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Design of Multiband Rectenna with Enhanced Band Width Using DGS

[I]Mahendra Pal Verma, [II]P.K. Singhal
[I,II]Dept. of Electronics Engineering, Madhav Institute of Technology and Science, Gwalior, M.P., India

Abstract

The wireless power is an alternative to replace wiring and batteries in certain new scenarios and environments and we can also get rid of harmful effects of batteries on environment. We present an idea discussed here, how energy can be transmitted as microwaves, so as to reduce the transmission and allocation losses, known as Microwave Power transmission (MPT). Wireless power technology offer the assurance of cutting the last cord, allowing users to faultlessly recharge various devices as simply as data is transmitted through the air. In this paper we have mainly focused on increasing the bandwidth of rectenna by using defected ground structure. For this purpose in place of simple RMPA we have used C- slot RMPA with DGS. Proposed rectenna is a combination of c-slot RMPA antenna, followed by 3rd order stepped impedance Low Pass Filter and rectifier essential for high microwave power - DC power (RF-DC) conversion efficiency

Keywords

MPT, RMPA, DGS, rectenna, rectifier circuit.

I. Introduction

In future, the technology of wireless will be extending up to the ability to transport the energy wirelessly. Nowadays, there are reported some effort to harvest clean and infinite energy from space, known as space solar power station, and transmit it wirelessly using microwave wireless power transmission technology to the earth station. The process of wireless power transmission is divided into three main step[1]: i) the electrical power is converted to RF power, ii) then the RF power is transmitted through free space to some distant point, and iii) the RF power is collected and converted back into electrical power at the receiving point. The overall efficiency of the system depends on the efficiency of each component; the signal conversion dc-to-rf, transmission wirelessly, the signal conversion rf-to-dc. Studies have shown that, the aspects of component development for signal conversion process especially at the receiver has been emphasized to achieve high efficiency. The most important component in receiver is rectenna, i.e. the rectifying circuit integrated with an antenna. The process of signal conversion from RF-to-DC signal is done by rectenna. Radio Frequency (RF) signal is received by the antenna and the rectifier converts it to direct current (DC) signal. In rectifier circuit, diode is used to rectify the rf-to-dc signal. Diode is a nonlinear device and this characteristic generates the radiation power at the harmonics frequencies. These unwanted harmonics is added together with the desired signal in the signal conversion process causing a degradation of output, hence the efficiency of rectenna is reduced. Consequently, the efficiency of the system is also decreased. Harmonic filter circuit can be used to attenuate these unwanted harmonics power.

The technology of wireless microwave energy harvesting is become popular very rapidly. Over hundred years ago, Nikola Tesla proposed and demonstrated the concept of wireless power transmission [2]. In 1964, a microwave-powered helicopter prototype was successfully demonstrated by W. C. Brown and his team. Four years later, P. E. Glaser proposed the concept of solar power satellite system (SPSS) [3], and the first experimental microwave power transmission in space was carried out by Hiroshi Matsumoto's team in 1983 [4]. In recent years, the research based on the technology of empowering very small devices like biomedical implant devices, wireless sensor nodes, storing the energy in rechargeable micro-batteries and super-capacitors by ambient RF energy recycling attracts the interests of engineers. Wireless energy harvesting is necessary for biomedical implants or wireless senor nodes because recharging or replacing the batteries of these very tiny devices is nonfeasible [6]. In most cases, to energize these devices, the best choice is energy recycling or harvesting from RF waves because the environment is full of radio energy. The sources of microwave signals are mainly the UHF band (885 to 915 MHz) mobile communication systems (GSM).

A. Global Form

Whatever the level of power that will be converted by the structures, the rectenna circuits generally have the same global form which is presented on fig. 1. As presented, a rectenna circuit is composed of an antenna, which transforms radiated RF energy into conducted energy, and a conversion circuit, which converts RF voltage to exploitable DC voltage. Patch antenna is usually used for applications that need a high gain antenna, after RMPA we have used HF LPF, matching circuit diode, smoothing capacitor and load is at last stage. Circular antenna is used for applications that need directional flexibility of RF source. HF and DC filters are designed to confine harmonic disturbances into the converter, and also to do optimal matching impedance between the antenna and the other part of the circuit. Indeed, for maximum power transfer, the antenna impedance would match the optimal circuit impedance [2].

