COMMISSION B : Fields and Waves (Nov. '01 - Oct. '04)

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B1. Scattering and Diffraction

In URSI Commission B, the topic "scattering and diffraction" is a broad and very important subject area. There has been a great progress during the last three years in developing various solution methods and new results related to this topic. There are a number of simple, canonical two-dimensional (2-D) and three-dimensional (3-D) targets.

Summarized below is the recent progress in the research carried out in Japan during the three-year period from November 2001 to October 2004 regarding the topic area B1: Scattering and Diffraction.

In the following, we have provided a summary of the research related to this topic, which, however, is closely related to all the other topics B2-B8. It is therefore suggested that readers also refer to the results summarized in Sections B2 to B8.

1.1 Basic Electromagnetic Fields Analysis

Recently there has been an increasing interest for the basic electromagnetic fields analysis such as Helmholtz's theorem, Kramers-Kronig relation , superluminal group velocity , optical ray fields, polarization of the Poynting flux ,and guided wave fields.

Hosono [2002] investigated a new extension for the Helmholtz's theorem, which is based on the vector fields. This new expression of the theorem has been applied to those fields which are finite at infinity .For the Kramers-Kronig relation, Hosono and Hosono [2003] proposed a new algorithm that uses the Kramers-Kronig relation extended to complex frequency domain, and that can easily be carried out by a computer, and also analyzed the problem of negative group velocity, and showed that the group velocity of a wave packet is nothing but the phase velocity of the envelope. For the superluminal group velocity, Hosono and Hosono [2004] studied the precise waveforms of a causal half-sine-modulated pulse and a triangle-modulated pulse propagating in the Lorentz medium, and also clarified the effects of analyticity of signal to deepen understanding of the mechanism of superluminal group velocity theoretic consideration of a network.

Tokumaru [2002] introduced an optical ray field which satisfies the law of electromagnetic energy density flow in geometrical optics , and also proved to be the electromagnetic plane wave field when the optical ray field satisfying Maxwell's equations. For the polarization of the Poynting flux, Tokumaru [2003a] investigated an elliptic locus of the tip of the real-time Poynting flux of electromagnetic fields by 4 in term of a concept of the polarization. For the guided wave fields, Tokumaru [2003b] investigated the E-type and H-type guided phenomena , a reversal conception toward the guided waves , as it guided wave fields based on energy-transport relations. This new guided wave fields agree with the usual guided waves, if the new guided wave field satisfy the Maxwell's equations.

1.2 Periodic Array Structures

Recently, the scattering problems of periodic dielectric or metallic grating with inhomogeneous media have been of considerable interest, such as photonic bandgap crystals , frequency selective devices, optical fiber gratings ,and so on.

For the dielectric grating, the multilayered periodic arrays , and crossed-arrays of circular cylinders has been analyzed by[Jandieri and Yasumoto[2004], Yasumoto and Jia[2004a], Yasumoto[2004b] and Yasumoto et al.[2004c]] using the lattice sums technique, the aggregate T-matrix algorithm, and the generalized reflection and transmission matrices for a layered system. They also analyzed the lossy circular cylinders embedded in a dielectric slab , and with multiple eccentric cylindrical inclusions by Yasumoto and Jia[2003] and Toyama et al. [2003], respectively. Yamasaki et al.[2002] analyzed the columnar dielectric gratings with elliptically layered medium using the improved Fourier series expansion method and the multilayer method. Watanabe K. [2003] analyzed the sinusoidal and echelette gratings in an anisotoropic medium using Li's Fourier factorization rules ,

but a coupled first-order differential-equation set is derived using only the Laurent rule , and also investigated the convergence of this formulation . Komatsu et al.[2003] analyzed the dielectric gratings in conical mounting by applying inverse rule to matrix eigenvalue method that is using the Fourier series expansion for relative permittivity and the spatial harmonics expansion for electromagnetic fields.

Guan et al.[2003] analyzed the scattering problems of electromagnetic waves by the boundary element method (BEM) using the wavelet transform approach, and this approach reduced both the computation costs of performing the wavelet transform and solving sparse linear equations if it is compared with the conventional one.

On the other hand, for the metallic gratings, Wakabayashi et al.[2003] analyzed the thin metallic grating with a thickness profile using a combination of the Fourier series expansion method and the multilayered step method. The convergence of this method is improved using the spatial harmonics of flux densities instead of electromagnetic fields normal to the surface of a metallic grating. Wakabayashi et al.[2004] also investigated a thin metallic grating placed in conical mounting as a lossy dielectric grating expressed by complex permittivity and thickness using the resistive boundary condition and the spectral Galerkin procedure, and investigated the availability of the resistive boundary condition for thin metallic gratings in conical mounting. Asai et al.[2002a] analyzed the electromagnetic waves interacting with a planar-stratified bianisotropic medium with a strip grating using the 4×4 matrix-based approach and the moment method, and investigated a periodically- apertured metallic sheet on a uniaxial chiral slab[Asai et al.[2002b]] and an anisotoropic chiral slab[Asai et al.[2002c]] using same methods. Asai et al.[2003] also analyzed the diffraction from a uniaxial chiral slab with a two-dimensional periodic array of conducting patches is by the matrix-based approach using the coupled mode equations and the moment method.

Jia and Yasumoto [2004a, 2004b, 2004c, 2004d] analyzed the scattering from periodic arrays of the metallic cylinders with arbitrary cross section using the generalized scattering matrix combined with the modal method ,and also shown that the convergence of the solution is very fast and the accuracy is very high.

Yamasaki et al.[2004] proposed a new method for the scattering of electromagnetic waves by inhomogeneous dielectric gratings with perfectly conducting strip using the improved Fourier series expansion and point matching method.

The solar cell module is recently installed on the periodic walls of multistory buildings with a public attention to the clean energy. However, it gives rise to a ghosting phenomenon in TV for much more wide area. Hatakeyama et al[2003, 2004] investigated a reflection reducing method of for a frequency range of the digital broadcasting by using solar cell module embedded in the windows and found that the reflection can be reduced over 10 [dB] by optimizing the module arrangement and the wire structure connecting the cell.

1.3 Cavity Structures

Ohnuki and Hinata [2003] have analyzed the transient scattering by a parallel-plate waveguide cavity numerically using the point matching technique and numerical inversion of Laplace transform.

Sekiguchi et al. [2003] proposed an algorithm to estimate non-destructively the depth of a crack using the electromagnetic waves, and investigated the periodical sharp dips in the scattering by a though on a conducting surface ,it the first dip frequency corresponds to the crack depth. This algorithm can estimate the depth of a crack within 3 percent error. Shirai and Sekiguchi [2004] also proposed a simple estimation formula and measurement method for a crack on metal surfaces, and studied the dependencies of the crack's aperture and the incident angle and considered as the depth obtained estimation parameters.

