Improvement of a ubiquitous power source

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Abstract

Ubiquitous power source can wirelessly transmit power anywhere in a space. In order to realize this system, we have examined an efficient power transmission system which sends power to necessary places only based on direction of arrival measurement. A simple in-phase transmission array is proposed and evaluated as useful and efficient. This system can send power to multiple receivers. In order to send the power to only necessary points, a pilot signal is sent from a receiver. A low power system is manufactured and evaluated.

1. Introduction

The electric power to IT apparatus is generally supplied by a battery. It has however problems like the standby power for a charger, increase of the environmental impact by through-away batteries, chargers different from apparatus to apparatus, and the over-production more than needed. As a result, "ubiquitous power source (UPS)," which supplies electric power by radio, were proposed. UPS can realize a battery-less drive and a codeless charge for an IT apparatus in a place filled with the electromagnetic waves below the intensity of safety standards. As shown in Fig. 1 (a), in a certain room was "radio electric power space", basic experiments were conducted [1]. In this experiment, more than necessary electric power was needed since all the space was filled with electromagnetic waves. We propose an improved system which can send energy to only apparatus which need power as shown in Fig. 1 (b) to save energy towards utilization of UPS.

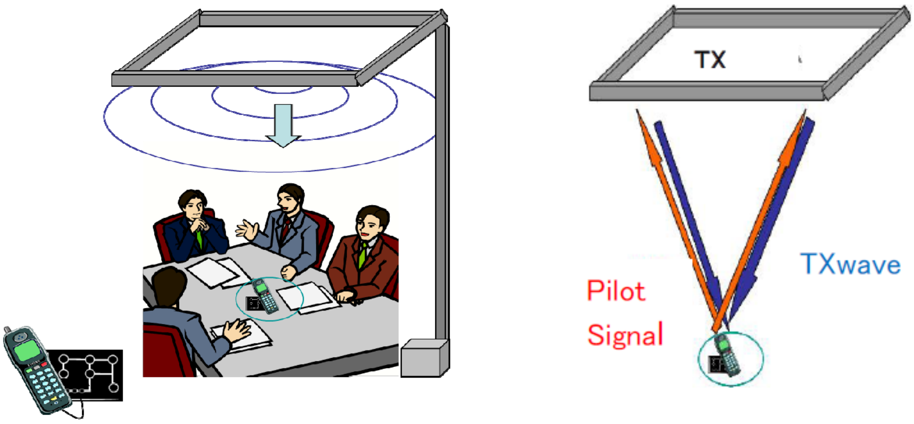

Figure 1 (a) Concept of ubiquitous power source (b) revised UPS.

2. Outline of Radio Electric Power Space [1]

Radio electric power space was designed mainly with the following plans.

- Frequency is in an ISM band. (2.45GHz or 5.8GHz)
- In a range where people can approach, power density is as uniform as possible at less than 1 mW/cm^2 (Radiofrequency Radiation Protection Guidelines) .
- Size of the room 3.8mx4.5mx3m (a conference room with 30dB shield, SPSLAB 1F, Kyoto University).

In the basic experiment, a 2.45-GHz commercial magnetron rated 800W CW and waveguide slot antennas in the ceiling were used as a power transmission system. It was confirmed that uniform power-flux-density distribution is obtained at

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each place of the room when the electric power of 150W was transmitted from the magnetron and the characteristics evaluation experiment was conducted. The peak value of the power flux density of 1.35 mW/cm2 when averaged over the area where a human body occupies. It does not seem that such intensity could cause a practical problem although the maximum level in the guide line is 1mW/cm2. Charging a mobile phone was tried.

3. Improved System

A system newly proposed by this research is the one which arranges many antennas on the ceiling and transmits power by only selected antennas near the place which needs power transmission. Since it is possible to concentrate the transmitted power to one place and not transmit power into other unnecessary portions, the necessary transmission power can be reduced remarkably. Since power transmission antennas changes as the position of a power receiving antenna changes in this system, it is possible to receive similar electric power below all the transmitting antennas. Moreover, when transmitting electricity to multiple places, correspondence is also possible by performing power transmission from the antennas near each receiver. This power transmission system needs markedly less power than the radio electric power space, and a new ubiquitous electric power system with little power dissipation can be realized.

