COMMISSION B: FIELDS AND WAVES

Edited by Mitsuo Tateiba

B1. Scattering and Diffraction

The topic "scattering and diffraction" is a broad and very important subject area covered by URSI Commission B. 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 such as half-planes, strips and slits, wedges, circular and elliptic cylinders, and spheres (see Bowman, J. J., T. B. A. Senior, and P. L. E. Uslenghi, eds., *Electromagnetic and Acoustic Scattering by Simple Shapes*, *Revised Printing*, Hemisphere Publishing, New York, 1987). Although significant results were already obtained by the late 1960s, there are still a large number of papers published recently treating these simple 2-D and 3-D obstacles, in which the diffraction phenomena are investigated from various new aspects. In addition, scattering problems involving more complicated geometries have also been analyzed using conventional or newly-developed analytical and numerical methods.

Summarized below is the recent progress in the research carried out in Japan during the three-year period from November 1998 to October 2001 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 Canonical Structures

Hongo and Serizawa [1999a] analyzed the diffraction of a plane electromagnetic wave by a perfectly conducting rectangular plate as well as its complementary problem, namely the diffraction by a rectangular aperture in an infinite perfectly conducting plane. The problem is solved using the Kobayashi potential method and the far field scattering characteristics are investigated. They also solved a related acoustic problem using the same technique [Hongo and Serizawa, 1999b]. A circular disk is also a canonical scatterer which has been investigated since long time ago. The scattering of electromagnetic waves from an electric dipole by a perfectly conducting circular disk has been analyzed by Kinoshita et al. [2001] from new aspects using the Kobayashi potential method. The Wiener-Hopf technique is a rigorous approach for solving diffraction problems related to canonical geometries. Shimoda et al. [2001] investigated the diffraction by an impedance wedge using the Wiener-Hopf technique, and expressed the solution in terms of the Maliuzhinets function. Kozaki, Sakurai, and their colleagues investigated the scattering characteristics of the Luneberg lens and related spherical obstacles numerically [Sakurai et al., 1999, 2000a, 2000b; Sakurai, 2001].

The strip is a well known 2-D target and has a long history of investigations on diffraction problems. Veliev, Kobayashi, and their colleagues developed a new analytical-numerical method based on the integral equation formulation and the orthogonal polynomial expansion in conjunction with the Fourier transforms, and solved the plane wave diffraction by an impedance strip [Veliev et al., 1999; Ikiz et al., 2001]. They have also analyzed the plane wave diffraction by a thin material strip using the analytical-numerical method together with approximate boundary conditions [Veliev et al., 2000]. A related technique involving orthogonal polynomials has been applied by Yashiro et al. [2000] to solve rigorously the plane wave diffraction by a perfectly conducting half-plane.

1.2 Cavity Structures

Waveguide cavities are encountered in many important radar targets such as aircrafts and ships, and are of great importance in connection with the prediction and reduction of the radar cross section (RCS). Since this geometry has resonance phenomena in the cavity regions, the analysis is more complicated than classical obstacles. There are a number of papers treating the diffraction involving 2-D and 3-D waveguide cavities. Tadokoro and Hongo [2001] carried out the RCS analysis of a large open-ended circular waveguide cavity with impedance walls using the iterative physical optics algorithm. Sato and Shirai [1999, 2000, 2001a] investigated the RCS of rectangular troughs on an infinite ground plane using the Kobayashi potential method. The RCS of parallel-plate and circular waveguide cavities has been rigorously analyzed by Kobayashi and his colleagues using the Wiener-Hopf technique [Kuryliak et al., 1999, 2001; Koshikawa and Kobayashi, 2000a]. Ohnuki and Hinata [1999] have analyzed the plane wave diffraction by a parallel-plate waveguide cavity numerically using the point matching method.

1.3 Waveguides and Periodic Structures

There are a number of papers treating scattering problems related to waveguides and periodic structures. The Kobayashi potential method has been applied by Serizawa and Hongo [2000, 2001] to the analysis of the radiation from a flanged rectangular waveguide. Okuno, Matsushima, and their colleagues analyzed the plane wave diffraction by a multilayered strip grating with the aid of the integral equation formulation and the moment method [Zinenko et al., 1999; Matsushima et al., 2000]. The scattering and guiding characteristics of inhomogeneous dielectric gratings with surface relief has been analyzed by Yamasaki et al. [2000] using the improved Fourier series expansion and the multilayer method. Yasumoto and Yoshitomi [1999] proposed a new method of calculating the lattice sums for the free-space Green’s function, which is useful in analyzing scattering problems involving gratings of infinite extent. Yasumoto and his colleagues analyzed the diffraction by various gratings using this new method and other related numerical methods [Kushta and Yasumoto, 2000; Visnovsky and Yasumoto, 2001; Yasumoto et al., 2001; Watanabe and Yasumoto, 2000a, 2001]. In addition, Motojima et al. [1998] analyzed the diffraction by sinusoidal metallic and dielectric gratings based on the point matching method.

