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Asrawati Arahman ✉; Elyas Palentei; Merna Baharuddin

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An Optimized Helical Antenna Suitable for WPT Part

Asrawati Arahman[1,a)], Elyas Palentei[1,b)], and Merna Baharuddin[1,c)]

[1]*Department of Electrical Engineering, Faculty of Engineering, Hasanuddin University, Makassar, Indonesia*

[a)]Corresponding author: arachmanasrawati@gmail.com
[b)]elyas_palantei@unhas.ac.id
[c)]merna.baharuddin@gmail.com

Abstract. Nowadays, wireless technology is not only used to transport data or files from one device to another, but also to deliver a certain amount of energy. The potential technique is the so-called wireless power transmission (WPT) system. One of the important components in WPT system construction is the antenna part to transmit and receive the electromagnetic waves. This study proposes a design of helical antenna with working frequency of 2.4 GHz by optimizing the parameters, i.e. the number of turns, the thickness of the copper, and the height of the helix. The constructed helical antenna is the preliminary stage of the whole WPT design to be fabricated later on. Based on the simulation performed using the licensed CST Microwave studio 2018 software, it has been shown that the best return loss of -15.16 dB was achieved at the targeted resonance frequency. Meanwhile, the excellent gain abruptly 10 dB and the narrow bandwidth operation of 57 MHz and VSWR value of 1.42 were also obtained from the numerical computing steps.

INTRODUCTION

Wireless Power Transfer (WPT) has been successfully applied to various technologies, such as electric vehicles, consumer electronics, medical devices, wireless sensors, IoT, and defense systems [1]. The WPT preliminary study was conducted by Tesla at the end of the 19th century, guided by the idea of "wireless" electricity providers around the world [2]. Microwave radiation-based WPT systems use highly directional antennas that can deliver power to great distances with high efficiency [3]. Electrical energy transfer wirelessly is an alternative solution to charge electronic devices with low power [4]. One of the equipment in wireless technology is the antenna. The antenna is defined by the IEEE standard as part of a transmitter or receiver system for radiation or electromagnetic wave receiver [5].

There are various types of antennas with various dimensions. Each dimension radiates signals with different strengths in each direction. The principle is known as the radiation pattern. Communication between points in wireless computer network requires an antenna that has a directional radiation pattern (specific to one direction). Type of the antenna that can be used in this situation is helix antenna.

Helix antenna has a geometrical structure similar to a spring, with the distance between coils, the diameter of the coils, and the number of the coils arranged so that it can meet the requirement. Geometric structure makes the manufacturing process of helix antenna more simple and can be used as an alternative antenna used in wireless networks. Helix antenna is specific due to the width of the beam up to 40°, relatively good gain in the range of 8 to 15 dB and suitable for air platforms [6]. It is important to pay attention to all components of the developed device to achieve an acceptable level of electromagnetic interference [7].

The drawback of this technique is the limited results, small magnetic fields are capable of only short distances. To improve the efficiency for long distances, consideration must be taken by resonant coupling. Resonance is achieved between two coils if the electromagnetic field around them oscillates at the same frequency. This can be done using a helix antenna as the inductor, which later will be combined with the capacitor plate. Wireless power transfer works using resonant coupling magnets when the transmitting and receiving antennas are in the same resonant frequency.

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This paper discusses an antenna design that functions as a wireless power transfer device. The material structure and dimensions of the antenna are optimized to operate at a predetermined frequency. Performance parameters of return loss, gain, and bandwidth shows good results for the proposed application. The experiment was carried out using a simulation CST Microwave Studio 2018 software.