4 In-Phase Power Transmission Simulation

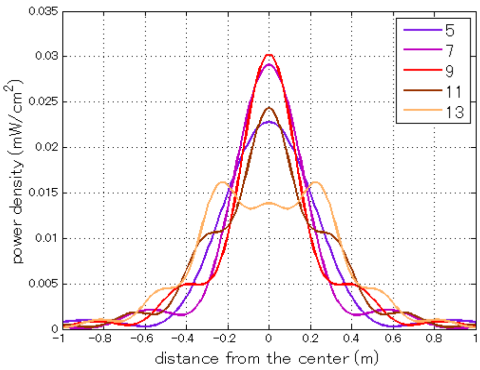


Fig. 2 Power density distribution for various numbers of antennas.

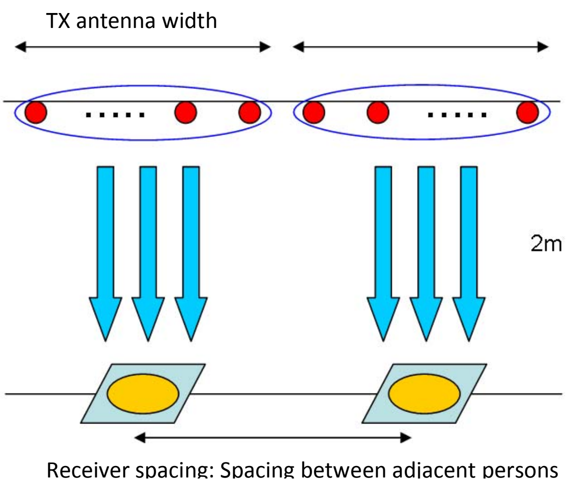


Fig. 3 Model on transmission to multiple receivers.

The first simulation is in-phase transmission from the transmitting antennas at the microwave frequency of 2.45 GHz with the spacing of 0.7 wavelength (about 8.6 cm). The radiation directivity of a patch antenna is taken into account. The power flux density distribution is calculated in the distance of 2m from the power transmission antenna. In order to save transmission power, the microwave power is sent from only antennas near the receiving antenna. The power flux density averaged over 30 cm is evaluated since we assume one dimensional array and the receiving antenna array with a size of A4 (21cm x 30cm). The total electric power emitted from antennas is set to 1W as a reference level. The result is shown in Fig. 2. The power-flux-density distributions are shown for numbers of antennas as a parameter. The figure indicates that the transmitted power is concentrated in the center as the number of antennas increases from 5 to 9. If the number of transmission antennas is 7 or 9, power flux density becomes largest. On the other hand, the number of transmission antennas is more than 11, the peak power flux density does not increase. When the number of power transmission antennas is more than 9, the phase difference by the distances between the receiving antennas from a central antenna and that from an edge antenna exceeds $\pi/2$ and electric fields cancel each other. The total electric power emitted from the antennas should be set to 40W in order to obtain 1mW/cm2 of the average power flux density over the width of 30 cm in this model.

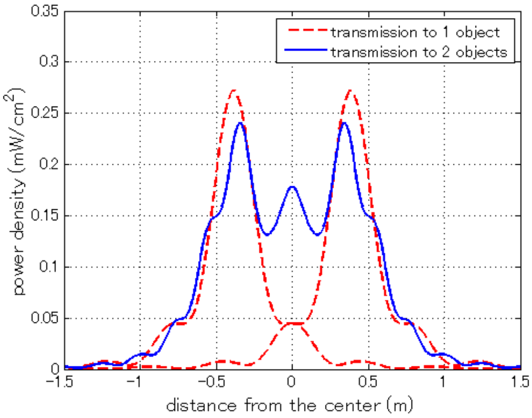
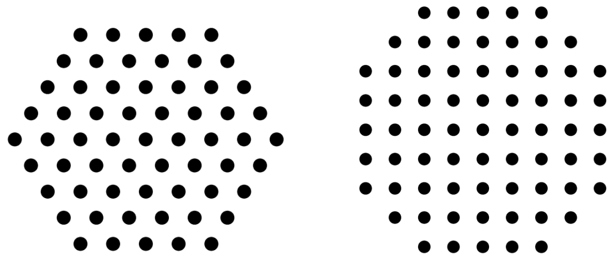


Fig. 4 Power density distribution under in-phase transmission from 9 antennas to 1 or 2 objects.

