Study on Ubiquitous Power Source with Microwave Power Transmission

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ABSTRACT

We propose a ubiquitous power source (UPS) with microwave power transmission (MPT) for ubiquitous information society. The MPT means wireless power transmission via microwave, such as 2.45 GHz-band and 5.8 GHz-band as ISM band. We use only carrier of the microwave to transmit the power. We bring a receiving system, rectenna, instead of heavy battery. Design of the ubiquitous power source system is limited a safety level of microwave to human beings because the concept is “power source in every time and in everywhere”. The safety level is under 1 mW/cm^2 for continuous all over the human body. Against the safety level, we would like to get higher power from the microwave.

We have designed the MPT system to satisfy the both requirements with help of numerical calculation and have carried out the experiments in the shielded room. For the experiments, we have selected a magnetron and slotted antenna array for a transmitting system of the UPS because of economical reason. We have developed new rectenna array, receiving system for the MPT, with higher efficiency under 1 mW/cm^2 microwave input. We adopted a dual-polarized antenna for the rectenna in order to catch the microwave power from everywhere. We have succeeded to charge a mobile phone only with microwave power in everywhere in the ubiquitous power source room.

INTRODUCTION

Weak point of future ubiquitous information society is power source. We can get information in every time and in everywhere in the ubiquitous information society. However, all information equipments like note PC, mobile phone, and PDA, need battery and the other power source. The power source restraints the time and the place of the ubiquitous information society. So we propose a ubiquitous power source (UPS) with microwave power transmission (MPT) in order to extend the ubiquitous information society. Image of the UPS is shown in Fig.1. We bring a receiving system, rectenna, instead of heavy battery.

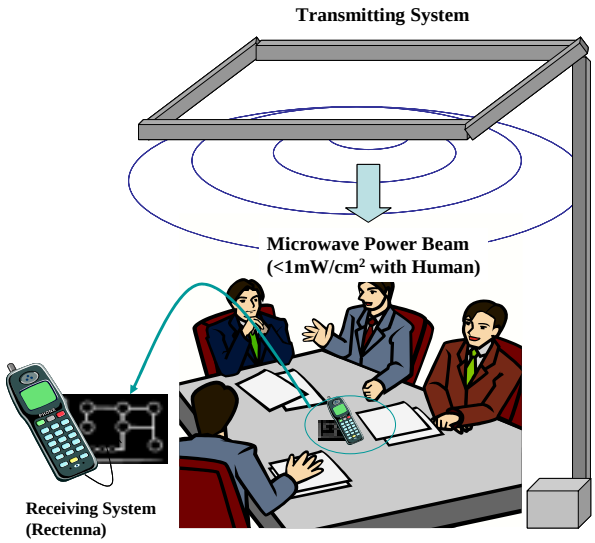

Fig.1 Concept of Ubiquitous Power Source

The MPT means wireless power transmission via microwave, such as 2.45 GHz-band and 5.8 GHz-band as ISM band. We use only carrier of the microwave to transmit the power. Recent commercial application of the MPT is RF-ID system. We have a long history of the MPT research. Original idea of the wireless power transmission via radio wave was proposed by Nicola Tesla in the early 1900’s[1]. During over a hundred years, there were many laboratory experiments and field experiments of the MPT in the world[2][3]. Most famous application is a space solar power satellite (SPS). The SPS is a large solar power station over 1GW in geostationary orbit and the generated electric power is transmitted from the SPS to Earth by way of radio waves. Many research group are designing various SPS in U.S.A.[4], in Japan[5][6], and in Europe[7].

Our research group of Kyoto University has developed many new MPT systems, for example, a phase and amplitude controlled magnetron[8] and high efficient rectenna, rectifying antenna[9]. We apply the MPT system for the ubiquitous power source system.

DESINGN OF UBIQUITOUS POWER SOURCE EXPERIMENT

In order to carry out laboratory experiment of the UPS, we set a design target as follows ;

(1) Frequency = in ISM Band （ex. 2.45GHz）
(2) Input Electric Power < 1kW (Because < 3 kW for common house)
(3) Keep Safety Level (<1mW/cm^2)[10], Power Density = Approximately Uniform
(4) Economical System for promotion

We chose the MPT system with 2.45GHzCW magnetron and waveguide slotted antenna for the experiment. If we keep the safety level 1mW/cm^2, power density of the UPS is smaller than that of solar cell which is approximately 10 mW/cm^2 in fine day with 10% efficiency solar cells. However, in night or in rainy day, the power density of the solar cell is much smaller than that of the UPS. We consider that the UPS is better system to generate stable electric power in every condition than the solar cell.