1.4 Novel Analytical and Numerical Methods

Recently there has been an increasing interest in the wavelet theory and its applications to electromagnetic wave problems. Several scattering problems have been investigated using the wavelet-based analysis by Yashiro and his colleagues [Guan et al., 1999; Kigoshi et al., 2000; Guan et al., 2000]. During the last three years, various new solution methods for electromagnetic wave problems have been developed by a number of scientists. Hashimoto [2000a, 2000b] introduced a new description of 2-D electromagnetic waves based on the bicomplex mathematics and discussed its applications to scattering problems at low and high frequency limits. Hosono and Hosono [2000, 2001] developed a new method for solving scattering problems, which is based on the atomic model of a scatterer. This method has been applied to diffraction problems involving circular and rectangular cylinders, and its validity has been discussed. Tokumaru [1998] investigated a geometrical structure of electromagnetic fields in terms of a concept of energy flux densities, and proposed a new description of polarized electromagnetic waves. These results have been applied by Tokumaru and his colleagues to a couple of scattering problems [Nakagawa and Tokumaru, 1999; Kitagawa and Tokumaru, 1999].

(K. Kobayashi)

B2. Inverse Scattering

We can find theoretical improvement in inversion algorithms. New iterative algorithms for the reconstruction of one-dimensional with an edge-preserving regularization was presented by Yoshida et al. [2000]. Harada et al.[2001] presented an efficient reconstruction algorithm in the frequency domain for three-dimensional scattering objects. A non-iterative method for reconstructing the object was also derived and investigated [Ishida et al. 2000]. Tanaka et al. [2000, 2001a] developed a novel method for choosing the optimal regularization parameter used in the Levenberg-Marquardt method, and they applied it to a fast inversion method for imaging of dielectric cylinders [Tanaka and Ogata 2001b]. When the cylinder is lossy, iterative solutions by time-domain data is presented by Takenaka et al. [2000] and Tanakaet al. [1999]. Meng et al. [1999] used a genetic algorithm (GA) approach for reconstruction of the locations and shapes of two-dimensional impenetrable objects from scattered field data, and used it to reconstruct the electrical parameters of a multilayered radome of finite size [Meng et al. 2000]. As more complicated material case, an inverse scattering problem for a stratified bianisotropic slab was considered in the frequency domain by He et al. [1999].

Novel radar sensing technologies were introduced. An imaging method based on the Range-Doppler Interferometry (also known as ISAR) is developed for the imaging of space debris, by Sato [1999]. Meteor storms and showers are now considered as potential hazard in the space environment, and Sato [2000b] developed a special observation scheme using the MU radar of Japan which enables us to determine the orbit of individual meteors. As for passive sensing, a new direction finding method applicable to plasma waves is proposed based on the wave distribution function (WDF). By the proposed method an ill-posed inverse problem was effectively solved [Goto et al. 2001]. Ground penetrating radar (GPR) is a good example of practical use of inverse problem with the combination of radar technologies. As theoretical works, Kudou and Saitou [2000] showed estimation of the unknown permittivity and position of a lossless cylinder buried in a lossy medium, Sanada and Ashida [1999] applied the reverse time migration formulated using FDTD and applied to model with lossless and lossy media. Hayakawa et al.[1998a, 1998b], showed that f-k migration works well for detection of buried pipes with real data sets, and also developed a 3-D imaging algorithm [Hayakawa et al. 2000]. A robust and high-resolution 2-D imaging algorithm is proposed for retrieving the shape of conductive objects embedded in a uniform lossy and dispersive medium by Sato et al. [2000a]. GPR is now used in many applications. Nakauchi et al. [2000] applied to horizontal drilling, Oota et al. [2000] and. Matsuyama et al. [2000] used GPR for concrete evaluation, and identification of subsurface material based on GPR was given by Inagaki [2000]. Zhou and Sato [200][2001] showed that GPR imaging is useful for archaeology. Beside GPR, for deeper subsurface exploration, DC resistivity method is useful. El-Qady and Ushijima [2001] applied this technique and used neural network algorithm for subsurface imaging.