The three – dimensional (3-D) cavity formed by a finite circular waveguide with a planar termination at the open end has been rigorously analyzed the case of the axial symmetric diffraction problem by Kobayashi and his colleagues using the Wiener-Hopf technique [Kuryliak et al., 2002a.200b].They also analyzed the vector diffraction problem for a circular waveguide cavity rigorously using Wiener-Hopf technique [Kuryliak et al., 2004a.2004b,2004c].

1.4 Canonical Structures

Hashimoto [2004] studied the scattering of the two dimensional electromagnetic waves by the infinite sequences of zeros arising on the complex plane, which just correspond to the null points of the far field pattern given as a function of the azimuthal angle θ, and also evaluated the convergent sequences of zeros around the point of infinity when the scattering objects are assumed to be N-polygonal cylinders. It was shown that if the

locations of zeros are determined appropriately, the every edge condition can be satisfied, also shown that there are N-directions of convergence, which tend to infinity.

Shimoda et al.[2004] analyzed the plane wave scattering by an inhomogeneous plane whose surface impedance changes locally on the plane with the aid of the Fourier transform derives an integral equation, which is approximately solved by the method of least-squares , and expressed the scattering phenomenon using the incomplete Lipschitz-Hankel integral .

Yokota and Kai[2002a] analyzed the Scattering of a Hermite-Gaussian beam wave which expressed as a superposition of multipole fields at complex source points by a chiral cylinder and the scattered near fields of the beam incidence are calculated and the effects of chirality, the polarization and the radius of the chiral cylinder on the fields are examined. They also analyzed the Scattering of a Hermite-Gaussian beam by two Chiral Cylinders[Yokota and Kinoshita[2002b]].

1.5 (3-D) Structures

For the 3-dimensional electromagnetic wave scattering problem , the choices of the parameters and the weighting functions are very important in the integral equation. Matsuhara et al. [2003] evaluated the choices of the parameters and the weighting functions by making the condition number into the evaluation basis for using integral equation.

Koba et al.[2003] proposed a rapid algorithm on the Yasuura method using an array of multipoles as well as a conventional multipole for the 3-D electromagnetic scattering problems by dielectric objects which we need to solve a big size simultaneous linear equation. They also obtained the radar cross sections of dielectric objects in the optical wave region over a relative wide frequency range and a TDG pulse response.

Murasaki [2002] proposed a new method by transforming a PO surface integral to a line integral along the boundary of the scatterer. The advantage of this method is to be able to reduce the time fur fields calculation compared with the original PO.

Miyamoto et al.[2003] analyzed the fiber grating, embedded and raised strip periodic waveguides with rectangular cross-section using revised Fourier series expansion method which is effective for the analysis on various kinds of 3-dimensional periodic waveguides with arbitrary number of periods.

The analysis of near optical fields around an aperture in metallic screens is fundamental problem in electromagnetic theory. Tanka et al. [2003a, 2004a] analyzed numerically the optical near-field in a small aperture and a subwavelength-size aperture in a thick metallic screen by the three-dimensional volume integral equation with generalized minimum residual method and fast Fourier transformation. Tanka et al. [2003b, 2004b] analyzed a thick metallic screen that provides a I-shaped subwavelength aperture for high intensity and small spot size ,and also proposed a modification of I-shaped aperture in a pyramidal structure on a thick metallic screen Tanka et al. [2004c, 200d].

(T. Yamasaki)

B2. Inverse Scattering

Accurate and effective mathematical approach to the inverse scattering problems will be useful in many applications of electromagnetic and optical engineering. The estimation of material using wave is a typical problem and Ishida. et al. [2004a] [2004b], described a novel approach using extended T-matrix elements.

Classification of surface condition can be extended from a small scale to a very large scale. Classical classification techniques were known for applications to land use classification in remote sensing, but new approaches have been proposed. Hirose et al. [2001] and Minami, et al. [2003], showed a method using neural-network for land classification.

Radar polarimetry for SAR is another very powerful approach for land use classification. This kind of research is active in Japan, because Japan is planning to launch a new earth observation satellite ALOS, which is equipped with a full polarimetric SAR, namely PALSAR in 2005. Most of the following researches are related to ALOS-PALSAR. Murase, [2001] dealed with polariemtric indices for extracting scattering characteristics of trees and shows that the correlation coefficient in the circular polarization basis best serves to classify conifer trees and broad leaf trees. Generally, a

scattering object has eight characteristic polarization states. Yang, [2002b] derived these characteristic polarization states via equi-power curves on the Poincare sphere. Yang [2002a] then examined the property of scattering matrix mathematically and has derived the periodicity of scattering matrix nature. The result is applied to classify the targets based on the periodicity. Pi-SAR is a Japanese airborne polarimetric SAR sensor, which can test some characteristics of the ALOS-PALSAR. Yamaguchi, [2002a] presented the image simulations using airborne Pi-SAR polarimetric data taking into account of radar resolutions. Pacific-Rim flight campaign provided the data acquired with both AIRSAR (JPL) and Pi-SAR (CRL/NASDA). The images over the same area were compared from the polarimetric scattering point of view [Yamaguchi 2002b]. It was shown that the scattering characteristics from urban area become different each other by small incidence angle within 2-3 degrees. On the other hand, the scattering characteristics remain the same for natural target. Polarimetric filtering technique was applied to the detection of objects buried in the underground by Yamaguchi [2002c]. Since the polarization state of earth surface can be measurable quantity, it is used as null state to image the entire detection image so that the surface clutter is eliminated. This suppresses surface clutter and provides better contrast image for detection of underground target. An X-band scatterometer was applied to monitor wheat chlorophyll. Singh, et al. [2003], showed that polarimetric power ratio varies with wheat growing stage which is related to the amount of chlorophyll contained within wheat. Kimura, et al. [2003] tried to classify terrain target using polarimetric entropy, alpha angle, and total power. Since the total power is one of the essential parameters for radar, it is expected to serve to classify targets in noisy cluttered environment. Based on unsupervised maximum likelihood method, it was shown that the method is effective for classification in complex environment. Generalized optimization of polarimetric contrast enhancement method was developed to find specific target in fully polarimetric SAR image. When the polarization states for transmitter and receiver are independent, there are two freedom for maximizing desired power vs. clutter power ratio. The optimization condition was solved by generalized eigen-value problem by Yang et al. [2004]. Kimura et al. [2004a] tried to classify terrain target using polarimetric entropy, alpha angle, and total power. Since the total power is one of the essential parameters for radar, it is expected to serve classify target in noisy cluttered environment. Using unsupervised maximum likelihood method, it was shown that the method is effective for classification in complex environment. The result was validated by experiment with Pi-SAR data over Niigata University area. More quantitative analysis for radar polarimetry have been studied. Kimura et al.[2004b] showed that the phase of the correlation coefficient in the circular polarization basis is effective for detection of man-made targets. The phase image of circular polarization correlation coefficient detected clearly man-made target such as buildings and building blocks not parallel to SAR flight path. Yamaguchi et al.[2004] showed that the phase in the circular polarization correlation coefficient is effective for detection of oriented targets with respect to SAR flight path. The phase image provided man-made target such as buildings and building blocks not parallel to SAR flight path. Moriyama et al.[2004] examined the correlation coefficients in the various polarization bases and shows that the phase in the circular polarization correlation coefficient is effective for feature extraction of polarimetric SAR data. A method is proposed to detect man-made target using the circular polarization correlation coefficient together with RCS of target.

