A Study on Drone Charging System Using Wireless Power Transmission

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Abstract**—** This paper presents the non-radiative method of wireless power transmission technology to be applied the battery charging system of drones which refers to unmanned aerial vehicles. The subject of research on wireless charging system that enables continuous and efficient duties to overcome the limits of duty area and the time allocation of sections where autonomous driving or drones are moving to a designated location for battery replacement and charging; it was designed, manufactured, and tested the power transmission, reception antenna unit and the charging unit for efficiently charging the transmitted power to the battery. In order to select the frequency band which is a design function of the power transmission antenna as a range applicable to the development and commercialization drone, the influence of the frequency interference is low, and the approval frequency band of domestic and overseas is applied to the industrial science and medical equipment, the home wireless power transmission device, the frequency band causing radio-active or conductive failure of the radio power transmission equipment of the engine driven equipment was investigated and the system was constructed using about 13.56Mhz. DC-DC converter system capable of charging 100W class transceiver and drone battery through the inductance mapping of the transmitter and receiver in the frequency band of 13.56Mhz, changing the shape and position of the ideal transmitting and receiving antenna, the efficiency was confirmed to be more than 60%. Therefore, if the unmanned charging system is used for the drones or similar equipment, it is possible to increase the utilization of the drones by the efficient arrangement of the duty range and the maintenance personnel that can be performed by the present power source. The experimental and simulation result of the drone charging system has satisfied.

Keywords—*Drones; Aerial Vehicles; Antenna; Power Transmission; Frequency Band; Charging System; Personnel.*

I. Introduction

The wireless power transmission technology can be broadly divided into four categories according to the transmission distance[1]. The characteristics of each transmission technology are as follows.

a) The contact-based charging technique (using inductive coupling)-the transmission distance is only a few centimeters, and the power source and the device which are not connected by the electric wire are in close contact with each other. Most of them use inductive coupling phenomenon and have excellent energy transfer efficiency. Inductive coupling uses a frequency of 125kHz or 13.56MHz to transmit several watts of power at a distance of several centimeters or tens of millimeters, and is used for transportation cards (T-money, etc.), wireless shaver, electric toothbrush, but there is a limitation that the distance is within a maximum of several centimeters, but this can be used in a lot of practical use (radio transmission, wireless charging pad for mobile) [2].

b) The wireless power transmission based charging technique: 1) Near-field transmission (Radiative Method) - the transmission distance is classified as short-distance transmission with a relatively short distance of about 10m from few meters to several meters. It uses frequencies of several tens of MHz or several hundreds of MHz that are used in cellular phones, and most of them use electromagnetic waves to emit radiation, which exposes the problem of damaging the human body when power is transmitted at a high output and the radiation-based short-range transmission means RFID service using UHF (Ultra High Frequency) band RFID / USN frequency band or 2.4GHz ISM band, commercialization since the early 2000s in distribution / logistics field, Only a maximum of several tens of mW of power transmission is possible.

2) Non-radiated transmission: In 2007, a non-radiated approach proposed by MIT's Marin Soljacic professor team, “type magnetic resonance is based on a resonant coupling method” in which electromagnetic waves are moved from one medium to another through a near magnetic field, when two media resonate at the same frequency and a large power transmission of 60 W at a distance of 2 m and it is emerging as promising technology for the future.

3) Long distance transmission: The transmission distance range from several kilometers to several hundred km was classified as long distance transmission. This includes technologies that generate electricity from solar energy from satellites and transfer energy from ground to the unmanned airplane using rectenna. 5.8GHz, etc. However, it has not been commercialized due to problems such as human influence and straightness. It applicable to commercial drones, it is necessary to analyze the applicable standards for radio-active or conductive disturbances necessary for the application of radio-frequency power transmission equipment for indu-strial science and medical equipment and household radio power transmission equipment, automobiles and internal com-bustion engine driven equipment, should be avoided. The ISM [3] (Industrial Scientific and Medical) refer to the frequency licensing standards for industrial science and medical, and in order to efficiently charge without affecting the frequency band of the drone, 13.56 MHz part was selected as the result of the study. In case of commercial drone, most of them are controlled by RC radio control, and the frequency for RC used in Korea is 4 frequency bands such as 27 MHz, 40 MHz, 72 MHz and 2.4 GHz.

In the 1980s, the first time the RC market was established in Korea, the 27 MHz frequency band of AM method was approved and the low frequency of AM method was used for a long distance and there is a merit that the obstacle is blocked somewhat in the middle, but there is a disadvantage that the resolution (precision) is not high because the whole transmission / reception is not performed even if there are no obstacles at all and we still use AM 27MHz for RC cars [4].

In the FM system, the FM 40MHz era was held together with the Ranger-II / III series of Taekwang Hitech (Hitec) in the 1990s. The FM system has a much cleaner resolution than the AM system, reception range. In addition to the introduction of Futaba's Japanese import products and high-tech new products, FM 72 MHz (75 MHz for automobiles) was also used. The 72 MHz also has the same advantages as 40 MHz and solved saturation in 40 MHz band.

II. Drone System

A. Configuration and Features

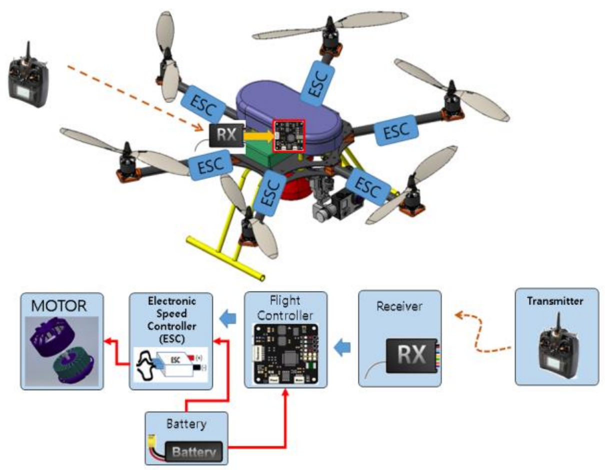


Fig. 1. Simplified structure of Drones.

