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ARTICLE

DESIGN AND IMPLEMENTATION OF CORRUGATED CIRCULAR LOOP ANTENNAS IN WIRELESS POWER TRANSFER TECHNOLOGY

A Gautami[1], S priya[2*], S Mythili[3], S.Baskar[4]

[1]AP/Department of ECE, SNS College of Technology, Coimbatore, INDIA

[2,3,4]AP/Department of ECE, Karpagam Academy of Higher Education, Coimbatore, INDIA

ABSTRACT

Electronic devices are essential part in our day-to-day lives. The invent of wireless power transfer (WPT) technology provides a gateway for charging multiple number of electronic gadgets simultaneously. Wireless power transfer denotes the transfer of power between a transmitting module and a receiving module for various applications such as charging mobile phones and electric cars wirelessly. While performing wireless power transfer, this technology encounters lot of challenges. This research paper analyzes the impact of orientation of antennas, its alignment, and the energy coupling losses of antennas at transmitting and receiving side. The design simulation is implemented by using Antenna Magus Software -frequency domain solver analyzed by Computer Simulation Technology.

KEY WORDS
Energy coupling, wireless power transfer, circular loop antennas, UHF RFID frequency, E Field norm distribution, S parameters.

INTRODUCTION

Wireless power transfer technology works on the principle on energy coupling by orientation of antennas [1]. This technology has the ability to charge multiple electronic devices concurrently, over long distances and through materials like glass, plastic and wood.[2] The wireless power transfer technology is used in electronic gadgets, smart phones, wearable electronics, in medical industry i.e. a new medical implant to replace power cord or the replaceable batteries in heart pumps and in hybrid electric vehicles, etc.[3] The WPT technology uses electromagnetic field to transfer energy between two objects. The power source is connected to a power transmitting unit (PTU), generates a magnetic field and a power receiving unit (PRU) converts the transmitted energy into usable power. [4] It is important to consider that a device must have to be carefully aligned on the transmitting unit for charging. The matched orientation between the PTU and PRU helps the devices to prevent the losses due to energy coupling.

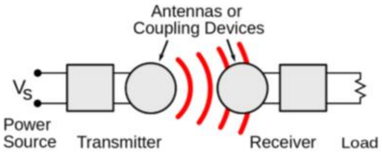

Fig. 1: An illustration of wireless power transfer

WORKING PRINCIPLE

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The wireless power transfer model analyzes the energy coupling between two circular loop antennas [5]. The model describes the wireless power transfer technology by evaluating the two circular loop antennae's energy coupling tuned for UHF RFID frequency [6]. The antenna is designed by reducing its size using chip inductors. The S parameters are investigated for proper coupling by configuring the transmitting antenna as fixed type, while the receiving antenna is rotating type. As shown in the [Fig.1].

***Corresponding Author**
Email:
mailtopriya.sri@gmail.com

In this model, the antennas [7] designed as a perfect electric conductor (PEC).the antennas are made of a material polytetrafluoroethylene (PTFE) board and have a thin copper layer on top. Each of the antennas is featured as a lumped inductor and a lumped port that can resonate or terminate the loop antenna [8]. The antennas are perfectly shaped to perform inductive coupling. To design [9] the characteristic the antennas should have a UHF RFID operating frequency of 915MHz.[10]

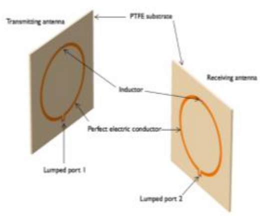

Fig. 2: Model geometry at receiving antenna orientation to determine the coupling effect between two circular loop antennas

MODEL DEFINITION

To model a perfect dielectric conductor ,the thickness of the copper layer is geometrically very thin at the operating frequency, but it must be much thicker than the copper skin depth, δs = (2/ωμσ)1/2 = 2.15 μm. The receiving power and the transmitting antennas are matched for coupling. The surrounding PMLs are made to absorb the radiation from the transmitting antenna which is coupled to infinite free space [11].