Radar interferometry is another classical approach to land use classification in SAR, and effective algorithms for phase unwrapping have been developed. Suksmono and Hirose tried adaptive signal processing [Suksmono et al., 2002a, 2002b], and they used space wave number domain approach [Suksmono etl.al.2003], and Monte-Carlo approach [Suksmono et al. 2002c] to this problem.

Super resolution techniques such as MUSIC have been applied to accurate target location in radar. Location estimation of cylindrical scatters using a MUSIC algorithm was applied to borehole radar by Miwa et al. [2004a]. The experiment in water is carried out so that this method can

estimate the location of the cylinders horizontally separated by 4 lambda. And a MUSIC algorithm was successfully introduced to locate point targets surrounded by transmitting and receiving linear array [Miwa 2004b]. The resolution of imaging is greatly improved in comparison with a conventional diffraction stacking method. Super resolution algorithm can be used for various kinds of applications. Akimoto et al. [2004] applied MUSIC algorithm for locating near-field electromagnetics emissional sources and applied it to PCB. Super resolution techniques can be used for geophysical parameter estimation in remote sensing, and Yamada, [2002 proposed an approach for polarimetric SAR interferometry based on the ESPRIT and showed accurate estimation technique of tree height. The proposed technique has a feature to detect local scattering centers corresponding to the canopy top and the ground. Then Sato [2003a] examined performance of ESPRIT-based polarimetric SAR interferometry for the forest analysis. The ESPRIT technique can resolve local scattering centers as many as independent observed channels, that means the technique can detect three local scattering centers in the forest at the maximum with fully polarimetric data sets. By using this feature, they showed experimentally that the tree height estimation accuracy can be improved when they analyze additional local scattering center between canopy top and the ground. This is a powerful technique for the forest analysis, however estimated tree height would sometimes be biased. Yamada et al. [2003] showed that strong volume scattering causes the bias, therefore the estimated results should be carefully evaluated for the dense forest analysis.

Due to recent development of powerful numerical forward simulation techniques such as FDTD, and the advanced time-domain measurement techniques, multi-dimensional time-domain inversion algorithm became quite practical inversion scheme. An iterative inverse-scattering approach to reconstruction of electrical parameter distributions of a three-dimensional object by using time-domain filed data was presented by Takenaka et al. [2003]. Numerical examples of simulation data were given to assess the effectiveness of the proposed algorithm. In order to improve the image quality from the FBTS method, Tanaka et al. [2003] proposed a new reconstruction algorithm. The measured time-domain data are low-pass filtered and the FBTS algorithm was used for the filtered data. Numerical results show the effectiveness. An iterative time-domain algorithm for reconstructing three-dimensional lossy objects using microwave data transmitted and collected by dipole antennas was presented by Zhou et al. [2003a]. Numerical examples showed that the algorithm can reconstruct simultaneously from noise-free and noisy data the permittivity and conductivity. A new iterative algorithm for the reconstruction of two-dimensional biaxial anisotropic objects was developed using time-domain scattering data by Takenaka et al. [2001]. All of the calculations in both the forward and inversion algorithms were carried out efficiently in the time domain using the finite-difference time-domain method.

Subsurface sensing is one of typical areas which requires powerful inversion technique. Researches for borehole exploration tools such as borehole radar, which is a radar system used in drilled boreholes, have many similarities to medical imaging engineering, but uses much lower frequency. Liu et al. [2002] proposed an electromagnetic logging technique based on borehole radar, which can measure the dielectric constant and conductivity of the formation rock simultaneously by radar technology. When multiple boreholes are available, we can measure electromagnetic wave propagation between two boreholes and tomographic imaging can be applied. However, in general, location of sensors are strongly limited, and the problem is quite difficult. Zhou et al [2004] compared travel time tomography and image reconstruction by migration for a subsurface cavity. The result of tomography indicates that there is an anomalous area, and the result of migration gave a more accurate position of the cavity. This result shows that borehole radar has a very high resolution, when signal processing is applied properly. A two-step iterative approach for imaging two-dimensional buried objects by cross-hole radar data in the time domain was proposed by Jia [2002]: the first step is to reduce the search region to a smaller one and the second step is the

accurate reconstruction of the targets in the small region.

Powerful inverse scattering algorithm is possible, only when data sets with high quality is available. Especially, recent development of inversion algorithm requires time-domain data and broad-band signal acquisition. Broad band radar systems have been developed for these purposes, and they are practically used in Ground Penetrating Radar (GPR) and UWB applications. Conventional GPR systems are quasi-monostatic radar systems. Sato [2003b] proposed a new Bistatic GPR system using a passive optical sensor for landmine detection and applied for landmine detection [Sato 2003c, 2004b]. This is a compact bistatic radar system, which is suitable for scanning above a ground surface, where possibly landmines are buried. Inaba et al. [2004] developed a wideband and compact microwave front-end circuit for adaptive plastic landmine imaging arrays, which is a Ku-band radar system.

Subsurface imaging and characterization of buried objects by radar is quite typical problem on inverse scattering. Last one decade, studies on landmine detection have been quite, and especially last few years this kinds of research gathered interest in Japan. Sato et al. [2004a], have developed an array GPR system for landmine detection, and array signal processing techniques to reduce strong clutter due to inhomogeneous soil and rough ground surface have been discussed [Sato et al. 2003c]. At the same time, Savelyev et al. [2004] showed deconvolution and feature extraction algorithms by UWB GPR for landmine detection. Feng, et al., [2004] applied pre-stack migration to SAR-GPR system for imaging of obliquely buried landmine. Fang, et al. [2002a], simulated GPR profiles for mine-like targets buried in rough ground surface and showed clutter removal by similarity measurement methods. Also, Fang et al. [2003] showed GPR detection of landmine by wavelet transform.

GPR for landmine detection requires very wide frequency operation to achieve very high resolution. This technology has many similarities to UWB for communication. Fang, et al. [2002b] showed optimization technique of Vivaldi antenna for demining by GPR, and Sato, et al. [2003d], developed antenna and a stepped-frequency GPR system, and Kobayashi, et al. [2004], showed a GPR system for landmine detection using an array antenna.

Detection and identification from radar signal is important in landmine detection. Nishimoto et al. have developed high range-resolution radar signatures using a hidden Markov Model [Nishimoto 2003, 2004a-c]. Another approach for identification of buried targets were reported by Hara [2004], and Hirose et al. [Hirose et al.204, 2003 a,b]using Complex-valued self-organizing map dealing with multi-frequency interferometeric data.