Radar polarimetry will be a useful method for radar imaging. Yang et al. [1998] introduced the idea of optimal polarization state in terms of Stokes vector formulation. Miwa et al. [2000a][2000b] have applied radar polarimetry to borehole radar. As an application of FC-CW Pol SAR, buried objects were seen by polarimetric information Moriyama et al. [1999][2000]. Radar hardware is also developed for more accurate data acquisition. Real-time and fully polarimetric FM-CW radar was developed by Nakamura et al. [2000]. A design of T-bar fed slot antenna is presented for GPR by Wakita et al. [1998] [1999] and its ultra wide-band characteristics was shown by FDTD [Wakita 2001].

For the remote sensing of the Earth, innovative researches have been carried out. Characteristics of the mean pulse response and the pulse-to-pulse correlation coefficient on a simulation of satellite altimeter were evaluated by Fujisaki et al. [1999]. Methods for estimating the ocean wavelength based on the first and second statistics was presented, and the possibility of detecting the ocean wavelength was considered by Fujisaki and Tateiba [2001a]. The efficiency of methods for estimating the ocean wave height was shown to an arbitrary ocean waves model, and methods for estimating the ocean wavelength based on the first and second statistics was presented [Fujisaki and Tateiba 2001b]. CRL and NASDA in Japan are cooperatively operating airborne polarimetric interferometric SAR. This Pi-SAR data was analyzed by Kimura et al. [2000], and Murakami and Sato[2001]. These are also good examples of radar polarimetry

(M. Sato)

B3. Computational Techniques

The computational techniques employed usually in solving EM wave problems can be classified broadly into three classes: finite-difference and finite-element methods; integral equation methods; and modal-expansion methods. Recent progress in these areas will be summarized in the three subsections below. A miscellanea section will follow for works that do not fit in one of the three classes. It is noted that the summary and the references are taken from the material that has been submitted by researchers who wish their works cited here. A great number of articles that are closely related to the computational techniques, hence, may be found in the review of other topic areas in accordance with the author's desire.

3.1 Finite-Difference and Finite-Element Methods

The FD-TD method has been employed in solving a wide range of problems. Here, we summarize the works in this field in the last three years. In most cases the paragraph separates research groups.

Awai and Oda [1998] and Awai et al. [1998] examined the coupling between two resonators and an external Q of a resonator both by employing the FD-TD method. Sanada et al. [1998a, 2000] made full-wave FD-TD analysis of ferrite devices and compared the results with existing theoretical or experimental data. Sanada et al. [1998b], again using the FD-TD method, solved the problem of coaxial-probe insertion in a rectangular waveguide. Okubo et al. [2000a, 2000b, 2000c] gave the results of FD-TD analysis of magnetized YIG or YIG-GGG film microstrip lines. Sanada et al. [1999] solved a similar problem also using the FD-TD method.

Ikuno et al. [2000] described a standard technique for the solution of optical devices using a

FD-TD method based on the principles of a multidimensional wave digital filter. Naka and Ikuno [2000a, 2000b, 2001], in their continuous work, examined the propagation characteristics and discontinuity of two-dimensional photonic crystal waveguides using the FD-TD method combined with the PML absorbing boundary condition and the multidimensional wave digital filter. Yata et al. [2001] solved the problem of junction between a photonic and a dielectric waveguide and examined the condition to have high coupling efficiency.

Kuroda and Kuroda [1999, 2000, 2001] and Kuroda and Kawano [2001], in their continuous research work, applied the FD-TD method with body-fitted grid generation to solve the problem of scattering by a moving object. Maeda and Tsumagari [2000] discussed the radiation characteristics of a nonlinear dielectric waveguide based on the FD-TD analysis combined with the Z transformation. Fujimoto et al. [1999, 2000] and Okuno et al. [2001a] gave the results of FD-TD analysis of diffractive-optics elements with binary subwavelength structures. Shibasaki et al. [2001] examined the propagation characteristics of a periodically corrugated waveguide using a FD-TD scheme combined with Floquet's theorem.

3.2 Integral Equation Methods

In this field a systematic study carried out by Tanaka et al. attracts attention although other researchers have made important and creative contributions.

Tanaka et al. [1998, 1999] and Yoshida et al. [2001] made computer simulation of a 2-D tunneling microscope using a guided-mode extracted integral equation formulation. Tanaka and Tanaka [1998] and Tanaka et al. [2000] made computer simulation of devices in near-field optics using boundary and volume integral equations. Extensive study was done and the results may be found in Tanaka and Tanaka [2001a, 2001b] and in Tanaka et al. [2001]. Takahashi et al. [2000, 2001a] solved the problem of scattering by a honeycomb sandwich structure by a 3-D volume integral equation approach. Takahashi et al. [2001b] gave an evaluation of iterative methods used in solving 3-D volume integral equations.