By inserting a [12] lumped inductor the diameter is reduced down to approximate value of 0.22 λ0 representing a surface mount device in the middle of each circular copper trace. On the dissected split section of each circular copper trace perfect dielectric antenna is configured as a lumped port .To excite or terminate the antenna the reference impedance is assigned to be 50 Ω.

DESIGN AND IMPLEMENTATION

The geometry parameters and the frequencies can be changed to optimize the antenna's coupling performance. [Fig. 2] shows E-field norm distribution on the xy-plane and an arrow plot of the power flow from the transmitting antenna as a function of the receiving antenna rotation angle. When the two antennas are facing each other; the angle of rotation of the receiving antenna is 0 degrees and the fields are strongly coupled. When the angle of rotation of the receiving antenna is 90 degrees, there is no hot coupling area around the receiving antenna that can be visualized. The red arrows describing the power flow are penetrating the receiving antenna without noticeable distortion. [13] The computed input matching characteristic of the transmitting antenna via S11 is below -20 dB regardless of the receiving antenna orientation.[14]

The coupling relation is summarized by approximating S21 in [Table 1] below:

Table 1: Rotation angle –S parameter function

Angle(degrees)	0	22.5	45	67.5	90
S21	-12.5	-13	-15.2	-20.1	-51.6

The positional set up is similar to mobile charging by having a fixed position for a charger and placing a mobile phone on it at different angles . The S parameter S21 value shows no coupling value at 90 degrees. In my simulation, the receiving power antenna is kept rotating and the transmitting power antenna is maintained in a fixed position. Energy coupling is made by setting the orientation is modeled by E-field norm distribution.

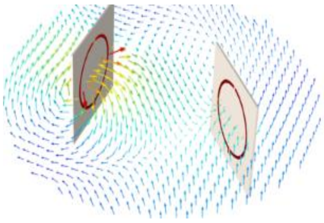

Fig. 3: The arrow plot shows E-Field norm and power flow of wireless power transfer antennas.

To visualize this effect, the E-field norm distribution is modeled and the power flow transfer from the transmitting antenna at different rotation angles of the receiving antenna is viewed. As shown the [Table 2] The results show that when the receiving antenna is adjusted to the angle of rotation to 0 degrees the fields are strongly coupled to each other. As shown in the [Fig.3]. By the time, when the receiving antenna reaches the angle 90 degrees of rotation, the power flow penetrates then receiving antenna has no distortion and no coupling or hot coupling area. As such, we can conclude that the power transfer between these two antennas is greatly reduced at this angle. As shown in the [Fig.4] and [Fig. 5].

Table 2: Design parameters of corrugated circular loop antennas

S_{21} CHARACTERISTICS	DESIGN MEASUREMENTS
Waveguide radius	0.183m
cutoff frequency	4.438Hz
Corrugation thickness	0.105m
Corrugation length	0.155m
Waveguide length	1m
Matching corrugation length	0.25m
Output cross polarization ratio target	5%
Input waveguide cross polarization ratio	17.65%
Output aperture cross polarization ratio	3.025

SIMULATION RESULTS OF WPT IN CIRCULAR LOOP ANTENNAS

The 3D far field pattern and E field normalization of the WPT antennas are simulated using Antenna Magus software tool with the waveguide length and matching corrugation length for energy coupling at 1m and 0.25m respectively.