THE 2.4 GHZ ANTENNA DESIGN AND WPT ARCHITECTURE

2.4 Ghz Helix Antenna Design

Helix antenna was chosen for this experiment. Helix antenna is an antenna with basic geometric shapes in three dimensions. Helix is a combination of straight lines, circles, and cylinders [8]. The geometry of the conventional helix is shown in Fig. 1 with the following parameters [9]:

D = diameter of helix
C = circumference of helix
S = spacing between turns
α = pitch angle
N = Number of turns

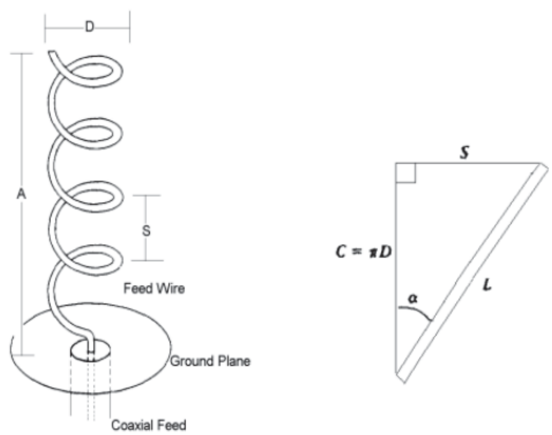

FIGURE 1. Helical antenna geometry

The relationships between *S*, *C*, *α* and the length of wire per turn [5], *L*, are obtained as:

$$S = L \sin \alpha \tag{1}$$

$$L = \left(S^2 + C^2\right)^{1/2} = \left(S^2 + p^2 C^2\right)^{1/2} \tag{2}$$

The diameter of the helical antenna is also closely related to its wavelength, so the wavelength can be calculated by this equation:

$$\lambda = C/f \tag{3}$$

C = Electromagnetic wave speed (3 x 10^8 m/s)
f = Centre frequency (Hz)

while the diameter of the helical can be calculated using the following equation:

$$D = \lambda/\pi \tag{4}$$

The circumference of the axial-mode helical antenna can be calculated using the following equation:

$$C = \pi\ D \tag{5}$$

Kraus defines pitch angle (α) using the following equation:

$$\alpha = \tan\frac{-1^{s}}{c} \tag{6}$$

Calculate the G (gain) value of the helical antenna using this formula :

$$Gain = 11.8 + 10\log\left\{\left(\frac{c}{\lambda}\right)^{2} * N * S\right\}(dB) \tag{7}$$

The impedance characteristics (Z) of the transmission line are as follow:

$$Z = 140 \times \left(C/l\right)\ \text{ohm} \tag{8}$$

To calculate the Bandwidth value of the helical antenna, the following equation is used:

$$Bw = f_H - f_L \tag{9}$$

where f_H and f_L are the upper and lower frequency limits respectively of the band in question.

Return loss is a parameter that indicates the amount of power that is lost to the load and does not return as a reflection. Similarly to voltage standing wave ratio, return loss is a parameter to indicate how well the matching between the transmitter and antenna has taken place. The return loss is given by:

$$\text{Return Loss} = -10\log|\Gamma| \tag{10}$$

TABLE 1. Helical antenna design parameters

Parameter	Value	Unit
Frequency	2.4	GHz
λ	12.34	cm
N	8	-
D	50	mm
A	120	mm
α	13	-
Copper Thickness	3	mm
Impedance	50	Ohm

A WPT Architecture

The design of 2.4 GHz helical antenna is connected to the WPT system so that it can serve as the desired application that is low power consumption. Figure 2 shows the configuration of the WPT system.

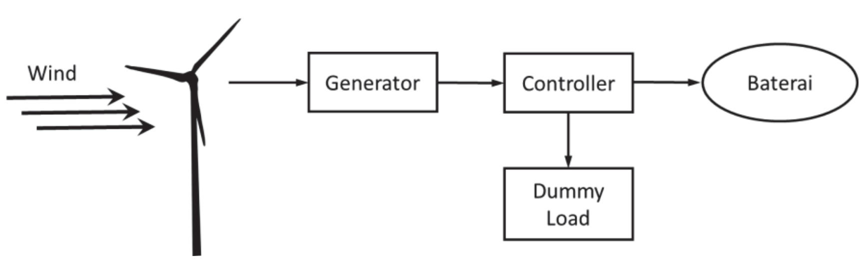

FIGURE 2. Wind turbine research focus

In conducting research about wind turbines, several components have to be taken care such as the turbine, generator, power storage, etc. as shown in Fig. 1. Therefore, the present study will focus on developing controller system which will connect generator and power storage.

