COMMISSION B: Fields and Waves (Nov. 2013 - Oct. 2016)

Edited by Jiro Hirokawa and Naobumi Michishita

This report presents a summary of Japanese contributions, including those of international collaborations, in the field related to URSI Commission B during the last three years. It is not intended to be an exhaustive survey of all relevant works, but rather an omnibus of important works around the authors of each section or subsection.

B1. Scattering and Diffraction

1.1 Basic Electromagnetic Fields Analysis

In [Iwashige J., Barolli L., Iwaida M., and Kameyama S, 2014], estimation of the scattering of electromagnetic waves by buildings and other obstacles is very important for wireless communications in urban area. In our previous work, we have examined the diffracted fields by two horizontal edges with an arbitrary angle. In this paper, we consider the diffracted fields by two edges with an arbitrary angle which change in both horizontal and vertical directions. The numerical evaluation is carried out for two wedges and we compare the diffracted fields between parallel and arbitrary angle of edges. The results show that when the angle between two edges increases, relatively strong orthogonal polarized wave components appear, but the principal components are almost the same as the incident wave, and the effect of edge slant in vertical direction is smaller than horizontal one.

In [Sygisaka J., Yasui T., and Hirayama K., 2016], an algorithm is proposed for the scattering analyses of gratings with various local defects based on the difference-field boundary-element method (DFBEM). In the algorithm, the defect in the grating is partitioned, and the DFBEM is sequentially applied for each defect section. The proposed algorithm is validated by demonstrating its flexibility for various defect topologies for a locally deformed grating.

[Tamura Y., 2016] proposes a novel image integral equation of the first type (IIE-1) for a TE plane wave scattering from periodic rough surfaces with perfect conductivity by means of the method of image Green's function. This paper firstly points out that the branch point singularity of the bare propagator inevitably appears on the incident wavenumber characteristics of the scattered wavefield and its related quantities just at the critical wavenumbers. [Nakayama J., and Tamura Y., 2014b] proposes a new method to obtain a numerical solution that satisfies the reciprocity in the theory of periodic gratings. Numerical examples are given for the diffraction of a transverse magnetic (TM) plane wave by a very rough periodic surface with perfect conductivity. By use of the average filter, the energy error is much reduced in some case.

(J. Hirokawa)

1.2 Periodic Array Structures

Scattering and Guiding of periodic array structure such as photonic fiber and photonic crystal waveguides is both theoretical and practical interest in many areas of physics and engineering.

In the scattering problem, Jandieri, Yasumoto and Cho [2013] proposed scattering and radiation from a line source placed inside the eccentric configuration of the cylindrical electromagnetic bandgap (EBG) structure and plane wave incident on the cylindrical EBG structure is numerically studied based on the method proposed by the authors in their early papers. Using the developed formulation, it is shown first time that when the cylindrical EBG is illuminated by plane wave of particular resonance frequencies, the field are strongly enhanced or shaded inside the cylindrical EBG structure and this effect depends on the angle of incidence of the plane waves. We give a deep physical insight into explanation of this phenomenon based on the Lorentz reciprocity relation for cylindrical structures.

Meng, Yasumoto, and Liu [2014] investigated the scattering of TE polarized plane wave by metal-coated dielectric nanocylinders with a particular emphasis on the enhancement of the near fields. If the wavelength of illumination is properly chosen, two unique near field distributions can be excited through the surface plasmon resonances. The enhanced near fields are localized along the inner or outer interface of the coating metal, being dependent on the wavelengths. It is shown that the scattering cross-section of the nanocylinders is also enhanced when the illuminating field resonates to the surface plasmons of the structures.

Nguyen-Huu, Cada, Pistora, and Yasumoto [2014] investigated the doubled-sided grating structures including two identical single-layered metal gratings separated by a dielectric layer exhibit enhanced optical transmission in the visible region for transverse magnetic polarized light. The maximum transmission (71%) is attributed to a resonance of magnetic polaritons while the minimum one (5%) is found to be caused by surface plasmons between metal and dielectric layers. The transmission resonance of the grating structures is analyzed by varying their geometrical parameters and materials in order to evaluate different potential applications such as tunable optical filters, polarizers, and selfsuspended-type plasmonic sensors.

Jandieri, Meng, Yasumoto, and Liu [2015] investigated the light scattering by a grating of the metal (Ag)-coated nanocylinders supported on the dielectric substrate using an accurate and rigorous formulation based on the recursive algorithm combined with the lattice sums technique. Special attention is paid to the three types of resonances: (a) surface plasmon resonances associated with the metal nanocylinders, (b) Rayleigh anomalies related with the periodic nature of the grating, and (c) resonances due to the coupling between the grating and the dielectric substrate. Physical insight is given to the localization of the field along the interfaces of the metal nanocylinders, formation of the strong reflected field by the grating, and the field enhancement at the surface of the dielectric substrate.

Jandieri, Yasumoto, Liu, and Pistora [2016] investigated scattering of light by metal-coated dielectric nanocylinders periodically distributed along a cylindrical surface both theoretically and numerically. Scattering cross section and absorption cross section of three and four silver (Ag) coated-dielectric nanocylinders periodically situated along a cylindrical surface are studied. Near field distributions are investigated at particular wavelengths corresponding to the resonance wavelengths in the spectral responses. Special attention is paid to the unique and interesting phenomena characterizing the cylindrical structure composed of the metal-coated nanocylinders such as: a) localization of the field; b) excitement of the field and c) strong confinement of the field inside the cylindrical structure. Yokota and Matsumoto [2014] proposed an effective permittivity of the two-dimensional multilayered periodic structures which consist of the rectangular dielectric cylinders is examined numerically. The original periodic structure is replaced with a simple structure such as the dielectric slab. By using the reflectance of the periodic structure obtained by the FDTD method, the effective permittivity of the dielectric slab, which has the same reflectance as that of the periodic structure, is obtained by using the transcendental equation. In order to reduce the procedure to obtain the reflectance from the multilayered periodic structures, the reflectance from one-layered structure is used. The range of the application and validity of this procedure is examined.

Sugisaka and Hirayama [2016] proposed an algorithm for the scattering analyses of gratings with various local defects based on the difference-field boundary element method (DFBEM). In the algorithm, the defect in the grating is partitioned, and the DFBEM is sequentially applied for each defect section. We validate the proposed algorithm by demonstrating its flexibility for various defect topologies for a locally deformed grating.

Nakayama and Tamura [2014] proposed a new method to obtain a numerical solution that satisfies the reciprocity based on the shadow theory. The shadow theory states that the scattering factor is an even function. However, a scattering factor obtained numerically becomes even function only approximately. It can be decomposed to even and odd components, where an odd component represents an error with respect to the reciprocity and can be removed by the average filter. Using even components, a numerical solution that satisfies the reciprocity is obtained. Numerical examples are given for the diffraction of a TM plane wave by a very rough periodic surface with perfect conductivity.

Tamura [2016] proposed a novel image integral equation of the first type (IIE-1) for a TE plane wave scattering from periodic rough surfaces with perfect conductivity by means of the method of image Green’s function. Since such an IIE-1 is valid for any incident wavenumbers including the critical wavenumbers, the analytical properties of the scattered wavefield can be generally and rigorously discussed based on the shadow theory.

Komiyama [2014] analyzed the scattering of TE plane wave from the end-face of a waveguide system is treated by solving straightforwardly a wave equation for the electric field. The unknown scattered field is expanded into a perturbation series. The first and second order terms are analytically derived and it is shown that the second order term is sufficiently small compared with the first order term and can be ignored. And also, [2015] the scattering of the ordered waveguide system is numerically treated by a differential method. The results obtained by the perturbation method are compared with the numerical results and the accuracy of the perturbation solution is clarified. For a TM plane wave [2016a], the scattering by a dielectric grating is treated by the perturbation method and the diffraction amplitudes are analytically derived. By comparing with the results obtained by the numerical method it is shown that the properties of the high order diffraction amplitudes can be fairly described by the perturbation solution. It is shown that the results obtained analytically by the perturbation method are in relatively good agreement with the numerical results [2016b].

On the other hand, in the guiding problem, Ozaki and Yamasaki [2016a, 2016b] investigated the propagation constants at the first stop band region and the energy distribution at the guided area for case with dielectric circular cylinders or dielectric hollow cylinder and equivalent rhombic cylinder structure along a middle layer for TE mode by using the combination of improved Fourier series expansion method and multilayer method. And they also, in the transient scattering problem for periodic structure [2016c] analyzed the pulse response of plane gratings in the dispersion media by utilizing the parameters for permittivity properties of complex dielectric constants, and investigated the influence of both dielectric and perfect conductor by using the fast inversion of Laplace transform method and the point matching method. In addition, we confirmed the effectiveness and validity for present method comparing exact solution of perfect conductor plate in dispersion media.

Nakatake and Watanabe [2013] proposed a novel formulation for the modeling of electromagnetic wave propagation in pillar-type photonic crystal waveguide devices. The structure under consideration is formed in an infinitely extended pillar-type photonic crystal and the wave propagation is controlled by removing some cylinders from the original periodic structure. The structure is considered as cascade connections of straight waveguides, and the input/output properties of the devices are obtained using an analysis method of multilayer structure. Each layer includes periodic circular cylinder array with defects, and the transfer-matrix is obtained by using a spectral-domain approach based on the recursive transition-matrix algorithm with the lattice sums technique and the pseudo-periodic Fourier transform.

Naka and Nishimoto [2016] proposed an efficient sharply bent waveguide with a microcavity constructed by an air-bridge type two-dimensional photonic crystal slab is analyzed. The method of solution is the three-dimensional finite difference time domain (FDTD) method. The bent waveguide has a microcavity structure that connects to an input and an output waveguide ports. The radius and position of air-holes surrounding the microcavity are modified to adjust the resonant frequency to the single-mode regime of the waveguides. It is confirmed that input optical power is transmitted efficiently to the output waveguide due to resonant tunneling caused by the microcavity.

Maeda, H., K. Tomiura, H. Chen, K. Yasumoto [2013], proposed the best configuration for bending part of the post wall waveguide. post wall waveguide is important structure for microwave transmission of integrated circuits with multi-layered substrates. It has simple periodic array of metallic or dielectric cylinders between parallel conducting plates. In this study, loss of bending part with the angle of 120° in post wall waveguide was evaluated both numerically and experimentally for microwave.

Maeda, Chen, Tomiura, and Yasumoto [2014] investigated the numerical and experimental study on confinement in Y-shaped post wall waveguides consist of dielectric or metallic cylinders for microwave around 4 GHz. In straight waveguide with dielectric cylinders, confinement of microwave is poor, when the post wall was composed of a pair of single row of cylinders. After confirming confinement of the electromagnetic field, Y-shaped branches of post wall waveguide consisted of dielectric cylinders for microwave were similarly investigated for dielectric rods. The confinement was also improved by increase of post wall up to 3 layers. These results are applicable for fundamental design and fabrication of integrated circuit for microwave and millimeter wave.

Jandieri, Yasumoto, and Pistora [2014] proposed a self-contained coupled-mode theory for the coupled two asymmetric photonic crystal waveguides (PCWs). The first-order coupled-mode equations are derived under a weak coupling assumption. The coupling coefficients are obtained systematically by a matrix calculus using the modal solutions of each PCW in isolation. The coupled-mode equations are solved for contra-directional coupling between two asymmetric PCWs formed by a hexagonal lattice of circular air holes in a dielectric medium. It is shown that the self-contained coupled-mode analysis is useful to characterize a peculiar feature of the contra-directionally coupled PCWs as a drop filter.

Arai, Shibazaki, and Kinoshita [2016] investigated the accuracy of the finite-difference time-domain (FDTD) method for approximating a waveguide consisting of a periodic structure with a conducting iris of nonzero thickness. They consider a model for a single stage of a periodic structure – an individual conducting iris of nonzero thickness- and determine optimal grid spacings for FDTD calculations. They also determine the optimal grid spacings using benchmark numerical solutions obtained with the modified residue-calculus method (MRCM), an accurate solution procedure that incorporates boundary conditions, and obtain agreement by choosing a grid spacing on the order of 1/100th of the wavelength.

(T. Yamasaki)

1.3 Cavity Structures

Cavity structures appear in many radar targets and it is important to investigate their scattering phenomena in detail.

As a geometry that can be classified as cavity structures, Shirai et al. [2014, 2016b, 2016c] considered a slit formed by two thick semi-infinite plates, and analyzed the plane wave scattering based on high-frequency asymptotic methods. They obtained solutions that are valid for the case where the slit width is large compared with the wavelength. Based on the results, numerical examples on the far field intensity are shown and scattering characteristics of the slit are discussed in detail.

Kobayashi [2015, 2016] considered a finite parallel-plate waveguide with material loading as a geometry that can form cavities, and analyzed the plane wave diffraction with the aid of the Wiener-Hopf technique. Numerical examples on the radar cross section (RCS) are presented for various physical parameters and far field scattering characteristics of the waveguide are discussed.
(K. Kobayashi)

1.4 Canonical Structures

Scattering and diffraction by canonical structures and their solutions are treated in some papers. Goto et al. [2016b, c] discussed high-frequency scattering by a coated conducting cylinder covered with a thin lossy medium. From an exact solution of this canonical structure, they derived a frequency-domain uniform asymptotic solution that is uniform in the transition region adjacent to the shadow boundary and is valid for a source point and/or an observation point located either near the coating surface or in the far-zone. Goto et al., [2016d] and Hagiwara et al. [2016] also proposed a frequency-domain asymptotic solution for scattered field by a coated conducting cylinder when the coating layer is thick compared with the wavelength. The obtained asymptotic solution includes multiple reflected waves passing through the coating medium and its validity is confirmed by comparing with an exact solution.