The drone system consists of a three-axis gyro sensor, a three-axis acceleration sensor, a GPS receiver, and an atmospheric pressure sensor measures the state of the drones in order to stably control the drones, and the flight controller (hereinafter referred to as "FC" the control signal is transmitted to the electronic speed controller (ESC), which is a motor transmission, by reflecting the control algorithm to the received operating signal is shown in the Fig.1. The Electronic Speed Controller (ESC) [5] drives the motor to control the movement of the drones in response to a command from the operator and all power sources are supplied from batteries and the small unmanned aerial vehicles such as drones are mainly powered by batteries, so flight times do not exceed one hour. Therefore, after flying for a certain period of time and returning to the origin of the flight, when flying after the charge, the drone returns to the origin of the flight, the battery is consumed in time and the battery is consumed again while moving again after charging.

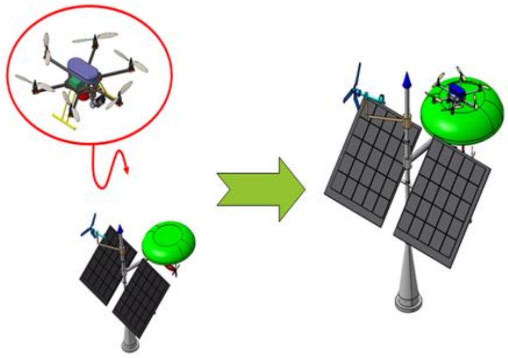
As a result of this problem, the battery is consumed during the flight from the take-off point to the target point rather than the time used for the drone to perform the mission. Therefore, development of the charge system to compensate this is a necessary study for utilizing the drone. There are many kinds of batteries such as Ni-Cd (Nickel-Cadmium), Ni-MH (Nickel-Metal Hydride), Li-Fe (Lithium-Iron) and Li-polymer, but the most suitable battery for Drone or Multi Copter is lithium polymer (LiPo). The polymer battery is labeled 1 Cell or 2S, has a 3.7V voltage per cell, and can be operated in parallel but not in series. The unit of the discharge rate of the battery is denoted by C, 1C means that it can output 1 times of magnetic capacity. If the battery is 15C of 3S 2200mHA, it can output 15 times and can be discharged up to 2200 * 15 = 33A. The charging system is designed as if the voltage drops then the control circuit must be built in to protect the battery. When discharging, heat will be generated. If discharging more than the performance, the battery [6] will heat up a lot and the battery will be damaged.

B. Application of drones

If there is a charge docking facility capable of continuous charging operations in mountainous, terrestrial, and maritime areas, it can play a role in periodic pregnancy. Facebook's Aquila succeeded in flying for three months at a height of 50 km above sea level using solar light, and Korea Institute of Materials (KIMS) succeeded in flying the hydrogen fuel cell drone in 2013 for one hour. However, hybrid drones are still in their infancy, and hydrogen fuel and the like are at risk of explosion and are not suitable for commercialization. In the case of solar drones, space for mission is limited to more than upper class space and is not suitable for various missions. However, the new material, a solid oxide fuel cell, is made of a porous support which is resistant to heat or mechanical impact and has high stability against oxidation or reduction reaction. The porous support is coated with a thin film that minimizes the heat capacity to improve both performance and durability. For the first time in the world, Professor Choi Kyung-man and Professor Kyung-Man Choi announced the development of the Scientific Report in the March issue of Nature Sisters.

Professor Oh Seung-hwan, a pioneer in domestic drones, said, If the primary industry is manufacturing, it is hard to compete with China because it is encroaching the market and it is difficult to compete and if research and technology are superior, 99% is concentrated in military use, and civilian production and research are almost non-existent. We have to invest time, money, and manpower until development for manufacturing, but we are aware of the necessity in recent years and Korean drones that meet the Korean situation and regulations, but there is no manufacturing base, so it will be difficult to industrialize in the future. The US has already developed tertiary and Japan has developed a second industry, the industry is not enough, and now it is at a level that responds to the fashion of drones. Even if the drones industry in Korea is omitted from the first and second industries and progresses to the tertiary industry, the charging system is a very important part due to the operating time of the battery. Even if a new material battery is developed and commercialized, battery charging systems, including operating systems, are at the core of the drones industry as shown in the Fig 2.There is a common disadvantage that the design and specification of commercial drones are different, but their flight time does not exceed 30 minutes. In order to utilize the drones efficiently, it is necessary to supplement the disadvan-tages of running time for continuous mission execution.Currently, there is a method of replacing the battery by retur-ning to the start of flight (home location) or designated char-ging place, but a charging induction system that can be easily charged at a short distance while driving is being actively studied at home and abroad. When the drones are landed on the chargeable transmission unit as described above, a minimum interval is required by the landing unit for attachment and landing of the special purpose image device and the gimbals. It is necessary to utilize the magnetic resonance method in structure, but it has a disadvantage that coil design is difficult. Therefore, this study investigated factors to be considered for high efficiency charging by applying self resonant wireless power transmission to drone battery [7]-[10].

