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Proposal of Electric Far Field Suppression Helical Antenna for High Efficiency WPT System

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1. Introduction

Wireless power transfer(WPT) system is very important technology in order to realize a ubiquitous society. This technology is a very effective to provide the energy to a communication device without the power unit. Strongly-coupled WPT system is proposed and experimentally demonstrated in 2007[1]. Principle of the system is able to be considered as two-stage bandpass filter using resonant antennas[2]. High efficiency is obtained in the conditions of high Q value of antenna and appropriate load matching to port impedance[3]. It is necessary to suppress the far-field radiation even though the antenna is a resonant state. Open type helical antenna, which encourages the magnetic coupling,is used on WPT in many cases[1-3] . This antenna also has a dipole mode which generates a far field radiation and the radiation field is a factor in transmission loss. This paper proposes a double-helical antenna to suppress the far-field radiation caused by dipole mode.

2. Antenna Structure and Operating Concept

A proposed structure of WPT antenna is an opposite winding double helix, shown in Figure 1. There are two concentric helical elements which wound in the opposite direction to each inside and outside. A feed point is put on the bottom between two helixes. Figure 2 shows the operating principle of the antenna. At first, the antenna is considered as a dipole in which two elements are folded, and then the antenna is also considered as a helix in which the element is wound the same direction of the current. Therefore electric field becomes the opposite direction but the magnetic field is summed in the vicinity of the antenna. This antenna structure becomes not only miniaturization, but also suppression of the electric far field radiation.

3. Characteristics of the single antenna

Single antenna characteristics were investigated by computer simulation. Figure 3 shows the input impedance characteristics. Real part of input impedance is almost zero because the antenna does not radiate far field and It is almost the same as Lecher wire. E and H near field distribution and direction are shown in Figure 4. State of component E and H are almost the same as the principle of operation Strong magnetic field can be observed towards the same direction as the flow into the helical antenna in Figure 4(a). But electric field in the opposite direction has occurred in the helical antenna in Figure 4(b). The resonant antenna, which does not radiate the far field, is expected to be high WPT efficiency in condition of near field coupling.

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4. WPT Characteristics

The wireless power transmission characteristics were calculated as the antenna spacing of 15cm (1.5 times of the antenna diameter). Figure 5 shows the simulation state of WPT system. The antennas are opposed to each other and feed points (port) are placed on the far side of each other. It has been reported that transmission efficiency is depend on relation between the port impedance and the load impedance[3] . So, a load of 5 ohms was connected to each port in order to meet a matching impedance. The input characteristics of the transmitting antenna (S11) is shown in Figure 6. Impedance matching at about 8 MHz can be taken as consistent with the load of 5 ohms by coupling between the antennas. It has a bimodal shape for the two modes are in close proximity[2,3] . Figure 7 shows the transmission efficiency(S12) at this situation. Maximum efficiency is about 70%. The efficiency is considered possible rise by accurate adjusting the load resistance. Figure 8 shows the magnetic field distribution on coupling condition. Magnetic field has the opposite direction to each other near each antennas, then it is understood that operating mode is odd. Odd mode is a mode that can further suppress the radiated field. On the other hand, it must be converted the input impedance in order to actually use. A stub type impedance transformer is appropriate for this proposed antenna because feed point is on the bottom. Figure 9 shows an example of the stub type impedance transformer.

5. Conclusion

This paper proposed a double-helical antenna to increase the efficiency of wireless power transmission system. The structure is opposite winding double helix and it causes not only miniaturization, but also suppression of the electric far field radiation. Single antenna does not radiate the far field and its input characteristics is almost as Lecher wire. But impedance matching can be taken as consistent by coupling condition between the antennas and WPT efficiency is about 70% when antenna spacing is 1.5 times of the antenna diameter. This paper proposed a new antenna structure of the WPT system for high efficiency. It is expected to be applied to the charging system of electric vehicles.

References

[1] A.Kurs,A.Karalis,R.Moffatt,J.D.Joannopoulos,P.Fisher,M.Solja, “Wireless Power Transfer via Strongly Coupled Magnetic Resonances,”Science.., vol.317, no.5834, pp. 83-86, June 2007.

