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Research paper

Development of High Gain Circularly Polarized Antenna Array for RF Renewable Energy

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Abstract

RF energy has become very attractive in the engineering and scientist field for green substainbility. A novel high gain circularly polarize antenna array for RF renewable energy is presented in this paper. The antenna structure was investigated using full wave electromagnetic field analysis. Finally, the entire structure of the antenna array was fabricated and measured. A comparison between simulated and measured results has been observed. The results show that high gain 5.0dBi at 956MHz had been achieved for circularly polarize antenna array and the works concludes that the investigation of high gain antenna system was successful and it can use as an alternatif sources for renewable green energy. The antenna structure that presented is also an important part of the IoT and 5G development.

1. Introduction

There are many different types of renewable energy sources like temperature gradient, solar energy, vibration energy and wind energy (Sravanthi and Conrad, 2008). The temperature gradient will harvest through the heat transfer. Thermal generator such as TEGs was following the principle of thermoelectricity to generate electric energy (Stecanella et al., 2015). Solar energy can be harvested from outdoor due to nature of sunlight. The disadvantages of solar energy are effectively of location and weather condition. The vibration energy is harvested by using piezoelectric material to convert the energy either from pressure or vibration (Henry et al., 2005). All this energy is free and can be converted into DC power. Radio frequency is one of the free energy that broadcast for 24 hours from anyway. Radio frequency signals are considered as an electromagnetic wave that has the same radiation as ultraviolet and light source. As a result, antenna polarization is one of the important key points in design an antenna for renewable energy harvesting. The polarization of an antenna is divided into 3 types which is horizontal, vertical and circular. Antennas typically use to transmit the electromagnetic and radiate it to the space by input the radio frequency electric current. The vertical polarization antenna only can effectively receive and transmit the incoming signal on vertically polarized plane and vice versa(Ullah et al., 2017). If the antenna polarization does not match with the incoming signal polarization, there will be a huge signal loss(Chandak, 2012). Whereas, for the circular polarization antenna, it transmit and receiving the signal in circular spiral pattern. The pattern is included the vertical or horizontal orientation and all the planes between them. Thus, it will always match the incoming signal. In this way, the research is aim to implement the spiral antenna array that can harvest more RF energy from different sources and different directions as in Table 1 below. Due to that, the collecting RF signal will be increasing and the energy and subsequently convert it into useful DC power. By this way, the battery can be eliminated because deposition of battery will cause environmental issue.

Table 1: Available Frequency Bands for Energy Harvesting (Ali et al., 2013)

Standard	Frequency Band	Band of Interest
DTV	470-862 MHz	470-862 MHz
Global System for Mobile (GSM)	900,1800 MHz	925-960 MHz/1.805 MHz-1.879.8 MHz
Universal Mobile Telecommunications System (UMTS)	2.1 GHz	2.11GHz-2.17 GHz
Wi-Fi, Bluetooth	2.4 GHz	2.4 GHz
Tolling System, New Wi-Fi	5 GHz	GHz

2. Antenna Configurations

The key characteristics of an ideal antenna when considering for the implementation of RF energy harvesting including small physical size of antenna, lighter weight, a feeding point that can easily attach to the antenna along with the rest of the harvesting circuit and inexpensive to manufacture. Due to that, fabrication of the antenna on printed circuit board will be the main selection and are growing popularity compared to traditional loop wire or helical antenna. This is because the printed antenna can be easily used in standard electronic consumer devices like wireless applications. A proposed circular polarize antenna array is designed at frequency 956MHz as illustrated in Fig.1. Fig.2 shows the proposed two arm circular polarized antenna array.

The amount of magnetic energy storage is represented by an inductance (Yue et al., 1996), L given in as below (Yechuri, 2003).

