern in *xz*-plane. The cross polarization level is more than 20 dB below than the co-polarization level on both the orthogonal plane.

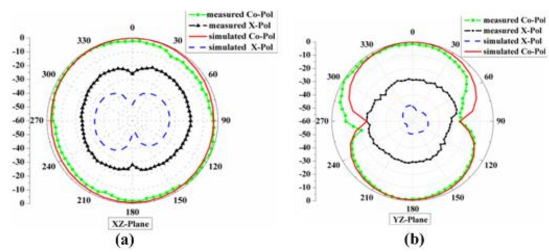


Fig. 6. Simulated and measured co and cross polarized radiation pattern of the proposed antenna at 2.45 GHz for (a) Phi=0^0, and (b) Phi=90^0.

IV CON CLUSION

This paper presents a 2.45 GHz circular patch antenna with harmonic rejection capability. The antenna has 2.7 dB gain and 78% radiation efficiency. A rectangular shape DGS has been used for harmonic suppression. Measurement has been carried out upto 10 GHz which shows supression up to fourth harmonics. The 10 dB return loss bandwidth of the antenna ranges 2.20 to 2.52 GHz, which also covers the Bluetooth band.

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