Matsushima and Sakamoto [2001], introducing a wire model combined with an integral equation formulation, examined the AC resistance and inductance of a transmission line. Shimoda et al. [2000] dealt with transient scattering caused by a time-dependent resistive screen in a waveguide by using the Wiener-Hopf technique. Ohki et al. [2000], employing the boundary-element method combined with the extended boundary condition, solved the problem of scattering of a wave beam by a dielectric rectangular cylinder.

3.3 Modal Expansion Methods

Komatsu et al. employed an improved Fourier-expansion method in solving the problem of diffraction by a lamellar [2000] and a sinusoidal [2001] grating placed in conical mounting. Wakabayashi et al. examined the validity of Galerkin's procedure in solving the problem of a surface-relief [1999] and a metallic plane grating [2001] described by a resistive boundary condition making comparison with the results of the Fourier-expansion method.

Matsuda et al. [1999a], Okuno et al. [2001b], and Zhou et al. [2001c] examined the plasmon resonance absorption on the surface of a metallic grating using Yasuura's mode-matching method. Matsuda et al. [1999b], using the same method, gave numerical results for a grating whose surface is corrugated periodically in two directions. Zhou et al. [2001a, 2001b] and Matsuda et al. [2001], having established an efficient way in solving a large-sized least-squares problem, gave diffraction efficiency of multilayer-coated bigratings.

Tomita [1999] and Tomita and Karasawa [2000a, 2000b, 2000c, 2001] examined the coupling efficiency of a directional coupler for dielectric waveguides using the mode-matching method in the sense of least squares (or Yasuura's mode-matching method).

Ikuno et al. [2001] presented a rapid algorithm based on Yasuura's modal expansion technique using arrays of multipoles in addition to the conventional multipoles at the origin.

3.4 Miscellanea

Nishimoto et al. [1998, 2000], using a time-frequency domain analysis based on the wavelet transform, examined the target information and scattering mechanism that were not apparent in time or frequency domain response. Matsunaga et al. [1999, 2001], using the coupled-mode analysis, found the propagation characteristics of various kinds of microstrip lines. Asai et al. [2000, 2001a, 2001b] solved the problem of diffraction by a combined structure consisting of a chiral slab and a periodic array employing a 4×4 matrix-based analysis. Hayashi [2000] has shown a stable method for solving a linear functional equation that appears in handling the problem of scattering by a hollow pipe of finite length. Ikuno [2000] gave a review on the research trends in computational electromagnetics and stressed that the use of first-order equations in time domain is promising. Tanaka and Iizuka [2001] applied the least-squares method to step frequency-imaging technique.

(Y. Okuno)

B4. High Frequency Techniques

A Fock-type representation of the surface fields has been obtained for the transition region of the circular cylinder with impedance boundary conditions [Hongo et al., 1999]. This current supplements the Physical Optics (PO) current approximation near the transition region. A method of evaluation of the surface fields scattered by an impedance polygonal cylinder has also been developed [Hongo et al., 2001]. The PO currents are corrected by adding the transition currents near the edge, which are determined by solving the canonical impedance wedge problem. A method that uses PO with transition currents has been extended to a three-dimensional (3-D) smooth convex impedance surface [Kobayashi et al., 2000]. While, the Physical Theory of Diffraction (PTD) with transition currents is applied to the fields diffracted by obstacles with edges [Hongo et al., 2000a]. Edge and transition currents are borrowed from the solution of canonical problems. Also, the expressions for the surface fields of curved impedance wedge have been derived by applying the theories of Fock for curved surface and Maliuzhinets for impedance wedge [Hongo et al., 2000b]. In addition, the scattering from a thin rectangular plate of a perfect conductor illuminated by an electromagnetic plane wave at glancing incidence has been studied using a formula derived by the method of the Kobayashi potential, which is a form of Weber-Schafheitlin discontinuous integrals [Serizawa et al., 2001]. Numerical results for the current density distribution and far-field pattern are presented. The RCS calculation software system has been developed, which contains the transition currents [Kobayashi et al., 1999].