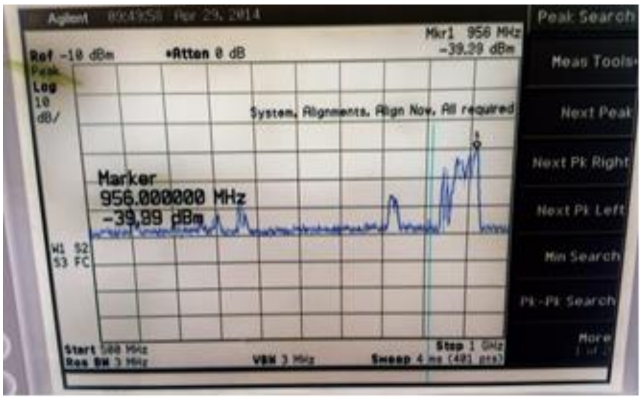

Figure 1: Proposed frequency at 956MHz

$$L = 0.03937\frac{a^2n^2}{8a+11c}\times K_g \quad (1)$$

where a is

$$a = \frac{D_o + D_i}{4} \quad (2)$$

$$c = \frac{D_o - D_i}{2} \quad (3)$$

$$D_o = D_i + 2Nw + 2(N-1)s \quad (4)$$

$$K_g = 0.57 - 0.145\ln\frac{w}{h}, \frac{w}{h} \rangle 0.05 \quad (5)$$

The diameter D_0 and D_i of the inductor (Kavimandan, 2008) is stated by Eq. (3). Equation (4) describes the relationship between the outer, and the inner diameters with respect to the numbers of turn (N), conductor width (w) and their spacing (s). Also, K_g is the presence of a ground plane. Finally, the resonant frequency of the antenna array was determined using the popular equation stated in Eq. (6) (Hau-Yiu and Lau, 2005).

$$F = \frac{1}{2\pi\sqrt{LC}} \quad (6)$$

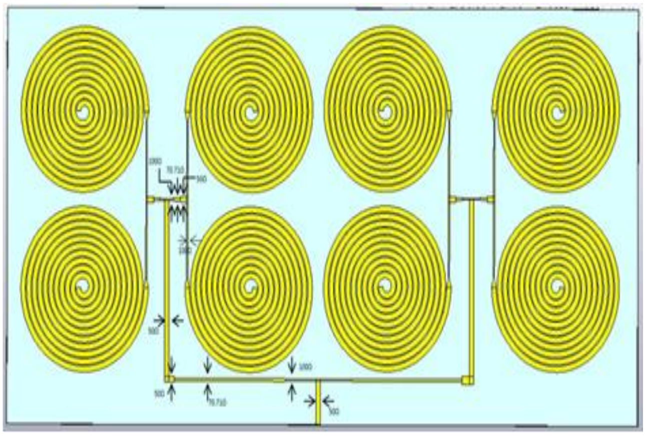

Figure 2: *Antenna array*

From the antenna array, it can be shown that the entire antenna array is connecting together by 50 ohm transmission feed lines (Barinov and Zhgoon, 2001). The development of the array consists of 2 rows and 4 columns with reactive power divider network which is feed into each spiral element. As a result, the direction X and Y is used to calculate the array factor as in Eq. (7) below(Bahl, 2003) .

$$AF = \frac{1}{nm}\frac{\sin\left[m\left(k_o s_x \sin\theta\cos\theta\right)/2\right)\right]}{\sin\left[\left(k_o s_x \sin\theta\cos\theta\right)/2\right)\right]}\frac{\sin\left[m\left(k_o s_x \sin\theta\cos\theta\right)/2\right)\right]}{\sin\left[\left(k_o s_x \sin\theta\cos\theta\right)/2\right)\right]} \quad (7)$$

Therefore, the designs were modelled using the transient analysis method in Computer Simulated Technology (CST) software so as to better characterize them. The arrangement of the antenna array can affect various type of performance such as operating frequency; gains of antenna, input value of microstrip feed line, returns loss or other related parameters (Woldeamanuel, 2013). Besides that, the performance of the circular spiral antenna itself also affect by factors such as average diameter of single element spiral, microstrip feed line mechanism or conductor width (Sharma and Gupta, 2014).

3. Results and Discussions

The resulting designs were then fabricated on laminate Roger Duroid RO4003C microwave board of size 27.3 x 13.5 sq. mm, with a thickness of 0.813mm, loss tangent of 0.0027, and ground thickness of 35μm is excited by the microstrip line. The dielectric constant (ε_r) value of 3.38 (Ain et al., 2013) is consider in the range between $2.2 \leq \varepsilon_r \leq 12$ (Huque et al., 2011). This is because when the dielectric constant is lower, it will produce large bandwidth and results in better efficiency.