We also researched user applications of the UPS. Unfortunately, required power of note PC, PDA, and Personal Liquid Crystal TV are over watt and it is difficult to generate enough power from the UPS system under the condition of 1mW/cm^2 and limited receive antenna area. However, mobile phone in waiting mode, MP3 player, and IC recorder only require 10 – 100 mW and it is easy to generate enough power from the UPS system under the condition of 1mW/cm^2 and limited receive antenna area. So our first experimental target is decided to charge a mobile phone with the UPS system.

ESTIMATION OF POWER DENSITY LEVEL BY FDTD METHOD

At first, we have simulated the microwave power density in the shielded room by FDTD method. The size of the room is 3.0 (h) x 5.8 x 4.3 m and is shielded (Fig.2). From the antennas in edges of the ceiling, we emit the 2.45 GHzCW microwave. If we do not consider the power loss by air and the wall with conductor, the emitted microwave power will be accumulated and will be finally diffused. Therefore, we assume the power loss by air and the wall with conductor and estimate validity of the simulation. We conclude the simulation with loss leads valid result.

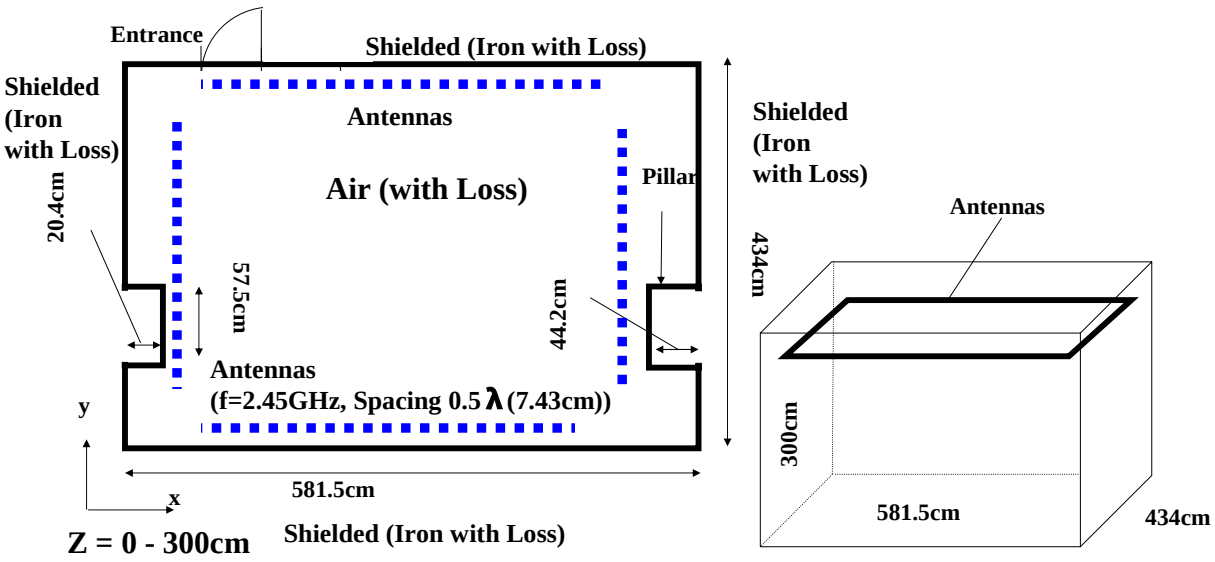

Fig.2 Simulation field for the UPS experiment with FDTD method

We have confirmed that approximate uniform power density was realized. The calculated results are shown in Fig.3. We have adjusted the total emitted microwave power in the condition that maximum power density is under 1mW/cm^2. As a result, we have estimated that the microwave power which satisfied 1 mW/cm^2 in everywhere in the shielded room was under 150W.

