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Seoul Chapter

13:40~14:00 [FB-3] Design of Platform-Mounted HF/VHF Antennas Using the Characteristic Modes Theory
Ting-Yen Shih and Nader Behdad (University of Wisconsin, USA)

14:00~14:20 [FB-4] Impedance Prediction of Broadband Antenna Using Neural Network Through Pole Model
Youngwook Kim (California State University, USA)

14:20~14:40 [FB-5] Small-Size Circuit-Defined Antenna for the LTE Tablet Device
Kin-Lu Wong (National Sun Yat-sen University, Taiwan)

14:40~15:00 [FB-6] Non-Foster Circuit Matching of a Near-Field Resonant Parasitic, Electrically Small Antenna
Jeffrey S. Roberts and Richard W. Ziolkowski (University of Arizona, USA)

Coffee Break (Mozart Hall): 15:00~15:20

[FC] Sensor/Wireless Power Transfer with Antennas and Metamaterials (Mozart Hall): 15:20~17:00
Session Chairs: Prof. H. Arai (Yokohama National University, Japan), Prof. B. Lee (Kyunghee University, Korea)

15:20~15:40 [FC-1] Inkjet-printed Meta-material Inspired Passive Antenna Sensor for UHF RFID Systems
Apostolos Georgiadis, Ana Collado (CTTC, Spain), Sangkil Kim, and Manos Tentzeris (Georgia Institute of Technology, USA)

15:40~16:00 [FC-2] Research and Standardization Activities of Wireless Power Transfer via Microwaves at Kyoto University
Naoki Shinohara (Kyoto University, Japan)

16:00~16:20 [FC-3] Wireless Power Transfer Using Coil Arrays
Bingnan Wang (Mitsubishi Electric Research Laboratories, USA)

16:20~16:40 [FC-4] Influence of Metal Plate on Longitudinal Winding Coils in Wireless Power Transfer with Magnetically Coupled Resonance
Hisamichi Mori, Yuya Aoki, Nobuyoshi Kikuma, Hiroshi Hirayama, and Kunio Sakakibara (Nagoya Institute of Technology, Japan)

16:40~17:00 [FC-5] Characterization of Wireless Power Transfer System in Environment Using Equivalent Currents
Yoon Goo Kim and Sangwook Nam (Seoul National University, Korea)

Characterization of Wireless Power Transfer System in Environment Using Equivalent Currents

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***Abstract*—Antennas used in near field wireless power transfer are approximated by canonical minimum scattering antennas. The self- and mutual-impedance can be calculated using the induced EMF method. When the self- and mutual-impedance between two canonical minimum scattering antennas in an environment are calculated using the induced EMF method, current distribution of an original antenna can be replaced by the equivalent currents that generate the same field as the field of the original antenna in transmitting mode.**

Keywords—mutual-impedance; self-impedance; wireless power transfer

I. Introduction

Recently, wireless power transfer using near field have received much attention. In practice, some objects such as ground, wall, and desk exist around wireless power transfer system. In order to investigate the behavior of wireless power transfer system exactly, we should consider objects around system. In this paper, we analyze a coupling between two antennas in an environment to model a wireless power transfer.

The mutual coupling between two antennas can be described by the impedance parameter.

$$V_1 = Z_{11}I_1 + Z_{12}I_2 \tag{1}$$

$$V_2 = Z_{21}I_1 + Z_{22}I_2 \tag{2}$$

where V_n and I_n are voltage and current at the input port of antenna #n (n = 1, 2), respectively. Once we know an impedance parameter, we can calculate the maximum power transfer efficiency and optimum load impedance [1]. In this paper, we investigate the method to calculate the self- and mutual-impedance.

II. Induced EMF Method

One of the method to calculate the input impedance of an antenna and the mutual impedance between two antennas is to use the induced EMF method. The input impedance, Z_n^i, and mutual impedance, Z_{mn}, are as follows [2]

$$Z_n^i = -\frac{1}{(I_n^t)^2}\int_V \mathbf{E}_n^t \cdot \mathbf{J}_n^t dv \tag{3}$$

$$Z_{nm} = -\frac{1}{I_n^t I_m^{on}}\int_V \mathbf{E}_n^t \cdot \mathbf{J}_m^{on} dv \quad (m \neq n) \tag{4}$$

where $\mathbf{J}_n^t$ is the current distribution of antenna #n in transmitting mode in the absence of antenna #m and I_n^t is the current at the input port of antenna #n in this situation. $\mathbf{E}_n^t$ is the electric field generated by transmitting antenna #n with port current of I_n^t in the absence of antenna #m. $\mathbf{J}_m^{on}$ is the current distribution of antenna #m when antenna #n is open-circuited and antenna #m is excited at a input port with current of I_m^{on}. Here n and m are 1 or 2.

An antenna that does not scatter electromagnetic fields when its feed ports are open-circuited is called a canonical minimum scattering antenna. An antenna that is small compared with wavelength can be regarded as a canonical minimum scattering antenna. The antennas used in near field wireless power transfer are small, thus antennas can be modeled as canonical minimum scattering antennas.