Radar Sensing and related techniques can be applied in various aspects of security of a society. Radar imaging is a promising candidate for the environment measurement of rescue robots. However, it requires long calculation time to obtain the shape of targets close to antennas by using conventional algorithms, which cannot be applied to real-time applications. Sakamaoto[2004b] found a reversible transform between the received signals and the target shapes under a certain condition, which enables us to estimate target shapes quickly and accurately. Then Sakamoto[2004d] expanded the fast 2-D imaging algorithm SEABED [2004b] in order to estimate 3-D target shapes. They showed that the proposed algorithm can obtain 3-D image in a short time. It is indispensable to utilize the phase of signals to obtain high-resolution image, especially for UWB pulse radars. However, the scattered signal is affected by a phase rotation effect which depends on the shape of target. Sakamoto[2004e] proposed a phase compensation method by using the characteristic of received signals. This method enables us to obtain an accurate image regardless the target shape.

(M. Sato)

B3. Computational Techniques

The *Computational Techniques* is an important topic area today: Although the number of references cited here is relatively small, we cannot forget that the great part of research works mentioned in other topic areas are

supported by recent improvements in numerical computation. Here, the recent progress in the area is summarized with a reference to several important papers published during the last three years.

3.1 Finite-Difference and Finite-Element Methods

Uno et al. [2002] solved the problem of radiation from a dipole antenna placed near a human head phantom using the finite-difference time-domain (FD-TD) method combined with a surface-impedance boundary condition. Arima and Uno [2002] and Arima et al. [2002] introduced quasi-static approximation in the FD-TD scheme for a linear and a patch antenna to improve the accuracy of solutions. Arima et al. [2003] and Pongpaibool et al. [2003] employed the same method in calculating the input impedance of a bent antenna and in solving the problem of radiation from a short dipole antenna. Uno [2003] published a review paper on antenna design using the FD-TD method. Kida et al. [2004] proposed an FD-TD scheme to analyze the problem of an obliquely fed planer antenna.

Mochizuki et al. [2002] examined the proper size of a human head phantom for the standard measurement of SAR based on FD-TD simulation. Mochizuki et al. [2004] proposed a hybrid formulation combining the method of moments and the FD-TD for solving Bio-EMC problems.

Yokota and Sugio [2002a, 2002b] applied a multigrid method in the investigation of lightwave propagation in a 2-D optical waveguide.

Kuroda and Kawano [2002] and Kawano et al. [2003] applied the FD-TD method to the problem of a moving or rotating body. Kawano et al. [2003], Kawano et al. [2004] and Kuroda et al. [2004], employing a body-fitted grid generation technique, solved the problems of MEMS-based variable devices.

3.2 Integral Equation Methods

Nakashima et al. [2003] and Nakashima and Tateiba [2003a] applied Greengard-Rokhlin's fast multipole algorithm in solving the problems of diffraction by many cylinders made of dielectric and perfect conductor. Nakashima and Tateiba [2003b] employed the algorithm to analyze the problem of conducting sphere and examined the computational complexity. They used the algorithm for numerical computation of scattering from randomly distributed circular cylinders [Nakashima and Tateiba 2003c]. The same authors proposed an improved Greengard-Rokhlin fast multipole algorithm to reduce computational complexity [Nakashima and Tateiba 2004].

Yokota [2004a, 2004b] combined a multigrid method with the method of moments in analyzing the scattering of a Gaussian beam by a nonlinear and an inhomogeneous dielectric cylinder.

3.3 Modal Expansion Methods

Zinenko et al. [2002] combining the modal expansion and a semi-inversion technique, analyzed the diffraction by an impedance strip grating.

Okuno et al. [2002], in solving the problem of diffraction by a deep relief grating, employed a combination of up- and down-going plane waves to extend the range of application of the modal expansion approach. Matsuda et al. [2002] and Okuno et al. [2004] applied Yasuura's modal expansion method to investigate plasmon resonance absorption.

3.4 Miscellanea

Matsuoka et al. [2003] proposed a dedicated computer to obtain high performance computation in simulation of microwave devices. The computer copes with finite-difference time-domain (FD-TD) and finite integration technique (FIT) schemes and achieves terra-flops performance.

(Y. Okuno)

B4. High Frequency Technique

The approximation principle of Physical Optics (PO) has been reviewed in view of diffraction theory[Ando, 2003]. Two key error factors are identified for PO, that is, errors in edge diffraction coefficients and fictitious penetrating rays. Improved methods named PO-AF and PTD-AF are proposed as the methods which suppress the fictitious penetrating rays from PO and PTD respectively. In deep shadow regions of the reflector antennas, PO-AF and PTD-AF approach to PO-EEC and UTD respectively, while the smooth connection is assured. The effectiveness is numerically demonstrated for two dimensional scatterers. Novel interpretation of PO is discussed

and two mechanisms are identified as the error factors, that is, (1) errors in diffraction coefficients and (2) fictitious penetrating rays [Shijo and Ando, 2003a]. Based upon these observations, new methods named PO-AF and PTD-AF are proposed which eliminate the fictitious penetrating rays from PO and PTD, respectively. PO and Aperture Field Integration Method (AFIM) are merged with the help of special elementary diffraction coefficients. These can uniformly cover whole the angular region and only the error factor (2) is removed in PO-AF while both of (1) and (2) are removed in PTD-AF [Shijo and Ando, 2003b]. The theoretical backgrounds of PO currents are discussed in terms of field equivalence theorem and visualization of EM waves. Then new methods are proposed and their validity is numerically confirmed for 2-D scattering problems of a strip, a corner reflector and circular arc reflectors.

The visualization of the scattering and diffraction phenomena by PO has been studied to provide the intuitive understanding of local property of HF diffraction as well as the relations between PO and the ray techniques such as GTD, UTD etc. [Shijo et al., 2004a], [Shijo et al., 2004b]. PO visualization demonstrates (i) local property of the high frequency scattering, (ii) defects associated with ray techniques, (iii) PO error factor, fictitious penetrating rays disturbing the geometrical shadow behind the opaque scatterer. They have been scarcely recognized if not for visualization, though they disturb the geometrical shadow behind the opaque scatterer and can be the leading error factors of PO in shadow regions. Finally, visualization is extended to slot antennas with finite ground planes by hybrid use of modified edge representation (MER) to assess the significance of edge diffraction. The surface to line integral reduction of PO currents by using Modified Edge Representation (MER) was empirically proposed for the observer without the Stationary Phase Point (SPP) on the scatterer and was later on reinforced mathematically. It was shown also that the observer with SPP inside the scatterer surface, the MER line integration around the SPP gave GO terms. These results have been unified to conclude that MER line integration along the periphery and inner SPP extracts the diffraction and GO components of PO surface integrals, respectively, irrespective of the observer position [Ando and Rodrigues, 2004].

