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Research paper

Circularly polarize antenna array for electromagnetic energy harvesting

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Abstract

Electromagnetic energy harvesting from ambient sources have been presented more than 50 years. In this paper, electromagnetic energy harvesting by using circular polarize antenna array is presented. The proposed antenna is having 2 similar size of spiral inductor that feed by microstrip feed line. The gain, momentum visualization were investigated. The circular polarize antenna are fabricated on Roger 4003 substrates. Based on the observations, it is expected that the gain obtained by the antenna array is higher than the single element antenna. The simulation results show that 3.22 dBi gain can be achieved for single spiral antenna whereas the antenna array can achieved as high as 5.14dBi at frequency 527MHz. The work concluded that investigations of electromagnetic energy harvesting antenna array is successful.

Keywords: *Circular Polarize; Electromagnetic Energy Harvesting; Antenna Array*

1. Introduction

In recent years, energy harvesting has drawn a lot of attention from scientist and researcher. There are many types of energy harvesting like environmental vibration, sunlight or wind and geothermal heat. For example, aircraft airframe (1) can be attached by a vibration sources such as piezoelectric transducer to harvest the small strain into electrical energy (2). Besides that, the electromagnetic wave that broadcasted 24 hours from the base station such as TV, mobile station is allowed for scavenged anytime and everywhere (3). This is the reason the electromagnetic energy harvesting has been very attractive. The process of converting this energy to become an electrical power (4) that will useful to human is called energy harvesting. It is an alternative method for batteries and usually to power up low power sensor modes.

2. Literature Review

The important characteristics of an ideal spiral antenna when considering for the performance of electromagnetic energy harvesting was lighter weight, physical size of antenna, inexpensive to manufacture. Besides that, the feeding point is very important because it can attach easily to the input of a spiral antenna with the rest part of the harvesting circuit. Due to the reason, antenna fabrication especially on printed circuit board become the main consideration and increasing in popularity compared to old type of helical antenna and loop wire antenna. This is because the standard electronic consumer device can be easily integrated with the patch antenna to be applied in the wireless application.
In RF integrated circuits, planar inductors usually become one of the important element use to store energy in the form of magnetic fields (5). Others than that, planar spiral inductor also can be fabricated on metal layers. In research, there are many different types of shape and geometries coil, all this different type will be used in different wireless applications. For example, toroidal coil used in high inductance discrete components but solenoid coil usually used for radio receiver antenna applications or electromagnet. In order to develop RF electromagnetic energy harvesting system, a circular polarize planar spiral inductor is taking into consideration. The reason is it was widely used in printed circuit board (PCB) applications nowadays. Besides that, the geometry of the spiral antenna have different type of shape (6) such as octagonal (7), star spiral (8) or square spiral (9) and it is easily to integrated in the circuit board design. Figure 1 shows the basic shape of a spiral planar inductor.

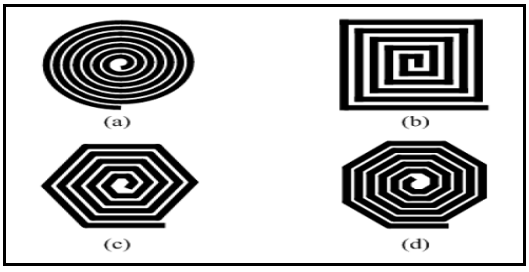


Fig.1: General Shape of Spiral Inductor

3. Methodology

This section focus on designing, simulate and measure of circularly polarize antenna array to harvest electromagnetic energy. To accomplish the design of the antenna array, Agilent ADS is using to simulate momentum visualization and gain of the antenna respectively (10). After that, the fabrication is carry out on Duriod 4003C printed circuit board that have relatively permittivity of 3.38, thickness of 0.813mm and loss of tangent 0.0027. Patch

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antenna is chosen for the electromagnetic energy harvesting because the efficiency is much more higher compared to other type of antenna (11). In these designs, the circular polarize spiral inductor are used due to circular shape inductor lack of sharp field discontinuities at 90 degree edge (12). Thus, it will minimize the resistance problem and yield better performance (13). In order to calculate for the resonant frequency of the antenna array, the first step is to determined the inductance parameter which are stated in Eq. 1 below (14).

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

Where Kg represent the ground plane,

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

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

Where Di and D0 is the inner and outer diameter of inductor, n is number of turns of antenna array. Thus, the resonant frequency the
of the antenna array can be calculated by

$$F = \frac{1}{2\pi\sqrt{LC}} \quad (4)$$

Figure 2 and figure 3 below show the single element antenna and circular polarize antenna array where *s* is spacing and *w* is width of the copper track. The input is excited by 50 ohm microstrip feeder and the dimension of line width is 1.89mm.

