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Improvement in Efficiency of Wireless Transmission Using Metamaterials

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Abstract- **A wireless power transmission (WPT) is one of the transmissions in modern era which is undergoing with lots of research and has been employed in many applications, including wireless charging of portable electronic devices, electrical vehicles & powering on of implanted bio medical devices. This WPT uses magnetically coupled resonant circuit to transmit the power without using any wiring medium. However, transmission efficiency decreases sharply due to the divergence of magnetic field, especially under coupled regions. Electromagnetic Meta material can manipulate the direction of electromagnetic fields due to its abnormal effective permittivity or permeability. Here in this paper, we are going to show the designing of metamaterial in two different shapes and compare their simulation results [12]. A split ring resonator type meta material is employed to enhance the power transmission. The designing of Metamaterials is done through CST MW studio software and results are obtained and demonstrated.**

Keywords: Metamaterials, split ring resonator(SRR), Wireless power transmission, Square shaped SRR, Circular shaped SRR.

1. INTRODUCTION

We live in a world of technological advancement. New technologies emerge each and every day to make our life simpler. Despite all these, we still rely on the classical and conventional wire system to charge our everyday use low power devices such as mobile phones, digital camera etc. and even mid power devices such as laptops. The conventional wire system creates a mess when it comes to charging several devices simultaneously. It also takes up a lot of electric sockets and not to mention the fact that each device has its own design for the charging port. At this point a question might arise. —What if a single device can be used to charge these devices simultaneously without the use of wires and not creating a mess in the process? We gave it a thought and came up with an idea. The solution to all these dilemma lies with inductive coupling, a simple and effective way of transferring power wirelessly [1][2][3]. Wireless Power Transmission (WPT) is the efficient transmission of electric power from one point to another through vacuum or an atmosphere without the use of wire or any other substance. This can be used for applications where either an instantaneous amount or a continuous delivery of energy is needed, but where conventional wires are unaffordable, inconvenient, expensive, hazardous, unwanted or impossible. The power can be transmitted using Inductive coupling for short range, Resonant Induction for mid-range and Electromagnetic wave power transfer for high range. WPT is a technology that can transport power to locations, which are otherwise not possible or impractical to reach. Charging low power devices and eventually mid power devices by means of inductive coupling could be the next big thing [4][5][6]. The objective of this project is to design a method to transmit wireless electrical power using Meta materials which enhances the efficiency by its property through space and charge a designated low power device. The system will work by using resonant coils to transmit power from an AC line to a resistive load. Investigation of various geometrical and physical form factors evaluated in order to increase coupling between transmitter and receiver by Meta materials.

A success in doing so would eliminate the use of cables in the charging process thus making it simpler and easier to charge a low power device. It would also ensure the safety of the device since it would eliminate the risk of short circuit. The objective also includes the prospect of charging multiple low power devices simultaneously using a single source which would use a single power outlet [7][8][9].

II. MATH

DESIGNING OF FREQUENCY

Square Ring: SRR & CSRR

Microstrip Structure

❖ Average loop lengths:

$$L_1 = 4 \times l_1 \times -S - 4 \times W$$

$$L_2 = 4 \times l_2 \times -S - 4 \times W$$

❖ Resonant frequency for each loop:

$$F_1 = \frac{c}{2 * L1 * \sqrt{Eeff}}$$

$$F_2 = \frac{c}{2 * L2 * \sqrt{Eeff}}$$

Figure 1(a) Design of square ring SRR

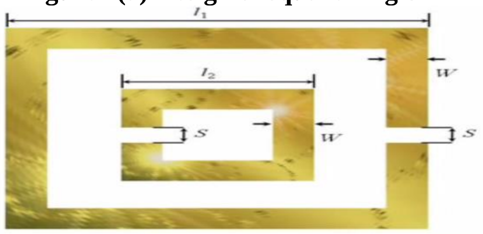

Figure 1(b) Square shaped SRR

Circular Ring: SRR & CSRR

Microstrip Structure

❖ Average loop lengths:

$$L_1 = 2\pi \times r_1 - S$$

$$L_2 = 2\pi \times r_2 - S$$

❖ Resonant frequency for each loop:

