Second Harmonic Exploitation for Wireless Power Transfer Using Duplexing Rectenna

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Abstract—This project presents a design of a duplexing rectenna with harmonic feedback capability for WPT applications. The duplex dipole antenna is designed to receive RF power at 0.915 GHz and transmit the 2nd harmonic signals at 1.83 GHz back to the source for positioning. The rectifier converts the incoming waves at 0.915 GHz and the unavoidable 2nd harmonic waves are collected and used as a feedback. Simulation results show a relative high RF-DC conversion efficiency of 71% (with Pin=15 dBm). Thus, a closed-loop feedback system is formed and it offers the potential to fulfil an effective and efficient WPT system.

Introduction

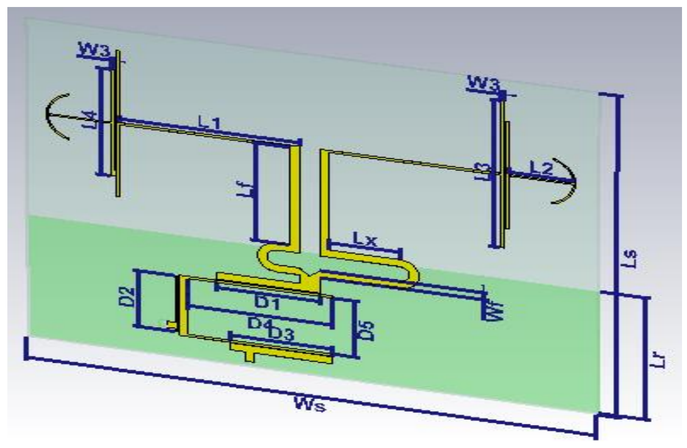
With the increase in distributed communication networks, there is a need to enhance the efficiency of remotely communicating and powering these devices. The rectifying-antenna (rectenna) system is the key element for WPT as it receives radio waves and directly converts the power from RF to dc. This project will focus on exploiting the unavoidable 2nd order harmonics generated by this system with a novel design of duplexing rectenna that resonates at frequencies of 0.915 and 1.83GHz [1].

Methodology

1. Design of Antenna

The geometry of the proposed duplexing antenna is as follows. It consists of a capacitive gap, a top loading, and stub loading structure at each pole to realize as a compact dual-band dipole antenna which is printed on a Rogers RO4350B substrate with a relative permittivity of 3.48 and thickness of 1.52 mm.

The capacitive gaps help with the generation of the dual-band resonances and the harmonic feedback can be transmitted through port 2 at 1.83 GHz.

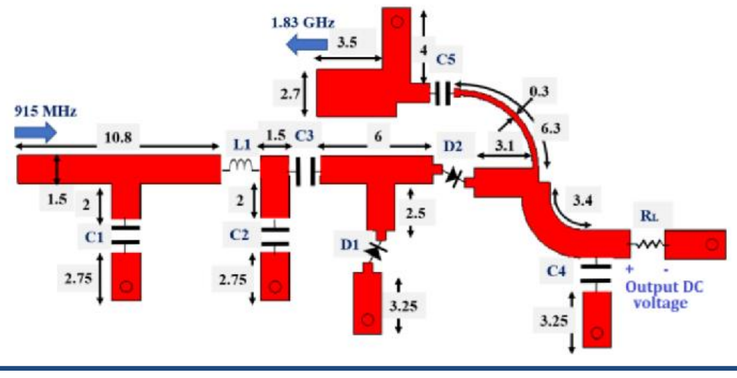


Parameter	Value (mm)
L1	47.2
L2	17
L3	52
L4	38
Lx	23
Lr	43.3
Ls	114
Wf	2.5
Lf	37.2

2.Design of Rectifying Circuit

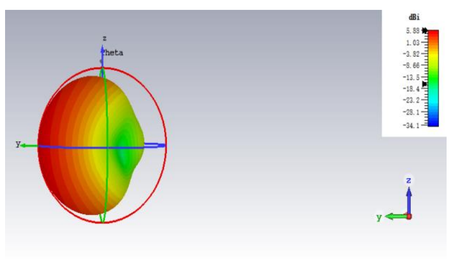
The layout of the rectifying circuit is as follows. The RF power received from the antenna is converted to dc power by the rectifying circuit after passing through a filtering and matching network. A matching network ensures that the antenna is matched to the rectifier and the harmonics generated by the rectifying element are not radiated back into the environment through the antenna [2].

The design flow of the rectifier starts with determining the operating power level and expected output power. Both large signal S-parameter (LSSP) and harmonic balance (HB) simulations are used to analyse the impedance matching and conversion efficiency of the system.

