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Increasing the transmission distance in wireless power transfer with the size of coil

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ABSTRACT

Process of transferring electricity between two points is referred to as Wireless Power Transfer (WPT). One of the problems to implement WPT is a distance. Most of the system needs to put the transmitter and receiver closely. This paper discusses the transmission power using the resonant frequency method. 100Watt of power transmission had been designed to transmit electrical energy. The method was used to analyze the different size of the coil. The coil with diameter size 160cm had been tested with open area, embed to the earth's surface and coil size 16cm as a reference. The purposed of design to identify the performance of coil transmission in WPT system. To get the larger area cover for WPT system, the larger size of the coil had been developed. In the experimental transmission with a larger size is in demand in many applications. Increasing the size of the coil can increase the distance approximately to 10 times. The power transfer also shows less than 1% of power losses when embedding into the soil.

1. Introduction

WPT technique is still in a small number of researches in order to identify the method of transmission power with a large distance. Some of the applications had been transferred energy in high power, but the distance is very low compared to the high distance in which it is still small in a number of proving and experiments. However, high power transmission is suitable to the certain application such as in online power transfer (Lee et al., 2016; Huh et al., 2011a; Huh et al., 2011b). The demand on the distance is very high and Wireless Power Consortium had been released a standard of 5W of application in WPT and collaborates with various types of company in developing WPT (Waffenschmidt, 2011). The demand is always in the industry since the user of the electricity is unlimited especially for a single phase of electrical energy. In a research by Mur-Miranda et al. (2010), WPT system can be achieved a good distance and efficiency by increased the quality factor up to 1000. In a research by Zambari et al. (2013), 240Watt of solar panel had been revealed in transmitting the energy using a few types of design in coil for the WPT. The Radin coil transmits the highest distance, but the frequency of 800kHz which is very high compare to another two type spiral and loop coil both at the frequency of 200kHz and the distance was 25cm. Compared to the both design, loop coil is an advantage due to lower power quality factor but the distance is still high. To improve certain parameter, a few parameters need to be considered.

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) had been put a few guidelines, such as the magnetic flux density is limited to 6.25 μT for general public in the frequency of 0.8 ~ 150 kHz and under IEC 62110 (Lee et al., 2016; Li et al., 2016). The design chosen in the experiment is a loop coil and the frequency is below 150 kHz. The biggest on the size of the coil was studying with the same frequency in order to identify the effect on the power transmission.

In a research by Jonah and Georgakopoulos (2013) based on the transmission inside the beam, different distance achieved different power transmission. The highest efficiency is 59% for 10cm, 35% for 30cm and 12% for 50cm. The frequency setting is 39.75MHz. The result performed though the experiment and simulation. The experiment conducted with a barrier of beam and beam with humidity. In a research by Hassan et al. (2016), wireless power transfer was studied to a high temperature and high pressure zone for aerospace application. The power resonance in power transfer with efficiency 38% with titanium and 15.5% with a steel metal booster at the frequency of 450Hz and 220Hz. The demand on the wireless power transfer increase in many applications. In this study, the experiment with 160cm of coil embedded in the soil in order to identify the new mechanism of power transmission especially to achieve higher distance. The experiment was beginning with 16cm and will continue with 160cm of diameter. Both types of coil will be tested in the embedded soil.

2. Problem formulation for 16cm of coil

WPT had been developed based on a combination of inverter (Mohd et al., 2015) and transmission in a coil as shown in Fig. 1. It shows the schematic diagram for transmission circuit. The circuit can be operated with minimum of 6V input voltage. For the 16cm of diameter coil, input voltage was tested from 12V, 15V, 18V, 20V and 22V for 16cm of the coil. The physical experiment as shown in Fig. 2. The coils are facing each other. Different type of capacitor had been tested in this experiment. Capacitor with the size of 0.1uF, 1.0uF, 2.2uF, 3uF and 4uF had been set up. Inductor with a size of 100mH, 200mH, 300mH, 400mH and 500mH as a third parameter had been set up in the experiment. The fourth parameter setup in the experiment is the coil from 14 core, 28 cores, 35cores and 60cores of the coil. The resonance frequency used in this experiment was 43.75 kHz and

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under the standard as mention in Lee et al. (2016), ICNIRP (2014) and Li et al. (2016).