The local corrections to PO have been considered that the currents only at the critical regions are derived by MoM after defining PO currents in other regions. Since the unknown currents are assigned not the entire but only the critical regions, computational load is not increasing so fast with the frequency. The scattering from 2D corner reflector has been analyzed by this method. It is found that the perturbation to PO is larger at the center corner and the MoM region should be wider there than in the edge [Goto et al., 2004]. Also a general purpose program for calculating the edge diffraction from a finite ground plane by MER has been developed [Kosugi et al., 2004]. The calculated values for the slot arrays are compared to measurements and the improved agreements are confirmed.

A spatio-temporal channel characterization of a suburban non line-of-sight microcellular environment, in which azimuth-delay profiles obtained by the experiment are compared with ray-tracing simulation, has been reported in [Takada et al., 2002]. The results are statistically treated step by step to extract model parameters in order to characterize the spatio-temporal channel. The experimental results are used to improve the accuracy of the simulation process. A very good agreement between the simulation and the experiment has been obtained, with the exception of the exponential decay of the delay profile. The results can be directly used to implement the stochastic spatio-temporal channel model, based on the deterministic ray-tracing simulations.

Simulation techniques for the estimation of non specular wave propagation characteristics on the building surface have been developed in [Budiarto et al., 2004a] and [Budiarto et al., 2004b]. Physical Optics (PO) approximation is performed to approximate equivalent currents and the total fields on the integration surface. Model of the rectangular microstrip array antenna was scanned spatially to detect multipath wave scattering. Superresolution method was also applied as an approach to handle the signal parameters (DOA, TOA) of the individual incoming waves scattered from building surface roughness. The experimental and simulation results of signal parameter of arrival waves are compared in order to investigate accuracy of the prediction model. Also, the Method Of Moments (MOM) analysis of the electromagnetic wave scattering from the 2D rough surface model of the building is presented in the mobile communication area [Budiarto and Takada, 2001]. The fluctuation of the field strength due to the change of the specular reflection point on the surface has been evaluated by the Nakagami-Rice distribution and the autocorrelation function.The effects of incident angle and frequency are also clarified.

Novel high-frequency uniform asymptotic solution (extended UTD) for the scattered field by a conducting circular cylinder has been derived in [Ida and Ishihara, 2004a]. The modified UTD has also been derived from the new extended Pekeris caret function by applying the residue theorem. The extended UTD and the modified UTD can be applied in the wide area extending from the transition region near the shadow boundary to the deep shadow region where the current UTD becomes increasingly inaccurate. The studies on the scattering by the conducting cylinder have been extended to the scattering problem by an impedance circular cylinder [Ida and Ishihara, 200b]. The novel extended UTD and the modified UTD derived by applying the higher-order asymptotic formulas for the cylindrical functions, can be applied even in the region where the current UTD becomes increasingly inaccurate. The extended UTD and the modified UTD derived above have also been extended to the scattering problem by a dielectric cylinder [Ida and Ishihara, 2004c]. Comparisons with the exact solution calculated from the eigenfunction expansion confirm the validity of the extended UTD and the modified UTD solutions for the dielectric cylinder.

The new modified UTD for the scattered fields by a dielectric circular cylinder has been derived which is

applicable in the transition regions near the geometrical boundaries produced by the incident ray on the dielectric cylinder from the tangential direction [Ida and Ishihara, 2004d], [Ida and Ishihara, 2004e]. Also derived are the uniform geometrical ray solutions applicable near the geometrical boundaries and near the caustics produced by the ray family reflected on the internal concave boundary of the dielectric cylinder. A time-domain asymptotic analysis has been discussed for the scattered electromagnetic fields when the cylindrical wave is incident on a dielectric cylinder [Ida and Ishihara, 2003]. The Gaussian-type modulated pulse source has been applied. The time-domain scattered field solutions are applicable in the transition regions near the geometrical boundaries, and near the caustics. Comparisons of the time-domain asymptotic solution with the reference solution confirm the validity of the proposed asymptotic solution.

Diffraction of electromagnetic waves by an aperture in a thin conducting screen has been treated by the aperture field methods (AFM) [Kawano and Ishihara, 2003]. The new extended Fraunhofer solution applicable in the Fresnel region and the uniform AFM solution applicable in the transition regions near the geometrical boundaries have been derived. Also derived are the new criteria for applying the Fraunhofer solution and the non-uniform asymptotic AFM solution. Comparisons with the reference solutions obtained form the numerical integration and from the method of moments reveal the applicable ranges of the various solutions for the diffracted field. Also, the high-frequency scattered field by the conducting strip has been obtained by applying the UTD [Kawano and Ishihara, 2004]. From the UTD, the two versions of the Keller's GTD have been derived without applying the "trick" introduced in the paper by Keller. The first version (the second version) is applicable in the region close to (far away from) the conducting strip. Also derived is the novel criterion for applying the GTD. It is shown that, as the observation point moves far away from the strip in the illuminated region, the geometrical ray appeared in the UTD is cancelled by the portions of the edge diffracted rays, thereby validating the second version of Keller's GTD, which does not include the geometrical ray term. The validity and applicable range of the GTD and the UTD are confirmed by comparing with the reference solution calculated from the method of moments.

(T. Ishihara)

B5. Transient Fields

The analysis of transient scattering has been of great interest in conjunction with ultra-wideband and ultra-short pulse technologies and their applications. The research has progressed in fundamental theory of transient phenomena, analytical and numerical techniques for transient analysis, and joint time-frequency analysis of scattering data. It is noted that this summary is based on the papers submitted to the topic area "Transient Fields" from researchers. There are many other papers that are closely related to this area and they can easily be found in summaries of other topic areas.

5.1 General Theory

Yoshida [2003, 2004] simulated rotational and divergent components of near fields around changing charges using the condensed node Spatial Network Method (SNM) for vector and scalar potential fields, and investigated the fundamental properties of the near fields around changing charges.

5.2 Scattering and Diffraction

Nishimoto et al. [2001] analyzed scattering responses from a dielectric sphere in the time-frequency domain by using two types of wavelet transform in order to reveal the scattering mechanism. In the resulting time-frequency display, various scattering processes including reflection, refraction, and diffraction were clearly resolved and identified. Nishimoto et al. [2004] also analyzed electromagnetic pulse responses from multi-layered plasma media in time-frequency domain by using the short-time Fourier transform (STFT) and investigated the scattering mechanism of electromagnetic waves in plasma media.

5.3 Guided Waves and Propagation

Shimoda et al. [2002, 2003] analyzed transient phenomena of electromagnetic waves caused by a time dependent resistive screen in a waveguide. In this work, the Wiener-Hopf technique was employed in the formulation of the problem and closed form expressions of transient fields were obtained. Numerical results were given for some typical cases and propagation characteristics of the transient waves for sudden and gradual change of the resistivity of the screen were investigated.

5.4 Numerical Techniques

Kawaguchi [2003] presented a formulation of time domain boundary element method (TDBEM) for high frequency electromagnetic fields and applied it to some practical problems. The formulation is suitable for solving time-domain boundary integral equations and can give stable numerical solutions. As numerical examples, simulation results of wake fields in high-energy particle accelerator were shown.