[2] H Hirayama, T Ozawa, Y Hiraiwa, N Kikuma,”A Consideration of Electro-magnetic-resonant Coupling Mode in Wireless Power Transmission,”IEICE Electronics Express, vol. 6, no. 19, pp.1421-1425, September 2009.

[3] N Inagaki, T Maruchi, Y Okumura, K Fujii,” Propositions of Open Path Type Wireless Power Transfer System and the Characterization by the Improved Equivalent Circuit,”IEICE Trans.Commun.(B) B Vol.J95-B No.4 pp.576-583, April 2012.

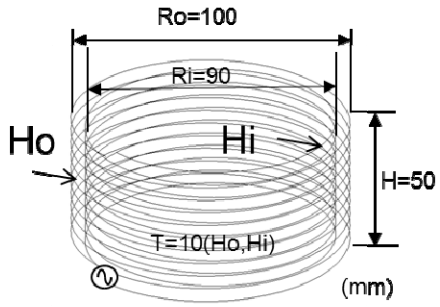
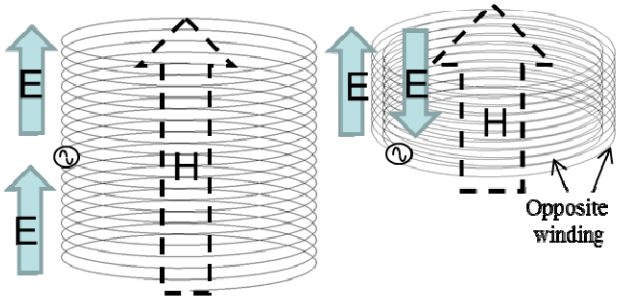
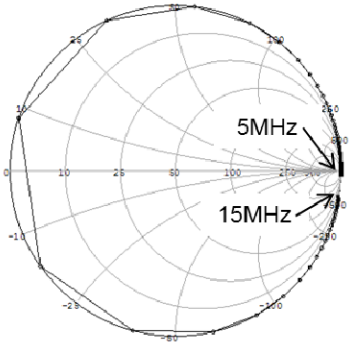


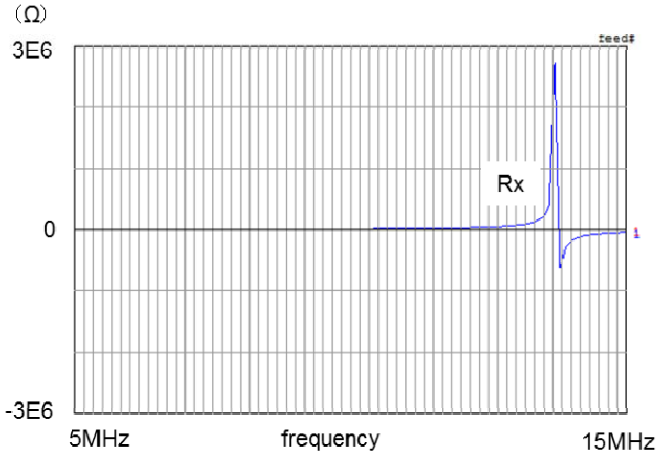
Figure 1:Opposite winding double helix



(a) Simple helix (b) Double helix

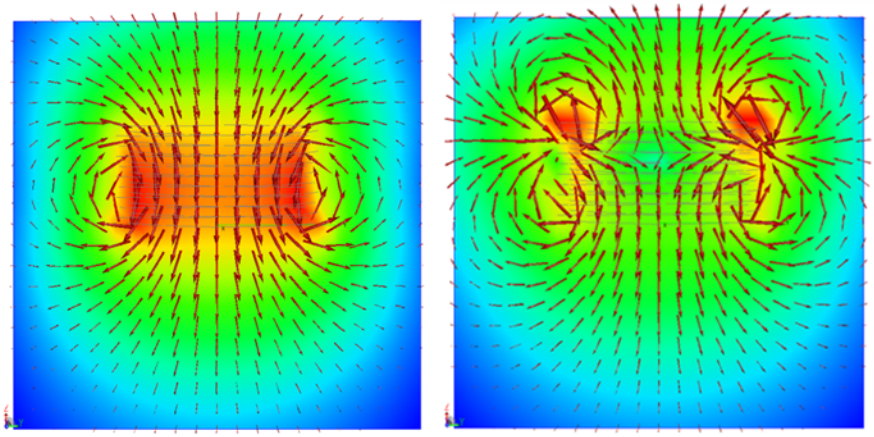
Figure 2:The direction of the electric and magnetic fields