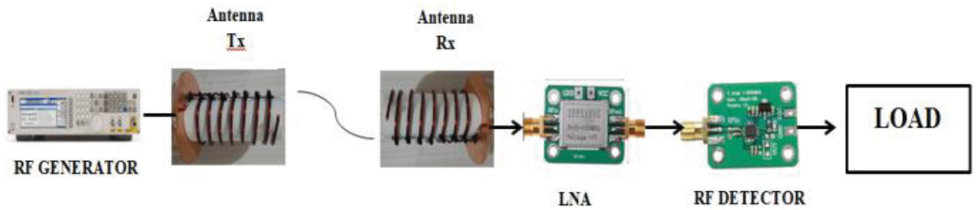

FIGURE 3. WPT system configuration

The transmitter unit deployed in the transmitting part is an Agilent N5182A RF Generator. It has operation a variable power for transmission purpose. The power output of the transmitter could be manually altered from -110 dBm up to +23 dBm. It operates from 100 kHz to 6 GHz.

On the receiver unit, several parts were added such as an LNA module and RF detector.

SIMULATION AND DISCUSSION

The design of the antenna was made using CST Microwave Studio 2018 software. Figure 3 shows the design of the antenna by optimizing the number of turns, copper thickness, and the helical height used so that the return loss value of $S_{11} < -10$ dB.

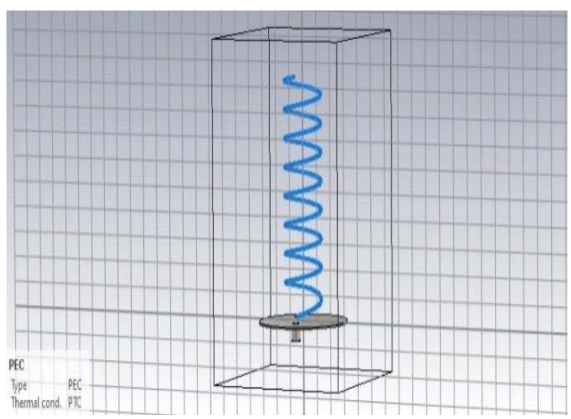

FIGURE 4. Helical antenna on CST Microwave Studio 2018 software

The Design of Helical Antenna by Changing the Number of Turns

In this section, optimization is done by changing the number of turns but the other parameters remain the same. The following graph is the simulation results by taking into account the value of S_{11}.

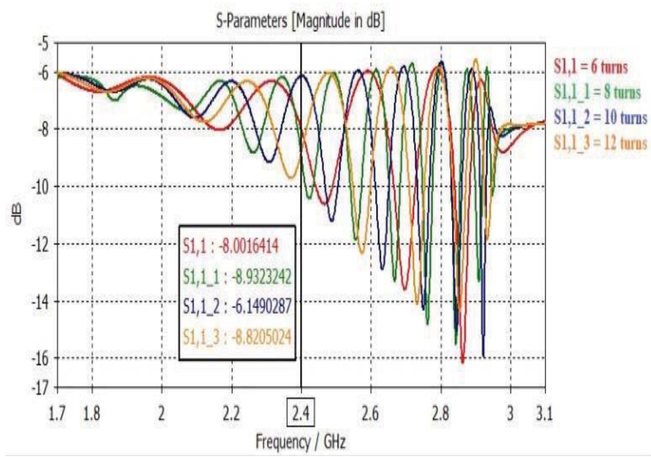

FIGURE 5. S_{11} to number of turns

Figure 4 shows a graph of S_{11} values for the number of turns. When the number of turns is changed from 6 turns to 12 turns it affects the value of S_{11} but the increase is not significant (changeable). The smallest S_{11} value is in 8 total turns. The S_{11} value is -8.932 dB.

The Design of Helical Antenna by Resizing Copper Thickness

In this section, optimization is done by changing the copper thickness but the other parameters remain the same. The following graph is the simulation results by taking into account the value of S_{11}.