(a)



(b)

Fig. 2. Charging system example of the drones (gap between the drones and the charging transmitter is required) (a) Operation example of charging system, (b) Examplae of charging unit.

a). Drones based information collection system application

The main function of the information gathering system using the drones of the researcher's patent application No. 10-2016-0078446 (reception number 1-1-2016-0606960-08) is to collect information by throwing sensors that collect data using drones And the mechanism of the information collecting device is as follows. It is possible to confirm real-time information of the disaster prevention site and the terror site, and it is possible to replace strategy / tactical and accident plan more accurately and promptly. If a fire or disaster occurs in a ship or a high-rise building, accessibility is difficult and people can not get to the disaster site quickly. And even if you arrive at the disaster site, there is a danger that the person is inaccessible due to the presence of toxic gas or flammable substances inside the site. Therefore, conventionally, there is a problem that it is often late to arrive at a disaster site, and since it is difficult to grasp the inside of the site, there is a problem that fire fighters and the like enter into the disaster site and additional human casualties occur. In this case, collection is possible as follows. Interworking with the unmanned wireless charging system of the proposed integrated system in conjunction with the drones of the information collecting device enables continuous, wide range of information collection, management and monitoring [11].

b). Application of drones based solar panel inspection system

The solar panel inspection system and the inspection method using the drones of the researcher's patent application No. 10-2016-0054648 (reception number 1-1-2016-0427353-05) are used for quick inspection of the solar panel Wide area power plants can also be easily inspected and continuous automatic inspection is possible when using the wireless charging system [12]. According to the application, only the photo-voltaic panel is automatically recognized and matched with the photographed image of the infrared ray and the special camera, so that the user can easily grasp the degraded or failed photovoltaic cell without manually checking the photographed image. In addition, according to the present invention, it is possible to determine whether the solar cell is normal or not through the photographed image, so that it is possible to easily determine whether the solar cell is normal regardless of the distance or time. In addition to, according to the present invention, it is possible to check whether a solar panel is normal by using an unmanned aerial vehicle, and it is possible to confirm whether or not a separate inspection system is installed in an existing power generation system, It is also advantageous that the panel is normal [13].

III. PROPOSED CHARGING SYSTEM FOR DRONE

We designed the receiver antenna inside the drone, the battery charger, and the transmitter antenna of the charging system, and experimented with the ideal shape and position by measuring the structure and interval to minimize the power loss according to the spacing of the antenna. The structure of the drone is designed as follows considering the size of the antenna and the frequency charging time as shown in the table 1 and the proposed charging system has explained in the table 2.

TABLE I. THE SUMMARY OF RESEARCH PAPERS ON POWER TRANSMISSION AND RECEPTION

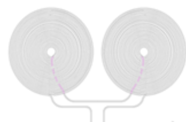
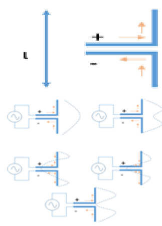
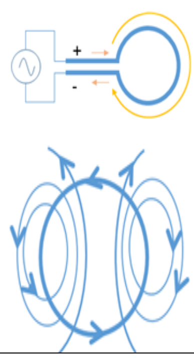
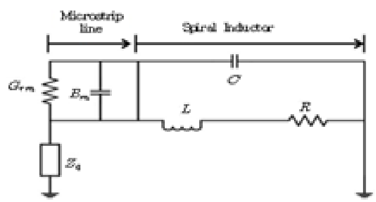
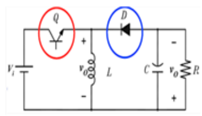
Item	***Radio Frequency Energy Harvesting Using Circular Spiral Inductor Antenna***	***Proposed Method***
Antenna Model		
Antenna classification	**Dipole antenna**  Random path current distribution	**Loop antenna** 
Equivalent circuit		
Z	$z = R + j\left(\omega L - \frac{1}{\omega C}\right) = R + jX$ here $X = \omega L - \frac{1}{\omega C}$	

TABLE II. THE PROPOSED CHARGING SYSTEM

Item	*Application*	*Comparison*
Frequency	13.56MHz	ISM (Industrial Scientific and Medical) Industrial Science Medical frequency license standards, applicable to commercial drone Frequency band
Antenna type		Radio Frequency Energy Harvesting Using Circular Spiral Inductor Antenna. 37.3% increase in the number of articles in the paper
Battery Live part	Lift-up type converter - Selection of lifting / lowering type for the characteristics of wireless power transmission	

The proposed primary antenna consists of two spiral antennas connected in series, and the secondary antenna consists of one short spiral antenna. Here, the alignment of the secondary antenna with the primary antenna is adjusted to maximize the power transmission. Although two spiral antennas are used on the primary side, they are the same as end side short type antennas as the secondary side antennas, and their respective equivalent circuits are the same.

$$z = R + j\left(\omega L - \frac{1}{\omega C}\right) = R + jX \qquad (1)$$

$$\text{here} \quad X = \omega L - \frac{1}{\omega C} \qquad (2)$$

In an antenna that is an RLC serial circuit, the resonance frequency and the Q factor [14]-[15] are respectively obtained from the above equations as follows.

$$\omega_r = \frac{1}{\sqrt{LC}} \qquad (3)$$

$$Q = \frac{\omega_r L}{R} \qquad (4)$$

Here, the total resistance R is the sum of the radiation resistance R_r and the conductive resistance or skin resistance R_s. To have a high Q factor, it means that the coil resistance is small, which is a necessary part of high efficiency power transmission. In order to design the coil of the antenna that meets the frequency band of 13.56 MHz for wireless power transmission, we need to calculate the inductance and capacitance of the resonator.

$$f_r = \frac{1}{2\pi\sqrt{LC}} \qquad (5)$$

The following equations and variables are used in designing the coil.

$$L(mH) = \frac{N^2 A^2}{30A - 11D_i} \qquad (6)$$

$$A = \frac{D_i + N(W + S)}{2} \qquad (7)$$

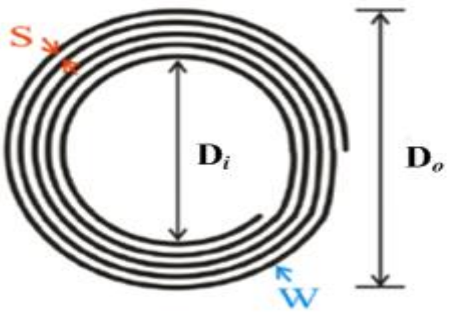


Fig. 3. Spiral coil configuration diagram.

