
 ABSTRACTS (PH D THESIS)

Advanced Beam Forming by Synthesizing Spherical Waves For Progressive Microwave Power Transmission

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Development of various beam electromagnetic field by synthesizing spherical waves is established to deepen microwave power transmission technology. For the realization of space-based solar power system with large-scale microwave power transmission, early social implementation of terrestrial systems with a short distance and continuous development in the market are important. Progressive microwave power transmission technology for suppressing the interference with other wireless systems and the effect for the human body is required especially for the terrestrial systems. To deal with the problem, we investigate the ideal electromagnetic fields designed by the set of spherical waves, which are basis functions of Maxwell's equation. Two tasks for the further technological progress are focused in this study: miniaturization of the receiving antenna for the ubiquitous power source, and minimization of energy leakage for beam-type microwave power transmission.

An operation principle of a high-directivity radiation phenomenon from the point source is clarified. It is well known the radiation from multipoles at the origin, which can be considered as the limit of small antennas, is the spherical wave. The high-directivity radiation phenomenon can be obtained by involving spherical waves of the different order. We derive the directivity of the synthesized spherical wave from the uncertainty relation of angular momentum and angle. It is also shown that the intrinsic wave source is assumed to exist on the surface of the cutoff region by the estimation of the effective aperture of the synthesized spherical wave (Fig.1). Moreover, we discover that multipoles can be replaced by a spherical dielectric resonator with finite size. By using a dielectric resonator that is smaller than the cutoff region, it is possible to realize a compact radiation system with the larger effective aperture than the physical cross-section. A design method for degenerating all spherical wave modes of the spherical dielectric resonator with a multilayered structure is developed (Fig.2). Degeneration of TE₁₁-mode and TM₁₁-mode is enabled by the spherical dielectric resonator structure with a center conductor. Degeneration of TE-mode and TM-mode of higher order is enabled by the spherical dielectric resonator structure with anisotropic permittivity. We also develop an evaluation method and equipment for spherical symmetry of the dielectric constant of a fabricated spherical dielectric resonator. The multilayered spherical dielectric resonator gives a basic structure of the compact receiving antenna for the ubiquitous power source.

An effective design method of low-leakage microwave beam by synthesizing spherical wave is developed. Beam electromagnetic field is optimized to the minimum leakage for the input of the array antenna element. The beam electromagnetic field is obtained by combining outgoing and incoming spherical waves with the same amplitude. It is shown that a strict Gaussian beam without paraxial approximation is synthesized by spherical waves when side lobes of the beam are minimized. The design formula of the optimum beam waist radius according to the transmission distance is also derived. The effective range where the edge level can estimate the leakage power of the system is investigated by the simulation. Moreover, we propose a single-frequency retrodirective system using a beam pilot signal with the low-leakage beam design. The multipath propagation caused by the ground or the sea surface of the terrestrial microwave power transmission can be eliminated by using the beam pilot signal. It is shown that the retrodirective system operates stably even when the atmospheric refractive index has a spatial distribution. We also develop a dual-mode dielectric resonator antenna element ideally with infinitesimal dipole characteristics. The dual-mode dielectric resonator antenna is proposed as a common array antenna element for the beam pilot signal and microwave power. This involves a cross-shaped hemispherical dielectric resonator structure, and an isolation level exceeding 60 dB has been experimentally measured between the orthogonal ports of the fabricated antenna. The single-frequency retrodirective system improves the reliability of the terrestrial microwave power transmission.

The comprehensive studies from the clarification of the principle for the compact antenna to the proposal of the terrestrial microwave power transmission system are pursued. This research is hoped to contribute to

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the early social implementation of progressive microwave power transmission and the realization of the space-based solar power station.