Nishimoto and Naka [2016] analyzed a scattering problem by a conducting circular cylinder with inhomogeneous lossy dielectric coating by using the multilayer division method. By solving the problem as a boundary value problem, an analytic solution for scattered field in frequency domain is derived. Using the solution, transient responses for incidence of ultra-wideband pulses are calculated. Numerical results for some different inhomogeneous parameters are given and the relationship between inhomogeneous parameters and corresponding waveforms is discussed.
(M. Nishimoto)

B2. Inverse Scattering

2.1 Iterative Approach

Moriyama et al. [2014] proposed a new time-domain imaging approach that combines the regularization capabilities of the filtered FBTS (Forward-Backward Time Stepping) method with the information-acquisition features of the IMSA (Iterative Multi-Scaling Approach). Representative numerical examples are presented. The accuracy and robustness of the proposed method are discussed.

Moriyama et al. [2015, 2016] proposed an inverse scattering approach for reconstruct electrical parameter profiles of unknown objects from only tangential component of total electric field

collected on an observation surface. The reconstructions of relative permittivity distributions are demonstrated in Moriyama et al. [2015]. The estimations of the size and location of unknown objects are demonstrated in Moriyama et al. [2016].
(M. Tanaka)

2.2 Other Approach

Recent studies have focused on developing security systems using micro-Doppler radars to detect human bodies. However, the resolution of these conventional methods is unsuitable for identifying bodies and moreover, most of these conventional methods were designed for a solitary or sufficiently well-spaced targets. Saho et al. [2014] proposed a solution to these problems with an image separation method for two closely spaced pedestrian targets. The proposed method first develops an image of the targets using ultra-wide-band (UWB) Doppler imaging radar. Next, the targets in the image are separated using a supervised learning-based separation method trained on a data set extracted using a range profile. They experimentally evaluated the performance of the image separation using some representative supervised separation methods and selected the most appropriate method. Finally, they reject false points caused by target interference based on the separation result. The experiment, assuming two pedestrians with a body separation of 0.44 m, shows that their method accurately separates their images using a UWB Doppler radar with a nominal down-range resolution of 0.3 m. They described applications using various target positions, establish the performance, and derive optimal settings for their method.

A novel algorithm was proposed for separating multiple moving targets in radar images in the slow time-range domain [Sakamoto et al. 2015a]. Target discrimination is based on an image texture angle that is related to the target's instantaneous velocity. The algorithm efficiency has been successfully verified for targets with variable velocities.

Sakamoto et al. [2015b] demonstrated an accurate remote measurement of heartbeats using an ultra-wideband radar system. Although most conventional systems use either continuous waves or impulse-radio systems for remote vital monitoring, continuous waves suffer from non-stationary clutters, while impulse-radio systems cannot detect heartbeats. Their ultra-wideband radar system has a moderate fractional bandwidth intermediate of these systems, resulting in both the suppression of clutters and high sensitivity in measuring accurate heart rates even in a dynamic environment. A simultaneous measurement of the vital signal of a participant employing the ultra-wideband radar and electrocardiography reveals the high accuracy of the radar system in measuring the heart rate varying over time.

Sakamoto et al. [2015c] presented a method of imaging a two-dimensional section of a walking person using multiple ultrawideband Doppler radar systems. Although each simple radar system consists of only two receivers, different line-of-sight velocities allow target positions to be separated and located. The signal received using each antenna is processed employing time–frequency analysis, which separates targets in the time–range–velocity space. This process is followed by a direction-of-arrival estimation employing interferometry. The data obtained using the multiple radar systems are integrated using a clustering algorithm and a target-tracking algorithm. Through realistic simulations, they demonstrated the remarkable performance of the proposed imaging method in generating a clear outline image of a human target in unknown motion.

Sakamoto et al. [2015d] proposed a fast and accurate radarimaging algorithm that combines Kirchhoff migration with Stolt's frequency-wavenumber (F-K) migration. F-K migration is known as a fast-imaging method in the F-K domain, while Kirchhoff migration is reported to be more accurate. However, Kirchhoff migration requires the reflection points to be located as a function of the antenna position and the delay time. This prevents the use of fast Fourier transforms (FFTs) because Kirchhoff migration must be processed in the time domain, and this can be extremely time consuming. The proposed algorithm overcomes this hurdle by introducing the texture angle and the inverse boundary scattering transform (IBST). These two tools enable the locations of the reflection points to be determined rapidly for each pixel of a radar image. The radar signals are then modified according to the Kirchhoff integral, before Stolt F-K migration is applied in the frequency domain to produce an accurate radar image. To demonstrate the performance of the proposed method, the conventional delay-and-sum (DAS) migration, Kirchhoff migration, Stolt F-K migration, and the proposed method are applied to the same measured datasets.

Measurement of heartbeats is essential in cardiovascular magnetic resonance imaging because the measurement must be synchronized with the phase of cardiac cycles. Many existing studies on radar-based heartbeat monitoring have focused on echoes from the torso only, and such monitoring cannot be applied to subjects in magnetic resonance scanners because only the head and soles can be seen from the outside. Sakamoto et al. [2015e] demonstrated the feasibility of the remote monitoring of heartbeats from the subject's soles using a 60-GHz ultra-wideband radar. The heartbeat intervals measured using the radar are quantitatively compared with those measured using conventional electrocardiography.

Microwave systems have a number of promising applications in surveillance and monitoring systems. The main advantage of microwave systems is their ability to detect targets at distance under adverse conditions such as dim, smoky, and humid environments. Specifically, the wide bandwidth of ultra-wideband radar enables high range resolution. In a previous study, Yamazaki et al. [2016] proposed an accurate shape estimation algorithm for multiple targets using multiple ultra-wideband Doppler interferometers. However, this algorithm produces false image artifacts under conditions with severe interference. They proposed a technique to suppress such false images by detecting inconsistent combinations of the radial velocity and time derivative of image positions. They study the performance of the proposed method through numerical simulations of a two-dimensional section of a moving human body, and demonstrate the remarkable performance of the proposed method in suppressing false image artifacts in many scenarios.

Sakamoto et al. [2016a] proposed a method that can accurately estimate the human heart rate (HR) using an ultrawideband (UWB) radar system, and to determine the performance of the proposed method through measurements. The proposed method uses the feature points of a radar signal to estimate the HR efficiently and accurately. Fourier- and periodicity-based methods are inappropriate for estimation of instantaneous HRs in real time because heartbeat waveforms are highly variable, even within the beat-to-beat interval. They defined six radar waveform features that enable correlation processing to be performed quickly and accurately. In addition, they proposed a feature topology signal that is generated from a feature sequence without using amplitude information. This feature topology signal is used to find unreliable feature points, and thus, to suppress inaccurate HR estimates. Measurements were taken using UWB radar, while simultaneously performing electrocardiography measurements in an experiment that was conducted on nine participants. The proposed method achieved an average root-mean-square error in the interbeat interval of 7.17 ms for the nine participants. The results demonstrate the effectiveness and accuracy of the proposed method. The significance of this study for biomedical research is that the proposed method will be useful in the realization of a remote vital signs monitoring system that enables accurate estimation of HR variability, which has been used in various clinical settings for the treatment of conditions such as diabetes and arterial hypertension.

Sakamoto et al. [2016b] proposed a fast method of ultrawideband (UWB) radar imaging that can be applied to a moving target, having in mind such application as concealed weapon detection. They demonstrated the performance of the proposed method using simulations and measurements with static and moving targets. They also compared the computational complexity of the proposed method with that of a conventional method to clarify the feasibility of applying the proposed method to the intended real-time systems.

(T. Sato)

B3. Computational Techniques

3.1 Integral Equation Methods

The integral equation methods such as the method of moments (MoM), the boundary element method (BEM), and so on, are powerful and versatile solvers for various problems in electromagnetics. In common with many other methods, computational costs become a serious issue as the electrical size of objects increases and many attempts have long been made for this.

The one of effective approaches is the characteristic basis function method (CBFM). The CBFM uses characteristic basis functions (CBFs) constructed by M-partitioning objects, to reduce the resulting MoM matrix to M2 * M2. Tanaka et al. [2016] developed improved primary characteristic basis functions (CBFs) to reduce the number of characteristic basis functions, and successfully obtained high precision analysis results of monostatic radar cross section from a PEC plate. Konno and Chen [2014b] formulated a higher-order CBF in a general form and applied it to analyses of large-sized antennas in the vicinity of dielectric objects. The numerical results showed that the CPU time can be saved without large degradation in accuracy.

An alternative technique was presented by Sekine [2014]. They applied isogeometric analysis to MoM in order to take into account curved objects without mesh generation.

The integral equation methods in the time domain also attract much attention. Kawaguchi et al. [2014] presented an initial value problem formulation in 3D time domain boundary element method (TDBEM) to avoid the numerical instability and inaccuracy caused by the conventional TDBEM. Maeda et al. [2014] adopted the compressed row storage matrix in TDBEM, which is suitable for a message passing interface parallel processing. The numerical results showed the reduction of both memory consumption and computation time. Kawaguchi et al. [2015] developed a four-dimensional domain decomposition method for the TDBEM to save computational memory. Ohnuki et al. [2016] utilized the fast inverse Laplace transform to obtain time-domain solutions. They formulated the integral equations in the complex frequency domain and solved them by using the method of moments. The advantage of this method is that the observation time can be selected independently and that the accuracy does not depend on the observation time.

The one of attractive applications in the integral equation method is scattering problems from multiple objects. Tanaka [2014] applied the multilevel algorithm for superposition solution combined with the MoM to this type of problems. Yashiro [2015a, 2015b] adopted global basis functions for analysis of multiple circular cylinders. Matsushima [2016] analyzed the light scattering from nano-strips stacked in parallel by using the generalized boundary conditions, deriving singular integral equations, and solving them by choosing the Legendre and Chebyshev polynomials as the basis and testing functions.

(Y. Ando)

3.2 Modal Expansion Method

A modal expansion method is a quite powerful technique which is able to deal with a lot of guided structures, antennas, and filters. A specific field or current are expanded as a sum of fundamental field or current components, so-called modes. The modes associated with a specific structure are obtained analytically or numerically and their coefficients are obtained numerically.

Ohnuki et al. [2014] have analyzed electromagnetic scattering problems using the point matching method (PMM) with the mode expansion. A dielectric sphere with a PEC shell was numerically analyzed using the PMM and excellent agreement between the numerical results and exact Mie series solution was shown.

Fujita and Shirai [2015] have clarified a theoretical limitation of radiation efficiency for homogeneous electrically small antennas using spherical wave functions. According to their study, radiation efficiency of an antenna inside a sphere with a specific radius is less than that of a spherical antenna with the same radius. In addition, it is indicated that a uniform current distribution is preferable for high radiation efficiency.

Sato and Shirai [2016] have rigorously formulated a problem of electromagnetic plane wave diffraction by loaded N-slits on thick conducting screen via eigen function expansion. Performance of the formulation is demonstrated and compared with that of the geometrical theory of diffraction (GTD).

Konno et al. [2014a-c] have analyzed an antenna in the vicinity of a dielectric object using a characteristic basis function method (CBFM). The CBFM is able to reduce the size of the original problem using a characteristic basis function (CBF), which is numerically obtained mode-like function. Accuracy and computational cost of the CBFM have been clarified and enhanced in these studies. Recently, a novel CBFM for a finite periodic structure has been developed and performed by Konno et al. [2016].

(Q. Chen)

3.3 Finite-Difference and Finite-Element Methods

New FDTD modeling methods for Metamaterials have been developed. Arima et al. have developed new modeling method for meta-surface [2016a]. This method has utilized Surface Impedance of meta-surface. The effectiveness of this method is confirmed by analyzing dipole antenna which is placed above the meta-surface.

An efficient FDTD algorithm for relatively low frequency (around 10MHz) range problem has been developed by Asano et al. This method utilizes transfer function. In order to acetate calculation time of the transfer function. The Auto Regressive Moving Average (ARMA) algorithm has applied. This algorithm is named as ARMA-FDTD method. The effectiveness of ARMA-FDTD method was confirmed by calculating lightning problem [2016].

New efficient FDTD algorithms have been developed. The partially implicit FDTD algorithm was developed to the wideband analysis of spoof localized surface plasmons by Fujita [2015]. The effectiveness of the new FDTD algorithm has been confirmed in 3-D general orthogonal grids by analyzing EM fields [2016a]. This new FDTD algorithm was named as Magnetically mixed Newmark-Leapfrog (MNL-) FDTD method. Fujita applied this new FDTD algorithm for ESD problem of small gap [2016b, 2016c]. A time signature of short gap ESD problem is also analyzed [2016d]. An efficient absorbing boundary condition (ABC) for this new FDTD algorithm has also been developed [2016e].

Kushiyama et al. applied the FDTD method for metamaterial antenna development. The developed metamaterial antenna was leaky wave antennas. Kushiyama et al. confirmed the

effectiveness of FDTD method for leaky wave metamaterial antennas [2015].
(T. Arima)

B4. High Frequency Technique

4.1 Wave Optics

In [Ali M., Kohama T., and Ando M., 2015]. Equivalent edge currents (EECs) for high-frequency diffraction analysis are intermediate concepts between ray theory and wave optics [physical optics (PO)]. The methods of EEC present some ambiguity in the definition of currents at general edge points, which do not satisfy the diffraction law. Modified edge representation (MER) is a unique concept for a complete definition of EEC with simple and classical Keller-type knife-edge diffraction coefficients. Although singularities in the definition of EEC exist, the line integration of MER EEC results uniform and accurate fields everywhere including geometrical boundaries except for the case of grazing incidence, where reflection and incidence shadow boundaries (RSB and ISB) are close to each other. In this paper, fringe wave (FW) part of MER EEC is modified by introducing the weighting in terms of Fresnel zone number (FZN) distance from the reflection point to improve the accuracy at and near shadow boundaries even in grazing incidence. The corner diffraction, a contribution coming from edge point which does not satisfy the diffraction law, is extracted in MER by introducing another weighting function using the FZN distance from scattering centers on edge. Its remarkable accuracy fully validates MER EECs at general edge points. The dipole wave scattering from flat square and triangular plates are discussed with numerical examples.