The spiral configuration coil is shown in the Fig.3. It explains where the inner diameter (D_i): total radius of the coil minima, (unit- inches), outer diameter (D_o): overall radius of the outermost coil, (unit- inches), wire diameter (W): spiral coil thickness, (unit- inches), turn spacing(S): distance between the inner coil and outer coil, (unit- inches), and number of turns (N): number of turns of the coil [16]-[19].

Production type and structure are as follows.
The following mathematical analysis is required for energy transfer according to the interval between the primary and secondary transmission / reception antennas as shown in the Fig.4.

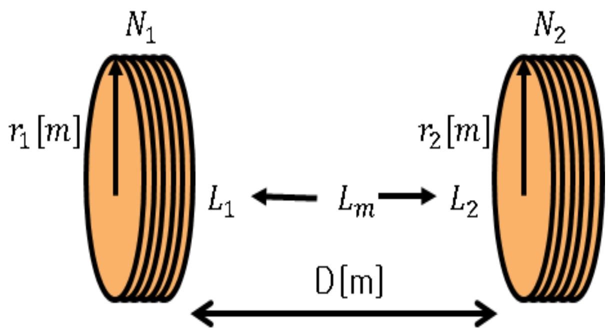


Fig. 4. Electronically Coupled Antenna Configurations for WPT (Wireless Power Transfer).

The resonance-enhanced electromagnetic wave coupling antenna uses L and C for high-efficiency energy transfer. The efficiency Q of the electromagnetic induction is given by the following equations (8) [20]-[21].

$$Q = \frac{\omega_0 L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}} \qquad (8)$$

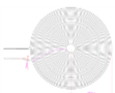
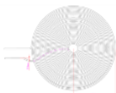
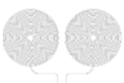
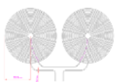
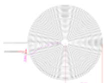
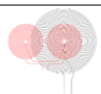
$$k = \frac{\omega L_m}{\sqrt{L_1 L_2}} \qquad (9)$$

$$L_m = \frac{\pi}{4} = \frac{\mu_0 N_1 N_2 (r_1 r_2)^2}{D^3} \qquad (10)$$

The coupling factor k equation (9) between the transmitter and receiver should be considered for very efficient Wireless Power Transfer (WPT).

Where, ω_0: resonant frequency
L : leakage inductance
L_m : magnetizing inductance
L_1 : self-inductance of transmitter
L_2 : self-inductance of receiver
μ_0 : permeability of air
N_1 : the turn number of transmitter coil
N_2 : the turn number of receiver coil
r_1 : radius of transmitter coil
r_2 : radius of receiver coil
D : transmission air-gap distance

TABLE III. THE STRUCTURE AND LAYOUT OF TRANSMITTING AND RECEIVING ANTENNAS

Topic	1st side antenna	2nd side antenna	Disposition	
(a) Identical phenomenon structural	 N: 36 D_0: 95.0mm	 N: 36 D_0: 95.0mm		
(b). 1st side structural suggestion	 N: 18 D_0: 52.5mm × 2 termination: End open type  N: 18 D_0: 52.5mm × 2 termination: End short type	 N: 36 D_0: 95.0mm	End open type	End short type
			 #1	 #1 (Proposed method)
			 #2	 #2
			 #3	 #3

Design draft transmission and reception, the basic circuit of the helical antenna is the equivalent circuit of the open ended type is shown in the Fig.5.

$$\omega_1 = \frac{1}{\sqrt{(L + L_m)C}} \tag{11}$$

$$\omega_2 = \frac{1}{\sqrt{(L - L_m)C}} \tag{12}$$

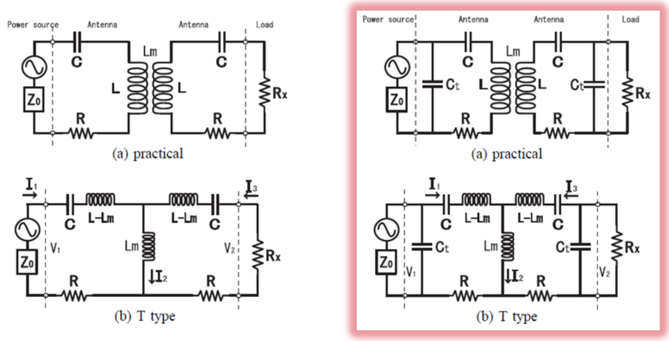


Fig. 5. By parameter optimization, an equivalent circuit with high power transfer efficiency.

Where, Assume $I_1 = I_3$, in case of resonant frequency ω_1: $I_2 = I_1 + I_3 = 2I_1$. The operation is similar to the boost type except that the reference directions of the output voltage is different and switch Q, diode D, LC filter is shown in the Fig.5 and the equivalent circuit of dc-dc converter type as shown in the Fig.6 [22].

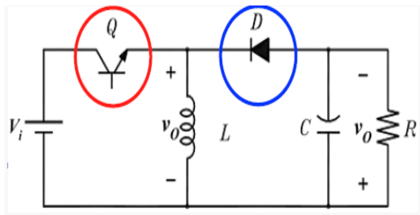


Fig. 6. DC-DC Converter Types.