EEPERIMENTS IN SHIELDED ROOM

We also have carried out experiments of the UPS in order to charge a mobile phone. The experimental setup is shown in Fig.4. We use one long waveguide with slotted antennas in edges of the ceiling. The VSWR of the long waveguide with slotted antennas is approximately 1.3 at 2.45 GHz. The microwave power level in the room has been measured with 150W microwave emission (Fig.5). Experimental Results are close to simulation results with production error.

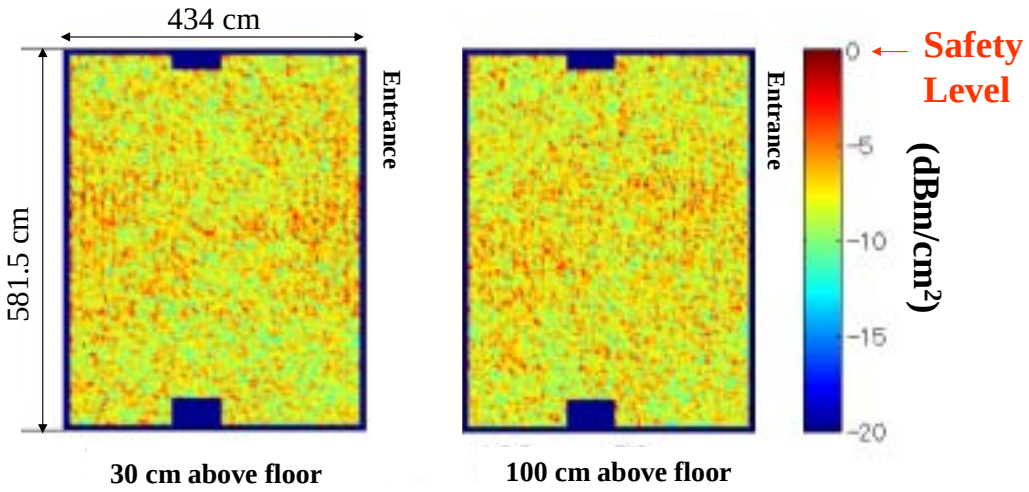

Fig.3 Power Density in the shielded room by FDTD simulation

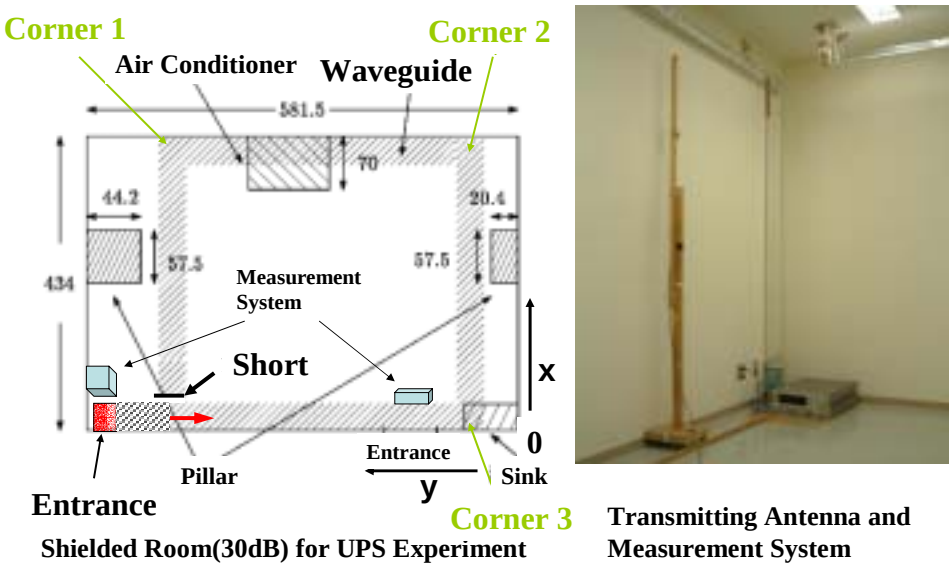

Fig.4 Experimental setup of the UPS

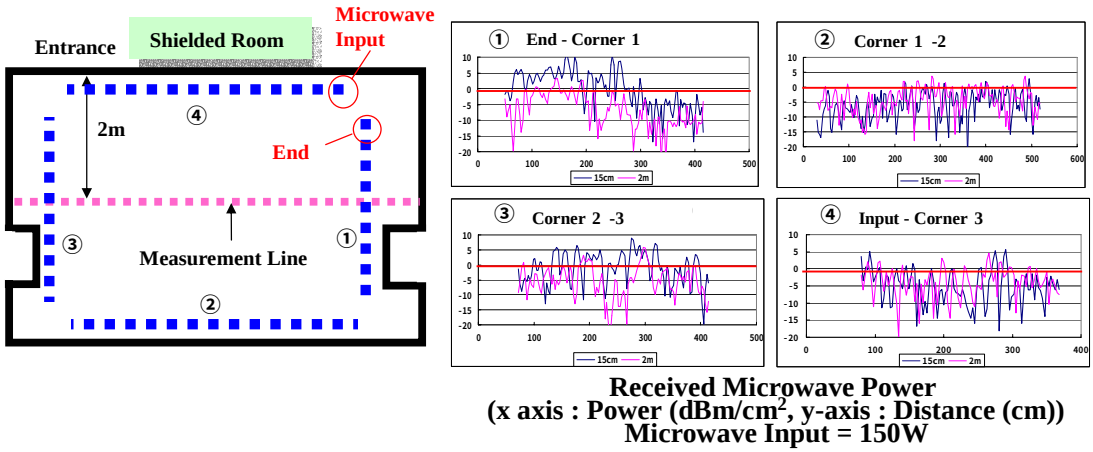

Fig.5 Measured microwave power density in the room with 150W microwave emission

Under the condition, we have succeeded to charge the mobile phone with 9 rectennas with dual polarized CMSA and with step-up transformer as shown in Fig.6.

SUMMERY AND FUTURE WORKS