In [Kohama T., and Ando M., 2014], the physical optics (PO) approximation is one of the widely-used techniques to calculate scattering fields with a reasonable accuracy in the high frequency region. The computational load of PO radiation integral dramatically increases at higher frequencies since it is proportional to the electrical size of scatterer. In order to suppress this load, a variety of techniques, such as the asymptotic evaluation by the stationary phase method (SP), the equivalent edge currents (EECs), the low-order polynomial expansion method and the fast physical optics (FPO), have been proposed and developed. The adaptive sampling method (ASM) proposed by Burkholder is also one of the techniques where the sampling points in radiation integral should be adaptively determined based upon the phase change of integrand. We proposed a quite different approach named "Localization of the radiation integrals." This localization method suggests that only the small portions of the integration with a slow phase change contribute to the scattering field. In this paper, we newly introduce the ASM in the localization method and applied the proposed method into the radar cross section (RCS) analysis of 2-dimensional strip and cylinder. We have confirmed that the proposed method provides the frequency-independent number of division in the radiation integrals and computational time and accuracy. As the starting point for extension to 3-D case, the application of the proposed method for a reflection from an infinite PEC plane and a part of sphere was also examined.
(M. Ando)

4.2 Ray Optics, and Others

High frequency reflection from and transmission through the wall is one of the important problem for outdoor/indoor penetration analysis, since these rays experience the multiple bouncing and lateral shift. This problem has been analyzed ray-optically by two dimensional slab structure [Sato et al., 2014a, b].

A high-frequency asymptotic method has been applied to formulate E-polarized plane wave diffraction by a thick slit. The slit structure is regarded as an open-ended parallel plane waveguide cavity, and the excitation of the waveguide modes and their re-radiation are derived from a ray-mode conversion technique. Comparison with another method reveals the validity and effectiveness of our formulation [Hasegawa et al., 2014, Sato et al., 2014c, Shirai et al., 2014, 2016, Shimizu etl al., 2015, Shirai et al., 2016a, b, c, d].

The above single thick slot problem has been extended to multiple slot cases to simulate the effect of an array of windows on building walls [Sato et al.,2014b, 2016].

Diffraction from dielectric bodies become an important problem for high frequency regime, since there is no rigorous analytical solution is available. Kirchhoff approximation has been applied to obtain the diffraction field from dielectric cubic bodies to consider the effect of internal multiple bouncing [Nguyen et al., 2015a, b]. Also, an effort has been made to estimate the shape of the dielectric bodies from their RCS variation [Kisumi et al., 2015].

The high-frequency scattering problem by a coated conducting cylinder covered with a thin lossy medium has been discussed in the papers by [Goto et al., 2016b, c]. The frequency-domain uniform asymptotic solution (FD-UAS) is uniform in the transition region adjacent to the shadow boundary and is valid for a source point and/or an observation point located either near the coating surface or in the far-zone.

The papers by [Goto et al., 2016d, Hagiwara et al., 2016] propose frequency-domain (FD) asymptotic solutions (FD-ASs) for scattered field by a coated conducting cylinder when a coating layer is thick as compared with the wavelength. The FD-ASs newly include the multiple reflection effect passing through the inner portion of a coating layer as compared with the FD-UAS [Goto et al., 2016b, c].

(H. Shirai)

B5. Transient Fields

Analysis of transient scattering phenomena from smooth curved conducting surfaces with edges or wedges plays an important role in developing ultra-wideband (UWB) (or short pulse) radars and their associated antennas for remote sensing and target identification applications.

The paper by [Goto et al., 2014a] proposes a time-domain (TD) asymptotic analysis method for the transient scattered field excited by the edges of a cylindrically curved conducting open sheet. Their proposed method is based on the Fourier transform method. The advantages of the proposed method are: (1) Each TD asymptotic solution of pulse wave elements of which the transient scattered field is made up is obtained easily, (2) The TD asymptotic solution is effective in understanding the transient scattering phenomena. The paper by [Goto et al., 2014b] investigates the arrival time difference between a creeping wave (CW) propagating along a convex portion and a whispering-gallery (WG) mode propagating along a concave portion. They confirmed the interesting phenomenon that the CW propagates along the curved sheet later than the WG mode. The papers by [Goto et al., 2014c, 2015a, 2016a] derive a novel TD asymptotic-numerical solution (TD-ANS) for transient scattered field from a cylindrically curved conducting open sheet excited by a UWB pulse wave. The advantages of the proposed method are: (1) The TD-ANS is highly accurate and a new reference solution on engineering applications, (2) The TD-ANS can extract and observe each pulse wave element from a response waveform, and (3) The computation rate of the TD-ANS is very fast as compared with that of a reference solution which is obtained numerically from the method of moment (MoM) and the fast Fourier transform (FFT) numerical code.

A study of scattering and radiation from a conducting surface with dielectric loading is great interesting because it provides an understanding of the effects due to loading on the scattered fields. Analysis of scattering phenomena from coating cylinders plays an important role in developing the application area such as the radar cross section (RCS), the development of radar absorbing material (RAM), and the radar target discrimination.

The papers by [Goto et al., 2016b, c] derive a frequency-domain (FD) uniform asymptotic solution (FD-UAS) for scattered field by a coated cylinder with a thin lossy medium. The FD-UAS is the high-frequency (HF) asymptotic solution applicable uniformly in the large area from the nearby region relatively of the coating surface to the far-zone. The papers by [Goto et al., 2015b, c, d] develop a time-domain (TD) asymptotic-numerical solution (TD-ANS) for a transient scattering problem by extending the FD-UAS.

The advantages of the TD-ANS are: (1) The TD-ANS is highly accurate and can extract and observe each pulse wave element from a response waveform, namely, a direct geometric optical ray (DGO), a reflected GO (DGO), a pseudo surface diffracted ray (pseudo SD), and a lowest order SD, (2) The computation rate of the TD-ANS is very fast as compared with that of a reference solution which is obtained from a FD exact solution and the FFT numerical code.

The papers by [Goto et al., 2016d, Hagiwara et al., 2016] propose frequency-domain (FD) asymptotic solutions (FD-ASs) for scattered field by a coated conducting cylinder covered with a thick dielectric medium. The FD-ASs newly include the multiple reflection effect passing through the inner portion of a coating layer as compared with the FD-UAS [Goto et al., 2016b, c]. By extending the FD-ASs, the papers [Goto et al., 2014d, 2016e] develop a novel time-domain (TD) asymptotic-numerical

solutions (TD-ANSs) which are composed of a geometric optical ray (GO) series solution and an extended uninform geometrical theory of diffraction (UTD) series solution. The advantages of the TD-ANSs are highly accurate and useful because they can extract and interpret each pulse wave element from a response waveform including the multiple reflection effect even when pulse wave elements overlap mutually.
(K. Goto)

B6. Wave in random, inhomogeneous, nonlinear and complex media

6.1 Wave Propagation and Scattering in Random Media

The conventional extinction theorem in grating theory does not work numerically for a critical angle of incidence. This drawback was overcome by a new formulation using the image Green's function. The extinction error field and the mean square extinction error were newly introduced as validity criteria and calculated numerically [Nakayama et al., 2014a]. Nakayama et al. [2014b] proposed the average filter as a new numerical technique to make up a diffraction field solution with reciprocal property. It was found that the energy error is much reduced by use of the average filter in some case.

Tamura [2016] proposed a novel image integral equation of the first type (IIE-1) for a TE plane wave scattering from periodic rough surfaces with perfect conductivity by means of the method of image Green's function. Since such an IIE-1 is valid for any incident wavenumbers including the critical wavenumbers, the analytical properties of the scattered wave field can be generally and rigorously discussed. Then, it is firstly pointed out that the branch point singularity of the bare propagator inevitably appears on the incident wavenumber characteristics of the scattered wave field and its related quantities just at the critical wavenumbers. The proposed IIE-1 gives a numerical solution satisfying sufficiently the optical theorem even for the critical wavenumbers. Moreover, it is then confirmed that the branch point singularity clearly appears in the numerical solution. It is highly expected that the IIE-1 be applied to numerical simulations of waves scattering from randomly rough surfaces for low grazing angle incidences.

In order to analyze quantitatively the depolarization due to random medium, Nanbu et al. [2016, 2014] derive an integral equation using the dyadic Green's function on the assumption that there exists a random medium layer of which the dielectric constant is fluctuating randomly. On the integral equation, the depolarized EM wave is analyzed by using a perturbation method, and the first order perturbed EM wave is given in a compact far-field form by using an ordered exponential function.
(S. Ohnuki)

6.2 Inhomogenenous, nonlinear and complex media

Ozaki et al. [2014] propose a method for deciding the parameters to satisfy the experiment values, and checked the effectiveness of this method based on Kramers-Kronig (K.K.) relation. In their method, they expressed as matrix the Sellmeier's formula, and solved the simultaneous equation until the satisfied the experiment value. The influence of pulse responses using the medium constants, which can be found by proposed method, is shown numerically. Ozaki and Yamasaki [2016b] investigated a new structure, which combines dielectric cylinders with air-hole cylinders array, and analyzed the guiding problem for periodically dielectric waveguides by arbitrary shape of dielectric constants in the middle layer. In the numerical results, they examined an influence of the dielectric circular cylinder along a middle layer by using the energy distribution and complex propagation constants at the first stop band region compared with hollow dielectric cylinder. In addition, we also investigated the influence of dielectric structure with equivalence cross section compared with dielectric cylinders, and clarified an influence of dielectric structures in the middle layer by energy distribution analysis for TE0 mode.

Nakayama and Tamura [2014b] proposed a new method to obtain a numerical solution of diffraction grating that satisfies the reciprocity. The shadow theory states that, by the reciprocity, the m-th order scattering factor is an even function with respect to a symmetrical axis depending on the order m of diffraction. However, a scattering factor obtained numerically becomes an even function only approximately, but not accurately. It can be decomposed to even and odd components, where an odd component represents an error with respect to the reciprocity and can be removed by the average filter. Using even components, a numerical solution that satisfies the reciprocity is obtained. Numerical examples are given for the diffraction of a transverse magnetic (TM) plane wave by a very rough periodic surface with perfect conductivity. It is found that, by use of the average filter, the energy error is much reduced in some case.

Yokota and Matsumoto [2014] examined the effective permittivity of the two-dimensional multilayered periodic structures, which consist of the rectangular dielectric cylinders, numerically. The original periodic structure is replaced with a simple structure such as the dielectric slab. By using the reflectance of the periodic structure obtained by the FDTD method, the effective permittivity of the dielectric slab, which has the same reflectance as that of the periodic structure, is obtained by using the transcendental equation. In order to reduce the procedure to obtain the reflectance from the multilayered periodic structures, the reflectance from one-layered structure is used. The range of the application and validity of this procedure is clarified.
(M. Yokota)

B7. Guided Waves

7.1 Dielectric and Optical Waveguides

PLC-based mode multi/demultiplexer devices are designed and fabricated based on a mode coupling and/or incorporating a mode rotator to the mode-division multiplexing transmission in few mode fibers [Hanzawa, N., et al., 2013, Saitoh, K., et al., 2014, Hanzawa, N., et al., 2014, Hanzawa, N., et al., 2015]. Fiber-based multi/demultiplexer devices are also investigated for six modes based on multi-core fiber couplers [Nishimoto, S., et al., 2016]. To realize a low bending loss, large effective area, and large effective-index differences between core modes, optimized fiber parameters are investigated in few mode fibers [Kasahara, M., et al., 2013, 2014]. As for multi-core fibers, a simple analytical expression for estimating a crosstalk in homogeneous [Ye, F., et al., 2014, 2016a, 2016b] and an efficient design method are derived considering a low crosstalk, large effective area and single-mode operation in heterogeneous [Tu, J., et al., 2016] trench-assisted fibers. Optimized fiber designs are investigated with a low crosstalk, large effective area, and low differential mode delay for heterogeneous trench-assisted few-mode multi-core fibers [Tu, J., et al., 2014, 2015]. Various few-mode multi-core fibers are also fabricated and demonstrated with spatial channel count of 36 with 3 modes × 12 cores [Sasaki, Y., et al., 2015], 108 with 3 modes × 36 cores [Sakaguchi, J., et al., 2016], and 114 with 6 modes × 19 cores [Igarashi, K., et al., 2016]. Long-haul transmission over 500 km is achieved with spatial channel count of 36 with 3 modes × 12 cores employing a few-mode erbium-doped fiber amplifier with low mode-dependent gain as well as a newly developed graded-index core with low differential mode delay which is also compensated by a novel digital technique in few-mode multi-core fibers [Shibahara, K., et al., 2016]. Aiming for suppression of group delay spread in strongly coupled multi-core fibers, a group delay spread analysis and a novel fiber design are discussed [Fujisawa, T., et al., 2016]. As for all-solid photonic bandgap fibers, optimized structural parameters for realizing large effective area are investigated while at the same time keeping single-mode operation for high-power laser applications [Saitoh, S., et al., 2014].

A 3-D finite-element time-domain beam propagation method is developed, which enables the analysis of transmission characteristics of any kind of photonic structures [Makino, S., et al., 2015a]. In order to calculate nonlinear Kerr effects rigorously in periodic optical waveguides, a nonlinear guided mode solver is developed based on the 3-D finite element method [Sato, T., et al., 2014]. A rigorous definition of nonlinear parameter for high-index-contrast periodic optical waveguides is also proposed, which agrees well with the results by the rigorous nonlinear mode solver and experiments [Sato, T., et al., 2015]. In order to suppress reflection of L-shaped photonic crystal cavity-based all-optical diode, a simple design method is proposed using a linear numerical scheme and nonlinear coupled mode theory [Sato, T., et al., 2016]. Aiming for enhancing the optical nonlinearity, a coupled resonator optical waveguide based on a slotted 1-D photonic crystal cavity is proposed and analyzed [Makino, S., et al., 2015b]. For a novel light source expected in the future mid-infrared photonics, material gain of GeSn/SiGeSn quantum wells is investigated by using the microscopic many-body theory where GeSn becomes direct bandgap material without any strain and doping contrary to Ge [Fujisawa, T., et al., 2015a]. Moreover, quantum-confined Stark effect of the material is analyzed for electroabsorption device applications such as a modulator, switch, and so on

[Fujisawa, T., et al., 2015b]. To reduce bend and transition losses, contribution of the adjustment of the core location is discussed for a buried waveguide on a silicon substrate [Nito, Y., et al., 2016]. To realize an ultra-broadband polarization beam combiner/splitter, a silicon waveguide structure is proposed, composed of three identical directional couplers and two identical delay lines [Uematsu, T., et al., 2014]. For an efficient optical coupling to fibers, a vertically curved Si waveguide coupler is proposed and fabricated [Yoshida, T, et al., 2016]. To achieve a low loss wavelength-division multiplexing and optical coupling between electroabsorption-modulator-integrated lasers and a single-mode fiber, a precise lens manipulation technique [Murao, T., et al., 2014], as well as a monolithic integration technique with a low-loss cascaded Mach-Zehnder multiplexer [Fujisawa, T., et al., 2013] is proposed and demonstrated.