If the duty ratio is lower than 0.5, the output voltage can be smaller or larger than the input voltage by different arrangements of the switching device, the LC low-pass filter, and the reflux diode.

A. Analysis by inductor current

Switching element (**turn-on**): The Voltage across the inductor is:

$$v_L = V_s = L\frac{d}{dt}i_L \tag{13}$$

The Current variation of the inductor is:

$$(\Delta i_L)_{closed} = \frac{V_s}{L}\cdot D.T \tag{14}$$

$$\frac{d}{dt}i_L = \frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{DT} = \frac{V_s}{L} \tag{15}$$

The current variation of the inductor is calculated by dividing the two equations (14) by (15).
Switching element (**turn-off**): The Voltage across inductor is:

$$v_L = V_0 = L\frac{d}{dt}i_L \tag{16}$$

The Current variation of the inductor is

$$(\Delta i_L)_{open} = \frac{V_o}{L}\cdot(1 - D).T \tag{17}$$

$$\frac{d}{dt}i_L = \frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{(1 - D)T} = \frac{V_o}{L} \tag{18}$$

The current variation of the inductor is calculated by dividing the two equations (17) by (18), during steady state, the change in inductor current during a control period of switching is 0, and the following equation s (19) by (20) is established.

$$\frac{V_s}{L}DT + \frac{V_o}{L}(1 - D)T = 0) \qquad (19)$$

$$(\Delta i_L)_{closed} + (\Delta i_L)_{open} = 0 \qquad (20)$$

The average output voltage is expressed by the following equa tion (21).

$$V_o = -\frac{D}{1 - D}V_s \qquad (21)$$

B. *Analysis by Inductor Voltage*

$$V_L = V_s DT + V_o(1 - D)T) = 0 \qquad (22)$$

The average output voltage is expressed by the following relationship.

$$V_o = -\frac{D}{1 - D}V_s \qquad (23)$$

Since the secondary side of the wireless power transmission is arbitrary voltage, to charge the battery with the output voltage determined according to the input voltage, one switching device with function of step-down type and step-up type or a step-up / step type converter with combination of two switching devices is selected as shown in the Fig.7 [23]-[25].

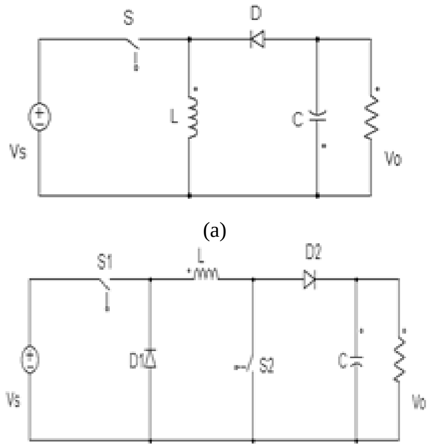


Fig. 7. Lift-up type converter, (a)1 switching , (b)2 switching combinations.

IV. SIMULATION AND EXPERIMENTAL ANALYSIS

A. *Simulation*

(a) Charging system:

For the main device configuration, the rectifier diode module is selected as a high-frequency MOSFET device (SiC semiconductor device) considering the input frequency of 13.56 MHz, and the electrolytic capacitor and the film capacitor (or high-frequency capacitor) are selected when the output capacitor of the diode rectifier is selected. The simulation result of the charging system, charging the received power to the battery is as shown in the Fig.8.

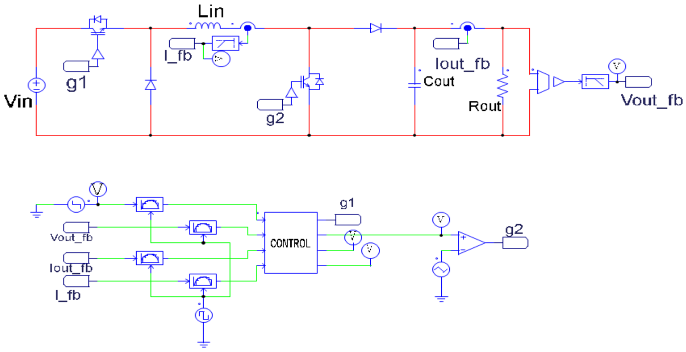


Fig. 8. Battery charging circuit for voltage control.

Simulation condition is set as output 50W. Impedance resistance is set to 12 ohm load. Input voltage 12V Output voltage 16V, 24V control based on inductor 70uH and capacitor 670uF, the control simulation results are as shown in the Fig.9.

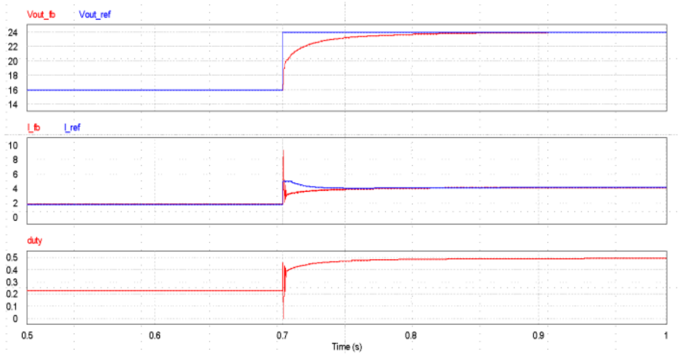


Fig. 9. Battery Charging Circuit Simulation Results.