The equivalence between Aperture Field Integration Method (AFIM) and Physical Optics (PO) has been discussed for polyhedron surface [Cui et al., 1998], [Cui et al., 1999]. The importance of the exact expressions for both incident and reflected fields in constructing equivalent surface currents is emphasized. The equivalent edge currents (EECs) for AFIM are used to extract the mechanism of the equivalence between AFIM and PO. Also, mathematical proof for the EECs for PO (POEECs) has been given for plane wave incidence and the observer in far zone [Cui et al., 2000]. POEECs have been extended to those for impedance plates. Meanwhile, a novel approach for asymptotic reduction of PO integration has been proposed for two-dimensional line source diffraction from a half-sheet [Sakina et al., 2000]. Field equivalence principle provides alternative integration surfaces not on the original half-sheet but on the geometrical shadow and reflection boundaries, where analytical integration leads us to well known Fresnel-type uniform PO (UPO) diffraction coefficients. Furthermore, the mathematical derivation of Modified Edge Representation (MER) empirically proposed is investigated in [Sakina et al., 2001a] by using Stokes theorem. It proves remarkable applicability of MER. Also, the novel line integral representation for PO diffracted fields has been derived [Sakina et al., 2001b], which has a high accuracy even near zone.

A random-phase-assisted ray-tracing computer code for predicting spatio-temporal-wireless channel parameters has been presented [Zhu et al. 2001a]. A two dimensional-three dimensional (2D-3D) hybrid ray-tracing algorithm is implemented in code for the prediction of channel parameters in outdoor micro- and pico-cellular urban environments. It was found that measured fluctuation of path loss and delay profiles are almost fully confined within the 90% confidence interval. The conventional verification of path loss and delay profiles predicted by ray-tracing is extended to include the verification of angle of arrival [Zhu et al., 2001b]. The spetio-temporal channel impulse response is also transformed to have limited bandwidth and limited beam-width characteristics [Zhu et al., 2001c]. While, an adaptive Shooting and Bouncing Ray (SBR) technique has been used to predict the field strength map [Shirai, 1999a]. A bundle of rays will be shot from a transmitted antenna, then each ray is traced until it decreases to a certain field strength level. This technique considers the field interaction between multiple scattered rays, so that the interference pattern may be generated. Edge diffracted rays are also included to fill the map in the deep shadow region [Watanabe, 2001].

An E-polarized electromagnetic plane wave scattering by a staggered finite parallel plate waveguide cavity has been analyzed by the Equivalent Source Method (ESM), which is one of the powerful high-frequency asymptotic methods [Shirai et al., 1999b]. The ESM is a modified version of the Geometrical Theory of Diffraction (GTD) and it can be easily used for accounting multiple edge diffracted waves. Numerical calculations are performed for the RCS and the results are then compared with the other method and measurements. Good agreement has been observed between them. An electromagnetic wave scattering by a material loaded rectangular trough on a ground plane has been approximately analyzed by using standard impedance boundary condition (SIBC). The validity of the derived approximate solution is examined by comparing with the rigorous one [Sato et al., 2001]. An applicability condition has been clarified. The ESM described above has been applied to predict the electromagnetic wave scattering fields from automobile models [Shirai et al., 2000]. Good agreements between the theoretical values and the simulation measurements have been obtained.

The modified UTD (uniform GTD) solution has been derived for the asymptotic analysis of the diffracted fields in the transition region and shadow region of a perfectly conducting convex cylinder [Ishihara et al., 2000]. The validity of the modified UTD solution is assessed by numerical comparisons with the exact solution. Also the asymptotic representations for the scattering of the fields by the cylindrically curved open surfaces have been derived [Ishihara et al., 1998], [Goto et al., 2000a]. It has been shown that the asymptotic solutions agree excellently with the numerical solution calculated from the method of moments (MoM) and the measurements. A uniform physical optics solution (UPO) has also been derived for the scattered fields by the cylindrically curved surface with edges [Goto et al., 1998]. By applying the saddle point technique to evaluate the inverse Fourier transform, the time-domain uniform asymptotic solution (time-domain UTD) has been derived for the scattered fields by the cylindrically curved open surfaces [Goto et al., 2000b], [Ishihara et at al., 2001]. Also, a uniform asymptotic solution for the scattered fields when the electromagnetic wave is incident on the plane dielectric interface has been derived [Ishihara et al., 1999]. The solution uniformly approaches the conventional totally reflected ray and lateral wave as the observation points move away from the transition region.