(T. Murao, M. Otsuka)

7.2 Transient Fields in Guided Waves

Shibayama et. al. [2014] calculate the transient electromagnetic fields of a plasmonic rod waveguide and the reflection coefficients in a plasmonic grating, in which the dispersion is expressed by the Drude and Drude-Lorenz models, with the body-of-revolution finite-difference time-domain method based on locally one-dimensional scheme.

Ohtera Y. [2016] investigates on the accuracy and computational performance of the FDTD calculations for the transient electromagnetic field of the obliquely propagating waves in an air/Si sub-wavelength periodic structure.

(Y. Kogami)

B8. Antennas

8.1 Fundamental Antenna

Ito et al. [2016] have described the review of wearable antennas as well as implantable antennas that have been studied in their laboratory. Antennas for particular uses, Sekiguchi et al. [2016] have developed a technique to reduce performance degradation of near field communication (NFC) antennas nearby metal objects by modifying the magnetic sheet shape attached on the metal. Nguyen et al. [2015] have proposed the space-saving design of built-in antennas for handset terminals based on the concept of requisite design antenna volume. As the antenna theory topic, Fujita [2015] have derives the maximum radiation efficiency for homogeneous electrically small antennas using the spherical wave expansion. To analyze the radiation source of the EM interference, Nishina and Chen [2016] have developed a method including near field measurement in time domain and matrix inversion to estimate the equivalent current distribution of incoherent radiation source. In computational electromagnetics, Konno and Qian [2014b] have formulated the higher-order characteristic basis function method (HO-CBFM) to provide results accurately even if a block division

is arbitrary.
(H. Arai)

8.2 Wideband Antennas

So et al. [2014] have proposed a sector base station antenna for mobile wireless communication systems employing multiple woodpile metamaterial reflectors and a multiband radiator that establishes the same beamwidth in the horizontal plane for more than two frequency bands. Sumi and Cho [2014] have proposed a new small multiband printed antenna for wireless telecommunications modules that can realize Machine-to-Machine applications. Nguyen et al. [2015] have presented the detailed investigations on a simple multi-band method that allows inverted-F antennas (IFAs) to achieve good impedance matching in many different frequency bands. A tri-band Multiple-input-multiple-output (MIMO) antenna system for LTE 700, LTE2500 and GSM 1800/1900 mobile handset application has been presented [Yang, et al., 2016].

A frequency-reconfigurable dipole antenna, whose dual resonant frequencies are independently controlled, has been introduced [Onodera, et al., 2016]. The antenna's conductor consists of radiating conductors, lumped and distributed elements, and varactors. The dual resonant frequencies are controlled with the embedded series and shunt inductors.

Yamauchi and Fukusako [2016] have proposed design techniques to reduce the cross-polarization (XPOL) generated from a circular waveguide antenna using an L-shaped probe. As a result, XPOL is reduced by around 10 dB, and CP is radiated over a wide angle range of 120-150° covering frequencies from 7.35 to 9.75GHz.
(N. Michishita)

8.3 Antenna Elements

Monopole, microstrip, meander line, slit ring, inverted L, spiral, bowtie slot, body of revolution (BOR), and loop antennas have been researched from novel engineering aspects. (1) Monopole antenna: Fujimoto et al. [2014] have proposed a monopole antenna for circular polarization, while Yamamoto et al. [2015] have proposed a MIMO antenna composed of leaf-shaped monopoles and notches. (2) Microstrip antenna: A circularly-polarized microstrip antenna has been proposed by Fujimoto et al. [2015a], where dual-band operation is achieved by installing L-shaped slits at all edges of a square patch. In addition, the same group has investigated a stacked microstrip antenna fed by an L-probe for quadruple band operation [Fujimoto et al., 2015b]. Other researches on microstrip antennas are found in the activities at Kumamoto and Hosei Universities. Maruyama et al. [2014] have realized a broadband patch antenna that radiates a circularly polarized wave using an artificial ground structure. Nakano et al. [2014b] have investigated a one-plate system composed of a patch antenna and a single inhomogeneous plate in order to create a tilt beam. Furthermore, the same group has revealed that a two-plate system creates a larger tilted beam than the one-plate system [Nakano et al., 2016a]. (3) Line antenna: Maema et al. [2014] have discussed the radiation efficiency of an electrically small and low-profile meandered-line antenna. This antenna uses a capacitive feed structure and two meandered elements. (4) Split-ring Antenna: Lertsakwimarn et al. [2015] have designed an antenna consisting of an inner small fed ring, an outer coupled split ring, and a ground plane, where an omnidirectional radiation pattern with horizontal polarization to the ground is obtained. (5) Inverted L antenna: Rohadi et al. [2014a] have investigated numerically and experimentally a low profile antenna based on two inverted L elements, which are located on a square conducting plane. This antenna is applied to a single-band MIMO antenna system. The same group has also investigated a dual-band MIMO antenna system [Rahadi et al., 2014b]. (6) Spiral antenna: Tanabe [2016] has discussed the antenna characteristics of a two-arm Archimedean spiral antenna above a hybrid HIS-EBG reflector. The hybrid HIS-EBG is effective for improving the input impedance and axial ratio. Nakano et al. [2016b] have investigated a metaspiral antenna with unbalanced excitation. Simple equations are derived for the unbalanced excitation. (7) Bowtie slot antenna: The design of a wideband printed antenna has been presented by Yamamoto [2014], where a leaf-shaped bowtie slot is employed as a radiating element. (8) BOR antenna: Nakano et al. [2014a] have introduced slots into a BOR-SPR antenna to obtain a stop band within an extremely wide VSWR frequency band. The same technique has been employed for an iCROSS antenna [Nakano et al., 2016c], which is a modification of the BOR-SPR antenna. The advantages of the iCROSS are as follows: the low-profile structure, high stopband VSWR, small cross-polarization component in the azimuth plane, and low fabrication cost. (9) Loop Antenna: Pal et al. [2014] have presented a dual-band low-profile switched beam square-loop antenna fed by capacitive coupling. The capacitively coupled feeding arrangement introduces capacitance into the antenna input impedance and cancels the high inductance due to close proximity of ground plane and feeding probes. Hirose et al. [2015a] have discussed the radiation from a circular loop with parallel wires. When the distance between the parallel wires is appropriately chosen, the antenna radiates a circularly polarized wave. Subsequently, the same group has proposed a triangle loop antenna as a circularly polarized element [Hirose et al., 2015b]. An application of the triangle loop to a comb-line antenna is presented.

(H. Nakano)

8.4 Arrays and Phased Arrays

A novel technique to replace some elements in an array antenna with parasitic elements is described [Takano et al., 2013]. First, the antenna characteristics are studied by simulation for a basic unit array with one driven and two parasitic elements. The parasitic elements are excited by the neighboring driven elements through the electromagnetic coupling effect. It is shown that at the optimal coupling condition, the radiation patterns are almost identical with those of an array antenna whose elements are all driven without coupling. The simulation result is confirmed by performing an experiment at 5.8 GHz. Finally, a 12-element array is formed by combining four unit arrays. The simulation results show that the maximum antenna gain indicates no penalty with respect to the antenna gain of a fully driven 12-element array. Therefore, the array antenna can be considerably simplified by replacing 67% of its elements with parasitic elements.

A solar power satellite system as an application of a large-scaled phased array antenna is described [Takano et al., 2013]. Key technologies are extracted, and their solutions are presented. Consequently, a paradigm shift from a-la-carte production to mass-production is pointed out.

A novel method to generate a beamed wave by a phased array antenna is presented [Takano et al., 2016]. Each radiating element of the antenna is fed with a phase correspondent to a spherical wave front of a Gaussian beam. Simulation results reveal that the convergence characteristics are strongly dependent on the transmitting antenna size, distance, and frequency. This work could be used in wireless power transmission through a long distance.

The design and radiation properties of a linearly polarized radial line microstrip antenna array (RL-MSAA) with U-slot circular microstrip antennas are presented [Kimura et al., 2014]. A circular microstrip antenna (C-MSA) with U-shaped slot is used as a radiation element of the RL-MSAA. Radiation phase of the U-slot C-MSA is controlled by tuning the radius of the C-MSA and dimensions of the U-slot on the C-MSA; therefore, the desired phase distribution of the RL-MSAA can be realized. In the paper, a linearly polarized RL-MSAA with three concentric rows of C-MSAs at a spacing of 0.65 wavelengths is designed for 12 GHz operation. In order to realize uniform phase distribution, the U-slot C-MSAs are arranged for inner two rows and normal C-MSAs are arranged for the termination row. Validity of the linearly polarized RL-MSAA with U-slot C-MSAs for radiation phase control is demonstrated by simulation and measurement.

Parallel-plate slot array antenna fed by rectangular waveguides at its lower-edge sides has been proposed [Akbar et al., 2016]. This antenna panel can be applied for dual circularly polarized deployable synthetic aperture radar (SAR) antenna onboard small satellite. As to confirm the feasibility of the antenna implementation, a development of one panel antenna system with single polarization (RHCP) has been conducted. The antenna design with simplified model by high-frequency structure simulator (HFSS) and antenna measurement results are explained in this paper. It is shown that antenna with gain and efficiency of 34.9 dBic and 54%, respectively, are achieved at the targeted center frequency (9.65 GHz).

A partially dielectric-filled structure of low-temperature cofired ceramics (LTCC) oversized rectangular waveguide slot array antenna with air layers both in the radiating and the feeding parts is presented [She et al., 2015]. It has a new structure of partially filled coupling junctions in the feeding waveguide. The efficiency evaluation shows that the air-layer addition reduces the transmission loss both in the radiating and the feeding parts. The gain and bandwidth have been enhanced. The effective dielectric constant is reduced and it broaden the bandwidth of the series-fed feed junctions and the slot array. Using the LTCC with ε_r = 6.6 and tanδ = 0.013, the dielectric losses of the feeding waveguide are reduced from 4.5 to 0.5 dB. The losses of the radiating waveguide are reduced from 3.7 to 0.45 dB. Experimentally, the gain was shown to increase 5.5 dB. The 3-dB-down bandwidth was improved from 1.4 to 2.1 GHz.

A point-to-point fixed wireless access (FWA) system with a maximum throughput of 1 Gbps has been developed in the 39 GHz band [Zhang et al., 2014]. A double-layer plate-laminated waveguide slot array antenna is successfully realized with specific considerations of practical application. The antenna is designed so as to hold the VSWR under 1.5. The antenna input as well as feeding network is configured to reduce the antenna profile as well as the antenna weight. In addition, integrating the antenna into a wireless terminal is taken into account. A shielding wall, whose effectiveness is experimentally demonstrated, is set in the middle of the wireless terminal to achieve the spatial isolation of more than 65 dB between two antennas on the H-plane. 30 test antennas are fabricated by diffusion bonding of thin metal plates, to investigate the tolerance and mass-productivity of this process. An aluminum antenna, which has the advantages of light weight and anti-aging, is also fabricated and evaluated with an eye to the future.

A double-layer waveguide slot array antenna is developed for a 40-GHz-band directional division duplex (DDD) system, which exhibits extremely high utilization efficiency of frequency [Zhang et al., 2016]. To minimize the interference from the surrounding buildings, the Taylor distributions are adopted in both longitudinal and transverse directions over the antenna aperture to suppress the sidelobe levels (SLLs) below −30 dB. A four-corner-fed structure instead of the typical center-feed one is introduced for wideband operation. The perfect magnetic conductor (PMC) terminations are also adopted at the center of feeding waveguides due to the symmetric feed from right-and-left ends. As the predicted antenna performance using HFSS, the antenna gain of more than 31.8 dBi and the reflection of less than −10 dB are estimated over the operating frequency range of 39.5-41.0 GHz. The test antennas are fabricated by diffusion bonding of copper plates. As the measured antenna performance, the antenna gain higher than 30.6 dBi and the reflection lower than −10 dB are achieved over the desired frequency range. The sidelobes are suppressed below −30 dB, and the isolation between two antennas arranged in *H*-plane is achieved at the level of more than 76 dB.

A 16 x 16-element corporate-feed waveguide slot array antenna in the 60-GHz band is designed to achieve broadband reflection and high antenna efficiency [Tomura et al., 2014]. The sub-arrays consisting of 2 x 2-elements are designed to improve the reflection bandwidth by implementing lower *Q* and triple resonance. The designed antenna is fabricated by diffusion bonding of thin copper plates. A wide reflection bandwidth with VSWR less than 2.0 is obtained over 21.5%, 13.2 GHz (54.7-67.8 GHz). The measured gain is 32.6 dBi and the corresponding antenna efficiency is 76.5%. The broad bandwidth of more than 31.5-dBi gain is realized over 19.2%, 11.9 GHz (56.1-68.0 GHz). The gain in bandwidth covers the whole of the license-free 60-GHz band (57-66 GHz).