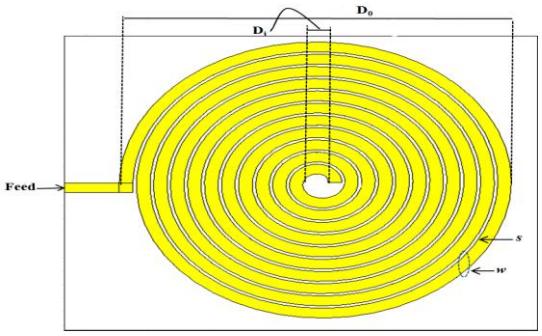


Fig.2: Single Element Antenna

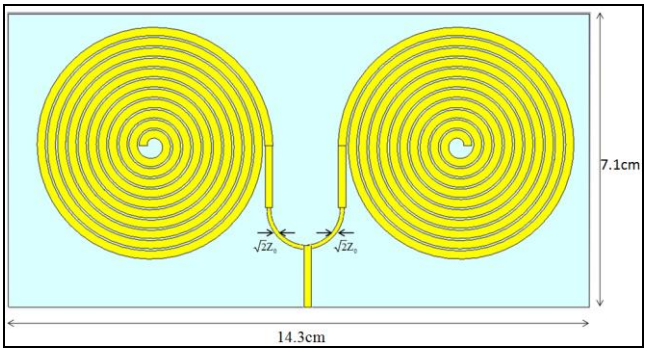


Fig. 3: Circular Polarize Antenna Array

4. Results and Findings

The simulated and measurement results are described in this section. Figure 4 show simulated gain of single element antenna and circular polarize antenna array respectively. The frequencies observe range is from 500MHz to 560MHz. The gain was considered in the direction of the center frequency.

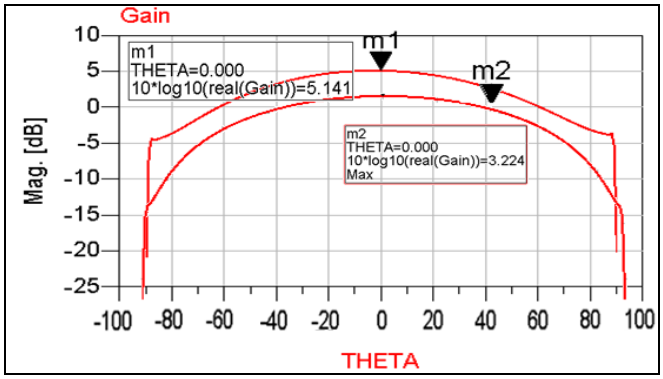


Fig. 4: Gain Plot Single Antenna vs Antenna Array

The gain of the antenna obtained is 5.14dBi at 527MHz whereas compare to single circular polarize antenna which was only 3.22dBi. The results obtained show that there is an increasing in gain with antenna array harvesting by using circular polarize type antenna. This is due to the spiral polarize antenna type will received the incoming electromagnetic signal from different direction. Figure 5 below represent electric current visualization of the antenna array.

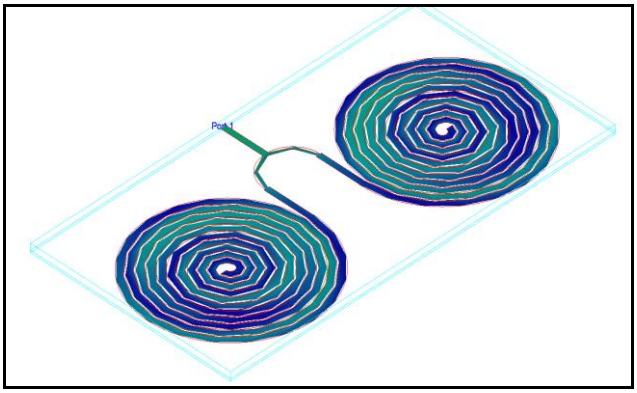


Fig. 5: Momentum Visualization of Antenna Array

The blue colour indicate the original colour and green colour indicate electric current. When the electric current is flowing to one direction through the copper trace, it will produce electromagnetic field that will be use to transmit. The electromagnetic field across the circular spiral inductor that generated by current will determine the inductance. When the gain is increased, the energy harvesting will be enhanced.

5. Conclusion

An experimental had presented the study of circular polarize antenna array for electromagnetic energy harvesting. The performance of the antenna array was observed using Agilent ADS and momentum visualization. A detail discussion regarding the circuit parameter value and design frequency were extracted and analyzed. The antenna array has been fabricated and good performance of gain value was obtained compared to single spiral antenna. Thus, it is expected that the proposed antenna structure available for low power consumption application. The proposed circularly polarize antenna array having simple geometry design, cost effective and easy to fabricate.

Acknowledgement

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