(a) Smith chart (b) Reactance characteristic

Figure 3: Input impedance characteristics



(a) H-field (b) E-field

Figure 4: Near-field distribution

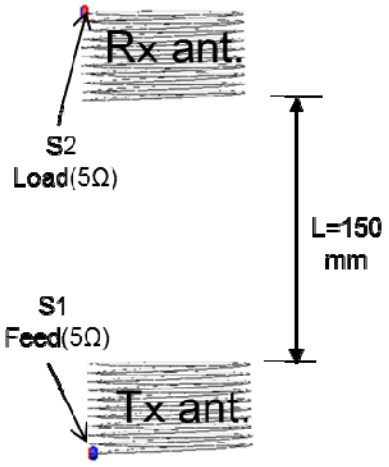


Figure 5: WPT system

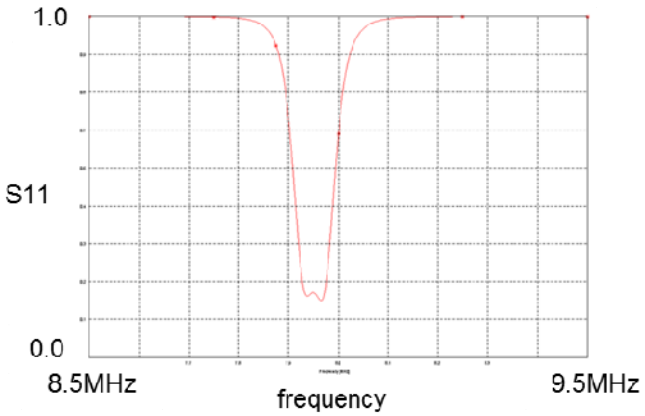


Figure 6: S11 characteristics

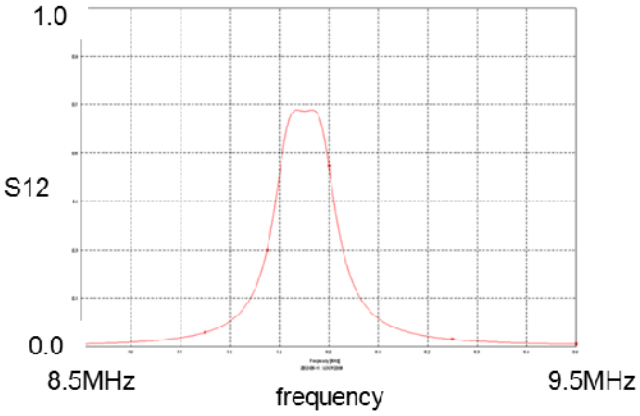


Figure 7: S12 characteristics

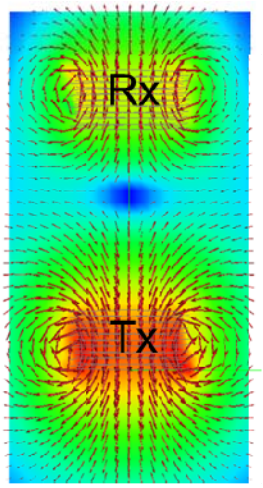


Figure 8: H-field distribution

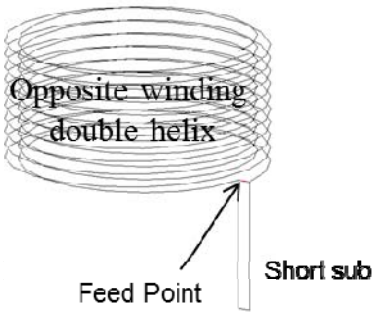


Figure 9: Impedance matching method