When antennas are small compared with wavelength, the current distributions on a transmitting antenna in free space and an environment are the same. In this case, the difference between the input impedance of an antenna in free space and the input impedance of an antenna in an environment can be calculated using the following equation.

$$\Delta Z_n^i = -\frac{1}{(I_n^t)^2}\int_V (\mathbf{E}_n^e - \mathbf{E}_n^f) \cdot \mathbf{J}_n^t dv \tag{5}$$

where $\mathbf{E}_n^f$ is the electric field generated by $\mathbf{J}_n^t$ in free space and $\mathbf{E}_n^e$ is the electric field generated by $\mathbf{J}_n^t$ in an environment.

When antennas are canonical minimum scattering antennas, $\mathbf{J}_m^t = \mathbf{J}_m^{on}$. Therefore, we use the current distribution of transmitting antenna #n in the absence of antenna #m in the calculation of the mutual impedance. Furthermore, the self-impedance (Z_{nn}) for canonical minimum scattering antennas is the same as the input impedance of an isolated antenna in environment.

III. CALULATION OF THE IMPEDANCE PARAMETER USING EQUIVALENT CURRENTS

Another method to calculate the impedance parameter is to use the generalized scattering matrix and spherical waves [3]. In the spherical wave method, impedance parameter between canonical minimum scattering antennas is determined solely from the modal transmitting pattern. Comparing the impedance parameter in terms of the generalized scattering matrix and the impedance parameter expressed as (3) and (4), we can find that self-impedance change and mutual-impedance can be calculated using the equivalent currents that generate the same field as the field of the original antenna in transmitting mode.

If the equivalent currents are composed of point sources, the impedance change and mutual impedance can be calculated using the following equation.

$$\Delta Z_n^i = -\frac{1}{(I_n^t)^2}\left(\sum_{p=1}^{N_e^n}(\mathbf{E}_n^s \cdot \mathbf{e}_p^n) - \sum_{p=1}^{N_m^n}(\mathbf{H}_n^s \cdot j\omega\mu\mathbf{m}_p^n)\right) \quad (6)$$

$$Z_{nm} = -\frac{1}{I_m^t I_n^t}\left(\sum_{p=1}^{N_e^m}(\mathbf{E}_n \cdot \mathbf{e}_p^m) - \sum_{p=1}^{N_m^m}(\mathbf{H}_n \cdot j\omega\mu\mathbf{m}_p^m)\right) \quad (7)$$

where $\mathbf{E}_n$ is the electric field generated by the equivalent sources for antenna #*n*, $\mathbf{H}_n$ is the magnetic field generated by the equivalent sources for antenna #*n*. The superscript '*s*' in (6) denotes the scattered field, i.e. the difference between the fields in environment and free space. I_n^t is current at the input port of the original antenna in transmitting mode. $\mathbf{e}_p^n$ is *p*th electric moment of the equivalent sources for antenna #*n* and $\mathbf{m}_p^n$ is the *p*th magnetic moment of the equivalent sources for antenna #*n*. When the current value and length of the *p*th infinitesimal electric dipole is I and l, respectively, $|\mathbf{e}_p^n| = Il$, and when the current value and area of the *p*th small loop is I and A, respectively, $|\mathbf{m}_p^n| = IA$. The direction of $\mathbf{e}_p^n$ is the same as the direction of electric current and the direction of $\mathbf{m}_p^n$ is perpendicular to the plane of a loop. $\mathbf{e}_p^n$ and $\mathbf{m}_p^n$ generate the same field as the field produced by transmitting antenna #*n* alone when its input port current is I_n^t. N_e^n and N_m^n are the number of electric dipoles and small loops for antenna #*n*, respectively.

Note that the input impedance of an antenna cannot be calculated using the equivalent currents. Before calculating the impedance parameter using equivalent currents, we require the input impedance and electromagnetic fields for an original antenna.

IV. DISCUSSION

The proposed method has several advantages. First, we can find the factors that affect the behavior of wireless power transfer. If we know the factors, we can determine the parameter values of an antenna that make wireless power transfer efficient.

Second, the impedance parameter of a wireless power transfer system can be calculated using only the field pattern and input impedance of an isolated antenna in free space. Therefore we do not need to know the detailed structure of an antenna to determine the behavior of wireless power transfer.

Third, the computation speed is fast, because a few point sources are used. Therefore, we can guess the behavior of wireless power transfer quickly.

REFERENCES

[1] Y. G. Kim and S. Nam, "Spherical mode-based analysis of wireless power transfer between two antennas," IEEE. Trans. Antennas Propag., vol. 62, no. 6, pp. 3054-3063, Jun. 2014.

[2] R. S. Elliott, Antenna theory and design, Prentice-Hall, Englewood Cliffs, 1981.

[3] R. J. Pirkl, "Spherical wave scattering matrix description of antenna coupling in arbitrary environment," IEEE. Trans. Antennas Propag., vol. 60, no. 12, pp. 5654-5662, Dec. 2012.