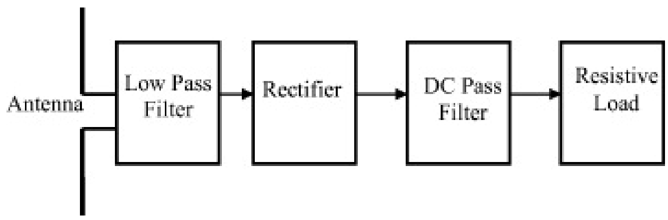

Fig.1: Basic Rectenna block diagram

II. Designing And Fabrication Process Of Rectenna

For designing purpose CST Microwave Studio 2010 Software is used. The constants that we had used for the entire design and fabrication process are Dielectric constant=4.4 Substrate thickness=1.6mm

In the designing and fabrication process of rectenna first we designed the RMPA (Rectangular Microstrip Patch Antenna) at 2.45 GHz. As shown in Fig.

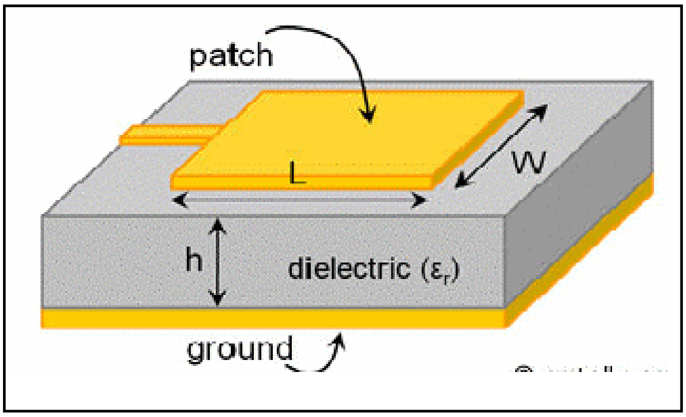

Fig. 2 : Rectangular patch

The formulae that we used to calculate the length and width of patch are[5]

$$W = \frac{v_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

$$L = \frac{v_0}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L \qquad (2)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\sqrt{\left[1+12\frac{h}{w}\right]} \qquad (3)$$

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(^{w}/_{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(^{w}/_{h}+0.8\right)} \qquad (4)$$

Length = 72 mm
Width = 92 mm
The dimensions of C slot are as given in table below

Table 1 : Dimensions of C Slot

S.No	Parameters	Dimensions(mm)
1.	a	55.5
2.	b	30
3.	c	52.5

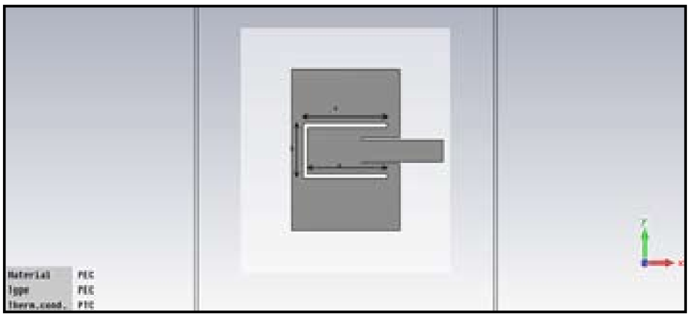

Fig. 3: RMPA With C Slot.

Table 2. Dimensions of Filter

S. No.	Parameter	Matching Section	Inductor section	Capacitor section
1.	Characteristics impedence	Z0 = 50Ω	Z0L = 93Ω	Z0C = 24Ω
2.	Effective Dielectric Constant	εreffZ = 3.332485	εreffL= 2.983417	εreffC= 3.640488
3.	Width of Microstrip Line	WZ= 2.99438 mm	WL= 0.847290 mm	WC= 8.708496 mm
4.	Length of Microstrip Line	Zl= 16.76914 mm	lL= 6.633275 mm	lC= 5.95740 mm
5.	Wavelength	λo = 67.7215 mm	λL= 17.72303 mm	λC= 64.1764 mm