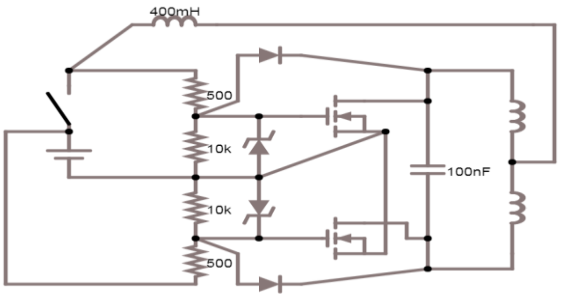

Fig. 1. Wireless power transfer circuit (transmitter system).

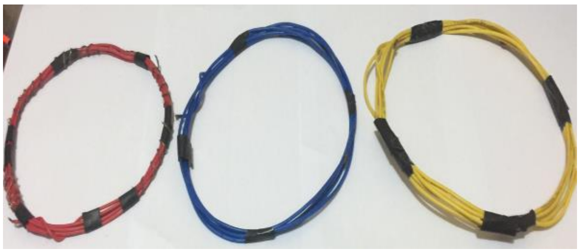

Fig. 2. Coil with 16cm of coil in various type of cores.

The main thing is to get the resonance on the size of capacitor that must be fixed throughout the experiment. The schematic diagram as shown in Fig. 3.

The experiment was conducted in open areas and data are taken as shown in Table 1, Table 2, Table 3 and Table 4.

Table 1
Parameter setup with 14 copper in cable.

		12V			
Cap/Inductor	1	2	3	4	5
0.001	9/9.2	9.7	8.1	8.3	7.5
0.1	27.9	29.9	27.9	25.3	24
1	25.4	25.1	23.5	24.6	22.2
2.2	19.2	22.5	18.5	20	17.4
3	18.4	19.1	17.6	18.3	22.4
4	16.1	17	15.6	15.2	14
		15V			
Cap/Inductor	1	2	3	4	5
0.001	10.9	10.8	10.2	9.3	10
0.1	28.9	30.4	31	27.7	27
1	27	27.1	25.4	26.6	23.6
2.2	21.2	24.6	21.6	21.4	19
3	20.6	21.2	19	18.5	15.6
4	17.6	17.9	17.8	18.4	15.2
		18V			
Cap/Inductor	1	2	3	4	5
0.001	12.1	11.1	11.1	11.1	13.4
0.1	32.1	32.5	31.6	28.8	28
1	26.9	29.2	27.4	28	24.9
2.2	23.4	25.9	22.8	22.1	19.6
3	22.6	22.8	20.1	19.8	17.7
4	18.1	19.2	19.3	17.9	15.4
		20V			
Cap/inductor	1	2	3	4	5
0.001	12.6	10.8	11.9	12.5	15
0.1	33.2	33.4	33.5	29.6	29.1
1	29.4	31.7	29	28.7	25.4
2.2	23.7	25.8	25.7	21.2	20.1
3	22.8	24.9	21.6	20.4	18.6
4	18.4	19.1	20.1	19.6	16.7
		22V			
Cap/Inductor	1	2	3	4	5
0.001	13.3	12	12.4	11.9	16.5
0.1	34.1	34.5	34.7	32.9	29.4
1	31	32.1	30.3	31	26.4
2.2	26.1	27.1	26.8	23.2	20.1
3	24.4	23.4	22.8	21.4	19.6
4	20.8	21.8	21.2	20.7	17.7

Based on the experiment in the 16cm of the coil, the coil had been embedded in the soil as shown in Fig. 4. The plan of this experiment is to identify the performance of power transmission in the soil. The data as shown in Table 5, Table 6, Table 7 and Table 8.

Fig. 3. Schematic diagram for coil facing each other configuration.

Table 2
Parameter setup with 28 copper in cable.