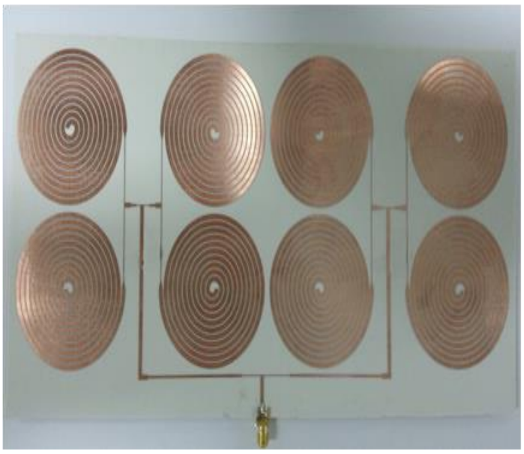

Figure 3: Fabricated antenna array

Fig. 4 below show that the return loss for the 4x2 circular spiral antenna array between simulated and measured resutls. The simulation frequency range is perform from 900MHz to 1GHz. From the obervation, the measurement of the return loss was -18.68dBi at 960MHz and the bandwidth is 3.5MHz. The obtained simulation for the return loss was -16.77dBi with a total bandwidth of 13MHz. The return loss managed to achieved lower than -10dB.

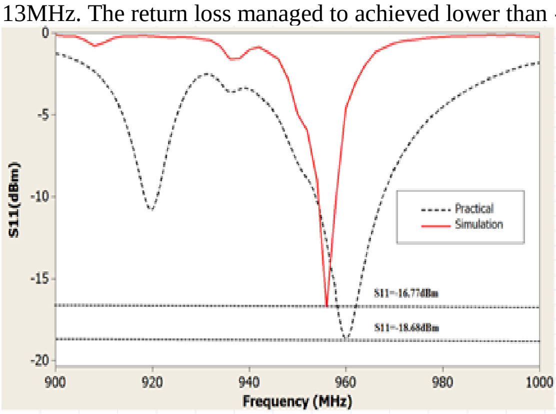

Figure 4: Return loss of antenna array

The pratical measurement were carried out by using N5245A network analyzer. Based on the observation, although there is some of the mismatch around 0.42% between the simulated and measured return loss of spiral antenna due to the surafce of microstrip line is not attached fully by the feeding ports of the connector, but overall performance had achieved relatively good agreement between them. The frequency range of the observed antenna esily cover the GSM band of the cellular system**.**

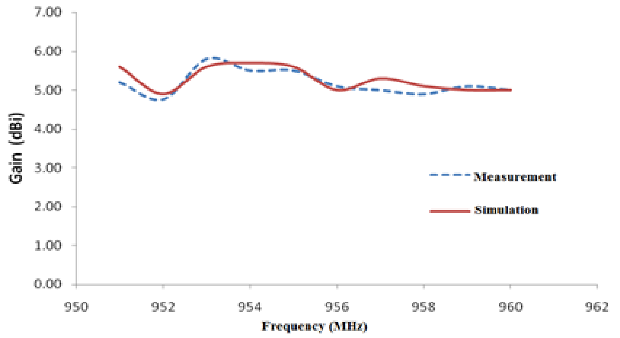

Figure 5: Gain of the antenna array

Base on the Fig. 5 above, the observation of the frequency range is from 951 MHz to 960 MHz. When the array plane was at Φ=0° direction, the gain was considered. The direction of the highest beam is at the direction located at the center frequency. The maximum measured gain obtained was 5.10dBi of 956MHz and the simulated gain obtained was 5.0dBi of frequency 956MHz. It is found that the results there is slightly loss between simulated and measured.

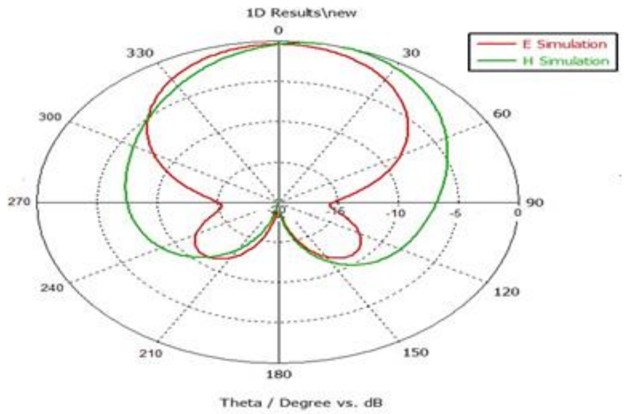

Figure 6: Radiation pattern of antenna array

Measurement units, numbers The characteristic of radiation pattern is investigated at 956MHz as shown in Fig.6 above. The patterns is radiated with towards one direction and having major main lobe shape.

4.Conclusion

To harvest the RF renewable energy, a high gain antenna with circularly polarized antenna array has been proposed and investigated. The entire structure was investigated using Computer Simulated Technology (CST). It is observes that the gain of the antenna demonstrated good correlation between the simulated and measured results. Due to ease of fabrication and simple structure of the antenna the antenna array will have good potential for further miniaturization. Thus, the high gain antenna also can be use as battery free for wireless sensor network that will also help in green sustainability.

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