The plane wave diffraction by a thin material strip has been analyzed by the Wiener-Hopf technique together with approximate boundary conditions [Koshikawa et al., 2000b]. Assuming that the thickness of the material strip is small compared with the wavelength, the strip is replaced by a strip of zero thickness satisfying the second order impedance boundary conditions. The resulting diffraction problem is analyzed by the Wiener-Hopf technique. The problem is formulated in terms of a Wiener-Hopf equation, which is solved by the factorization and decomposition procedure leading to a high-frequency asymptotic solution. The final solution is valid for the case where the thickness and the width of the strip are small and large compared with the wavelength, respectively. The results obtained are regarded as a reference solution to a canonical problem. The plane wave diffraction by a finite parallel-plate waveguide with three-layer material loading has also been analyzed using the Wiener-Hopf technique [Okada et al., 2001a], [Okada et al., 2001b]. The problems is formulated in terms of the simultaneous Wiener-Hopf equations, which are solved asymptotically for the case where the length of the waveguide plates is large compared with the wavelength. Numerical examples of the radar cross section (RCS) are presented and the far field backscattering characteristics are discussed.

(T. Ishihara)

B5. Transient Fields

5.1 Scattering and Diffraction

In electromagnetic wave scattering by dielectric objects, several scattering mechanisms contribute to the scattering responses. The research has progressed in the numerical study of the scattering data by using Wavelet Transforms(WT), and the Finite-Difference Time-Domain(FDTD) method combined with a general Perfectly Matched Layer(PML) absorbing boundary.

Nishimoto and Ikuno [2001] have analyzed the scattering responses from a dielectric sphere in the time-frequency domain by using two types of WTs. The advantage of the use of these two types WTs is that the different multi-resolution characteristics are available and the information that are not apparent in time or frequency domain analysis can be extracted from the responses.

Sato et al. [2000] have proposed a PML-based absorbing boundary condition for dispersive and anisotropic medium by using FDTD method.
Kobayashi et al. [2001] have investigated the transient scattering of a Gaussian pulse by a conducting rectangular cylinder with an open side-wall by using FDTD method.
Itoh and Hosono [2001] have studied the scattering from a plasma sphere by using the fast inversion of Laplace transform method (FILT) .

5.2 EMP/EM Coupling Effects

Wu and Awi [2000] have investigated the several types of coplanar waveguide (CPW) resonator by use of the field decay method based on the FDTD algorithm for numerically and experimentally.
Iida [1998] has proposed a new method for computing the external Q and unloaded Q of a resonator in the time domain using FDTD method, and has also reported the effects of the arrangement types and coarseness of the FDTD grid on the external Q.
Balasubramanan and Miyazaki [1998] have proposed a thin-film waveguide amplifier based on Erdoped Garnet crystals. Therefore very short signal pulse of nano- and pico-second duration are amplified without change in the pulse shapes.

5.3 Antennas

Nishioka et al. [1999] have analyzed the resistor-loaded bow-tie antenna, which is covered with the rectangular metallic cavity of which inner walls are coated partially or fully with the frequency dependent ferrite absorber by using a fully three-dimensional FDTD method.

5.4 Guided Waves and Propagation

Shimoda et al. [1999] have developed the Wiener-Hopf technique to the time domain analysis for transient phenomena of electromagnetic waves caused by the abrupt extinction of the interior terminative conducting screen in the waveguide applying the variable transformation for Fourier inverse transform obtained.
Shimasaki et al. [1998] have described a new approach for analyzing nonlinear characteristics of the magnetization and magnetic field vectors using FDTD method. Therefore under high power operation in time domain, it seems to take an importance not only for developing new devices of ferrites but also for nonreciprocal devices like isolators. Kodera et al. [2000] also applied the same method to the analysis of the magnetostatic wave in ferrite materials including the nonlinear effects of the input power on the propagation pulse.
Kawabata and Yoshida [1998] have proposed the condensed node expression in the Spatial Network Method (SNM) for vector potential, and its advantages and validity are presented in the gyro-anisotropic medium such as magnetized plasma.
Shibata et al.[2001] have proposed a method for estimating complex permittivity of a material using a rectangular waveguide with a flange by using FDTD method.
Arima and Uno [1998] have proposed the recursive convolution approach and later piecewise linear recursive convolution approach for analyzing the electromagnetic propagation through linear dispersive materials by using FDTD method.

5.5 Numerical Techniques

In the FDTD method, it has been a problem for the numerical dispersion. So Suzuki et al. [2000] have proposed a method in the which can reduce the numerical dispersion for the nonisotropic mesh as well as the isotropic case by modifying anisotropically the speed of light.