In next step LPF is designed.[6][7] now both RMPA and LPF are combined together now diode is placed in front of LPF after diode we had placed the matched termination line of λ/2, in this matched termination line we implement DC pass filter and load. The Fig. 5 below shows the design of rectenna in CST software ready for simulation, Fig. 6 shows the fabricated view of rectenna

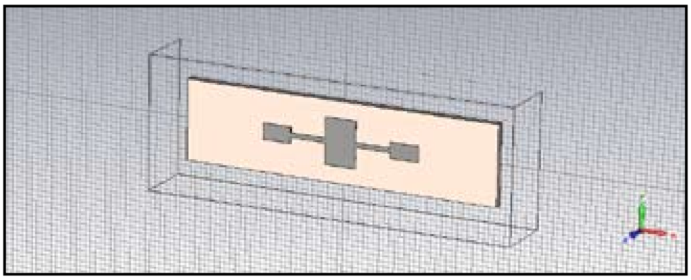

Fig. 4: Geometry of Filter

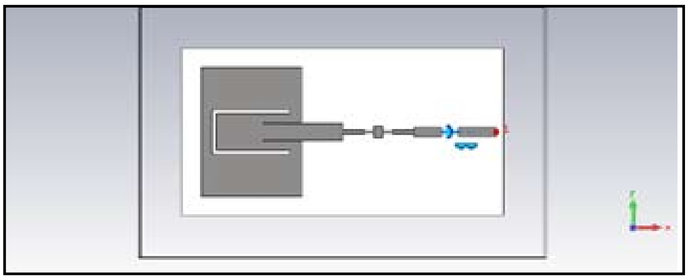

Fig 5 : Front view of Rectenna Geometry.

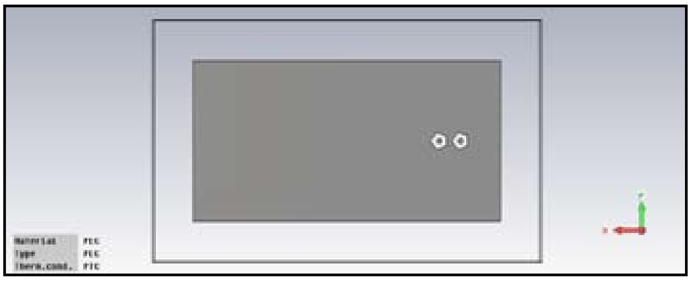

Fig. 6 : Back view of Rectenna Geometry.

III. Results

The Fig7. shows the radiation efficiency of RMPA which is -1.913 dB, the Fig8, Fig 9 shows the simulated result of Rectenna without DGS and with DGS respectively on CST software. It shows -24.29 dB at 0.685 GHz, -37.006 dB at 0.875 GHz, -17.001dB at 1 Ghz, -17.316 dB at 1.4 Ghz and 27.319 dB at 2.78 Ghz. Which is a quite improved result for rectenna using RMPA without DGS. Fig. 10 shows the comparision of returnloass of rectenna with and without DGS. Fig.11 shows radiaton pattern 3D plot and efficiency, which is improved to 63.44 % . Fig. 12 shows the polar plot. Fig. 13 and Fig. shows the front and back view of fabricated Rectenna respectively. Fig. 15 shows the measured and simulated results. Fig. 16 shows the comarision of efficiencies of rectenna(S1-efficiency with DGS, S2- efficiency without DGS).