A 45° linearly polarized hollow-waveguide 16 x 16-slot array antenna is proposed for point-to-point wireless communication in the 71–76 GHz and 81–86 GHz bands [Tomura et al., 2014]. The antenna is composed of an equally-split corporate-feed circuit and 2 x 2-element sub-arrays which radiate the 45° linear polarization. Low sidelobe characteristics are obtained in the E-plane by diagonal placement of the square antenna rotating by 45 degrees. To suppress cross polarization, a radiating narrow-slot pair is adopted. The sub-array is designed by a genetic algorithm and 25.7% reflection bandwidth for VSWR < 1.5 is obtained by decreasing the Q of two eigenmodes of the radiating element. A 16 x 16-element array is fabricated by diffusion bonding of thin copper plates. The total thickness is 3.2 mm which is less than 1 free space wavelength. A high gain of 32.9 dBi, high antenna efficiency of 86.6% and low sidelobe characteristics of -27.1 dB first sidelobe levels are measured at the center frequency of 78.5 GHz. Further, the broadband characteristics of reflection (VSWR < 2), show a gain of more than 31.4 dBi, and low cross polarization of less than -30 dB are achieved over the 71-86 GHz band.

A single-layer corporate-feed slot array antenna is presented [Sano et al., 2014]. The single-layer structure is realized by adopting hollow rectangular coaxial lines for the corporate-feed circuit and placing the feeding circuit and the radiating elements in the same layer. Based on this, a 16 x 16-element slot array for the 60-GHz band is designed and fabricated by diffusion bonding of laminated thin copper plates. A 32.3 dBi gain and 72.2% antenna efficiency are confirmed at the design frequency of 61.5 GHz in the measurements. The 1-dB down gain bandwidth is 8.8%. The conductor loss of the antenna is estimated to be 0.85 dB at 61.5 GHz.

High gain antennas having broad bandwidth characteristic for the 120 GHz band is proposed [Kim et al., 2014]. The proposed antennas are fabricated by diffusion bonding of laminated thin copper plates which have the advantages of high precision and low loss characteristic even in a high frequency region such as the 120 GHz band. For stable fabrication using diffusion bonding, we propose a feeding structure which has a double layer. A 32 x 32-element array antenna shows more than a 38 dBi antenna gain with over 60% antenna efficiency and 15 GHz bandwidth (119.0□134.0 GHz) and a 64 x 64-element array shows a higher than 43 dBi antenna gain with over 50% antenna efficiency and 14.5 GHz bandwidth (118.5-133.0 GHz), respectively.

A slot array antenna for dual-polarization operation in the 60 GHz band is proposed. To realize the dual-polarization, cross-shaped radiating slots and a multilayer feeding structure are employed [Kim et al., 2014]. A 16 x 16-element array is fabricated by diffusion bonding of laminated thin copper plates, which has the advantages of high precision and low loss characteristics. To suppress the grating lobes, we employ several design techniques, such as a thick cavity structure and dense element spacing. The high antenna gain higher than 32.0 dBi and the antenna efficiency near 80.0%

are obtained over 60.0-64.0 GHz for two different polarizations. The 1-dB-down gain bandwidths reach 10.4% and 10.9%. High isolation above 50 dB is achieved between the two input ports.

A 12 x 16-element corporate-feed slot array is presented [Ito et al., 2016]. The corporate-feed circuit for the 12 x 16-element array consists of cross-junctions and asymmetric T-junctions, whereas the conventional one is limited to arrays of 2^m x 2^n slots by its use of symmetric T-junctions. Simulations of the 12 x 16-element array show a 7.6% bandwidth for reflection less than −14 dB. A 31.7-dBi gain with an antenna efficiency of 82.6% is obtained at the design frequency of 61.5 GHz. The 12 x 16-element array is fabricated by diffusion bonding of laminated thin metal plates. Measurements indicate 31.1-dBi gain with 71.9% antenna efficiency at 61.5 GHz.
(K. Hashimoto)

8.5 Systems

Recently, the wireless power transfer (WPT) systems including SSPS are very remarkable and the relating papers have been reported.

An independent electrical coupled resonance WPT system to further increase such systems' power transfer distance is proposed [Yang and Tsunekawa, 2015]. The proposed system's power transfer function, critical coupling point, and resonance frequency splitting are investigated via the equivalent circuit, simulation, and experiment. Moreover, the input impedance characteristic of two electric coupled resonance antennas is also analyzed according to the transfer distance. In the region of under coupled, an appropriate impedance matching method is required to achieve effective power transfers. Further, a fixed configuration type matching loop with a series-connecting variable capacitance that can be added into both the source and load antennas is proposed. Experimental results demonstrate that the proposed matching loop can convert the two electric coupled resonance antennas' input impedance to the feed port impedance very well at varying transfer distances; these results are in good agreement with the simulation results.

Magnetic resonant coupling between two coils allows effective wireless transfer of power over distances in the range of tens of centimeters to a few meters. The strong resonant magnetic field also extends to the immediate surroundings of the power transfer system. When a user or bystander is exposed to this magnetic field, electric fields are induced in the body. For the purposes of human and product safety, it is necessary to evaluate whether these fields satisfy the human exposure limits specified in international guidelines and standards. The effectiveness of the quasistatic approximation for computational modeling human exposure to the magnetic fields of wireless power transfer systems is investigated [Laakso et al., 2015]. It is shown that, when valid, this approximation can greatly reduce the computational requirements of the assessment of human exposure.

"Disk-repeater" is proposed as a new structure alternative to the conventional resonator repeater [Sawahara et al., 2015]. Disk-repeater has a simple structure comprised of just copper plates and wire, non-resonant structure. First, coupling coefficients are measured as functions of disk diameter and wire length to characterize the basic performance of Disk-repeater. It is explained by several experimental evidences that Disk-repeater and resonator are not magnetically coupled but electrically coupled. It is also shown that the transmission distance extends dramatically longer than that of conventional resonator repeater. Further, two-dimensional arrangement, where multiple disks are connected, shows very high efficiency and uniform transmission characteristic regardless of positions of receiving resonator. Disk-repeater gives possibility of unprecedented versatile application with the simple structure.

A method for measuring the magnetic field strength for human exposure assessment closer than 20 cm to wireless power transfer (WPT) systems for information household appliances is investigated based on numerical simulations and measurements at 100 kHz and 6.78 MHz [Ishihara et al., 2015]. Four types of magnetic sources are considered: a simple 1-turn coil and three types of coils simulating actual WPT systems. A magnetic sensor whose cross sectional area is 100 cm2 as prescribed in International Electrotechnical Commission 62233 is used. Simulation results show that the magnetic field strength detected by the magnetic sensor is affected by its placement angle. The maximum coefficient of variation (CV) is 27.2% when the magnetic source and the sensor are in contact. The reason for this deviation is attributable to the localization of the magnetic field distribution around the magnetic source. The coupling effect between the magnetic source and the sensor is negligible. Therefore, the sensor placement angle is an essential factor in magnetic field measurements. The CV due to the sensor placement angle is reduced from 21% to 4% if the area of the sensor coil is reduced from 100 to 0.75 cm2 at 6.78 MHz. However, the sensitivity of the sensor coil is decreased by 42.5 dB. If measurement uncertainty that considers the deviation in the magnetic field strength due to the sensor placement angle is large, the measured magnetic field strength should be corrected by the uncertainty. If the magnetic field distribution around the magnetic source is known, conservative exposure assessments can be achieved by placing the magnetic sensor in locations at which the spatial averaged magnetic field strengths perpendicular to the magnetic sensor coils become maximum.

A novel resonator design that uses tightly coupled parallel coils to improve the quality factor (Q factor) in coupled magnetic resonance wireless power transfer is proposed [Yang and Tsunekawa, 2016]. Depending on the characteristics of the tightly coupled parallel-connected coils, the proposed resonator can offer significantly reduced resistance with very little self-inductance loss. A double-layer spiral coil structure is used for resonator design and evaluating its characteristics. Measured results show that a resonator consisting of two identical, tightly coupled parallel double-layer spiral coils can match the Q factor of a conventional double-layer spiral coil with the same number of turns, even though its equivalent resistance is approximately 75% less. Moreover, the system power transfer performance of the resonator was measured under the impedance matching condition. To further reduce the resistance, we propose another resonator comprising of three parallel and tightly coupled double-layer spiral coils, and measure its equivalent resistance characteristics for different wire gap sizes.

A technology and system which can be used for feeding electric vehicles by wireless means is proposed [Takano et al., 2015a]. In the system, input power is converted to microwave, and propagates in the form of a beam. At the receiving site, the microwave is reconverted to DC or AC power, and is output to users. The system analysis shows that the beam can be focused in a relatively short haul so that the receiving antenna can be made small in size. Concentration of power in a beam is beneficial to lessen the interference with other radio systems. Semiconductors in the input and output which should handle a large microwave power are studied. Finally, a concrete application of the technologies to a car feeding system is shown.

The design method of the antennas for beamed power transfer via radio wave is proposed [Takano et al., 2015b]. The transmission antenna is composed of arrayed radiating elements of which the phase is designed to form a concave phase front. The simulation analysis clarifies the characteristics of the transmitted beam. Accordingly, the focusing capability is dependent on the size of the transmission antenna, frequency, and the distance. The reception antenna is determined according to the obtained beam profile.

The COP 21 requires no total emission of man-made CO2 gas, which necessitates new energy systems without fossil fuel. A solar power satellite system (SPSS) is one of powerful solutions. At this stage, realistic SPSS models looking back R&D activities in the past is shown [Takano, 2016c]. In the future, we should demonstrate sending a weak beamed power from a satellite to earth, then increasing the power, and finally the system integrity of the commercial satellite. As an SPSS is a huge system, its R&D plan is deliberated to lessen the cost and risks, and to satisfy business conditions.
(S. Makino)

References

Akbar P.R., Saito H., Zhang M., Hirokawa J., and Ando M. [2016], “Parallel-Plate Slot Array Antenna for Deployable SAR Antenna Onboard Small Satellite,” IEEE Trans. Antennas Propag., vol.64, no.5, pp.1661-1671.

Ali M., Kohama T., and Ando M. [2015], “Modified Edge Representation (MER) Consisting of Keller’s Diffraction Coefficients With Weighted Fringe Waves and Its Localization for Evaluation of Corner Diffraction,” IEEE Trans. Antennas Propag., vol.63, no.7, pp.3158-3167.

Arai, S., Shibazaki T., and Kinoshita T. [2016], “Numerical Modeling of Thick Conducting Irises using FDTD Method -Comparison with the Modified Residue-Calculus Method-,” 2016 URSI Asia-Pacific Radio Science Conference (URSI AP-RASC2016), S-B12b-7, pp.212-214.

Arima T., Gunji M., Uno T. [2016a], “Effective Modeling Method of Metamaterials in FDTD Method by Utilizing Surface Impedance Boundary Conditions,” Proc. 2016 URSI Asia-Pacific Radio Science Conference (AP-RASC 2016), pp.528-529, Seoul, Korea.

Asano K., Uno T., Arima T. [2016], “ARMA/FDTD Analysis of Loop Antennas near Human Body for MHz Band Wireless Power Transfer System,” Proc. 2016 International Symposium on Antennas and Propagation (ISAP2016), pp. 568-569, Okinawa, Japan.

Fujimoto T. and Jono K. [2014], “Wideband rectangular printed monopole antenna for circular polarization,” IET Microwaves, Antennas & Propagation, vol. 8, no. 9, pp.649-656.

Fujimoto T., Yoshitake Y., and Yagyu D. [2015a], “Design and simulation based studies of a dual-band circularly-polarized square microstrip antenna,” Progress In Electromagnetics Research Letters, vol. 52, 129-134.

Fujimoto T. and Yoshitake Y. [2015b], “Stacked microstrip antenna fed by an L-probe for quadruple band operation,” IET Microwaves, Antennas & Propagation, vol. 9, no. 4, pp.360-368.

Fujisawa T., Kanazawa S., Ueda Y., Kobayashi W., Takahata K., Ohki A., Ito T., Kohtoku M., and Ishii H. [2013], “Low-loss cascaded Mach–Zehnder multiplexer integrated 25-Gbit/s × 4-lane EADFB Laser array for Future CFP4 100 GbE transmitter,” IEEE Journal of Quantum Electronics, vol. 49, 12, pp. 1001-1007.

Fujisawa T. and Saitoh K. [2015a], “Material gain analysis of GeSn/SiGeSn quantum wells for mid-infrared Si-based light sources based on many-body theory,” IEEE Journal of Quantum Electronics, vol. 51, 5, pp. 7100108.

Fujisawa T. and Saitoh K. [2015b], “Quantum-confined Stark effect analysis of GeSn/SiGeSn quantum wells for mid-infrared Si-based electroabsorption devices based on many-body theory,” IEEE Journal of Quantum Electronics, vol. 51, 11, pp. 8400207.

Fujisawa T. and Saitoh K. [2016], “Group delay spread analysis of strongly coupled 3-core fibers: an effect of bending and twisting,” Optics Express, vol. 24, 9, pp. 9583-9591.

Fujita K. and Shirai H. [2015], “Theoretical limitation of the radiation efficiency for homogeneous electrically small antennas,'' IEICE Trans. Electron., vol.E98-C, no.1, pp.2-7.

Fujita K. [2015], "A partially implicit FDTD method for the wideband analysis of spoof localized surface plasmons," IEEE Photonics Technology Letters, vol.27, no.10, pp.1124-1127.

Fujita K. [2016a], "3-D MNL-FDTD formulation in general orthogonal grids," IEEE Antennas and Wireless Propagation Letters, vol.15, pp.646-649.

Fujita K. [2016b], "Nonlinear MNL-FDTD scheme for short-gap electrostatic discharge simulation," Electronics Letters, vol.52, no.11, pp.932-934.

Fujita K. [2016c], "MNL-FDTD/SPICE method for fast analysis of short-gap ESD in complex systems," IEEE Transactions on Electromagnetic Compatibility, vol.58, no.3, pp.709-720.

Fujita K. [2016d], "Complex-frequency shifted PML formulation for the 3-D MNL-FDTD method," IEEE Microwave and Wireless Components Letters., vol.26, no.9, pp.651-653.

Fujita K. [2016e], "Multiscale modeling of a short relativistic electron bunch interacting with long resistive structures at cryogenic temperatures," IEEE Journal on Multiscale and Multiphysics Computational Techniques, vol.1, pp.107-119.