B. *Components and Description*

The configuration for finding ideal parameters through impedance matching has the form of the following block diagram as shown in the Fig.10 and Fig.11. The RF generator is a power supply of 13.56MHz (as shown in the Fig.12), 100W or more, and requires a SWR meter (standing wave ratio) to measure the power transmission and efficiency of a transmitting and receiving antenna made of a Litz wire material capable of transmitting and receiving high frequencies. The antenna tuna (impedance matching) measures the mapping of the most ideal impedance of the transmitter and receiver. In this study, antenna tuna is not applied and energy is produced by calculation based on calculated values. In order to convert the power to DC, the receiver needs to select the rectifier diode and capper to operate at 13.56 MHz, which improves efficiency.

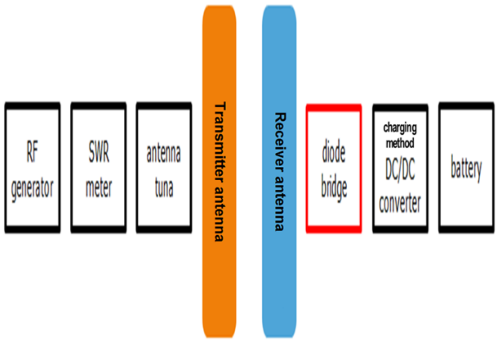


Fig. 10. Configuration for ideal test of magnetic resonance method.

The system configuration for measuring the characteristics of the transceiver and configuring the status is as follows.

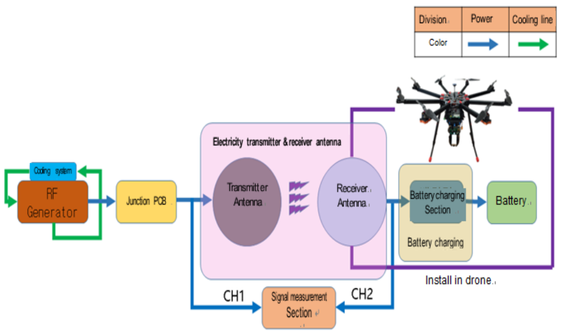


Fig. 11. Antenna Measurement System Configuration.

Fig. 12. RF Generator.

a) Charging system:

1) Design of live part pcb- First production:

The power conversion system consists of a combination of a diode rectifier and a lift-up converter is shown in the Fig.13 and the hard ware production is shown in the Fig.14.

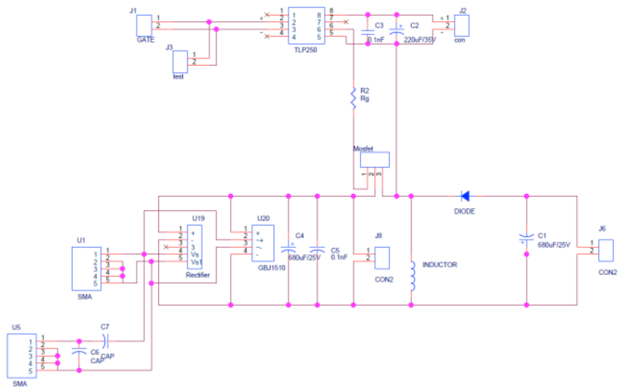
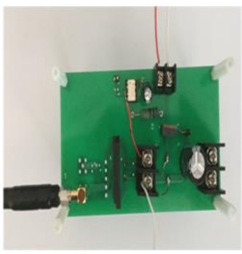
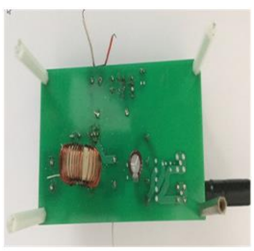


Fig. 13. Circuit configuration of power conversion system from antenna secondary terminal to battery charging terminal.



(a)

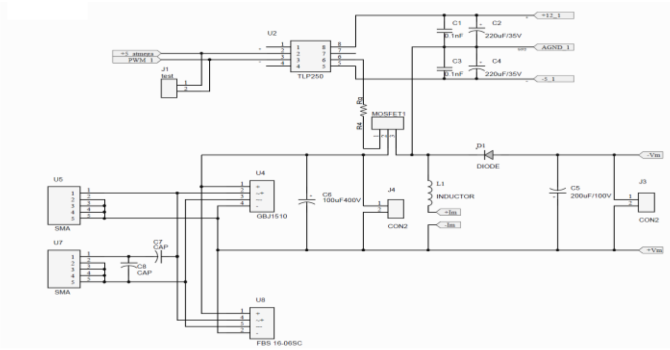


(b)

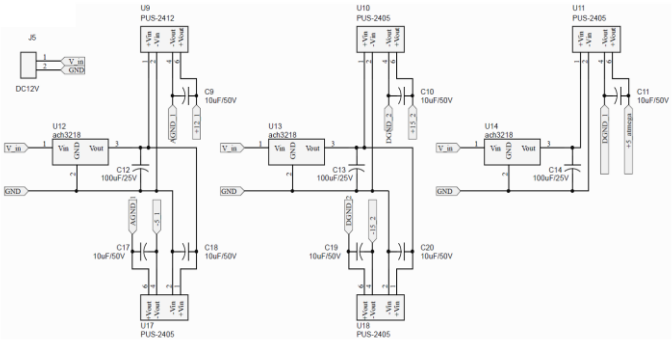
Fig. 14. (a) Hardware production (Top), (b) Hardware production (bottom).

2) Design of live part pcb- Second production:

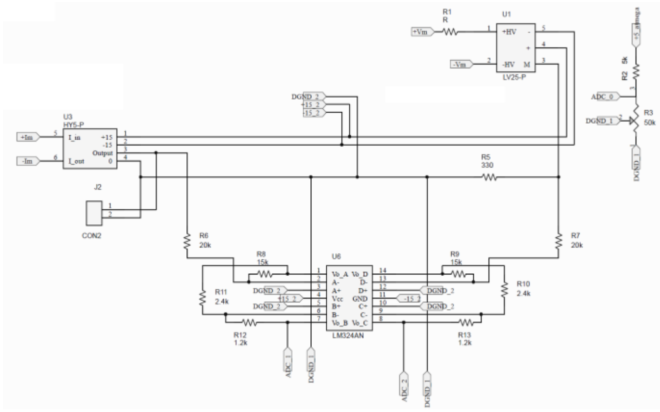
It includes MCU (ATmega128) integrated current and voltage sensors as shown in the Fig.15 , pcb art work,pcb board and MCU as shown in the following figures from Fig.16 to Fig.18.