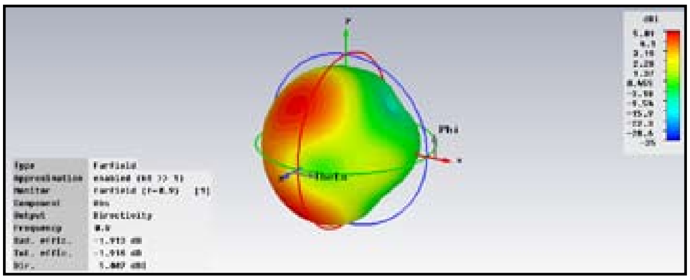

Fig. 7 : Radiation pattern of RMPA

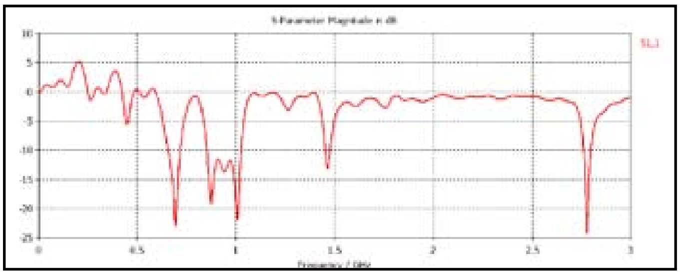

Fig. 8 : Simulated result without DGS

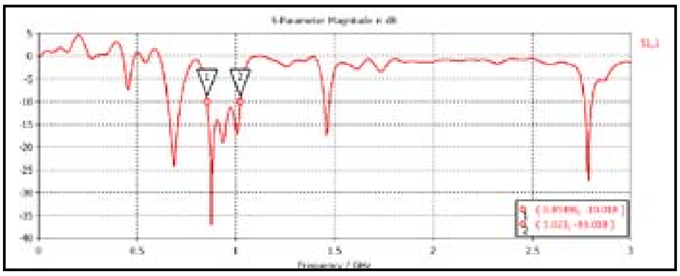

Fig 9. Simulated result with DGS

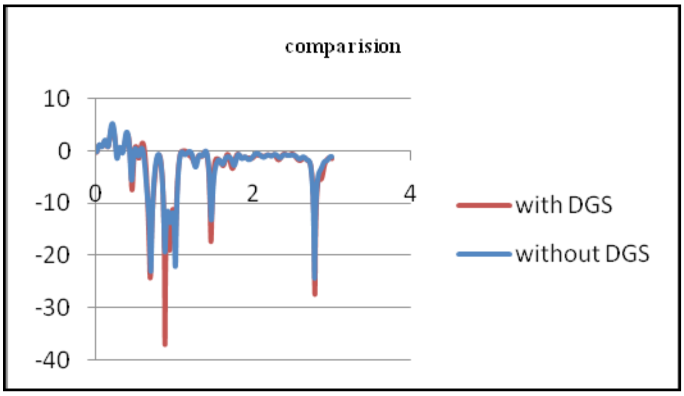

Fig. 10: comparision of simulated resulta with and without DGS

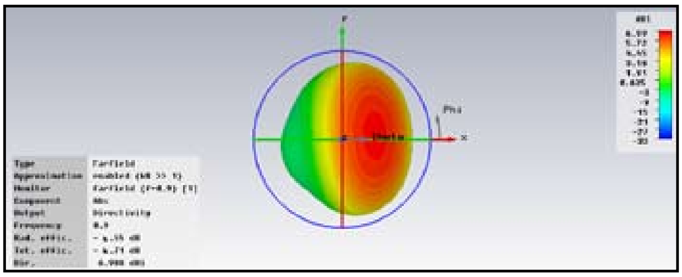

Fig 11 : Radiation pattern of Rectenna

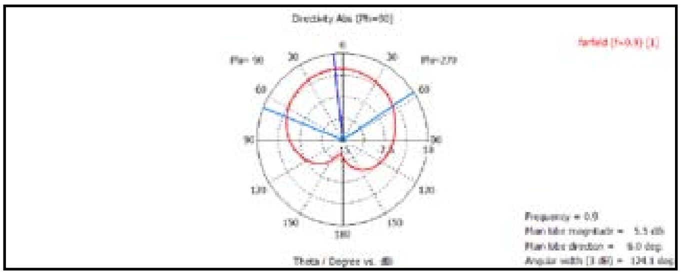

Fig. 12 : Polar plot of Rectenna

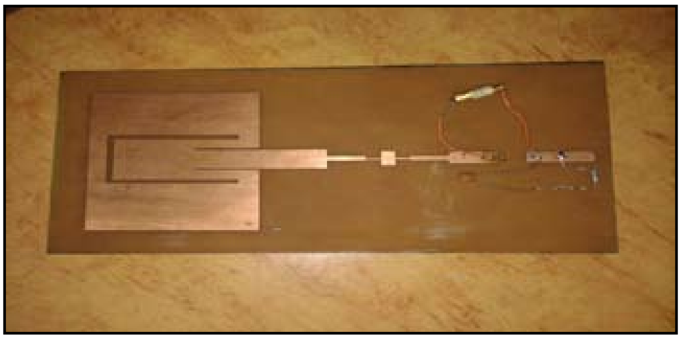

Fig. 13 : Front view of fabricated Rectenna.