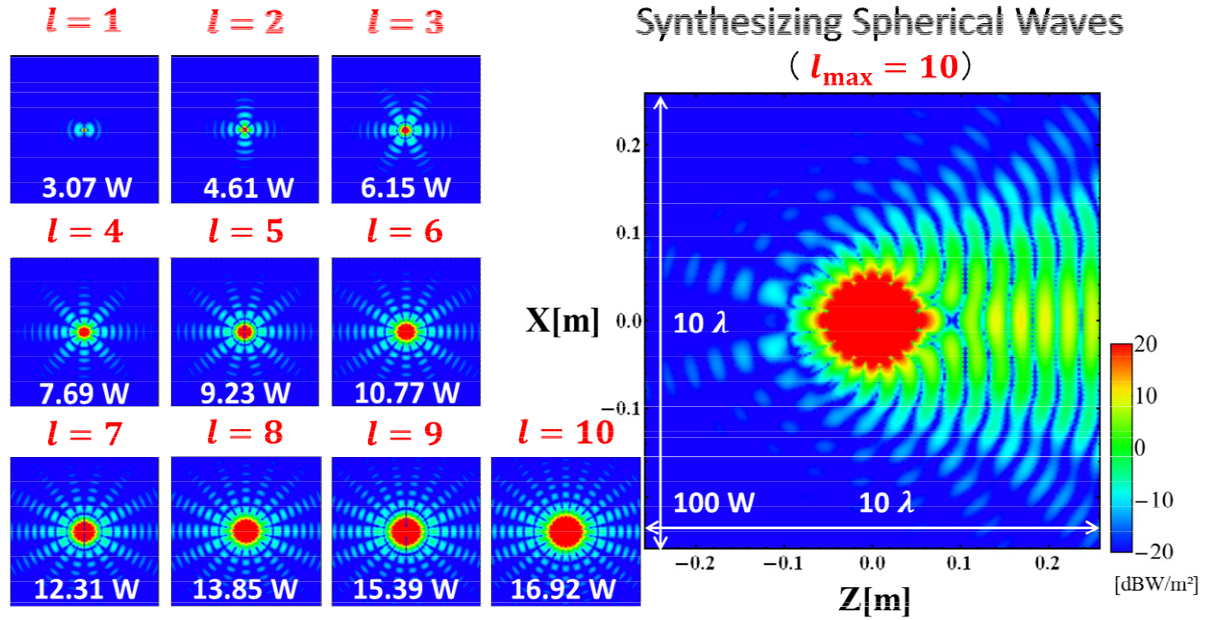


Fig.1. Electromagnetic Field by Synthesizing Spherical Waves

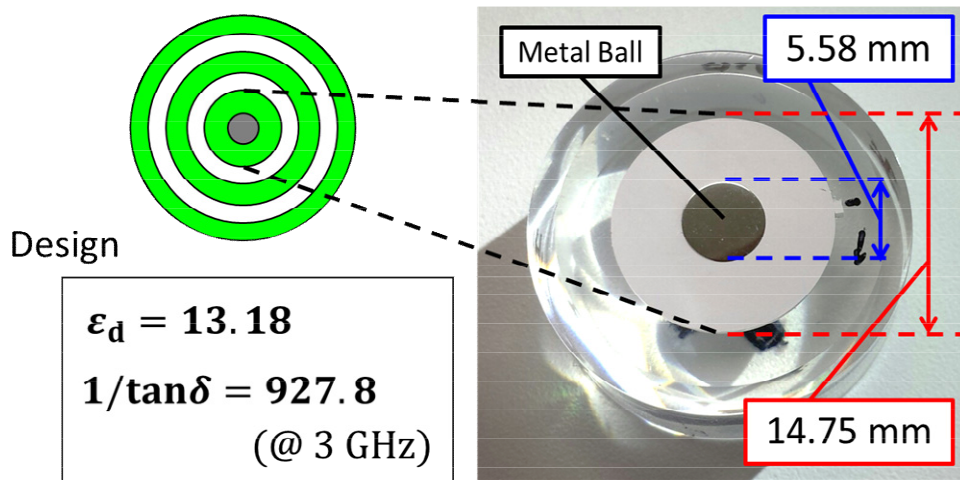


Fig.2. Developed Di-electric Resonator Antenna