(M. Nishimoto)

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

6.1 Wave propagation and scattering in random media

By use of a dense medium radiative transfer equation (DMRT), Tateiba and Matsuoka [2002] deal with the scattering from a layer, in which spherical lossy particles are randomly distributed. By four different multiple scattering theories, they estimated the parameters of DMRT, which largely affect the scattering cross section. Next, the backscattering from moisture soil is studied for detecting water content of soil. Regarding moisture soil as a dense random medium, Matsuoka and Tateiba [2002] calculated the backscattering cross section for both vertical and horizontal polarizations of incidence by DMRT, where the effective dielectric constant is obtained from a multiple scattering theory proposed previously by Tateiba. Two and three layer random media are introduced for modeling the inhomogeneous water distribution in soil in the depth direction [Matsuoka and Tateiba, 2003a; 2003b]. Then, the backscattering cross section is calculated against the fractional volume of water and against frequency [Matsuoka and Tateiba, 2004],

On the other hand, Tamura and Nakayama [2004] deal with the two-dimensional problem of scattering from a thin random film with one-dimensional disorder, which is anisotropic in statistical sense. Statistical properties of the scattering are calculated by use of the multiple renormalized mass operator.

6.2 Environmental propagation

Wave scattering from a conducting body surrounded by continuous random media is studied by use of a current generator and an approximate solution for the fourth moment of Green's function in random media. For both E-wave and H-wave incidence, the backscattering cross sections of a conducting circular cylinder and concave-convex cylinder with a concavity index is calculated as a function of target size, concavity index, and the spatial coherence length of incident wave [Ocla and Tateiba, 2002; 2003a;2003b;2004a;2004b]. From various numerical results, it was concluded that the enhancement of radar cross section becomes two when the target size is much smaller or larger than the spatial coherence length of incident wave. However, the enhancement of radar cross section oscillates irregularly close to two when the target size is comparable with the spatial coherence length of incident wave.

However, discussions were extended from the mono-static radar cross section to the bi-static cross section by use of the same method [Tateiba and Meng, 2001; Meng and Tateiba, 2004a]. From numerical calculations for a conductive cylinder target, the backscattering enhancement is shown to become weak and to disappear when the intensity of fluctuation of random media increases. They also analyzed the effect of scale size of the random media. It is then reported that a twin depression appears at the both side of the backscattering enhancement peak in the angular distribution and the scattering enhancement may occur not only in the backward direction but also in other directions [Meng and Tateiba, 2004b]. The bi-static cross section is also calculated for a convex-concave target in random media [Tateiba et al., 2002a; 2002b; 2004]. At a specific configuration of the target, a large enhancement is reported in H-wave case [Tateiba, 2004].

On the other hand, Ocla and Tateiba [2003c] propose an indirect method estimating the radar-cross

section of a conductive target in random media, where the random wave incident on a conductive target is replaced with a Gaussian beam with a beam width equal to the spatial coherent length of the random incident wave.

6.3 Rough surface scattering

By use of FVTD method and the Pierson-Moskowitz spectral model, Yoon et al. [2002] analyzed numerically the electromagnetic wave scattering from ocean-like lossy dielectric rough surface, where the scattering cross section for a low grazing angle of incidence is obtained successfully. On the other hand, Tamura and Nakayama [2003] studied a plane wave reflection from a flat surface, of which position is randomly distributed in the normal direction. A new mathematical formula expanding the reflection coefficient into Hermite polynomials is presented. The wave scattering from a finite periodic surface was studied on the basis of the periodic Fourier transform, where the scattered wave with a continuous spectrum is regarded as a sum of diffraction beams with discrete index of diffraction order [Nakayama and Tsuji, 2002]. Numerical examples of diffraction beam power are obtained against the angle of incidence for a sinusoidal rough surface [Nakayama and Kitada, 2003].

From optical speckle patterns observed for several disorder materials such as paper and ceramic surface, the probability distribution of scattering intensities was found to be a Laplace distribution even in the backscattering direction [Murakami and Nakayama, 2003],

6.4 Chiral media

Asai et al. [2004] give a review on natural and artificial chiral media, where electromagnetic wave propagation and several engineering applications are discussed.

However, wave propagation in a discrete random media containing randomly distributed chiral spheres is analyzed. Assuming a randomly deformed periodic array of chiral spheres and using the multiple scattering theory, Nanbu et al. [2002a] obtain the effective constitutive parameters, which are compared with those from the Maxwell-Garnett method. For several combined values of dielectric constants and chirality of spheres, the effective dielectric constant and the effective chirality are calculated against the volume fraction of spheres [Nanbu et al., 2002b; 2002c; 2004a; 2004b]. It is then found that the imaginary parts of effective dielectric constant and effective chirality become maximal when the volume fraction is about 0.1 or 0.2.

On the other hand, Ochi et al. [2004] deal with the wave propagation in composite random media, which consist of randomly and sparsely distributed sets of identical aggregate spheres. Each set of aggregate spheres is made up of two kind of spherical particles, dielectric or chiral particle. By use of T-matrix of a sphere, the effective propagation constants are estimated for left- and right-handed polarizations.

(J. Nakayama)

B7. Guided Waves

7.1 Guided Wave Theory

A high permittivity LSE-NRD guide has been proposed for a new type of millimeter-wave antenna application [Kuroki, F. et al., 2003a], and various types of comb lines have been employed for filter applications: a dual-plane comb line [Kitamura, K. et al., 2002, and Suizu, S. et al., 2003], a folded comb line [Yoshisha, K. et al., 2003a, Kitamura, T. et al., 2003, and Ochiai, N. et al., 2004], and a comb line with coupling windows or composite resonators[Kikuchi, K. et al., 2003 and Yoshida, K. et al., 2003b]. The dispersion behavior on modified microstrip lines has been also investigated [Murata, M., et al., 2003, and Tsuji, M. and H. Shigesawa, 2004]. Furthermore, a quasi-leaky mode has been discovered on slot line and conductor-backed coplanar strips [Tsuji, M. et al., 2002a].

7.2 Non Planar Waveguides

Reflector grating in a metallic rectangular waveguide has been investigated from points of metal loss and compactness [Kondoh, S. et. al., 2003, and 2004]. An efficient analysis of lossy discontinuities in waveguide has been proposed by Shiraishi, T. et al. [2002, 2003a, and 2003b], and an rigorous analysis using Fourier transform technique has been applied to a rectangular waveguide coupler [Jia, H., et al., 2004a] and rectangular groove waveguides [Jia, H,. et al., 2004b]. Stub-loaded ridge waveguide of single-mode operation has been also investigated for leaky-wave antenna application [M. Tsuji, et al., 2004]. Furthermore nonlinear propagation characteristics have been analyzed for various waves interacting with electron beam [Hirata, A. et al., 2002a and 2002b, Shiozawa, T., et al., 2002], and hollow ferrite waveguides have been investigated by Tsutsumi M. and K. Okubo[2002, 2003].

