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Electromagnetic Exposure on Human Phantom Model in Time-Reversed Wireless Power Transmission System

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***Abstract* - In this paper, the electromagnetic exposure effects on human body phantom model is described. The wireless power transmission (WPT) system consisting of transmitting array on the top and bottom of the room and the mobile receiving antenna at the center is operated by using time-reversal (TR) technique. The power transmission efficiency (PTE), the power loss in human body, and the specific absorption rate (SAR) level are simulated for a TR WPT system when human body phantom is considered. In addition, TR array and BF (Beam forming) array are compared in terms of the PTE and the electromagnetic effects on the human body.**

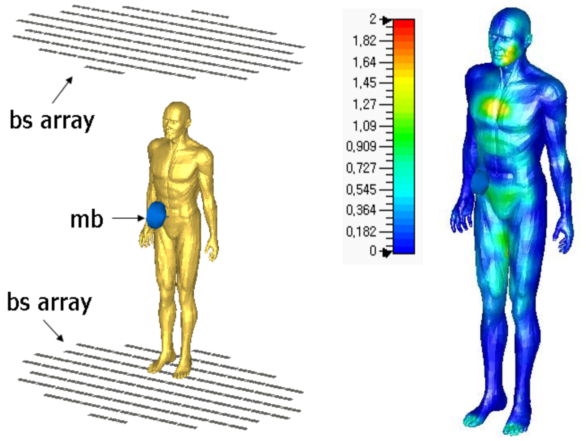
***Index Terms* — Radiative wireless power transfer, Time reversal, EMI/EMC, Electromagnetic exposure, Human phantom**

1. Introduction

In WPT technology, many research have suggested inductive coupling using near field, however, the efficiency drop rapidly with increasing the distance between a receiver and transmitter [1, 2]. For more practical WPT scenario, radiative microwave power transmission has been proposed which gives a freedom in position of mobile devices [3-5]. For radiative WPT applications, safety issue about a human exposure becomes more critical. In radio frequency, the human exposure on electromagnetic wave can have the effect on heating tissues above 10MHz, and stimulate nerve due to contact currents or induced currents below 10MHz [6]. Therefore, it is necessary to study SAR level of a human body in a radiative WPT system in addition to the power transfer performances such as the PTE and the loss in human body. Many research use specific absorption rate (SAR) as a human exposure evaluation especially in mobile devices [7, 8]. In this paper, a study on the human body effect due to electromagnetic field is performed using a homogeneous phantom model. The PTE of the TR WPT system, the power loss in human body, and SAR level are simulated for the typical TR WRT system. Also the performances of the TR WPT and the broadside Beam forming (BF) WPT systems are compared.

2. Simulation and Results

Electromagnetic time-reversal mirror (TRM), which can refocus a wave radiated by a source, is applied to WPT system to improve PTE. We simulated the TRM system in a room (7.5x8.5x2.6 m^3) operating at 1GHz. Two TRM (bs), which is composed of 96 half lambda dipole array distributed uniformly over a rectangular ground plane (2x1.4 m^2), are located on top and bottom walls whereas the mobile (mb) receiver is located at the center of the room as shown in Figure 1(a). The human body homogenous phantom with ε_r=42, σ=1 S/m, ρ=1000 kg/m^3 located at half lambda apart from the receiver is used to calculate PTE, body loss, and 10g average SAR. The PTE is defined as the received power at the mobile over transmitted power at the TRM base, which is equivalent to its vice versa in terms of reciprocity. The PTE of WPT system using TR with the regular half lambda dipole array is 19.6% and



(a) (b)

Fig. 1. (a) Radiative WPT scenario with human phantom. (b) 10g average SAR result of human phantom.

TABLE I
Comparison table of TR array and BF array results

	P_{in} [W]	P_{rec} [W]	PTE [%]	Body loss [W]	SAR [W/kg]
TR array	43.10	5.09	11.83	6.59	2.00
BF array	116.70	0.30	0.26	8.70	2.00

it drops to 11.8% when the human body phantom exist near the receiver. The total power loss in the body phantom is 15.3% of the input power of the TR transmitter. When the input power is 1 W, the 10g average SAR level is found as 0.04641 W/kg. According to IEEE or ICNIRP standard, the 10g SAR limit for the body is 2 W/kg. Within the limit value of SAR, the input power can be increased to 43.1 W at which the TRM WPT system can transfer the power of 5.1 W to the receiver. Fig.1 (b) describes the simulated 10g average SAR of human phantom when TR WPT system is operating. The SAR level is particularly high around chest and cheeks of human phantom. The PTE, the power loss in the body, and the SAR level of WPT system with TR array is compared with a broadside beam forming (BF) array in Table 1. The results show that PTE of TR array is 46 times higher than BF array when the SAR level is maximum of IEEE regulation. In addition, the body loss of TR array scheme is 75.7% of BF array while more power can be transferred to mobile receiver antenna.

3. Conclusion

The electromagnetic effect on the human body phantom in TR WPT system is described. The PTE of TR WPT system without the human body phantom is 19.6% and it drops to 11.8% when the human body phantom exists near the receiver. The total power loss in the body phantom is 15.3% of the input power of the TR transmitter. According to the maximum SAR level of IEEE standard, which is 2 W/kg, receiving power is up to 5.1 W while transmitting power is 43.1 W when TR array is used. In addition, the WPT system using TR array is compared with conventional BF array in the room. The results describes that the TR array shows superior performance than BF array in terms of PTE, power loss in body and SAR level.

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