		12V			
Cap / Inductor	1	2	3	4	5
0.001	8.7	9	9.2	6.5	9.3
0.1	24.1	27.1	26.6	25.4	24
1	22.8	26.9	26.2	20.9	23.2
2.2	19.3	20.1	20.6	22.5	18.7
3	19.2	19.1	19.9	19	17.2
4	16.9	16.4	19.2	18	15.7
		15V			
Cap / Inductor	1	2	3	4	5
0.001	8.9	10	10.2	9.7	10.4
0.1	25.9	28.5	28.8	28.4	26.6
1	25.6	27.5	27.6	24.2	25.8
2.2	21.3	20.5	20.8	24.6	20.6
3	20.3	20.1	22.5	20.3	19.1
4	17.6	18.7	20.1	19.6	17.8
		18V			
Cap / Inductor	1	2	3	4	5
0.001	10.2	11.8	10.5	10.4	11.1
0.1	29.5	30.4	30	30.8	28.5
1	28.4	30	29.4	25	27.4
2.2	22.6	23.7	23.6	27.4	20.8
3	20.5	21.6	22.3	23.1	19.4
4	18.1	20.5	22.8	20.9	18.5
		20V			
Cap / Inductor	1	2	3	4	5
0.001	11.8	12.2	11.4	11.6	12.2
0.1	29.7	30.9	32.5	30.1	28.9
1	28.5	30.6	31.9	25.6	27.6
2.2	23.6	24.3	24.2	27.3	21.9
3	22.9	23.8	23.2	24.7	21.1
4	18.9	22.9	22.9	24	18.9
		22V			
Cap / Inductor	1	2	3	4	5
0.001	12.1	12.4	12.2	12.1	13.5
0.1	30.2	31.5	33.5	31.2	30
1	29.4	31.1	32.8	26.3	29.5
2.2	22.5	25.2	26	28.1	22.8
3	23.4	24.1	24.4	23.8	21.8
4	21.9	23.7	23.9	22.7	19.9

Table 3
Parameter setup with 35 copper in cable.

		12V			
Cap / Inductor	1	2	3	4	5
0.001	10.7	10.1	11.9	9.8	11.3
0.1	26.2	30.2	30.5	26.8	30.1
1	25.8	28.5	29.4	25.1	29.3
2.2	21.5	22.1	22	24.1	24.2
3	20.4	20.1	20.6	20.1	21.4
4	19.6	19.3	19.8	18.3	19.5
		15V			
Cap / Inductor	1	2	3	4	5
0.001	12.2	11.4	12.2	12.1	17.8
0.1	26.8	31.1	31.1	30.1	31.5
1	25.9	27.1	30.6	27.8	30.8
2.2	21.5	22.9	24.1	26.1	24.4
3	21.4	22	23.6	21.5	22.7
4	20.5	21.1	20.8	20.4	21.1
		18V			
Cap / Inductor	1	2	3	4	5
0.001	13	13.2	13.5	12.5	18.7
0.1	28	31.3	31.9	31.2	32.1
1	27.5	30.5	31.2	28.3	31.5
2.2	24.2	25.1	24.9	27.6	24.9
3	24.7	24.6	23.4	22.8	23.2
4	22.8	22.7	22.1	21.6	22

		20V			
Cap / Inductor	1	2	3	4	5
0.001	13.8	13.3	14.2	12.9	19.3
0.1	28.4	33.9	32.1	32.8	33.2
1	27.8	31.2	31.9	30.1	32.5
2.2	24.7	25.6	25.3	29.1	26.2
3	23.5	23.5	24.7	23.9	26
4	24.9	23.1	23.5	23.8	23.8

		22V			
Cap / Inductor	1	2	3	4	5
0.001	13.9	13.5	14.3	12.6	20.6
0.1	31.5	33.2	32.4	33.1	36
1	28.5	30.5	32	30.2	32.1
2.2	25.6	24.4	26.3	30.6	28.5
3	25.3	22.9	25	25.1	25.9
4	25.2	23	23.8	24.8	22.6

Table 4
Parameter setup with 60 copper in cable.