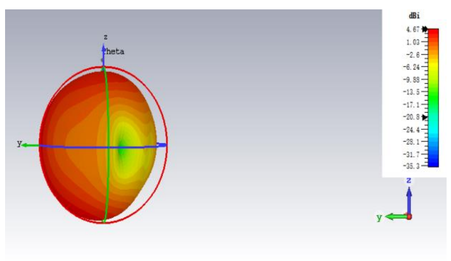


Results and Discussion

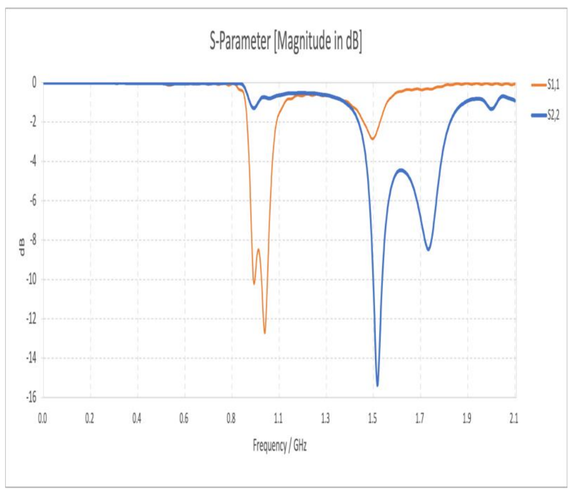
1. Simulated Results for Antenna



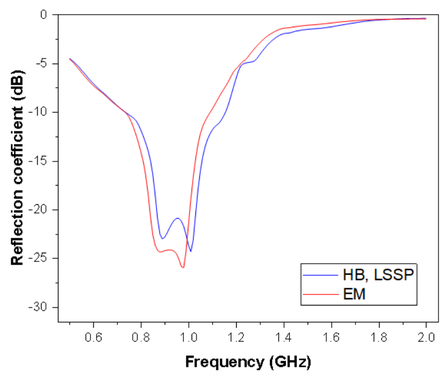
0.915GHz

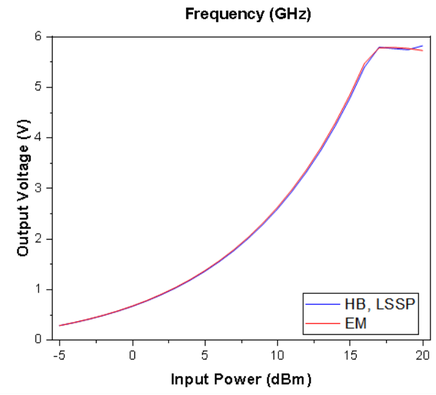


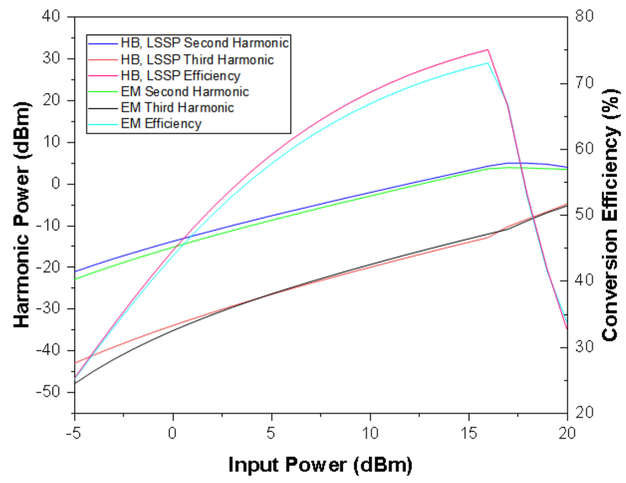
1.83GHz



2. Simulated Results for Rectifying Circuit







Conclusion and Future Work

This project presents a novel duplexing rectenna with a harmonic feedback capability for efficient WPT applications. The proposed rectenna system shows the ability of efficiently converting the incident RF power at 0.915 GHz to dc power, and sending a measurable harmonic signal back to the source at 1.83 GHz for tracking and improving the transfer efficiency without the need of extra alignment devices. The maximum measured conversion efficiency is of 71%. In future, the proposed system could be further optimized after combining the antenna and the rectifying circuit together. Experimental demonstration could be carried out after the manufacture. Up to now, the project can be consider as a success.

Selected References

[1] S. D. Joseph, Y. Huang, S. S. H. Hsu, A. Alieldin and C. Song, "Second Harmonic Exploitation for High-Efficiency Wireless Power Transfer Using Duplexing Rectenna," in *IEEE Transactions on Microwave Theory and Techniques*, vol. 69, no. 1, pp. 482-494, Jan. 2021.

[2] M. Piñuela, P. D. Mitcheson, and S. Lucyszyn, “Ambient RF energy harvesting in urban and semi-urban environments,” in *IEEE Trans. Microw. Theory Techn.*, vol. 61, no. 7, pp. 2715–2726, Jul. 2013.

Acknowledgement

Thanks for Xi'an Jiaotong Liverpool University for providing SURF opportunity, and to Dr. Zhenzhen JIANG for her guidance and assistance.