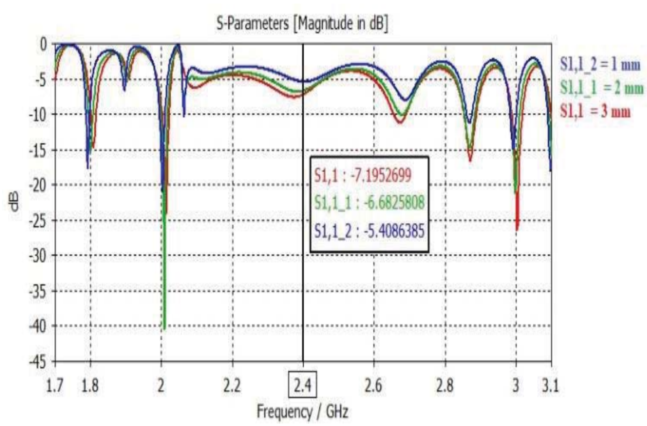

FIGURE 6. S_{11} to copper thickness

Figure 5 shows a graph of S_{11} values to copper thickness. When the size of the copper thickness is changed from 1 mm to 3 mm it significantly influences the value of S_{11}. The smallest S_{11} value is in the size of 3 mm copper thickness. The S_{11} value is -7.195 dB.

The Design of Helical Antenna by Changing the Helical Height

In this section, optimization is done by changing the helical height but the other parameters remain the same. The following graph is the simulation results by taking into account the value of S_{11}.

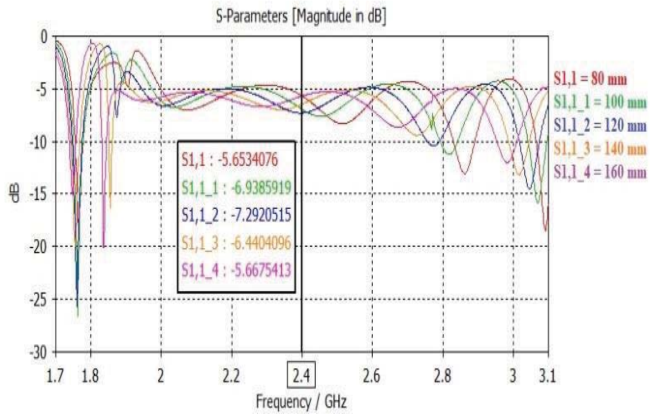

FIGURE 7. S_{11} to helical height

Figure 6 shows a graph of S_{11} values for the helical height. When the helical height is changed from 80 mm to 160 mm it affects the S_{11} value but not significantly (it changes). The smallest S_{11} value is in helical height of 120 mm. The S_{11} value is -7.292 dB.

Based on these three graphs, the design is made by taking into account the number of turns, the size of copper thickness, and the helical height. Figure 7 shows the simulation results using CST Microwave Studio 2018 software with S_{11} value is -15.18 dB. Figure 8 shows bandwidth value. To determine the bandwidth, the difference in frequency is taken at the points where the curve is cut at -10 dB level rendering which is 90% of the signal is absorb while 10% is reflected back [10]. The deeper the curve of S_{11} result, the more signal is been transmitted and the bandwidth frequency range between 2.3739 GHz until 2.4314 MHz.

The antenna is said to work well if VSWR ≈ 1 or 1≤ VSWR ≤ 2 [11]. In accordance with Fig. 9, it can be seen that the VSWR value obtained is 1.42. This is indicative that the impedance between the transmission line and antenna is well matched. Figure 10 shows the polar plot-gain of radiation pattern for simulation helical antenna. Based on the simulation results, it obtained Gain value of 10 dB at an angle of 90 degrees direction (main lobe direction).

The antenna with a high gain would reduce the size of the power amplifiers used to excite it, keeping the final physical size of the system to a minimum. Therefore, helical antennas were chosen as they are a good compromise between the gain/ bandwidth tradeoff [5].

The constructed helical antenna has a pretty good gain (10 ≥ 3 dB) [5]. FTBR property is also an excellence profile to achieve abruptly 14 dB. According to the antenna modeling setup the effective radiated power will be illuminated on the angle of 90-degree direction.