		12V			
Cap / Inductor	1	2	3	4	5
0.001	8.9	9.1	9.6	10.1	10.2
0.1	25.5	26.8	26.1	25.9	32
1	23.2	26.2	23.1	22.3	30.3
2.2	22.4	22.4	22.4	21.6	25.5
3	18.3	17.8	22.3	18.3	22.5
4	17.9	15.7	21.9	17.6	18.5

		15V			
Cap / Inductor	1	2	3	4	5
0.001	11.3	10	11.5	11.5	17.8
0.1	26.9	29.9	29.7	26.8	32.5
1	24.9	25.7	25.4	25.7	31.5
2.2	23.3	24.5	24.4	23.8	26.5
3	19.9	22.1	24.1	20	24.6
4	19.3	18.9	23.3	19	20.1

		18V			
Cap / Inductor	1	2	3	4	5
0.001	12.3	11.1	12.2	13.3	20
0.1	30.1	31.2	30.9	28.3	33.1
1	26.4	26.5	27.1	27.3	32.5
2.2	25.7	26.1	27	25.5	26.8
3	23.1	23.3	24.3	22.2	25.1
4	20.7	19.7	23.7	21.1	23

		20V			
Cap / Inductor	1	2	3	4	5
0.001	13.6	11.5	13.8	13.1	21.5
0.1	31	36	31.3	30.1	35
1	28.6	27	29.5	27.5	34.5
2.2	25.6	26.3	27.3	26.5	27.9
3	23.3	22.5	25.1	22.9	26.5
4	22.5	21.3	23.2	21.5	23.6

		22V			
Cap / Inductor	1	2	3	4	5
0.001	13.8	12.3	14.4	13.8	21.9
0.1	31.3	35.5	31.5	30.7	36.1
1	32.5	28.2	29.7	28.5	35.5
2.2	26	28	29.1	27.1	28.1
3	25.5	26.2	24.6	23.3	27.8
4	22.6	21.9	23.7	23.9	24.2

Fig. 4. WPT was embed in soil.

Table 5
Parameter setup with 14 copper in cable.

		12V			
Cap / Inductor	1	2	3	4	5
0.001	8.8	9.2	7.8	7.9	7.0
0.1	27.4	29	27	25	23.6
1	24.6	24.8	22.8	24.1	21.7
2.2	18.4	22.1	18.1	19.5	17.1
3	18.2	18.6	17.1	17.8	21.9
4	15.8	16.5	15.1	14.8	13.6

		15V			
Cap / Inductor	1	2	3	4	5
0.001	10.2	10.4	9.7	9.0	9.5
0.1	28	30	29.4	27.1	26.4
1	26.5	26.5	25	26	22.8
2.2	19.6	24.2	21.1	20.9	18.4
3	20.1	20.8	18.6	18.4	15.1
4	17.1	17.2	17.1	18.2	15

		18V			
Cap / Inductor	1	2	3	4	5
0.001	11.5	10.8	10.8	10.7	12.8
0.1	31.4	32	31	28	27.4
1	25.8	28.4	26.8	27.5	24.1
2.2	22.9	25.1	22.2	21.8	19.1
3	22.1	22.2	19.5	19.2	17.2
4	18	18.8	18.9	17.1	15.1

		20V			
Cap / Inductor	1	2	3	4	5
0.001	12.2	10.4	11.1	12.1	14.5
0.1	32.8	33	33	28.4	28.6
1	28.4	31.1	28.4	28.1	25.1
2.2	23.2	25.1	25.2	20.8	19.8
3	22.2	24.2	21.1	20.2	18.2
4	17.5	18.5	19.5	19.1	16.2

		22V			
Cap / Inductor	1	2	3	4	5
0.001	13	11.7	11.9	11.5	16
0.1	33.6	33.9	34.2	32.2	28.8
1	29.5	31.5	29.5	29.4	26
2.2	25.4	26.5	26.1	22.8	19.5
3	23.9	22.8	22.1	21.0	19.0
4	20.1	21.2	20.8	20.1	17.2

Table 6
Parameter setup with 28 copper in cable.