Goto K., Sawada M., Mori K., and Horii Y. [2014a], "Asymptotic analysis for transient scattered field excited by the edges of a cylindrically curved conducting open sheet," IEICE Electron. Express, vol. 11, no. 5, 20130963, pp. 1-11.

Goto K., Mori K., Horii Y., and Sawada M. [2014b], "Study on arrival times of transient creeping wave and transient whispering-gallery mode," Proc. of the 2014 IEEE AP-S, 441.9, pp. 2214-2215, Memphis.

Goto K., Sawada M., Mori K., and Horii Y. [2014c], "Time-domain asymptotic analysis for magnetic-type transient surface diffracted ray," Proc. of the 2014 IEEE AP-S, 441.11, pp. 2218-2219, Memphis.

Goto K., Horii Y., Mori K., and Sawada M. [2014d], "Study on transient scattered electric field by a coated conducting cylinder," Proc. of the 2014 IEEE AP-S, 441.10, pp. 2216-2217, Memphis.

Goto K., Sumikawa N., Santikul T., and Asai R. [2015a], "Study on transient scattered field from a cylindrically curved conducting open sheet with two straight edges excited by UWB pulse wave," Proc. of the ICEAA 2015, pp. 227-230, Torino.

Goto K., Asai R., Sumikawa N., and Santikul T. [2015b], "Time-domain asymptotic-numerical solution for transient scattered electric field by a coated conducting cylinder covered with a thin lossy dielectric material," IEICE Electron. Express, vol. 12, no. 3, 20141110, pp. 1-10.

Goto K., Okawa O., and Kishimoto N. [2015c], "Asymptotic-numerical analysis for transient scattered field by a coated cylinder with a thin lossy medium excited by a UWB pulse wave," Proc. of the URSI-JRSM 2015, B2, p. 40, Tokyo.

Goto K., Santikul T., Asai R., and Sumikawa N. [2015d], "Study on Transient Scattered Electric Field from a Coated Conducting Cylinder Covered with a Thin Lossy Dielectric Material Excited by UWB Pulse Wave," Proc. of the ICEAA 2015, pp. 231-234, Torino.

Goto K., Kishimoto N., and Okawa O. [2016a], "Time-domain asymptotic numerical solution for transient scattered field from a cylindrically curved conducting open sheet excited by UWB pulse wave," IEICE Electron. Express, vol. 13, no. 3, 20151041, pp. 1-9.

Goto K., Sumikawa N., Asai R., and Santikul T. [2016b], "Frequency-Domain Uniform Asymptotic Solution for Scattered Field by a Coated Cylinder with a Thin Lossy Medium," IEICE Trans. Electron., vol. E99-C, no. 1, pp. 18-27.

Goto K., Hagiwara K., Takeno Y., Tokumaru S., and Okada L. [2016c], "Frequency-Domain Uniform Asymptotic Solution for Scattered Electric Field by a 2-D Coated Conducting Cylinder Covered with a Thin Lossy Medium," Proc. of the ICEAA 2016, pp. 364-365, Cairns.

Goto K., Okawa O., and Kishimoto N. [2016d], "High-frequency asymptotic solutions for scattered magnetic field by a coated cylinder," Proc. of the 2016 IEEE AP-S, TH-A3.2A.1, pp. 1497-1498, Fajardo.

Goto K., Hagiwara K., Okada L., Takeno Y., and Tokumaru S. [2016e], "Interpretation method for response waveform of transient scattered magnetic field by a coated cylinder covered with a thick material," Proc. of the AP-RASC 2016, S-B12a-3, pp. 24-27, Seoul.

Hagiwara K., Goto K., Tokumaru S., Okada L., and Takeno Y. [2016], "High-frequency asymptotic solutions for scattered electric field by a 2-D coated conducting cylinder covered with a thick dielectric medium," Proc. of the ICEAA 2016, pp. 366-367, Cairns.

Hanzawa N., Saitoh K., Sakamoto T., Matsui T., Tsujikawa K., Koshiba M., and Yamamoto F. [2013], "Two-mode PLC-based mode multi/demultiplexer for mode and wavelength division multiplexed transmission," Optics Express, vol. 21, 22, pp. 25752-25760.

Hanzawa N., Saitoh K., Sakamoto T., Matsui T., Tsujikawa K., Koshiba M., and Yamamoto F. [2014], "Mode multi/demultiplexing with parallel waveguide for mode division multiplexed transmission," Optics Express, vol. 22, 24, pp. 29321-29330.

Hanzawa N., Saitoh K., Sakamoto T., Matsui T., Tsujikawa K., Uematsu T., and Yamamoto F. [2015], "PLC-based four-mode multi/demultiplexer with LP11 mode rotator on one chip," IEEE/OSA Journal of Lightwave Technology, vol. 33, 6, pp. 1161-1165.

Hasegawa H. and Shirai H. [2014], "E polarized plane wave diffraction by a wide and thick slit," 2014 IEEE International Symposium on Antennas and Propagation, CDROM, Memphis, TN, USA.

Hirose K., Shinozaki K., and Nakano H. [2015a], "A loop antenna with parallel wires for circular polarization—its application to two types of microstrip-line antennas," IEEE Antennas Wireless Propag. Letters, no.14, pp. 583-586.

Hirose K., Shinozaki K., and Nakano H. [2015b], "A comb-line antenna modified for wideband circular polarization," IEEE Antennas Wireless Propag. Letters, vol. 14, pp. 1113-1116.

Igarashi K., Soma D., Wakayama Y., Takeshima K., Kawaguchi Y., Yoshikane N., Tsuritani T., Morita I., and Suzuki M. [2016], "Ultra-dense spatial-division-multiplexed optical fiber transmission over 6-mode 19-core fibers," vol. 24, 10, pp. 10213-10231.

Ishihara S., Onishi T., and Hirata A. [2015], "Magnetic Field Measurement for Human Exposure Assessment near Wireless Power Transfer Systems in Kilohertz and Megahertz Bands," IEICE Trans. Commun., vol.E98–B, no.12, pp.2470-2476.

Ito K., Takahashi M., and Saito K. [2016], "Small antennas used in the vicinity of human body," IEICE Trans. Commun., vol. E99-B, no. 1, pp.9-18.

Ito S., Zhang M., Hirokawa J., and Ando M. [2016], “A 12 x 16-Element Double-Layer Corporate-Feed Waveguide Slot Array Antenna,” IEICE Trans. Commun., vol.E99-B, no.1, pp.40-47.

Iwashige J., Barolli L., Iwaida M., and Kameyama S [2014], “Evaluation of a Method for Finding Diffraction Points on Two Edges with Arbitrary Angle and Its Diffracted Fields,” 2014 IEEE Eighth Intl. Conf. Complex, Intelligent Software Intensive Systems, DOI: 10.1109/CISIS.2014.44.

Jandieri V., Yasumoto K., and Cho Y. K. [2013], “Resonances and Field Enhancement in Cylindrical Electromagnetic Bandgap Structures,” IEICE Transaction on Electronics, vol.E96-C, no.11, pp.1436-1439.

Jandieri V., Yasumoto K., and Pistora J. [2014], “Coupled-mode analysis of contra-directional coupling between two asymmetric photonic crystal waveguides,” Journal of Optical Society of America A, vol. 31, no. 3, pp. 518-523.

Jandieri V., Meng P., Yasumoto K., and Liu Y. [2015], “Scattering of light by gratings of metal-coated circular nanocylinders on a dielectric substrate,” Journal of Optical Society of America A, vol. 32, no. 7, pp. 1384-1389.

Jandieri V., Yasumoto K., Liu Y., and Pistora J. [2016], “Scattering of light by the metal-coated dielectric nanocylinders with angular periodicity,” Progress In Electromagnetics Research M, vol. 45, pp. 101–111.

Kasahara M., Saitoh K., Sakamoto T., Hanzawa N., Matsui T., Tsujikawa K., Yamamoto F., and Koshiba M. [2013], “Design of few-mode fibers for mode-division multiplexing transmission,” IEEE Photonics Journal, vol. 5, 6, pp. 7201207.

Kasahara M., Saitoh K., Sakamoto T., Hanzawa N., Matsui T., Tsujikawa K., and Yamamoto F. [2014], “Design of three-spatial-mode ring-core fiber,” IEEE/OSA Journal of Lightwave Technology, vol. 32, 7, pp. 1337-1343.

Kawaguchi H., Itasaka S., and Weiland T. [2014], “Initial value problem formulation of 3D time domain boundary element method,” IEEE Tran. Magn., vol. 50, no. 2, 7013104.

Kawaguchi H., Itasaka S., and Weiland T. [2015], “4-D space-time-domain decomposition simulation of particle accelerator wake field based on 3-D time domain BEM,” IEEE Trans. Magn., vol. 51, no.

3, 7201604.

Kim D., Hirokawa J., Ando M., Takeuchi J., and Hirata A. [2014], “64 x 64-Element and 32 x 32-Element Slot Array Antennas Using Double-Layer Hollow-Waveguide Corporate-Feed in the 120 GHz Band,” IEEE Trans. Antennas Propag., vol.62, no.6, pp.3019-3027.

Kim D., Zhang M., Hirokawa J., and Ando M. [2014], “Design and Fabrication of a Dual-Polarization Waveguide Slot Array Antenna With High Isolation and High Antenna Efficiency for the 60 GHz Band,” IEEE Trans. Antennas Propag., vol.62, no.6, pp.3019-3027.

Kimura Y., Saito S., and Kimura Y. [2014], “Radiation Properties of a Linearly Polarized Radial Line Microstrip Antenna Array with U-Slots,” IEICE Trans. Commun., vol.E97-B, no.10, pp.2883-2890.

Kisumi A. and Shirai H. [2015], “Dimension Estimation of Polygonal Dielectric Targets from Surface Reflection RCS,” Proc. of International Symposium on Antennas and Propagation (ISAP2015), pp.386--387, Tasmania, Australia.

Kobayashi K. [2015], “Radar cross section of a finite parallel-plate waveguide with material loading: A rigorous Wiener-Hopf approach,” Proc. 2015 URSI Atlantic Radio Science Conference (URSI AT-RASC 2015), p. 1.

Kobayashi K. [2016], “Rigorous RCS analysis of a finite parallel-plate waveguide with material loading,” Proc. 2016 IEEE International Conference on Mathematical Methods in Electromagnetic Theory (MMET*2016), pp. 24-29.

Kohama T., and Ando M. [2014], “Physical Optics Radiation Integrals with Frequency-Independent Number of Division utilizing Fresnel Zone Number Localization and Adaptive Sampling Method,” IEICE Trans. Electron., vol.97, no.12, pp.1134-1141.

Komiyama A. [2014], “Perturbation Analysis of the TE Plane Wave Scattering from the End-Face Of a Waveguide System,” XXXI General Assembly and Scientific Symposium of the International Union of Radio Science in Beijing.

Komiyama A. [2015], “Scattering of a TE Plane Wave by the End-Face of an Ordered Waveguide System,” 1st URSI Atlantic Radio Science Conference in Gran Canaria.

Komiyama A. [2016a], “Numerical Analysis of the Plane Wave Scattering by the End-Face of a Waveguide System: Near Field,” IEICE Transaction on Electronics, vol.E99-C, no.1, pp.68-71.

Komiyama A. [2016b], “Analysis of the TM Plane Wave Scattering from a Dielectric Grating by the Perturbation Method,” URSI Commission B International Symposium on Electromagnetic Theory in Espoo.

Konno K. and Chen Q. [2014a], “Numerical analysis of antenna near dielectric object by using CBFM with arbitrary block division,” Proc. IEEE AP-S Int. Symp., IF342.4, pp.2112-2113, Tennessee, USA.

Konno K. and Chen Q. [2014b], “The numerical analysis of an antenna near a dielectric object using the higher-order characteristic basis function method combined with a volume integral equation,” IEICE Trans. Commun., vol.E97-B, no.10, pp.2066-2073.

Konno K. and Chen Q. [2014c], “Numerical Analysis of Planar Dipole Antennas in the Vicinity of Dielectric Object Using HO-CBFM,” Proc. IEICE Int. Symp. Antennas. Propag., TH2B-01, pp.245-246, Kaohsiung, Taiwan.

Konno K., Chen Q., and Burkholder R.J. [2016], “Numerical Analysis of Finite Periodic Array Antenna Using Novel Characteristic Basis Function Method,” Proc. IEEE AP-S Int. Symp., pp.49-50, Fajardo, Puerto Rico.

Kushiyama Y., Arima T., Uno T. [2015], “Differential-Type CRLH Leaky-Wave Antenna Using Stepped Impedance Resonators,” IEEE Antennas and Wireless Propagation Letters，vol.15, pp321-324.

Laakso I., Shimamoto T., Hirata A., and Feliziani M. [2015], “Quasistatic Approximation for Exposure Assessment of Wireless Power Transfer,” IEICE Trans. Commun., vol.E98–B, no.7, pp.1156-1163.

Lertsakwimarn K., Phongcharoenpanich C., and Fukusako T. [2015], “A low-profile and compact split-ring antenna with horizontally polarized omnidirectional radiation,” Hindawi Publishing Corporation International Journal of Antennas and Propagation, vol.2015, pp. 1-11.

Maeda　H. , Tomiura K., Chen H., Yasumoto K. [2013], “Studies on loss evaluation of bending in post wall waveguide for microwave transmission,” Lecture Notes in Electrical Engineering, Springer, vol. 253, pp. 333-340.

Maeda H., Chen H., Tomiura K., and Yasumoto K. [2014], "Numerical and experimental study on confinement in Y-shaped post wall branching waveguide," Mobile Information Systems, vol. 10, no.2, pp. 217-228.

Maeda K., Shibata H., Kawaguchi H., and Itasaka S. [2014], "MPI parallel scheme of 3D time domain boundary element method with CRS matrix compression," IEEE Trans. Magn., vol. 50, no. 2, 7013104.

