A SMART RF HARVESTING ENERGY ABSORBER APPLIED FOR LOW ELECTRICAL POWER CHARGING UNIT

Nurfitri[1], Elyas Palantei[2], and Intan Sari Areni[3]
[1, 2, 3] Department of Electrical Engineering, Faculty of Engineering, Universitas Hasanuddin, Bontomarannu, Gowa, South Sulawesi Province, Indonesia

Abstract - The high potential of various harvesting energy such as light/solar energy, heat energy, RF energy, pressure energy and mechanical vibration energy to be optimally extracted into electrical power has been considered as one best option to provide the sufficient low power charging for large varieties of electronic appliances and IoT devices. Those type of energy are available everywhere in the vicinity and of large amount quantity existed. This paper presents the numerical computation and optimization of a typical smart printed RF antenna to absorb the transmitted microwave energy from the particular vicinity places. The printed Yagi-Uda antenna structure was theoretically designed in such manner using the complementary split ring resonator (CSRR) metamaterial structure. It was examined to properly operate at around 2.4 GHz band applications. The YagiUda absorber patch structure was constructed on top of both dielectric and grounding materials of 40 mm x 90 mm x 1.6 mm physical dimension. In practice, the printed Yagi-Uda has very unique structure where the center rectangular active element placed in between two wings consisted of three parallel rectangular small patches and connected each other using RF-PIN diode. Using CST microwave studio software, each patch element of each wing could be manually set-up to operate in two conditions ON and OFF, respectively. These resemble whether the patch is connected or unconnected one to another. In the practical implementation, the electronically steering of RF-PIN diodes status will be performed by a certain controller unit placed beneath the ground plane. The main purpose of the patch steering technique is to allow the absorber device to flexibly searching the maximum RF power from the two main possible directions, arbitrarily. Various numbers of excellent numerical computing results to justify the potential properties of the smart RF-harvesting energy absorber, while it is successfully manufactured, are described in this paper. These include the matching impedance, gain and the resonance frequency variations as the impact of RF-PIN diode status alterations.

1. INTRODUCTION

Independent energy is an important factor for this smart technology, one of the popular method is energy harvesting or ambience energy absorbing. Battery is often used as energy source for wireless applications, especially IoT device. However, this is constrained by its limited size and usage period. In this case, we need energy backup and or battery replacement. For this purpose, a device that can harvest energy is needed. The types of energy sources that are very potential to be carried out are solar light / heat, thermal energy, electromagnetic waves, vibrations, pressures that can be optimized become electrical energy for small power requirement in electronic applications and IoT devices [1]. Those type of energy are available everywhere in the vicinity and of large amount quantity existed.

In recent years, studies of energy harvesting using electromagnetic waves have already been investigated [2,3,4]. These are applied to the IoT system, a small energy harvester antenna with a high gain and wideband is required which is made from of the rectangular microstrip patch antenna (RMPA) and metamaterials methods. Metamaterial is an artificial structure that cannot be found in nature but can be fabricated from existing materials. This material has negative permittivity and permeability values. Nowdays, one of the most popular metamaterials is the complementary split ring resonator (CSRR). By placing the CSRR structure on this patch antenna, the antenna performance is better than conventional antennas. The advantages of energy harvesting antenna are size reduced, return loss decreased, gain and frequency bandwidth increased, and multiband resonant frequency as well [5,6,7].

In this paper, numerical computation and optimization of the RMPA smart antenna can harvest the energy of electromagnetic waves in the vicinity. The RMPA have been modified into a printed Yagi-Uda antenna by placing the CSRR metamaterial structure on the ground side. In this section, an antenna patch optimization and the CSRR metamaterial sructure optimization have been done so that antenna works in 2.4 GHz frequency. Antenna design uses a dielectric FR-4 substrate which dielectric constant is 4.5, a tangent loss is 0.02 and dimensions are 40 mm x 90 mm x 1.6 mm. In the centre, an active rectangular patch element with a coaxial feed enclosed by three wings parallel rectangular small patches and connected each other to RF-PIN diode. RF-PIN Diode is used to allow the absorber device to flexibly searching the maximum RF power from the two main possible directions, arbitrarily. Antennas with this method are commonly called reconfigurable antennas [8]. Simulations have been conducted using CST Microwave Studio 2018 software. In this study, return loss parameters, voltage standing wave ratio (VSWR), gain, resonant frequency, impedance and antenna size for this reconfigurable design have been investigated.