		12V			
Cap / Inductor	1	2	3	4	5
0.001	8.2	8.6	8.9	6.3	9.1
0.1	23.8	28.7	26.1	25.1	23.8
1	22.1	26.2	25.6	19.8	22.8
2.2	18.6	19.8	29.8	21.8	18.1
3	18.8	18.8	19.2	18.5	16.5
4	16.2	16	19	17.5	15.2

		15V			
Cap / Inductor	1	2	3	4	5
0.001	8.6	9.6	9.8	9.6	10.2
0.1	25.2	28.1	28.2	27.8	26.1
1	25.2	27.1	27.2	23.8	25.2
2.2	20.8	19.8	20.2	24.1	20.1
3	19.5	19.8	22.1	19.5	18.6
4	17.2	18.5	19.8	19.2	17.1

		18V			
Cap / Inductor	1	2	3	4	5
0.001	9.8	10.6	9.8	9.8	10.5
0.1	28.9	29.6	29.5	30.2	27.5
1	27.9	29.5	28.7	24.8	26.8
2.2	21.8	22.9	22.9	26.4	20.1
3	20.1	21.1	22	22.7	19.1
4	17.5	20.1	22.5	20.1	18.3

		20V			
Cap / Inductor	1	2	3	4	5
0.001	11.2	11.6	10.8	11.1	11.8
0.1	29.1	30.1	30.5	29.5	28.2
1	27.5	29.6	30.6	25.1	26.7
2.2	23.1	24	24	27	21.2
3	22.1	23.2	23	24.1	21
4	18.5	22.7	22.2	23.5	18.4

		22V			
Cap / Inductor	1	2	3	4	5
0.001	11.6	11.6	11.8	11.9	12.9
0.1	29.8	30.8	32.8	30.6	29.6
1	28.6	30.8	31.9	27.8	28.5
2.2	21.8	24.8	25.8	27.6	22.2
3	22.6	23.5	24	23.5	21.2
4	21.5	23.5	23.2	22.2	19.1

Table 7
Parameter setup with 35 copper in cable.

		12V			
Cap / Inductor	1	2	3	4	5
0.001	9.8	9.7	11.4	9.4	10.8

0.1	25.6	29.8	30.1	26.2	29.6
1	25.2	28.2	29	25	29
2.2	21.2	21.6	21.6	23.6	24
3	20.1	19.4	20.2	19.6	21.1
4	19.2	19	19.2	17.6	19.2
		15V			
Cap / Inductor	1	2	3	4	5
0.001	11.9	10.6	11.6	11.7	17.2
0.1	26.1	29.8	30.8	29.7	31.1
1	25	27	30.2	27.3	30.2
2.2	21	22.2	23.6	25.8	24.1
3	21.2	21.6	23.2	21.2	21.9
4	20.1	20.6	20.3	19.6	20.6
		18V			
cap / inductor	1	2	3	4	5
0.001	12.7	12.6	13.1	12.1	18.4
0.1	27.5	31.1	31.2	31	32
1	27.1	30.2	30.6	27.9	31.1
2.2	23.2	24.8	24.2	27.1	24.2
3	24.2	24.4	23.1	22.4	22.4
4	22.3	22.2	21.6	21.2	21.8
		20V			
Cap / Inductor	1	2	3	4	5
0.001	13.2	13.1	13.8	12.1	8.2
0.1	28	33.1	31.6	31.6	32.6
1	27.5	31.1	31.1	29.6	32.1
2.2	24.5	25.2	25.1	29	26
3	23	23.1	24.2	23.4	25.6
4	24	22.6	23.1	23.2	23.2
		22V			
Cap / Inductor	1	2	3	4	5
0.001	13.2	13.2	14.1	12.1	20
0.1	31.1	32.5	32.1	32.6	35.4
1	28.2	30.2	31.5	29.6	31.6
2.2	25	24	26	30.2	28.2
3	24.3	22.2	24.6	24.6	25.4
4	24.6	22.4	23.2	24.2	22.1

Table 8
Parameter setup with 60 copper in cable.