Maema H. and Fukusako T. [2014], "Radiation efficiency improvement for electrically small and low-profile antenna by stacked elements," IEEE Antennas Wireless Propag. Letters, vol. 13, pp. 305-307.

Makino S., Sato T., Ishizaka Y., Fujisawa T., and Saitoh K. [2015a], "Three-dimensional finite-element time-domain beam propagation method and its application to 1-D photonic crystal-coupled resonator optical waveguide," IEEE/OSA Journal of Lightwave Technology, vol. 33, 18, pp. 3836-3842.

Makino S., Fujisawa T., and Saitoh K. [2015b], "Enhancement of optical nonlinearity in coupled resonator optical waveguide based on slotted 1-D photonic crystal cavity," IEEE Photonics Journal, vol. 7, 6, pp. 4501608.

Maruyama S. and Fukusako T. [2014], "An interpretative study on circularly polarized patch antenna using artificial ground structure," IEEE Trans. Antennas Propag., vol. 62, no. 11, pp. 5919-5924.

Matsushima A. [2016], "Integral equation method of the expansion type applied to light scattering from nano-metal strips," 2016 Int'l Conf. Math. Methods Electromag. Theory, pp. 54-57.

Meng P. W., Yasumoto K., and Liu Y. F. [2014], "Surface plasmon resonant scattering in metal-coated dielectric nanocylinders," Optics Communications, vol. 332, pp. 18-24, 2014.

Moriyama T., Oliveri G., Salucci M., and Takenaka T. [2014], "A multi-scaling forward-backward time-stepping method for microwave imaging," IEICE Electron. Express, vol. 11, no. 16, pp. 1-12.

Moriyama T. and Takenaka T. [2015], "Inverse scattering approach with measurement of only total electric field," Microwave Opt. Technol. Lett., vol. 57, no. 1, pp-137-141.

Moriyama T., Salucci M., Tanaka T., and Takenaka T. [2016], "Image reconstruction from total electric field data with no information on incident field," J. Electromagn. Waves Appl., vol. 30, no. 9, pp.

1162-1170.

Murao T., Yasui N., Shinada T., Imai Y., Nakamura K., Shimono M., Kodera H., Morita Y., Uchiyama A., Koyanagi H., and Aruga H. [2014], “Integrated spatial optical system for compact 28-Gb/s × 4-lane transmitter optical sub-assemblies,” IEEE Photonics Technology Letters, vol. 26, 22, pp. 2275-2278.

Naka Y., and Nishimoto M. [2016], “Energy Distribution of Periodically Dielectric Waveguides by Arbitrary Shape of Dielectric Constants–The Influence of Dielectric Structure in the middle layer-,” IEICE Trans. Electron., vol.E99-C, no.1, pp.81-84.

Nakano H., Takeuchi M., Takeuchi K., and Yamauchi J. [2014a], “Extremely low-profile BOR-SPR-SLOT antenna with stop bands,” IEEE Trans. Antennas Propag., vol. 62, no. 6, pp. 2883-2890.

Nakano H., Mitsui S., and Yamauchi J. [2014b], “Tilted-beam high gain antenna system composed of a patch antenna and periodically arrayed loops,” IEEE Trans. Antennas Propag., vol. 62, no. 6, pp. 2917-2925.

Nakano H., Toida M., Okabe S., and Yamauchi J. [2016a], “Tilted beam formation using parasitic loop-based plates,” IEEE Antennas Wireless Propag. Letters, vol. 15, pp. 1475-1478.

Nakano H., Anjo K., and Yamauchi J. [2016b], “Simple equations for estimating decrease in broadside radiation from a metaspiral antenna,” IEEE Antennas Wireless Propag. Letters, vol. 15, pp.1951-1954.

Nakano H., Takeuchi M., and Yamauchi J. [2016c], “Low-profile wideband iCROSS antenna,” IEEE Trans. Antennas Propag., vol. 64, no. 7, pp. 2824-2831.

Nakatake Y., and Watanabe K. [2013], “Spectral-Domain Formulation of Pillar-type Photonic Crystal Waveguide Devices of Infinite Extent,” Progress In Electromagnetics Research, Vol. 143, pp.447-461.

Nakayama J., and Y. Tamura [2014a], “Method of Image Green's Function in Grating Theory: Extinction Error Field,” IEICE Trans. Electron., vol.E97-C, no.1, pp.40-44.

Nakayama J., and Y. Tamura [2014b], “Shadow Theory of Diffraction Grating: Reciprocity, Symmetry and Average Filter,” IEICE Trans. Electron., vol.E97-C, no.10, pp.1036-1040.

Nanbu Y., and Tateiba M. [2016], "Depolarization of electromagnetic waves propagated through random media," Proc. 2016 PIERS 2016 (IEEE Xplore), pp. 195-199, Shanghai China.

Nanbu Y., Tateiba M., and El-Ocla H. [2014], "Analysis of depolarized electromagnetic waves propagated through random medium by using perturbation method," Proc. 2014 ANTEM (USB memory stick), Victoria BC Canada.

Nguyen A. N. and Shirai H. [2015a], "Electromagnetic Scattering Analysis from Rectangular Dielectric Cuboids - TE polarization -," IEICE Trans. Electron., Vol. E99-C, No. 1, pp.11-17.

Nguyen A. N. and Shirai H. [2015b], "A Numerical Method for the Estimation of Relative Permittivity of Dielectric Materials," Proc. of 2015 International Conference on Electromagnetics in Advanced Applications, CDROM, Turin, Italy.

Nguyen-Huu N., Cada M., Pistora J., and Yasumoto K. [2014], "Tunable optical filter based on gold and silver double-sided gratings and its application as plasmonic sensor," Journal of Lightwave Technology, vol. 32, no. 21, pp. 3477-3484.

Nguyen T. H., Sato H., Koyanagi Y., and Morishita H. [2014], "A study on minimization of requisite design volume of small antennas inside handset terminals," IEICE Trans. Commun., vol. E97-B, no. 11, pp. 2395-2403.

Nguyen T.H., Oki T., Sato H., Koyanagi Y., and Morishita H. [2015], "Investigation on a Multi-Band Inverted-F Antenna Sharing Only One Shorting Strip among Multiple Branch Elements," IEICE Trans. Commun., vol.E98-B, no.7, pp.1302-1315.

Nishimoto M. and Naka Y. [2016], "Analysis of electromagnetic pulse responses by a conducting cylinder with inhomogeneous dielectric coating," Proc. of the ISAP2016, 3B1-2, pp. 24-27, Okinawa.

Nishimoto S., Fujisawa T., Sasaki Y., Uemura H., and Saitoh K. [2016], "Theoretical investigation of six-mode multi/demultiplexer based on fused-type multicore fiber coupler," IEEE Photonics Journal, vol. 8, 3, pp. 7802908.

Nishina B. and Chen Q. [2016], "Estimation of Equivalent Current Distribution of Modulated EM Radiation Source," IEEE Trans. Antennas Propag., vol. 64, no. 4 pp. 1334-1341.

Nito Y., Yatabe B., Yamauchi J., and Nakano H. [2016], “Reduction in bend losses of a buried waveguide on a silicon substrate by adjusting the core location,” IEEE/OSA Journal of Lightwave Technology, vol. 34, 4, pp. 1344-1349.

Ohnuki S., Kitaoka Y., and Takeuchi T. [2016], “Time-domain solver for 3D electromagnetic problems using the method of moments and the fast inverse Laplace transform,” IEICE Trans. Electron., vol. E99-C, no. 7, pp. 797-800.

Ohnuki S., Kobayashi K., Kishimoto S., and Yamasaki T. [2014], “Analysis of electromagnetic scattering from a conducting spherical shell by the 3D point matching method with mode matching,’’ IEICE Trans. Electron., vol.E97-C, no.7, pp. 714-717.

Ohtera Y. [2016], “Accuracy assessment of FDTD method for the analysis of sub-wavelength photonic structures,” IEICE Trans. Electron., vol. E99-C, no. 7, pp. 780-787.

Onodera S., Ishikawa R., Saitou A., and Honjo K. [2016], “Novel Design of Dual-Band Reconfigurable Dipole Antenna Using Lumped and Distributed Elements,” IEICE Trans. Commun., vol.E99-B, no.7, pp.1550-1557.

Ozaki R., Sugizaki N., and Yamasaki T. [2014], “Numerical Analysis of Pulse Responses in the Dispersion Media,” IEICE Trans. Electron., vol. E97.C, no.1, pp.45-49.

Ozaki R., and Yamasaki T. [2016a], “Distribution of Energy Density for Dielectric Waveguides with Various Properties of Dielectric Constants in the Middle Layer,” URSI Asia-Pacific Radio Science Conference in Seoul, pp.36-39.

Ozaki R., and Yamasaki T. [2016b], “Energy Distribution of Periodically Dielectric Waveguides by Arbitrary Shape of Dielectric Constants–The Influence of Dielectric Structure in the middle layer-,” IEICE Trans. Electron., vol.E99-C, no.7, pp.820-824.

Ozaki R., and Yamasaki T. [2016c], “Pulse Responses of Plane Gratings in Dispersion Media,” URSI Commission B International Symposium on Electromagnetic Theory in Espoo, pp.445-448.

Pal A., Mehta A., Mirshekar-Syahkal D., Deo P., and Nakano H. [2014], “Dual-band low-profile capacitively coupled beam-steerable square-loop antenna,” IEEE Trans. Antennas Propag., vol. 62, no. 3, pp. 1204-1211.

Rohadi E. and Taguchi M. [2014a], “Two low profile unbalanced fed inverted L elements on square conducting plane for MIMO applications,” Wireless Engineering and Technology, 5, pp. 34-43.

Rohadi E. and Taguchi M. [2014b], “Dual band MIMO antenna composed of two low profile unbalanced fed inverted L antennas for wireless communications,” Wireless Engineering and Technology, 5, pp. 54-61.

Saho K., Homma H., Sakamoto T., Sato T., Inoue K., and Fukuda T. [2014], “Accurate Image Separation Method for Two Closely Spaced Pedestrians Using UWB Doppler Imaging Radar and Supervised Learning,” IEICE Trans. Commun., vol.E97-B, no.6, pp.1223-1233.

Saitoh K., Uematsu T., Hanzawa N., Ishizaka Y., Masumoto K., Sakamoto T., Matsui T., Tsujikawa K., and Yamamoto F. [2014], “PLC-based LP11 mode rotator for mode-division multiplexing transmission,” Optics Express, vol. 22, 16, pp. 19117-19130.

Saitoh S., Saitoh K., Kashiwagi M., Matsuo S., and Dong L. [2014], “Design optimization of large-mode-area all-solid photonic bandgap fibers for high-power laser applications,” IEEE/OSA Journal of Lightwave Technology, vol. 32, 3, pp. 440-449.

Sakaguchi J., Klaus W., Mendinueta J. M. D., Puttnam B. J., Luís R. S., Awaji Y., Wada N., Hayashi T., Nakanishi T., Watanabe T., Kokubun Y., Takahata T., and Kobayashi T. [2016], “Large spatial channel (36-core × 3 mode) heterogeneous few-mode multicore fiber,” IEEE/OSA Journal of Lightwave Technology, vol. 34, 1, pp. 93–103.

Sakamoto T., Sato T., Aubry P. J., and Yarovoy A. G. [2015a], “Texture-based automatic separation of echoes from distributed moving targets in UWB radar signals,” IEEE Trans. Geosci. Remote Sens., vol.53, no.1, pp.352-361.

Sakamoto T., Imasaka R., Taki H., Sato T., Yoshioka M., Inoue K., Fukuda T., and Sakai H. [2015b], “Accurate heartbeat monitoring using ultra-wideband radar,” IEICE Electronics Express, vol.12, no.3, p.20141197.

Sakamoto T., Yamazaki H., and Sato T. [2015c], “Two-dimensional imaging of a pedestrian using multiple ultra-wideband Doppler interferometers with clustering-based echo association,” IEICE Trans. Commun., vol.E98-B, no.9, pp.1795-1803.

Sakamoto T., Sato T., Aubry P., and Yarovoy A. [2015d], “Ultra-Wideband Radar Imaging using a Hybrid of Kirchhoff Migration and Stolt F-K Migration with an Inverse Boundary Scattering Transform,” IEEE Trans. Antennas Propag., vol.63, no.8, pp.3502-3512.

Sakamoto T., Okumura S., Imanishi R., Taki H., Sato T., Yoshioka M., Inoue K., Fukuda T., and Sakai H. [2015e], “Remote heartbeat monitoring from human soles using 60-GHz ultra-wideband radar,” IEICE Electronics Express, vol.12, no.21, p.20150786.

Sakamoto T., Imasaka R., Taki H., Sato T., Yoshioka M., Inoue K., Fukuda T., and Sakai H. [2016a], Feature-based Correlation and Topological Similarity for Interbeat Interval Estimation using Ultra-Wideband Radar, IEEE Trans. Biomed. Eng., vol.63, no.4, pp.747-757.

Sakamoto T., Sato T., Aubry P., and Yarovoy A. [2016b], “Fast Imaging Method for Security Systems using Ultra-Wideband Radar,” IEEE Trans. Aerosp. Electron. Syst., vol.52, no.2, pp.658-670.

Sano M., Hirokawa J., and Ando M. [2014], “Single-Layer Corporate-Feed Slot Array in the 60-GHz Band Using Hollow Rectangular Coaxial Lines,” IEEE Trans. Antennas Propag., vol.62, no.10, pp.5068-5076.

Sasaki Y., Amma Y., Takenaga K., Matsuo S., Saitoh K., and Koshiba M. [2015], “Few-mode multicore fiber with 36 spatial modes (three modes (LP01, LP11a, LP11b) × 12 cores),” IEEE/OSA Journal of Lightwave Technology, vol. 33, 5, pp. 964-970.

Sato R.and Shirai H. [2014a], “Efficient reflection/transmission coefficient by two-layered dielectric slab for accurate propagation analysis,” Proc. of 2014 International Symposium on Electromagnetic Compatibility Tokyo (EMC’14/Tokyo), CDROM, Tokyo, Japan.