As a numerical results ,the method was applied to a non-uniform mesh in two-dimensional space.
Ichige and Arai [2001] have proposed the novel concept of a 2-D FDTD formulation, mainly based on the mid-point finite-difference approximation wave equation, and partially based on the trapezoid and parabolic methods.

(T. Yamasaki)

B6. Waves in Random, Inhomogeneous, Nonlinear and Complex Media

6.1 Wave Propagation in Random Media

Matsuoka and Tateiba [1999; 2000a] deal with the scattering from a layer containing randomly distributed particles of high dielectric constant. The dense media radiative transfer equation is solved to get the scattering cross sections, which largely depend on the methods estimating the effective dielectric constant of the random media [Matsuoka and Tateiba 2000b; Tateiba and Matsuoka 2001].
Kawanishi et al. [1999b] predict the conjugate memory effect caused by the interference of a complex-conjugate pair of scattering processes in a random media.
Okamura [1998] experimentally demonstrated that enhanced backscattering is observed without statistical averaging by use of low coherent light. Depth profiles of random media made up of binary and ternary suspensions are estimated from measured enhanced backscattering of light [Okamura et al., 1999; Okamura and Yamamoto 2000].
On the other hand, Komiyama discussed localization and density of propagation modes in several disordered waveguide systems numerically and analytically [Komiyama, 1998; 2000a; 200b; 2001; Komiyama and Tokimoto, 2000].

6.2 Enviromental Propagation.

Wave scattering from a conducting body surrounded by continuous random media is studied by use of a current generator. Series expressions of the current generator are derived for TE and TM cases [Tateiba and Meng, 1999]. Bistatic cross sections of a conducting circular cylinder and concave-convex cylinder are calculated to clarify the effects of random media [Meng et al., 2000a; 2000b; Meng and Tateiba 2000; 2001; El-Ocla and Tateiba 1998; 2000a; 200b], where effects of the spatial coherence length of the incident wave on the normalized RCS are discussed. Some anomalous increases in the normalized RCS are found for H-wave incidence [El-Ocla and Tateiba 2001a; 2001b; 2001c].
The effects of atmosphere and ionosphere turbulence on a microwave beam propagation are studied for satellite communication. Using spot dancing model, Yamada et al. [1999; 2001] evaluate bit error rate, which is found to increase at low elevation angle due to atmosphere turbulence.

6.3 Nonlinear Electromagnetics and Nonlinear Media

Yokota et al. [1998] formulate the second-harmonic generation in nonlinear grating coupler by a singular perturbation method. Yokota [2000] deals with propagation of light through a photo refractive nonlinear slab.
Numerical method is developed for analyzing the propagation of light in a nonlinear optical wave guide. Using a finite element beam propagation method (FE-BPM) , spatial soliton emission and soliton couplers are investigated [Yasui et al. 1999]. Second harmonic generation devices with triangular and semi-circular domain inversion profiles and conversion

efficiency are analyzed [Yasui and Koshiba, 2000a; 2000b; 2001].

6.4 Rough Surface Scattering

By a stochastic functional approach, Kawanishi studied Brewster's scattering angle, which depends on the loss of dielectrics but does not exist in case of rough metal surface [Kawanishi and Izutsu 1999; Kawanishi 2000a; 2000b; 2000c]. Kawanishi et al. [1999a] measured the light scattering from dielectric random surfaces and confirmed the existence of the quasi-anomalous scattering and Brewster's scattering angle. Tamura and Nakayama [1999] obtain solutions of the nonlinear integral equation for the mass operator representing multiple scattering effects. Gao and Nakayama [1999] and Hattori et al. [2001] discussed wave scattering from periodic random surfaces. Nakayama [2000a; 200b] propose the periodic Fourier transform as a new method of analyzing the wave scattering from finite periodic rough surface.

Finite volume time domain method was formulated for numerically analyzing the wave scattering from various types of rough surfaces [Yoon et al., 1999], and was successfully applied to scattering from random dielectric surfaces at low grazing angle of incidence [Yoon et al., 2000a; 2000b; 2000c]. Yoon et al. [2001] introduced ray tracing analysis to obtain delay time spread for a building like rough surface. The boundary-element method is applied to the wave scattering from a randomly rough cylinder surface to get the angular distributions of the coherent and incoherent components [Arita and Kojima, 2000; Kojima and Arita, 2000]

6.5 Anisotropic Media

Numerical methods of analyzing waves in anisotropic optical waveguides were developed extensively. Koshiba et al. [1999] developed a full-wave finite-element method (FEM) to investigate the frequency dispersion of microwave propagation in broad-band Mach-Zehnder optical modulator. Saitoh et al. [1999b] applied FEM to determine the distribution of thermal strain, in terms of which strain-induced optical waveguides were investigated. An integrated acoustooptic tunable filters on a piezoelectric substrate and strain-induced polarization mode converters are also investigated by Saitoh et al. [1999a; 1999c]. Tsuji et al. [1999] formulated a finite element beam propagation method (FE-BPM), which was applied to an anisotropic planar waveguide and a magnetooptic channel waveguide. Saitoh and Koshiba [2001a; 2001b] studied Gaussian beam excitation on anisotropic optical waveguide by a full-vector FE-BPM and by an approximate scalar FE-BPM.