$$F_1 = \frac{C}{2*L1*\sqrt{Eeff}}$$

$$F_2 = \frac{C}{2*L2*\sqrt{Eeff}}$$

Figure 2(a) Design of circular shaped SRR

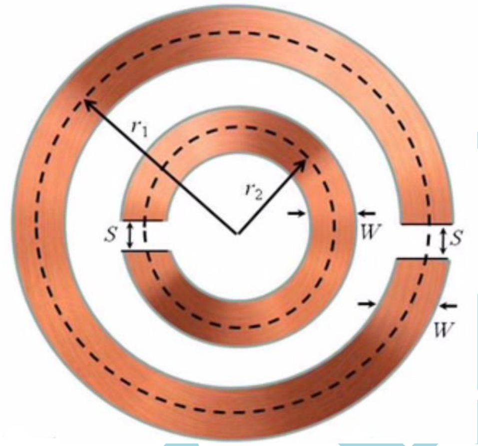

Figure 2(b) Circular shaped SRR

III. DESIGN APPROACH

Figure 1. shows the geometry of basic split ring resonator structure which uses square as its base shape.

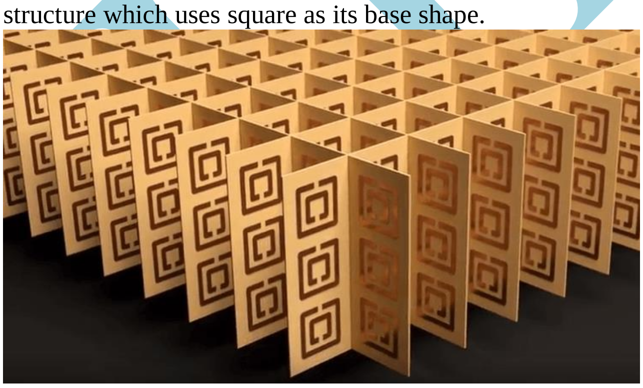

Figure 1 Split ring resonator

Metamaterials are made from assemblies of multiple elements fashioned from composite materials such as metals or plastics. The materials are usually arranged in repeating patterns, at scales that are smaller than the wavelengths of the phenomena they influence. Metamaterials derive their properties not from the properties of the base materials, but from their newly designed structures. Their precise shape, geometry, size, orientation and arrangement gives them their smart properties capable of manipulating electromagnetic waves: by blocking, absorbing, enhancing, or bending waves, to achieve benefits that go beyond what is possible with conventional materials. Appropriately designed metamaterials can affect waves of electromagnetic radiation or sound in a manner not observed in bulk materials. Those that exhibit a negative index of refraction for particular wavelengths have attracted significant research. These materials are known as negative-index metamaterials[1][2][3][4]. Figure 2(a), (b), (c) & (d) shows the shape of Square shaped SRR, Circular shaped SRR and the 2x2 Slabs of Square and circular SRR respectively.