2. ANTENNA DESIGN

The antenna is designed using a dielectric FR-4 Substrate. The thickness of FR-4 is 1.6 mm. The dimension of antenna are 50 mm x 120 mm x 1.6 mm and a coax feed impedance is 50 Ω. Calculating the dimensions of the antenna using the equation below [9].

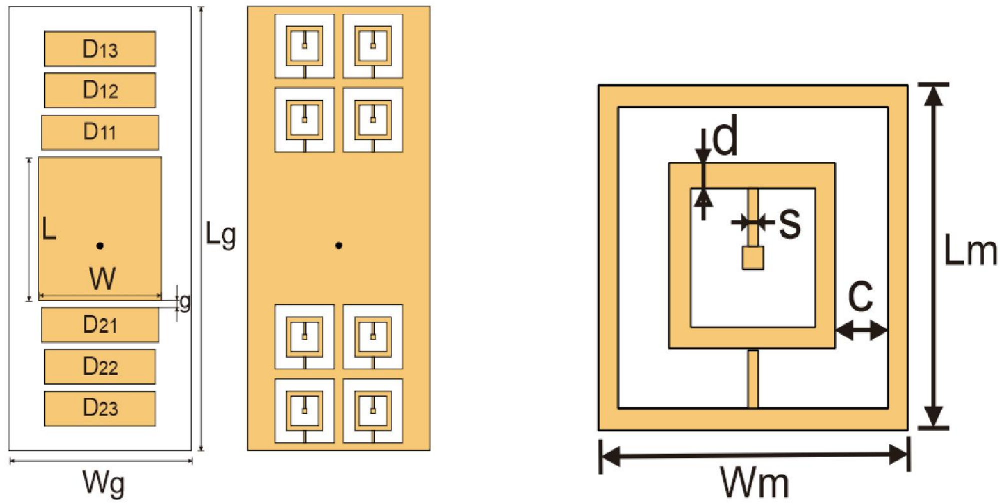
Optimized rectangular patch is placed in the centre as the active element of the antenna design that works at 2.4 GHz frequency. For two wings with each of the three small patches consisting of D_{11}, D_{12}, D_{13}, D_{21}, D_{22} and D_{23} as shown in Fig. 1. The space for each patch element, g is $0.1\lambda_g$ where:

$$\lambda_g = \frac{\lambda}{\varepsilon_{eff}} \tag{10}$$

The widths of D_{11} and D_{21} it is 5% of the patch width of W. Then, the widths of D_{12}, D_{13}, D_{22} and D_{23} of 10% of the patch width of W. Furthermore, the length of all wing elements is ¼ of the total patch width of W [10]. The feeding method for this antenna is a coaxial probe because it is easy to manufacture and can be placed on any patch. The antenna dimensions that have been optimized are W = 27.8 mm, L = 28 mm, g = 5.5 mm, L_g = 150 mm, and W_g = 50 mm.

3. THE PROPOSED ANTENNA AND METAMATERIAL STRUCTURE

In this section, the proposed antenna geometry is same as the feeding structure and impedance of the conventional antenna design. The CSRR metamaterial geometry is optimized and placed on the side of the ground plane to work at 2.4 GHz. The dimensions of CSRR unit cells L_m and W_m = 15 mm, c = 2.5 mm, d = 1 mm and s = 0.5 mm shown in Fig. 1(b).



(a) (b)

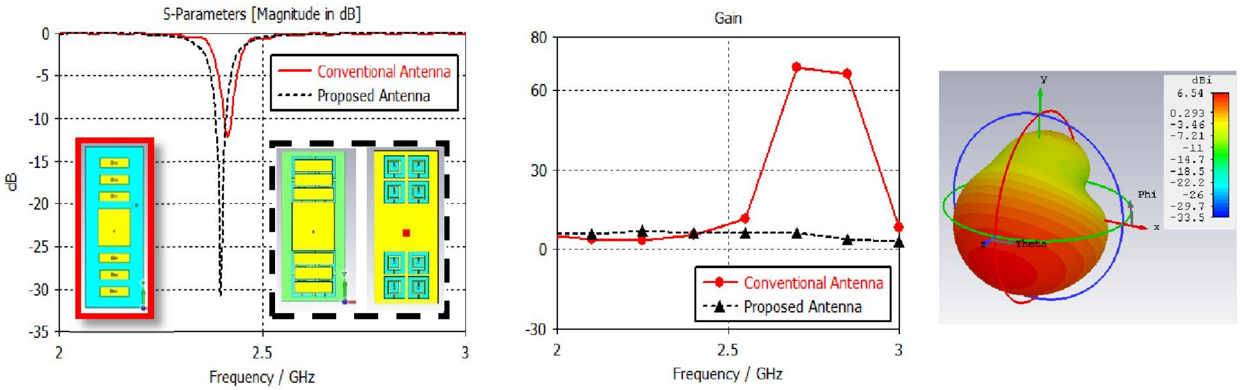
Figure 1. Proposed Antenna (a) Dimension of Antenna and (b) Dimension of CSRR