		12V			
Cap / Inductor	1	2	3	4	5
0.001	8.2	8.6	9.4	9.6	10
0.1	25.1	25.7	25.6	25.2	31.5
1	22.8	25.4	22.5	21.6	29.6
2.2	21.6	21.2	22.1	21.2	25.1
3	17.6	17.2	21.6	17.6	22.1
4	17.5	15.2	21.4	17.1	18.2
		15V			
Cap / Inductor	1	2	3	4	5
0.001	11	9.6	11.4	11.2	17.2
0.1	26	29.2	29.2	26.4	32.1
1	24.3	25.2	25.1	25.4	31.2
2.2	23.1	24	24	23.2	26.3
3	19.2	22	23.5	19.6	24.2
4	19	18.4	23	18.6	19.6
		18V			
Cap / Inductor	1	2	3	4	5
0.001	12	10.6	12	13	19.6
0.1	29.6	31	30.1	28	33
1	26	25.6	26.5	27	32
2.2	25	25.4	26.4	25.1	26
3	22.4	23	24	21.6	24.6
4	19.6	19.4	23.1	20.6	22.4
		20V			
Cap / Inductor	1	2	3	4	5
0.001	12.6	11.2	13.4	12.6	20.9
0.1	30.8	35.4	31.1	29.6	34.7
1	28.1	26.2	29.1	27	34.2
2.2	25.2	25.3	26.8	26	27.3
3	22.8	21.9	24.7	22.4	26.2
4	22.1	20.8	23	21.1	23.1
		22V			
Cap / Inductor	1	2	3	4	5
0.001	13.4	12	14.1	12.5	20.6
0.1	31	35	31.2	30	35.4
1	32	28	29.2	28	34.9
2.2	25.4	27.5	28.6	27	28
3	25	26	24.2	23.2	27.2
4	22.2	21.2	23.2	23.4	24

3. Problem formulation for 160cm of coil

The experiment continues with the larger coil ranging from 16cm to 160cm of diameter. As the experiment is shown in Fig. 5 and Fig. 6. The diameter of 6o core was used in the experiment. The experiment was conducted in an open area. The result is as shown in Table 9.

Fig. 5. WPT with a stand.

Fig. 6. Analysis on WPT for 160cm diameter size of coil.

Table 9
Data collection for 60 cores of coil in open area.

Capacitor Vin	0.1	1	2	10
6	93.2	94.5	87.1	48.5
8	113.4	114.1	102.7	74.1
10	129.7	124.6	111.8	89.2
12	141.5	131.2	121.7	98.7
14	151.9	139.9	126.1	108.8
16	159.8	146.7	132	114.2
18	164.5	150.1	141.7	120
20	171.3	159.7	151.1	126
22	176.5	168.1	160.7	133.4
24	181.7	172.3	166	138.7
26	184.2	177.3	173.3	145.1
28	188.7	183.2	177.9	149.2
30	195	186.7	181.5	153.2
32	200.4	193.2	183.7	172

The experiment was continued to embed the coil in the soil. The estimated depth 200cm was used as reference as shown in Table 9 with the parameter an input voltage and 0.1uF of a capacitor of 32V. To embed the coil in the soil, it must be to prevent the coil from damage and unexpected factor as shown in Fig. 7. As a safety purpose the ladder is used as shown in Fig. 8. The data were collected based on the parameter setting as shown in Table 10.

Fig. 7. Protection for coil.

Fig. 8. Identify the distance and put the cable inside the whole process.

Table 10
Data collection for 60 core of coil embed in soil.

Capacitor Vin	0.1	1	2	10
6	92.6	94.1	86.4	48.2
8	113	113.6	102.2	73.5
10	129.2	124.2	111.2	88.6
12	141.2	131	121.2	98.2
14	151.3	139.0	125.8	108.2
16	159.5	146.2	131.4	113.8
18	164.2	149.6	141.3	119.6
20	171.1	159.2	150.7	125.4
22	176.1	168	159.6	133.2
24	181.2	171.6	165.6	138.2
26	184	176.4	173.1	144.6
28	188.2	182.5	177.5	148.6
30	194.6	186.2	181.2	153
32	200	192.9	183.2	171.6

4. Results and discussion

The result shows in a few parts based on the experiment. For 16cm of coil experiment, the experiment between open area and embed in soil, the result shows the transmission power can be achieved and only have a differential based on distance. The lost is less than 1% and can refer to table in data collection. Randomly the data was taken from 14 core experiment with different size of the capacitor. In Figs. 9-13 show the comparison data taken from 14 cores of copper. From the graph shows the distance has a small drop and increasing the size of input voltage will increase the size of distance of power transmission.