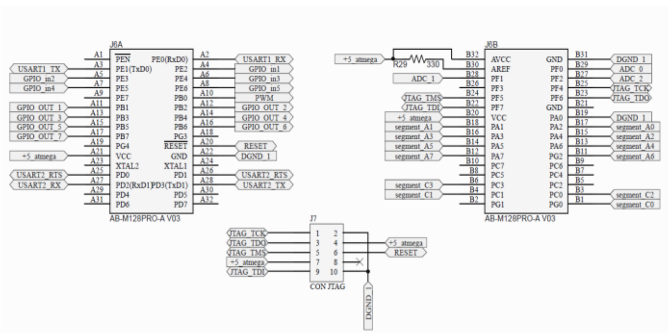
(a)



(b)



(c)



(d)

Fig. 15. PCB circuit diagram (a) main circuit, (b) control power, (c) CT,VT sensor and interfaces (d), MCU and interface.

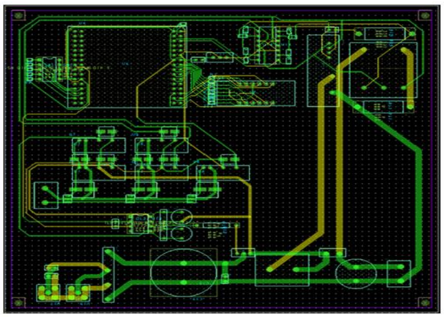


Fig. 16. PCB A/W.

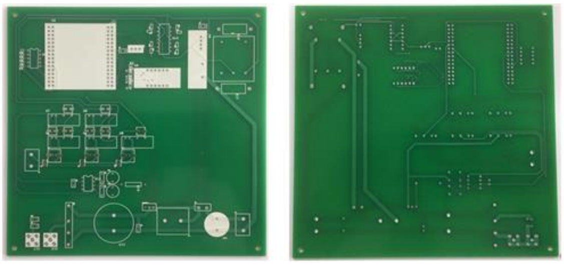


Fig. 17. PCB Board.

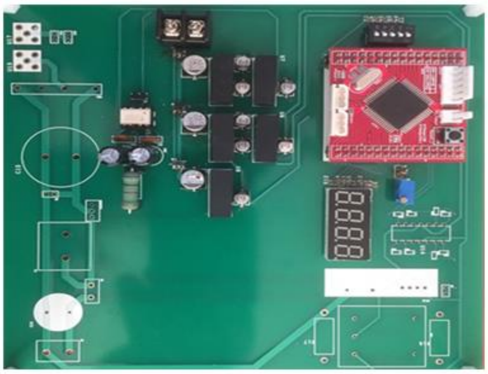


Fig. 18. MCU (ATmega128) integrated pcb production.

C. Experimental Results

a)RF power supply equipment configuration

It is constructed by reflecting power supply equipment and cooling equipment for varying input voltage is shown in the Fig.19.

Fig. 19. RF power supply and equipment Coolant system configuration.

When the arrangements of transmitting and receiving antennas are overlapped, the following test results are shown in the Fig.20. When 50w input power is transmitted, it can be confirmed that the voltage measured at the transmitting or receiving antenna is similarly transmitted.

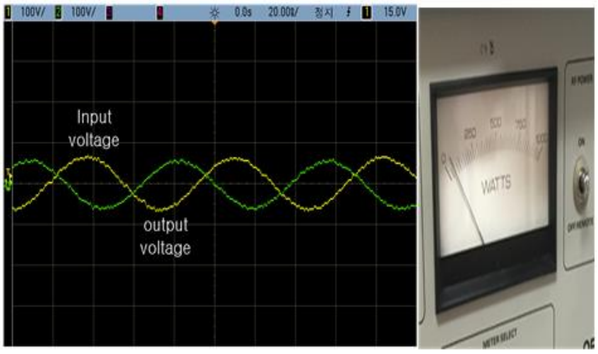


Fig. 20. Output resistance: 75 Ohm / 25 Watt Wattage Resistance Power of RF power: 50 W.

When 100w input power is transmitted, it can be confirmed that the voltage measured at the transmitting or receiving antenna is similarly transmitted as shown in the Fig.21 and when 150w input power is transmitted, it can be confirmed that the voltage measured at the transmitting or receiving antenna is similarly transmitted is shown in the Fig.22.

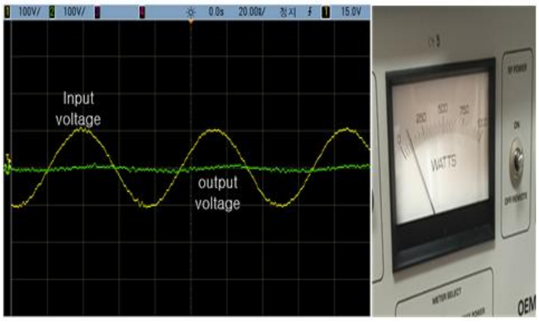


Fig. 21. Output resistance: 75 Ohm / 25 Watt Wattage Resistance Applied power of RF power: 100 W.