We can charge the mobile phone with the UPS system. We plan the UPS will be set in the limited space like a present wireless LAN in the first step. In the next step, we would like to extend the UPS and would like to realize the UPS in everywhere which includes outside like a mobile phone system.

We have to consider the interference to communication system, especially, the system in the same frequency band because it is difficult to put the eliminate filter if we use the same frequency band for the UPS and the communication system. We estimated and carried out the interference from the UPS to wireless LAN in 2.45GHz band. As a result, the UPS and the wireless LAN could coexist if the frequencies are enough separated within the ISM band. We have to continue to research the interference.

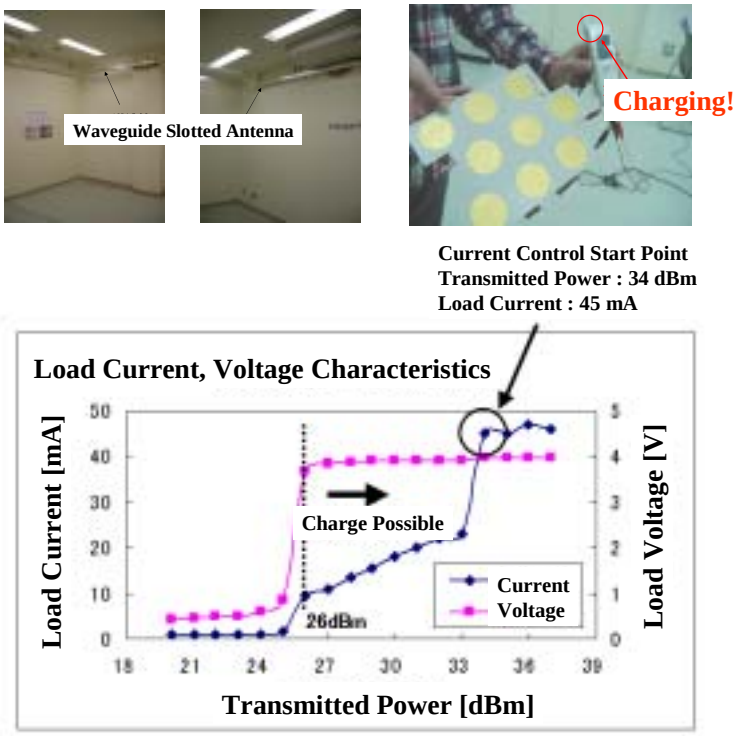

Fig.6 Experimental result of charging mobile phone with UPS system

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