In order to use this system as a ubiquitous power supply, power transmission to two or more objects must be possible. Fig. 3 shows a model of this simulation. When transmitting power to two or more objects, the spacing between power-receiving objects must be larger than the width of the power transmission antennas. We have calculated under the assumption that the distance between the centers of the adjacent receiving arrays must be larger than the size of the transmitting antennas for one object. The power density distribution transmitted from 9 antennas to one or two objects are shown in Fig. 4. The solid line of a figure is distribution of power flux density when electricity is transmitted simultaneously from adjacent antennas, and the dotted line expresses distribution of the power flux density at the time of transmitting electricity only to one of the two. We assume the distance between the centers of receiving antennas shortest, which is about 80 cm. This distance is reasonable since this is longer than the distance between the centers of adjacent persons who use their notebook PCs on a disk. In such situation, if the average power over 30 cm is considered, 85% of the power transmitted to one object. It should be noted that the in-phase transmission can transmit power to multiple objects by a little less power than that for one object. This system is satisfactory and practical without complex phase control or multiple-beam forming.

5. Power Transmission Simulation by a Planar Antenna

Power transmission with a planar array antenna of a two-dimensional arrangement is simulated. The most efficient number of the transmitting antennas is 9 when all the antennas are in phase and in a straight line array. Therefore, 81 (= 9 × 9) elements of power transmission antennas are arranged in a square array. In order to obtain the average value of the electric power density of 1mW/cm2 over a receiver array with the A4 size, the energy radiated from the power transmission antennas is 85mW per element and 6.9W in total. When the array is arranged in hexagon or octagon as shown in Figs. 5(a) and (b), the average powers and are 92mW for 61 elements and 88mW for 69 elements and 5.6W and 6.1W in total. Figure 6 shows the power density distribution in 2 dimensions. The rectangle at the center shows the A4 size. From those results, the best efficiency is obtained for the octagon array in the square arrangement and for the hexagon array in the triangle arrangement. The total transmission power is about 6W and that for each antenna element becomes about 90mW in those arrays. The total power over the A4 size is 600mW at the safe level. These results indicates that the total of the electric power that to be radiated from the antenna when electricity was transmitted in the room of 3.8m×4.5m×3m was about 150W in the original wireless electric power space system. That of the present system is only about 6W and saved by 96%.



(a) Hexagon (b) Octagon

Fig. 5 Antenna element allocation for (a) Hexagon and (b) Octagon.

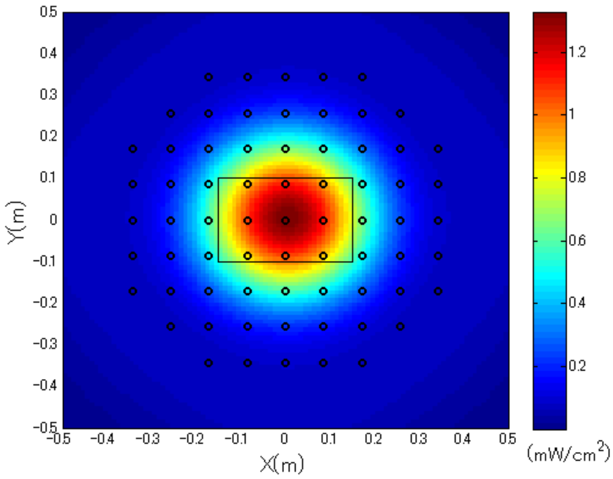


Fig. 6 Power density distribution by the octagon array

6. Receiver Position Estimation

A position estimating system which sends a pilot signal is manufactured and evaluated. The distance between the two places where the direction of arrival is estimated is 60 cm. The error of position estimation is very small. The pilot signal transmitter consumed only 4.8mW. Although there was an error about 1 degree in direction-of-arrival estimation, the error of position presumption was less than 1 cm. Since the error is much less than the length of the half of a power transmission antenna with the practical power transmission antennas.

7. Conclusion

The simulation about power transmission was performed and it verified about the examination about a concrete power transmission system, and the effect of power-saving. In 2-dimensional array antennas, as a result of performing the simulation at the time of making the output from an antenna in phase, it turned out that the electric power emitted from an antenna can be reduced to 6W, and the radiation from each antenna element is also set to about 90 mW. Thereby as compared with the conventional radio electric power space system [1], a 95% reduction of electric power was possible. The necessary power for the receiver to send a pilot signal is as low as 4.8 mW.

References

1. Naoki Shinohara, Tomohiko Mitani, and Hiroshi Matsumoto, Study on Ubiquitous Power Source with Microwave Power Transmission, URSI GA05, C07.5(01145).pdf, India, 2005