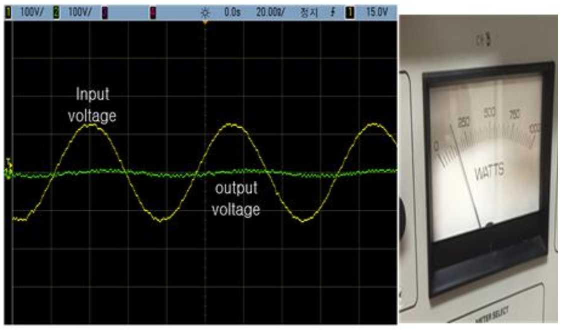


Fig. 22. Output Resistance: 75 Ohm / 25 Watt Wattage Resistance Applied Power of RF Power : 150W.

b) Charging system-part pcb test duty ratio 25%

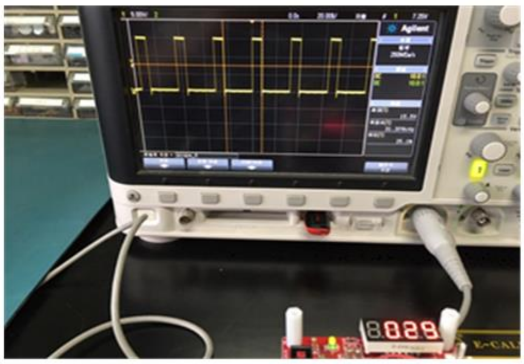


Fig. 23. Atmega128 7-segment duty ratio of 25% and waveform display.

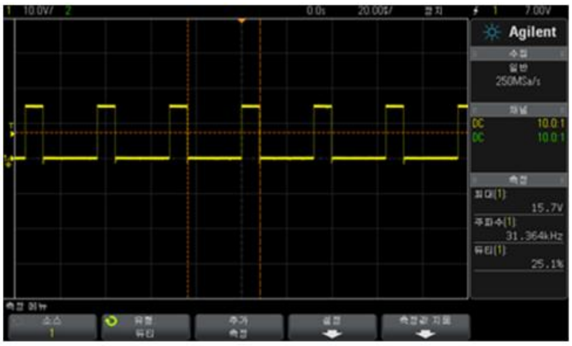


Fig. 24. TLP output waveform.

The charging system-part pcb test duty ratio 25% of the Atmega128 as shown in the Fig.23 and the corresponding output wave form as shown in the Fig.24.

C) Charging Part pcb Test duty ratio 50%

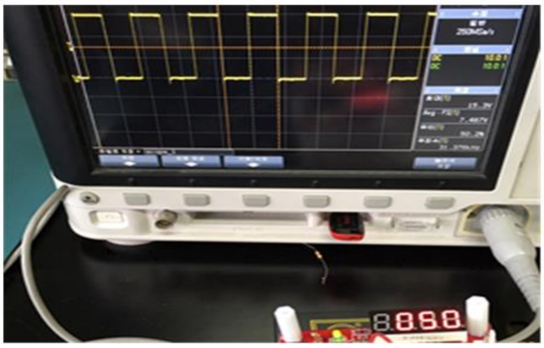


Fig. 25. Atmega128 7-segment duty ratio 50% and waveform display.

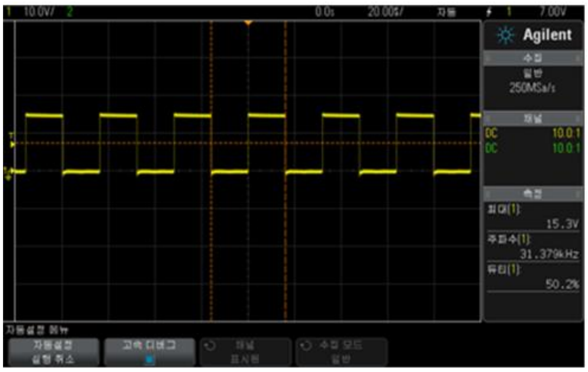


Fig. 26. TLP output waveform.

The charging system-part pcb test duty ratio 50% of the Atmega128 as shown in the Fig.25 and the corresponding output wave form as shown in the Fig.26.

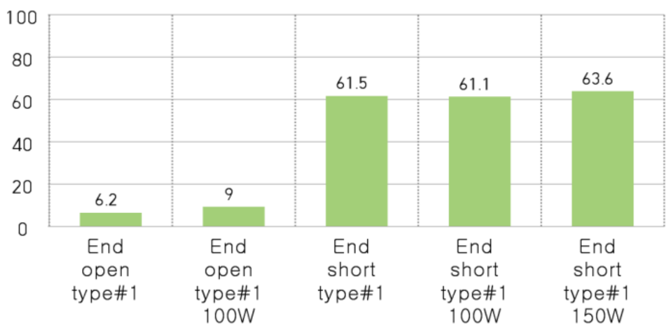


Fig. 27. Input / output ratio at 25mm interval.

It has satified that the experimental results are the best efficiency condition which is structure of end short type and #1 type in the spacing of 25mm is as shown in Fig.27.

CONCLUSION

In the conclusion, as a result of this study, it is found that the efficiency is the highest even if the spacing of 25 mm is maintained between the end short type transmission antenna and the # 1 configuration as shown in the test data, the output voltage transmitted at a distance of 25 mm from the primary and the secondary coil is transmitted by about 60% or more at 100 W, thus enabling the efficient transmission. In addition to, the measured result of the charger system is charging the received voltage to the battery is measured, and the proposed technique is based on the measurement of the output power of the charger, when the charger module is installed in the commercially available drones, and it can be applied to the marine sector that can be applied by applying the charging system is as follows: in the case of the intermittent and surveillance field, it is impossible to take off and land the helicopter below 1000 tons in the Korea. Hence, the testing results of the drone charging system has satisfied.

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