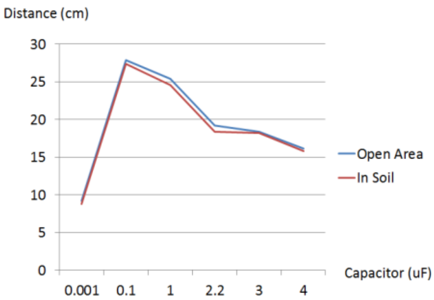

Fig. 9. Distance V/S size of capacitor for 14 cores of coil and 12V of input voltage.

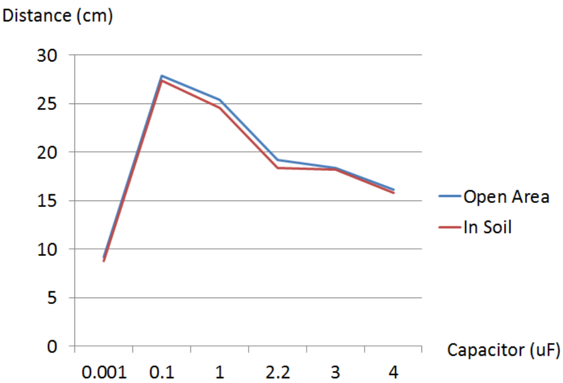

Fig. 10. Distance V/S size of capacitor for 14 cores of coil and 14V of input voltage.

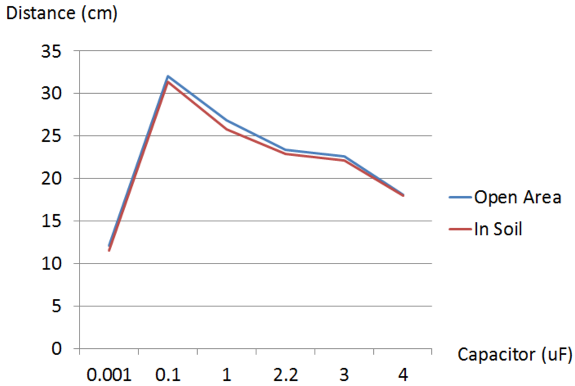

Fig. 11. Distance V/S size of capacitor for 14 cores of coil and 16V of input voltage.

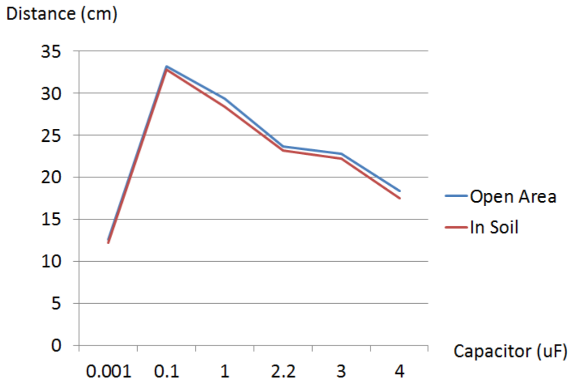

Fig. 12. Distance V/S size of capacitor for 14 cores of coil and 20V of input voltage.

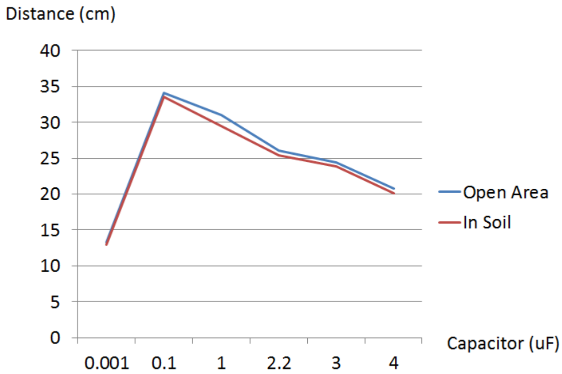

Fig. 13. Distance V/S size of capacitor for 14 cores of coil and 22V of input voltage.