Fig. 14 : Back view of fabricated Rectenna

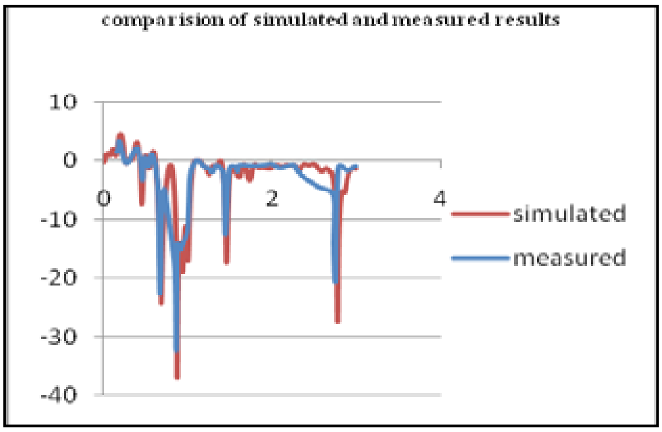

Fig. 15: comparision of simulated and measured results.

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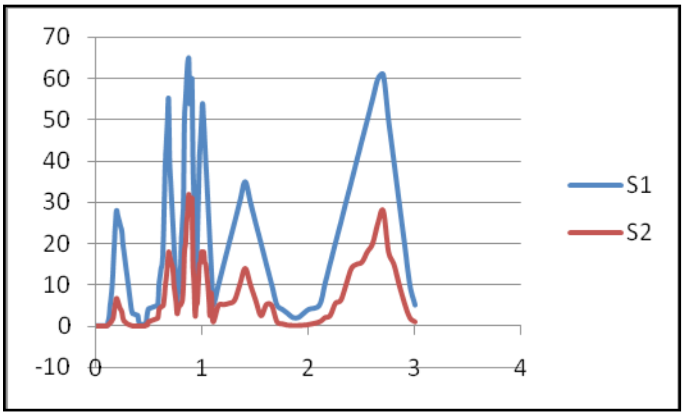

Fig. 16: Comparision of efficiency of Rectenna With and without DGS

IV. Applications

Generating power by placing satellites with giant solar arrays in Geosynchronous Earth Orbit and transmitting the power as microwaves to the earth known as Solar Power Satellites (SPS) is the largest application of WPT. Another application of WPT is moving targets such as fuel free airplanes, fuel free electric vehicles, moving robots and fuel free rockets. The other applications of WPT are Ubiquitous Power Source (or) Wireless Power Source, Wireless sensors and RF Power Adaptive Rectifying Circuits. It can also be used for GSM mobile.

V. Conclusion

The concepts of Microwave Power transmission, Wireless Power Transmission (WPT) history and basic implementation of Power System is discussed elaborately . Technological developments in Wireless Power Transmission (WPT), the merits, demerits, applications of WPT are also discussed in this paper. By this we are able to know the greater possibilities for transmitting power with negligible losses and ease of transmission in the years to come. It is envisaged that wireless energy would be really accomplished with a advantage of easy implementation and cost effective i.e., cost of transmission and distribution overhead would become less and moreover It is important that the cost of electrical energy to the consumer would also be reduced compared to existing systems. Efficiency can be further increased using array of rectenna to receive energy. Since power obtained from single rectenna element is less, the output can be enhanced by using Charge pump technique. This technique collects the power and stores in super capacitor. Capacitor starts charging with the power from rectenna. Once the desired threshold is reached, the energy is used to drive small motor of toy car, LED or sensors of different kind.

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