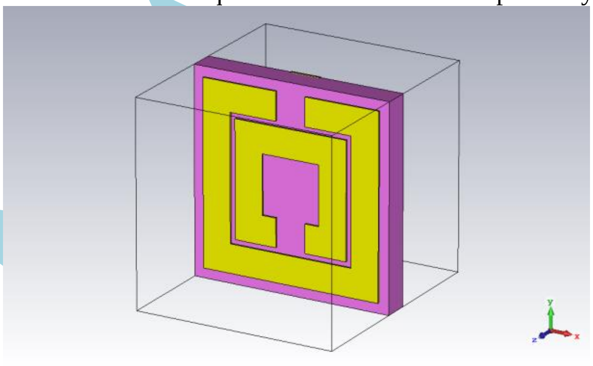

Figure 2(a) Square shaped split ring resonator

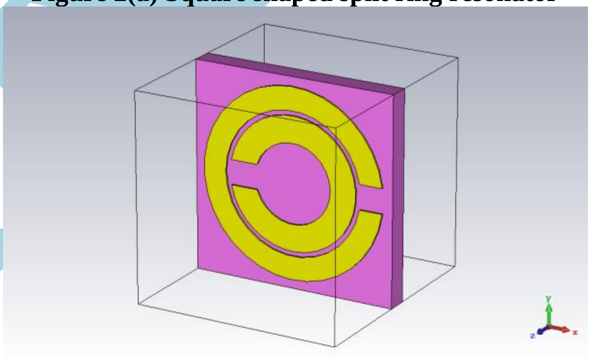

Figure 2(b) Circular shaped split ring resonator

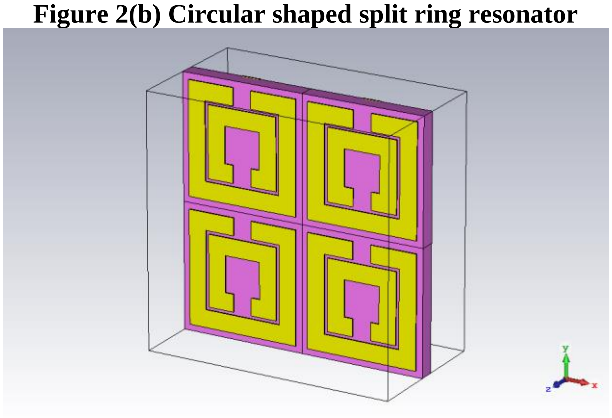

Figure 2(c) Square SRR 2x2 Slab

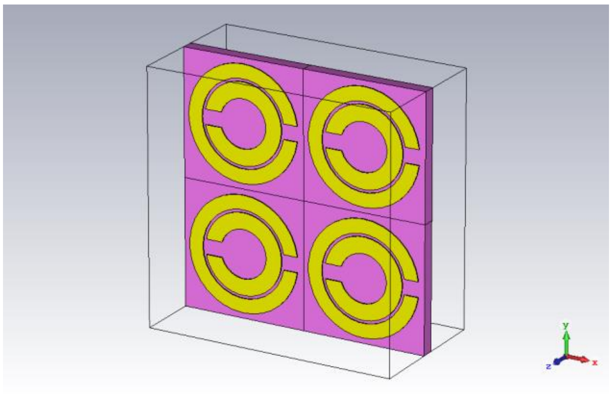

Figure 2(d) Circular SRR 2x2 Slab

As shown in figure 2(a) the Square Shaped Metamaterials are designed such a way that it meets desired LC resonance frequency. The resonant frequency of the outer ring and inner ring were found to be 11.2 GHz and 14.05 GHz theoretically [13] [14] [15]. Figure 2(b) the Circular Shaped Metamaterials are also designed such a way that it meets desired LC resonance frequency. The resonant frequency of the outer ring and inner ring were found to be 11.3 GHz and 17.7 GHz theoretically. Figure (c) & (d) demonstrates the actual 2x2 slabs which will be used in practical case for wireless power transmission [16] [17] [18]. The propagation direction is in the direction of x-axis, where H field is perpendicular to the SRR plane (i.e.) in the direction of x-axis) and the incident E field is perpendicular to the gap containing edges of the SRR rings (i.e., in the direction of y-axis). The PEC type boundary conditions are applied at the boundary surfaces perpendicular to the E-field while the PMC type boundary conditions are applied at the boundary surfaces perpendicular to the H-field. In the above shown design of Square shaped and circular shaped SRR the LC resonance frequency was designed to resonate almost at the same frequency at 11.2 and 11.3 GHz, respectively. Fr-4 substrate was used for base design of Metamaterial having permittivity of 4.4 and copper material was used for microstrip structures [18].

IV. SIMULATION RESULTS

Analysis and Simulation of proposed structure is carried out with the help of Computer Simulation Technology Suite (CST MWS) software. Transmission spectra, and phaser diagrams were obtained which indicates that the proposed structure is a metamaterial and is most suitable for multiband applications. The plots indicate the magnetic properties of Metamaterial in Square shape, circular shape and in 2x2 slabs format. The magnetic dips and rises was found more in slabs compared with single Metamaterial, as it had combination of Metamaterials [18] [19[20] [21] [22].

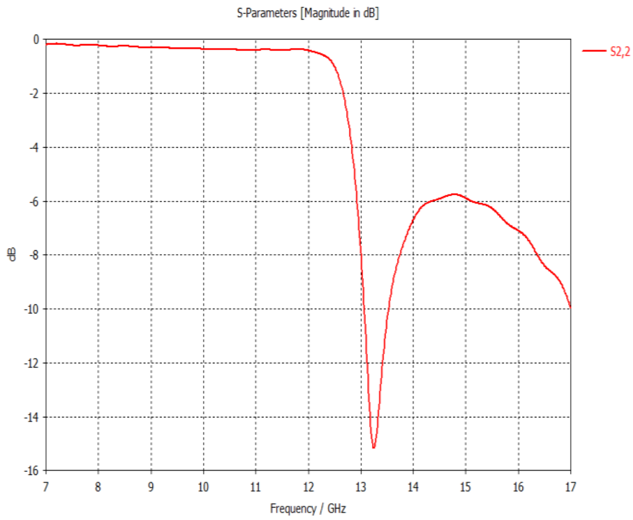

Figure 3(a) Magnetic spectra of Square shaped SRR

As shown in the above figure the magnetic property of Square shaped SRR was found and the curve shows the permeability and the propagation is constant till 12.4GHz and starts decreasing after reaching it and becomes least at 13.2GHz.