7.3 Planar and Quasi-Planar Waveguides

Various types of left-handed transmission lines have been proposed and its applications have been investigated [Caloz, C. et al., 2003a, 2003b, and 2004, and Sanada, A., et al., 2004a, 2004b, and 2004c]. Cylindrical coplanar waveguides with finite metallization thickness have been analyzed by extended spectral domain approach [Yamamoto, H. et al., 2004], and a YIG film microstrip line in a nonuniform bias magnetic field has been done by the FDTD method [Okubo, K. et al., 2001]. Tapered microstrip lines [Tsuji, M. et al., 2002b] and a CPW with a patch of conductor [Watanabe, S., et al., 2003] have been employed for filter applications. Furthermore, leaky-wave properties of planar-circuit transmission lines have been deeply investigated in the millimeter-wave region [Shigesawa, H. and M. Tsuji, 2001 and 2002] and existence of quasi leaky modes has been verified experimentally [Tsuji, M. and H. Shigesawa, 2003].

7.4 Dielectric and Optical Waveguides

Nonlinear optical waveguides or fibers have been analyzed by various methods: full-vector finite-element beam propagation method [Fujisawa, T. and M. Koshiba, 2002], full-vector finite element method [Fujisawa, T. and M. Koshiba, 2003], frequency-domain finite element method [Fujisawa, T. and M. Koshiba, 2004a], and time-domain beam propagation method [Fujisawa, T. and M. Koshiba, 2004b]. Koshiba M. et al., have deeply investigated characteristics of several types of fibers: photonic crystal fibers [Koshiba, M. and K. Saitoh, 2001, Saitoh, K. and M. Koshiba, 2002, and Saitoh, K. et al., 2003 and 2004b], holey fibers [Koshiba, M. and K. Saitoh, 2003a, 2003b, 2003c, and 2004], air-core photonic bandgap fibers [Saitoh, K. and M. Koshiba, 2003, and Saitoh, K. et al., 2004a], and hollow Bragg fibers [Skorobogatiy, M. et al., 2004a and 2004b].

Perfectly matched layers used in finite element methods have been developed for analyzing optical-waveguide discontinuities [Saitoh, K. and M. Koshiba, 2001, Tsuji, Y. and M. Koshiba, 2003, and Kono, N. et al., 2004a]. Finite element methods have been applied to extraction of coupling coefficients in natural, single-phase, unidirectional SAW transducers [Hasegawa, K. et al., 2001] and to nonreciprocal magnet-photonic crystal waveguides [Kono, N. and Y. Tsuji, 2004b], and also the beam propagation methods have been used for analyzing second harmonic generation [Tsuji, Y. and M. Koshiba, 2001] and photonic crystal waveguide couplers [Koshiba, M. 2001]. Various photonic crystal waveguides have been investigated by Iida, Y., et al. [Iida, Y. et al., 2003a, Kinoshita, T., et al., 2003, and Ogawa, Y. et al., 2004], and Yasumoto, K. et al. [Yasumoto, K. and H. Jia, 2003 and 2004, Yasumoto, K. et al., 2004].

Kuroki, F. et al. have developed various millimeter-wave devices based on NRD guide [2003b, 2004b, and 2004c] and also coupled-HNRD-guide directional couplers with flat coupling have been proposed [Kishihara, M. et al., 2003]. Nanometric optical circuits based on surface plasmon polariton gap-waveguides have been investigated by Tanaka, K. and M. Tanaka [2003a and 2003b] and 2D photonic crystal waveguide with uni-axial anisotropy or chiral medium have been analyzed

by Satoh. H. et al. [2003 and 2004].
Branch circuits and all-optical logic gates using optical nonlinear waveguide have been investigated by Yabu, T. et al. [2002a, 2002b, 2002c, and 2004]. Furthermore, Fourier series expansion methods have been developed for analyzing inset dielectric guides [Jia, H. et al., 2001], and optical waveguides with periodical structure [Miyamoto, T. et al., 2003, and Momoda, M., et al., 2004b].

7.5 Resonant Modes

Zeroth-order resonance in transmission line resonators with left-handed media have been investigated by Sanada, A. et al [2003a and 2004b] and also dielectric resonators based on artificial dielectrics have been applied to bandpass filter [Awai, I. et al., 2002 and 2003b, Kubo, H. et al., 2004, and Munir, A. et al., 2004]. Resonant characteristics have been investigated for high-temperature superconducting coplanar waveuigde stepped-impedance resonators [Sanada, A. et al., 2003b] and unloaded Q in image resonator has been improved due to shift of electromagnetic field distribution [Kubo. H. et al., 2003].
NRD ring resonators have been applied to channel dropping filters and duplexers at 60 GHz [Kuroki, F. et al., 2003c and 2004a]. Whispering-gallery modes of a dielectric disk in the millimeter-wave region have been used for complex permittivity measurement [Tamura, H. et al., 2003a and 2003b] and bandpass filter [Sato, Y., et al., 2003 and 2004], and resonance characteristics of such modes on an elliptical disk have been also analyzed [Matsubara, M., 2004]. Furthermore leaky wave in a dielectric ring resonator has been analyzed by the finite element method [Hirayama, K. et al., 2002].
In optical region, 2-D photonic crystal resonant cavities has been analyzed by a finite-element time-domain method [Rodriguez-Esquerre, V. F. et al., 2004] and a ring resonator with sharp U-turns using an SOI-based photonic crystal waveguide has been investigated [Iida, Y., et al., 2003b].

7.6 Miscellaneous

Broadband lossy conductor wall processing has been introduced for calculation of transmission characteristics [Tanaka, M. et al., 2003a and 2003b] and novel measurement method for dielectric properties of high permittivity materials has been developed in microwave region [Wakino, K. et al., 2004, and Kumagai, S. et al., 2004].

(M. Tsuji)

B8. Antennas

8.1 Antenna Theory

Hirokawa [2003b] proposed full double-layer configuration using rectangular waveguides of Butler matrix, where the hybrids are used with broad-wall slot coupling and the layers are changed only at places for the phase shifters. Hirano [2003a] designed an 8-element array of a waveguide crossed-slot with matching slots based upon the MoM with numerical eigenmode basis functions. Sudo [2004b] has been analyzed a full model structure of CA-RLSA with feeder by MoM. And, Inoue [2003c] investigated a design method of CP-DRA (Circularly Polarized Dielectric Resonator Antenna) made of a cuboidal dielectric and a single feeding probe located outside.

8.2 Antenna Elements

Various types of elements were developed, studied and designed in order to achieve the demands for the practical systems or to improve the antenna characteristics.
Kawai, H. and Ito, K. [2004b] proposed the simple evaluation method of estimating local average specific absorption rate (SAR) for the some wire antennas near phantom, such as a half-wave dipole antenna, monopole antenna mounted on a metal box, and so on. As for the thin microwave antenna,

Saito, K. et al. [2004g] confirmed the heating characteristics of the coaxial-slot antenna with two slots from a viewpoint of clinical use, and introduced the results of two clinical trials.
Two-arm spiral antennas which printed on a finite-size dielectric substrate was analyzed numerically by Nakano, H. et al. [2002a]. Since, in reality, the size of the dielectric substrate is finite, it is important scheme that one can obtain the effects of the finite size on the radiation characteristics.