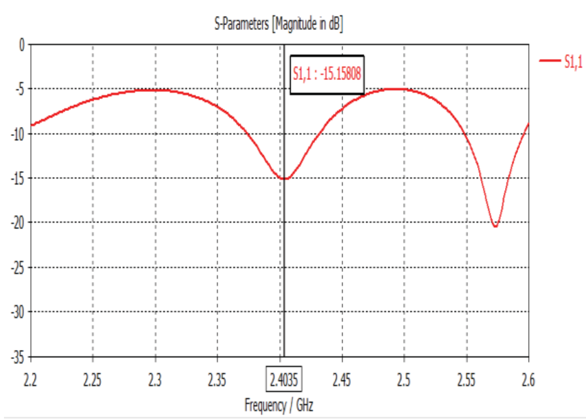

FIGURE 8. S_{11} to 2.4 GHz frequency

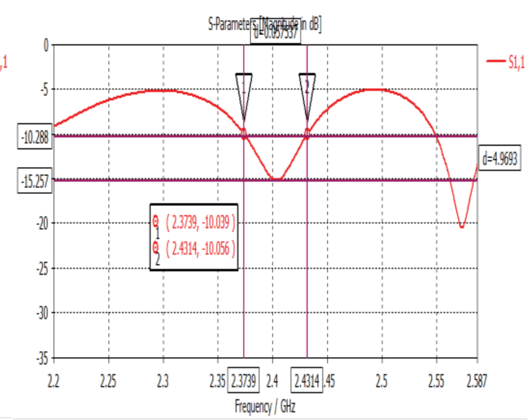

FIGURE 9. Bandwidth value

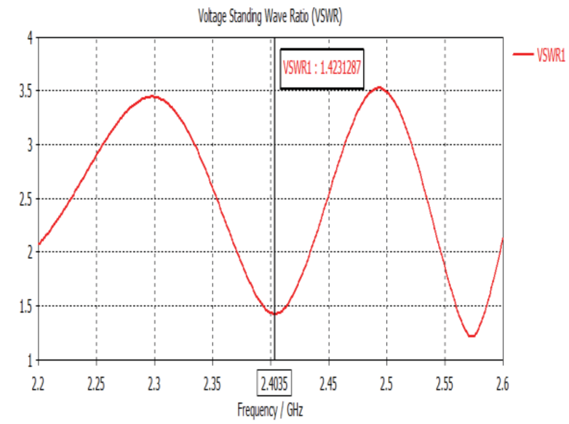

FIGURE 10. VSWR

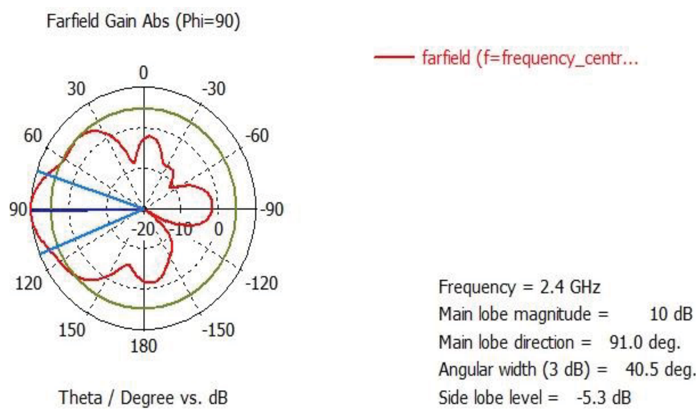

FIGURE 11. Polar plot - Gain

CONCLUSION

The simulation results of helical antenna using CST Microwave 2018 software have met the criteria to be connected to WPT devices. Optimization was carried out with 8 total turns, copper thickness of 3 mm, and helix length of 120 mm to produce return loss (S_{11} = -15.16 dB), Gain = 10 dB, VSWR = 1.42, and Bandwidth = 57 MHz. In addition, the size of helical antenna is smaller than other conventional antennas so that it is easily applied as a transmitter and receiver of electromagnetic waves for mobile applications. In further study, this antenna can be designed in a smaller size but with greater gain value so that the wireless power applications can be maximized**.**

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