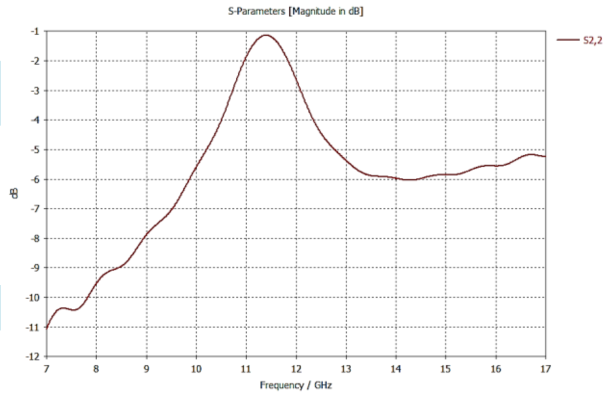

Figure 3(b) Magnetic spectra of Circular shaped SRR

As shown in the above figure the magnetic property of circular shaped SRR was found and the curve shows the permeability and the propagation was linearly increasing till 11.4GHz and starts decreasing after reaching it and becomes least at 13.5GHz.

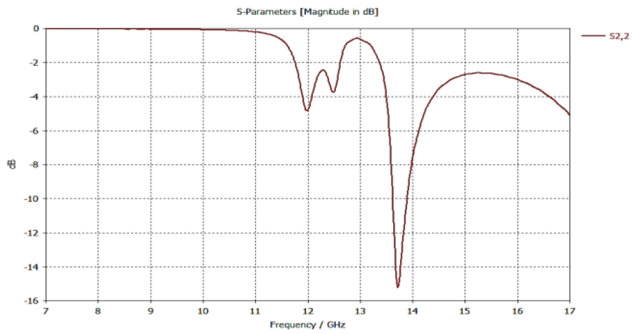

Figure 3(c) Magnetic spectra of 2x2 Slab Square shaped SRR

As shown in the above figure the magnetic property of circular shaped SRR was found and the curve shows the permeability and the propagation was constant till 10.4GHz and starts decreasing after reaching it and becomes least at 12GHz.It had magnetic dips at 12GHz,12.5Ghz and 13.7Ghz and gradually increases from there.

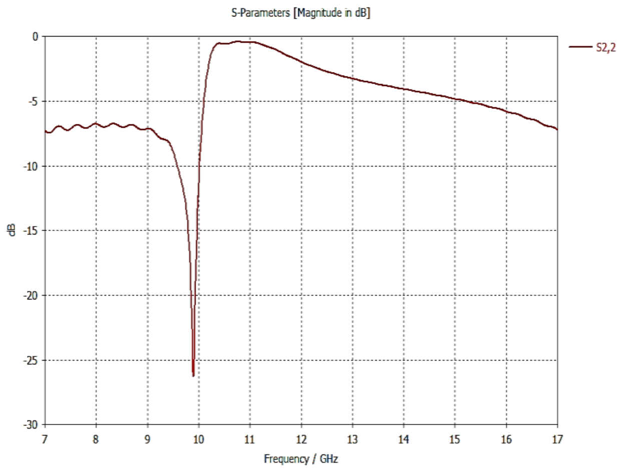

Figure 3(d) Magnetic spectra of 2x2 Slab Circular shaped SRR

As shown in the above figure the magnetic property of circular shaped SRR was found and the curve shows the permeability and the propagation was constantly had magnetic dips till 9GHz and starts decreasing after reaching it and becomes least at 9. 9GHz.It had magnetic dips from starting 1Ghz to 9Ghz and from 9.9Ghz gradually increases from there [18] [22] [23] [24] [25].

V. CONCLUSION

With more devices using short-range wireless power transfer, it has become critical to design systems with high efficiencies. In this paper, a metamaterial with Square shape and circular shape was designed for short-range systems. The metamaterial unit cell was miniaturized deep into the sub-wavelength range and a compact material consisting of these unit cell was constructed. Experiments with a realistic two coil power transfer system showed that efficiency increases were achievable even when the absolute separation between the coils were greater and the metamaterial was placed close to the transmitting or receiving coil. This gives considerable latitude in the design of short-range wireless power transfer systems and allows optimum solutions to be found within the constraints of specific applications [18]. From the above obtained results it was seen that the Square shaped SRR had more effectiveness than Circular shaped SRR. It would be seen that by using a metamaterial slab could potentially alleviate the effects of coil offsets on system efficiency. Thus, using a compact metamaterial slab is a viable solution to increase the efficiency of a wireless power transfer system and can be helpful in applications like wireless charging and powering implantable biomedical devices.

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