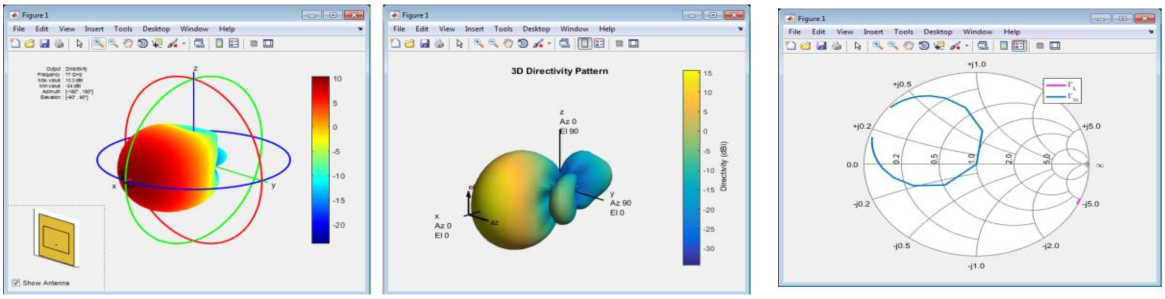

Fig. 4: Far field 3D radiation and directivity pattern for circular loop antenna.

Antenna Magus software Tool-S Parameter comparison

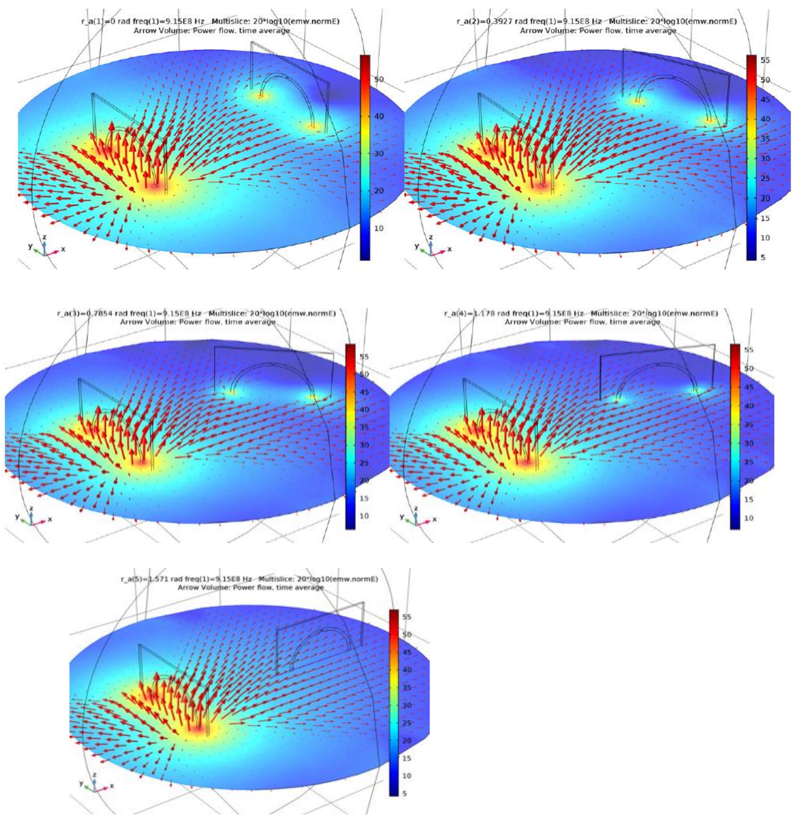

Fig. 5: Plot of E-field norm and power flow at z = 0 while the receiving antenna is rotating from 0 to 90 degrees with a step of 22.5 degrees.

CONCLUSION

This model addresses the concept of wireless power transfer by simulating the energy coupling between two circular loop antennas. The Antenna magus software tool helps to accelerate the antenna design and modeling process. The angles are set at various rotating degrees to identify the energy coupling at exact ranges. The circular antennas are designed to tune for UHF RFID frequency provides inherent inductive coupling by its shape.

The best coupling configuration is examined in terms of S-parameters by adjusting the angle of rotation. The energy coupling is improved by designing the transmitting antenna in fixed state, and a receiving

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antenna to be rotating state. In future, we can increase the operation functionality of Wireless Power Transfer antennas by creating systems that function at a wide range of orientations.

CONFLICT OF INTEREST

There is no conflict of interest.

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FINANCIAL DISCLOSURE

None

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