The bandwidth of the CSRR unit cell can be increased size of c. The proposed antenna design can be seen in Fig. 1(a). The number of CSRR cell units on the ground plane side is 8 unit cells. The position of the unit cell is at the wide side of the active patch element so that the antenna operating frequency is 2.4 GHz.

4. RESULT AND DISCUSSIONS

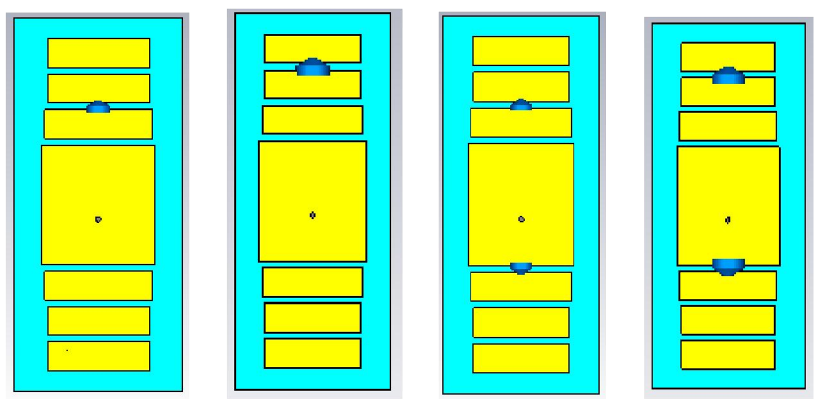
Simulation results show antenna dimension optimization has been done both for conventional antenna and proposed antenna. The proposed antenna has dimensions W = 27 mm, L = 29 mm, g = 1.5 mm, W_g = 40 mm and L_g = 90 mm. The length and width dimensions of each wing patch correspond to the percentage of the size of the conventional antenna.

The proposed antenna design can been seen in Fig. 1(a) which the space between elements is designed to be smaller so that the PIN diode plecement when fabrication process is easier. The simulation results show return loss is decreasing into -23.9 dB and the gain increasing from 5.75 to 6.15 compared to conventional antenna (see Fig. 2(a) and 4(b)). In addition, antenna size is 52% smaller than conventional antenna size. The maximum performance of the tested parameters achieve by placing 8 CSRR cell units on the ground. To find the maximum RF power output from two possible directions of the antenna, an antenna is reconfigurable by connecting one patch element to another patch in ON and OFF state using RF-PIN Diode. Placement of this PIN Diode on the antenna patch element can be seen in Fig. 5 and the parameter results obtained in Table 1.



(a) (b) (c)

Figure 2. Proposed antenna performance (a) S-Parameter Compared, (b) Gain Compared dan (c) Radiation Pattern 2.4 GHz



(a) (b) (c) (d)

Figure 3. The position of PIN diode in patch antenna

Table 1. Reconfigurable antenna perfomance

Figure	**(a)**	**(b)**	**(c)**	**(d)**
Frequency	2.39 GHz	2.4	2.36	2.37
Return Loss	-46.07 dB	-19.99 dB	-26.12 dB	-16.12 dB
Gain	4.49	5.48	6.03	5.7

5. CONCLUSION

Numerical computation and design optimization of smart microstrip antennas to absorb the energy of electromagnetic waves in the vicinity has been done. The modification of the RMPA into the Yagi-Uda antenna structure was designed by placing several CSRR metamaterial unit cells on the antenna ground plane. The number and position of CSRR metamaterial structures affect the retutn loss, gain, and frequency of the antenna design so that these metamaterial structures can be modified as needed. In this paper, the CSRR metamaterial is optimized so that it works at the same frequency as the proposed antenna. Moreover, antennas has been reconfigurabling to maximally absorb electromagnetic waves from two directions by connecting RF-PIN diodes to patches in ON or OFF state. The proposed antenna can reduce the size of 52% smaller than conventional antenna which it is dimension 40 mm x 90 mm x 1.6 mm and operating 2.4 GHz band frequency applications.

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