A novel design method was proposed to attain low cross-polarization in dual-polarized patch antennas by Takahashi, T. et al. [2003]. The proposed one is to perturb the feed points to the certain directions, which is very simple and requires no special feeding networks.
Taguchi, M. et al. [2004b] analyzed the resistance-loaded planar monopole antenna located within a rectangular parallelepiped cavity for impulse radar. This antenna is capable to operate over broadband.

Takano, T. and Thumvichit, A. [2004] proposed a dipole antenna in the proximity of PEC plate with high gain and being matched by the offset feeding.

8.3 Arrays and Phased Arrays

In addition to traditional type of arrays, modern arrays such as active antenna arrays, switching arrays and adaptive arrays have been presented and discussed. And, some DOA estimation algorithms are proposed.

Since phased array antenna needs many phase shifters, high cost is significant problem. Then, Sakakibara, K. [2003a] propose feeding circuit of wave guide antenna to produce beam scanning function by using only one phase shifter with four slotted waveguide linear array antennas. High efficiency and low cost planar waveguide arrays have been proposed and developed by using four kinds of single-layer waveguides by Ando, M. [2004]. Among the four, alternating phase fed arrays are recently applied for commercial fixed wireless access(FWA), where the cost and the size of the wireless terminals are drastically reduced to 1/10 and 1/5. Takemura, N. et al.[2002] propose an improved Rotating-element Electric-field Vector (REV) method taking into account amplitude and phase error of phase shifters, in order to achieve more precise calibration for phased array antennas. A gigantic antenna aboard a Space Solar Power System (SSPS) satellite, or a space-tenna is one of the most challenging devices to build. Takano, T. et al. [2004e] describe the requirements for a space-tenna from a SSPS, and system considerations for the configuration of space-tennas.

In the OFDM systems, Hori, S. et al. [2002] propose the MMSE adaptive array utilizing GI (Guard Interval). The blind adaptive arrays can allow signal extraction to be performed in many applications where it is impractical or impossible to provide knowledge on the desired signal. Kikuma, N. et al. [2003b] improve the Cross-SCORE (Spectral Self-Coherence Restoral) algorithm, which is one of the blind adaptive algorithms, by using multiple cyclostationaly properties of the desired signal. Ichikawa, Y. [2002a] propose the ST-SPE (Space-temporal Simultaneous Processing Equalizer) that can reduce the computational complexity. Suksmono et al. [2004] propose a complex-valued multilayer perceptron (CVMLP) neural network for adaptive beam forming. He demonstrates that the beamforming by using CVMLP outperform beamforming using complex-valued least mean square (CLMS) algorithm in terms of faster learning and better interference suppressions. An adaptive array antenna for the suppression of high-power interference in direct-sequence code-division multiple access (DS-CDMA) systems is presented by Kihira et al.[2003a] . In an SLC (Sidelobe Canceller) for radar system, Hirata, K. et al. [2004] show that the SLC with large interval of auxiliary antennas needs two more auxiliary antennas than the number of interference waves. And, the arrangement method of auxiliary antennas is also presented by them.

About the DOA estimation algorithm, Zainun et al. [2004] propose the recusive unitary MUSIC to improve the computation efficiency toward real-time DOA estimation. Hirata, A. et al. [2003]

propose the DOA estimation algorithm of ultra-wideband EM waves with MUSIC and interferometry. ESPRIT that is well know as the DOA estimation algorithm is also studied by Inagaki, Y. et al.[2004]. They improve the cyclic ESPLIT by using the noise subspace.

8.4 Reflector and Lens Antennas

A large deployable antenna, which is formed in the tensioned truss concept, with 10 m maximum diameter was developed, and successfully launched and deployed in space in 1997 to be used for space VLBI mission. Electrical design of it and the verification method of electrical characteristics were described by Takano, T. et al. [2004].

8.5 Radomes, Periodic Structures and Gratings

Kuroda, S. et al.[2004a] propose the simple and efficient analysis method based on the shooting and bouncing rays (SBR) method in order to evaluate effects of multi-reflection inside a radome. By comparing with the experimental results, they verify the proposed analysis method. Inasawa, Y. et al.[2004] propose a novel method to reduce undesired scattered waves and higher order sidelobes from the connection parts of the large sandwich radomes. The scattering characteristics of the radome seams are simplified by using physical optics technique with some corrections. This method achieves the fast computation that is appropriate for iterative optimization.

Sorwar Hossain, M. G. et al.[2004b] propose a novel technique for grating lobe suppression in transverse slot array by making use of parasitic strip dipoles. This technique does not require a change in the interior design of the waveguide to suppress the grating lobes. Yamamoto, Y. et al.[2004] propose a narrow wall slotted waveguide array antenna using post in order to prevent gain reduction due to the grating lobes.

8.6 Antenna Measurement

Fukasawa, T. et al. [2003a] proposed an accurate measurement method for radiation and impedance characteristics of an antenna on a portable telephone. In order to remove the undesired influence of the coaxial cables, this measurement is characterized by using the fiber optics for feed instead of coaxial cables.

As for the large reflector antenna deployed in space, Takano, T. et al. [2001] was described the measurement methods of the large radio astronomy antenna on Halca satellite.

8.7 Horns and Feeds

It is worthy of note that novel components suitable for the application in millimeter-wave band have been reported. A planar feeding circuit exciting a rotating mode in a parallel-plate waveguide was proposed by Jin, R. et al. [2001]. Cost-effective 60GHz-band transmitter and receiver modules were presented by Nakano, H. et al. [2003a]. A thin and planar 70GHz-band waveguide circuit composed of a microstrip line to waveguide transition and a waveguide E-plane corner without matching elements was reported by Sakakibara, K. [2003b]. Moreover, a feeding structure through an aperture to a post-wall waveguide designed in V-band was proposed by Kai, T. et al. [2004].

8.8 Microstrip Elements and Arrays

A stacked square microstrip antenna with a shorting post was proposed as a car application for a road-vehicle communications system by Fujimoto, T. et al. [2004a]. Although its size is much smaller than that of the conventional rectangular microstrip antenna, effective results are obtained for the radiation performances.

Simple satellite-tracking stacked patch array antenna for mobile satellite communications has been presented by Delaune et al. [2004]. By using a simple left-handed circularly polarized four-element stacked patch array antenna, high gain at low elevation angle is capable. The characteristics of this antenna are confirmed by the two numerical methods (the method of moments and the finite

element method) and by measurements.

Nishimoto, K. et al [2004a] presented the cross polarization characteristics in the tilted plane for dual-polarized patch antennas. The optimum substrate permittivity in order to achieve low cross-polarization was obtained analytically and validated by the FDTD simulations and the experiments.

(S. Makino)

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