Sato R. and Shirai H., [2014b], “Reflection/transmission coefficient for two-layered dielectric slab with internal multiple reflections,” 2014 IEEE International Symposium on Antennas and Propagation, CDROM, Memphis, TN, USA.

Sato R. and Shirai H. [2014c], “Perturbation analysis of the TM plane wave scattering from the end-face of a waveguide system,” Proc. of 2014 International Conference on Electromagnetics in Advanced Applications (ICEAA), CDROM, Palm Beach, Aruba.

Sato R. and Shirai H. [2016], “Electromagnetic plane wave diffraction by loaded N-slits on thick conducting screen,’’ IEICE Trans. Electron., vol.E99-C, no.1, pp.72-75.

Sato T., Makino S., Ishizaka Y., Fujisawa T., and Saitoh K. [2014], “Three-dimensional finite-element mode-solver for nonlinear periodic optical waveguides and its application to photonic crystal waveguides,” IEEE/OSA Journal of Lightwave Technology, vol. 32, 21, pp. 4011-4019.

Sato T., Makino S., Ishizaka Y., Fujisawa T., and Saitoh K. [2015], “A rigorous definition of nonlinear parameter γ and effective area Aeff for photonic crystal optical waveguides,” Journal of the Optical Society of America B, vol. 32, 6, pp. 1245-1251.

Sato T., Makino S., Fujisawa T., and Saitoh K. [2016], “Design of a reflection-suppressed all-optical diode based on asymmetric L-shaped nonlinear photonic crystal cavity,” Journal of the Optical Society of America B, vol. 33, 1, pp. 54-61.

Sawahara Y., Ikuta Y., Zhang Y., Ishizaki T., and Awai I. [2015], “Proposal of a New Disk-Repeater System for Contactless Power Transfer,” IEICE Trans. Commun., vol.E98–B, no.12, pp.2370-2375.

Sekiguchi T., Okano Y., and Ogino S. [2016], “Effective Magnetic Sheet Loading Method for Near Field Communication Antennas,” IEICE Trans. Commun., vol.E99-C, no.10, pp.1211-1214.

Sekine T., Miura K. T., and Asai H. [2014], “Method of moments based on isogeometric analysis for electrostatic field simulations of curved multiconductor transmission lines,” IEEE 23rd Conf. on EPEPS, pp. 195-198.

Shibahara K., Lee D., Kobayashi T., Mizuno T., Takara H., Sano A., Kawakami H., Miyamoto Y., Ono H., Oguma M., Abe Y., Matsui T., Fukumoto R., Amma Y., Hosokawa T., Matsuo S., Saitoh K., Yamada M., and Morioka T. [2016], “Dense SDM (12-core × 3-mode) transmission over 527 km with 33.2-ns mode-dispersion employing low-complexity parallel MIMO frequency-domain equalization,” IEEE/OSA Journal of Lightwave Technology, vol. 34, 1, pp. 196-204.

Shibayama J., Oikawa T., Hirano T., Yamauchi J., and Nakano H. [2014], “Fundamental LOD-BOR-FDTD method for analysis of plasmonic devices,” IEICE Trans. Electron., vol. 97-C, no. 7, pp. 707-709.

Shimizu M., Shirai H. and Sato R. [2015], “Multiple Edge Interaction Effect to Plane Wave Scattering by a Wide and Thick Slit," Proc. of International Symposium on Antennas and Propagation (ISAP2015), pp341--343, Tasmania, Australia.

Shirai H. and Sato R. [2014], "Ray-mode conversion method for high frequency scattering analysis," Proc. of 2014 International Conference on Electromagnetics in Advanced Applications (ICEAA), CDROM, Palm Beach, Aruba.

Shirai H. and Shimizu M. [2015], "Ray-mode Conversion Technique Applied To Plane Wave Diffraction By a Thick Slit," Proc. of Korea-Japan Joint Conference on EMT/EMC/BE (KJJC2015), Sendai, Japan.

Shirai H., Shimizu M., and Sato R. [2016a], "Evanescent Modal Effect to E Polarized Plane Wave Diffraction by a Wide and Thick Slit," Proc. of 2016 IEEE International Symposium on Antennas and Propagation, pp.1503-1504, Puerto Rico, USA.

Shirai H., Shimizu M., and Sato R. [2016b], "Ray-mode Conversion Technique Applied to Thick Slit Diffraction," Proc. of the 16th International Conference on Mathematical Methods in Electromagnetic Theory, pp.43-45, Lviv, Ukraine.

Shirai H., Shimizu M., and Sato R. [2016c], "Diffraction by Thick and Loaded Slit -E-polarization Case-," Proc. of International Symposium on Electromagnetic Theory (EMTS 2016), pp.665-667, Espoo, Finland.

Shirai H., Shimizu M., and Sato R. [2016d], "Hybrid Ray-Mode Analysis of E-Polarized Plane Wave Diffraction by a Thick Slit," IEEE Trans. on Antennas and Propagation, Vol.64, No. 11, pp. 4828-4835.

She Y., Hirokawa J., Ando M., Hanatani D., and Fujimoto M. [2015], "LTCC Oversized Rectangular Waveguide Slot Array Antenna With Air Layers," IEEE Trans. Antennas Propag., vol.63, no.12, pp.5850-5854.

So H., Ando A., Seki T., Kawashima M., and Sugiyama T. [2014], "Multiband Sector Antenna with the Same Beamwidth Employing Multiple Woodpile Metamaterial Reflectors," IEICE Trans. Electon., vol.E97-C, no.10, pp.976-985.

Sugisaka J., Yasui T., and Hirayama K. [2016], "Efficient Scattering Analysis of Arbitrarily Shaped Local Defect in Diffraction Gratings," IEICE Trans. Electron., vol.E99-C, no.1, pp.76-80.

Sumi M. and Cho K. [2014], "Operating Mechanism of Small Quad-Band Printed Antenna Comprising Symmetrically Arranged Trapezoidal Elements and Rectangle Strip Elements," IEICE Trans. Commun., vol.E97-B, no.10, pp.2050-2058.

Sygisaka J., Yasui T., and Hirayama K. [2016], "Efficient Scattering Analysis of Arbitrarily Shaped Local Defect in Diffraction Grating," IEICE Trans., Electron., vol.99, no.1, pp.76-80.

Takano T., Imura T., and Okumura M. [2013], "A partially driven array antenna backed by a reflector with a reduction in the number of driven elements by up to 67%," IEICE Trans. Commun., vol.E96-B, no.11, pp.2883-2890.

Takano T., Saegusa K., and Hosono H. [2013], "A Large-Scale Phased Array Antenna – Its applications and key technologies," International Conference on Microwave & Photonics (ICMAP 2013), INVM03, Dhanbad, India.

Takano T., Uno T., Shibata K., and Saegusa K. [2016], "Generation of a Beamed Wave Using a Phased Array Antenna," 2016 URSI Asia-Pacific Radio Science Conference, Seoul.

Takano T., Miyazaki Y., Saegusa K., Uno T., Fujino Y., Maki K., Furukawa M., and Shinohara N. [2015a], "Design of Beamed Power Transfer Systems for Feeding Electrical Vehicles," Conference on Energy Transfer for Electric vehicles, Nuremberg.

Takano T., Uno T., Shibata K., and Saegusa K. [2015b], "Design of the Transmission and Reception Antennas for Beamed Power Transfer," ISAP2015, S5.4.5, Hobart, Australia.

Takano T. [2016], "R&D Strategy toward a Realizable Space Solar Power System," ICEF (Innovation for Cool Earth Forum) 2016, Tokyo.

Tamura Y. [2016], "Efficient Scattering Analysis of Arbitrarily Shaped Local Defect in Diffraction Gratings," IEICE Trans. Electron., vol.E99-C, no.1, pp.76-80.

Tamura, Y. [2016], "TE Plane Wave Scattering from Periodic Rough Surfaces with Perfect Conductivity: Image Integral Equation of the First Type," IEICE Trans. Electron., vol. E99-C, no. 2, pp. 266-274.

Tanabe M. [2016], “A spiral antenna above a Hybrid HIS-EBG reflector,” IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications (APWC), pp 208-211.

Tanaka M. [2014], “numerical calculation of electromagnetic scattering from multiple objects by superposition solution combined with MoM,” EMC' 14 Tokyo, pp. 793-795.

Tanaka T., Inasawa Y., Nishioka Y., and Miyashita H. [2016], “Improved primary characteristic basis function method for monostatic radar cross section analysis of specific coordinate plane,” IEICE Trans. Electron., vol. E99-C, no. 1, pp. 28-35.

Tomura T., Hirokawa J., Hirano T., and Ando M. [2014], “A Wideband 16 x 16-Element Corporate-Feed Hollow-Waveguide Slot Array Antenna in the 60-GHz Band,” IEICE Trans. Commun., vol.E97-B, no.4, pp.798-806.

Tomura T., Hirokawa J., Hirano T., and Ando M. [2014], “A 45° Linearly Polarized Hollow-Waveguide 16 x 16-Slot Array Antenna Covering 71-86 GHz Band,” IEEE Trans. Antennas Propag., vol.62, no.10, pp.5061-5067.

Tu J., Saitoh K., Takenaga K., and Matsuo S. [2014], “Heterogeneous trench-assisted few-mode multi-core fiber with low differential mode delay,” Optics Express, vol. 22, 4, pp. 4329-4341.

Tu J., Saitoh K., Amma Y., Takenaga K., and Matsuo S. [2015], “Heterogeneous trench-assisted few-mode multi-core fiber with graded-index profile and square-lattice layout for low differential mode delay,” Optics Express, vol. 23, 14, pp. 17783-17792.

Tu J., Long K., and Saitoh K. [2016], “An efficient core selection method for heterogeneous trench-assisted multi-core fiber,” IEEE Photonics Technology Letters, vol. 28, 7, pp. 810-813.

Uematsu T., Kitayama T., Ishizaka Y., and Saitoh K. [2014], “Ultra-broadband silicon-wire polarization beam combiner/splitter based on a wavelength insensitive coupler with a point-symmetrical configuration,” IEEE Photonics Journal, vol. 6, 1, pp. 4500108.

Yamauchi R. and Fukusako T. [2016], “A Broadband Circularly Polarized Waveguide Antenna Design for Low Cross-Polarization,” IEICE Trans. Commun., vol.E99-B, no.10, pp.2187-2194.

Yamamoto M. and Nojima T. [2014], “Design of a leaf-shaped bowtie slot antenna electromagnetically fed by a microstrip line," Proc. ISAP, pp. 261-262.

Yamamoto M. and Maeda S. [2015], "A wideband MIMO antenna using leaf-shaped monopole and notch antennas," Proc. ISAP, pp. 542-545.

Yamazaki H., Sakamoto T., Taki H., and Sato T. [2016], "False image suppression in two-dimensional shape estimates of a walking human using multiple ultra-wideband Doppler radar interferometers," IEICE Trans. Commun., vol.E99-B, no.1, pp.134-142.

Yang L., Li T., Wang F., and Yoshitomi K. [2016], "Compact Tri-Band MIMO Antenna for LTE/GSM Mobile Handset Application," IEICE Trans. Commun., vol.E99-B, no.1, pp.177-185.

Yang C. and Tsunekawa K. [2015], "Analysis and Performance Improvement of Independent Electric Coupled Resonance WPT System with Impedance Transformer," IEICE Trans. Commun., vol.E98–B, no.4, pp.630-637.

Yang C. and Tsunekawa K. [2016], "A Novel Resonator Design for Q Factor Improvement Using Tightly-Coupled Parallel Coils in Coupled Magnetic Resonance Wireless Power Transfer," IEICE Trans. Commun., vol.E99–B, no.3, pp.685-694.

Yashiro K. [2015a], "Analysis of scattering from a finite array of various circular cylinders by using global basis functions," 2015 Int'l Conf. Electromag. Adv. Appl. (ICEAA), pp. 598-601.

Yashiro K. [2015b], "Scattering from a finite array of axially magnetized ferrite cylinders," 2015 Int'l Symp. Antennas Propagat. (ISAP2015), Hobart, Australia, pp.823-826.

Ye F., Tu J., Saitoh K., and Morioka T. [2014], "Simple analytical expression for crosstalk estimation in homogeneous trench-assisted multi-core fibers," Optics Express, vol. 22, 19, pp. 23007-23018.

Ye F., Tu J., Saitoh K., Takenaga K., Matsuo S., Takara H., and Morioka T. [2016a], "Wavelength-dependence of inter-core crosstalk in homogeneous multi-core fibers," IEEE Photonics Technology Letters, vol. 28, 1, pp. 27-30.

Ye F., Tu J., Saitoh K., Takenaga K., Matsuo S., Takara H., and Morioka T. [2016b], "Design of homogeneous trench-assisted multi-core fibers based on analytical model," IEEE/OSA Journal of Lightwave Technology, vol. 34, 18, pp. 4406-4416.

Yokota M. and Matsumoto K. [2014] “Numerical Examination on Effective Permittivity of Two-Dimensional Multilayered Periodic Structures,” IEICE Trans. Electron., vol. E97-C, no.12, pp.1150-1153.

Yoshida T, Omoda E., Atsumi Y., Nishi T., Tajima S., Miura N., Mori M., and Sakakibara Y. [2016], “Vertically Curved Si Waveguide Coupler with Low Loss and Flat Wavelength Window,” IEEE/OSA Journal of Lightwave Technology, vol. 34, 7, pp. 1567-1571.

Zhang M., Hirokawa J., and Ando M. [2014], “Double-Layer Plate-Lminated Waveguide Slot Array Antennas for a 39 GHz Band Fixed Wireless Access System,” IEICE Trans. Commun., vol.E97-B, no.1, pp.122-128.

Zhang M., Hirokawa J., and Ando M. [2016], “A Four-Corner-Fed Double-Layer Waveguide Slot Array With Low Sidelobes Developed for a 40 Ghz-Band DDD System,” IEEE Trans. Antennas Propag., vol.64, no.5, pp.2005-2010.