Fig. 14 shows the result on the voltage versus distance for various type of capacitor. The capacitor in from 0.1uF, 1uF, 2uF and 10uF for 160cm of coil. The results show the increasing size of capacitor was increased the distance of power transmission. Based on the electrical circuit setting in both size of experiment, the same parameter are input voltage and the capacitor. Input voltage 14V, 16V, 18V, 20V and 22V had been set. For capacitor size from 0.1uF, 1uF and 2uF had been tested.

Fig. 15, Fig. 16 and Fig. 17 show the comparison result based on the 16cm and 160cm for two conditions which are open area and embed area in the soil. The data show the data increased 10 times longer from 16cm to 160cm of diameter coil. The difference between the transmission powers with obstacle using coil is not a boundary to transmit the electrical energy. The transmission power is less than 1% of the drop. Higher voltage will increase the distance of power transmission.

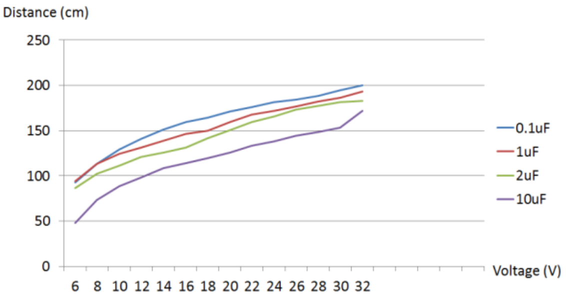

Fig. 14. Voltage V/S distance for various type of capacitor.

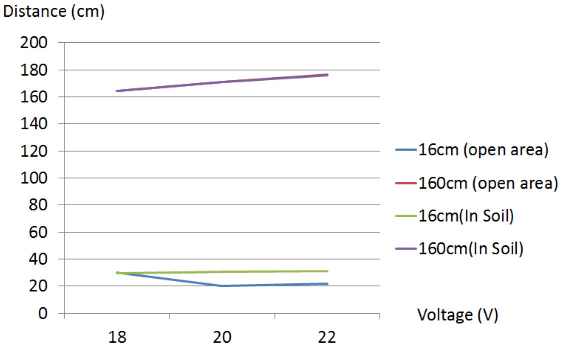

Fig. 15. Voltage versus distance for 0.1uF capacitor.

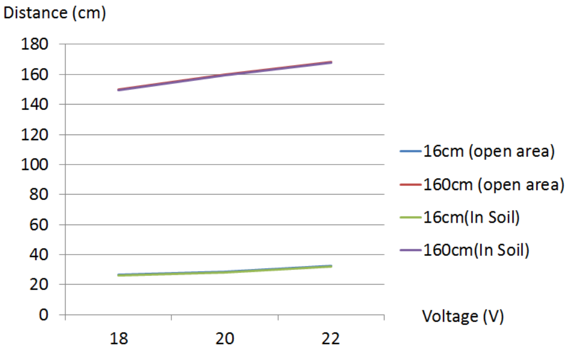

Fig. 16. Voltage versus distance for 1uF capacitor.

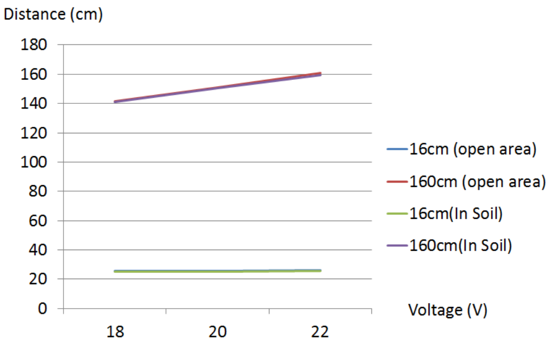

Fig. 17. Voltage versus distance for 2uF capacitor.

5. Conclusion

Larger size of diameter can increase the distance of power (Dahalan et al., 2016) transmission and embed the coil in the soil will benefit from WPT application.

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