6.6 Chiral, Bi-isotropic and Bi-anisotropic Media

Scattering of a Hermite-Gaussian beam field from chiral cylinder [Yokota and Kai [2001] and chiral sphere [Yokota et al. 2001] was studied by the complex-source-method to obtain the effective dielectric constant. However, Kusunoki [1998] formulates scattering by a chiral coated dielectric cylinder using the FDTD method, where time variation of the polarization conversion is presented for the Gaussian pulse wave.

Diffraction by chiral or bianisotropic gratings is analyzed by a 4×4 matrix-based method. A uniaxial chiral slab with a plane metallic grating, a plane metallic grating in a planar-stratified bianisotropic medium and other structures are considered [Asai et al. 2000a; 2000b; 2001; Asai and Yamakita 2001]. On the other hand, Kunishi et al. [1999] applied the finite element method to the diffraction by a chiral slab with periodically deformed surface, where parameters to generate circularly polarized wave were presented.

Inverse problem is studied by use of Levenberg-Marguardt-Morrsion method. It is numerically demonstrated that chiral parameters can be determined from frequency response or time response of transmission and reflection in case of a stratified chiral slab [Kusunoki, 2000;Kusunoki and Tanaka, 1999].

On the other hand, Nanbu et al. [2000a; 2000b] deal with random media containing randomly distributed chiral particles by multiple scattering method and obtain the effective constitutive parameters, which are much better than those from the Maxwell-Garnett method [Nanbu et al. 2001a; 2001b; 2001c; 2001d].

6.7 Other Complex Media

Light-beam scattering from a three dimensional MO (magneto-optical) disk structure was studied numerically [Kobayashi et al. 2000]. By FDTD method, the scattering pattern from a recording bit was analyzed [He et al, 1998; Kobayashi et al. 2001]. Hotta et al. [2001] applied the frequency dependent FDTD method to analyze the scattering from Au or Al pregroove layer. Fukai et al. [2000] deal with a four-layer structure of a phase-change optical disk to obtain how scattering patterns change before and after recording.

(J. Nakayama)

B7. Guided Waves

7.1 Non Planar Waveguides

Rigorous and efficient methods based on the Fourier transform technique have been proposed for characterizing rectangular waveguide junctions [Jia, H. et al., 1998 and 1999a] and a rectangular groove waveguide [Jia, H. et al., 1999b], and also they have been improved by adding modified perfectly matched boundary to analyze open waveguide structures [Jia, H. et al., 2000], such as an inset dielectric guide [Jia, H. et al., 2001]. A coupled-mode equation has been successfully applied to the analysis for NRD-guide coupler [Watanabe, K. and K. Yasumoto, 1999], and radio wave propagation through modified T-junction in two-dimensional tunnel has been analyzed by the finite volume time domain method (FVTD) [Han, K. K. and K. Yasumoto, 1999].

The characteristics of a Cherenkov laser have been investigated for several types of waveguides: a step-wised taper dielectric waveguide [Hirata, A. et al., 1998], a plasma-filled waveguide [Thumvongskul, T. et al., 2000], a dielectric waveguide with a DBR [Hirata, A. and T. Shiozawa, 2000] and a waveguide filled with a inhomogeneous and lossy background plasma [Thumvongskul, T. and T. Shiozawa, 2001].

Zaginaylov, G. A. et al. [2000] have investigated the dispersion characteristics of the rectangular waveguide grating analyzed by the singular integral equation method, and Thumvongskul, T. et al. [1999] have investigated the growth and saturation characteristics of the EM wave in a Smith-Purcell free-electron laser with a Bragg cavity.

On the other hand, Tsuji, M. and H. Shigesawa [2001] have investigated a ridge effect on complex propagation constant of a stub-loaded rectangular waveguide by using the modified mode-matching method, and Hsu, J. P. et al. [2000] have derived the equivalent circuit consisting of multi-transmission lines and multi-port ideal transformers for the rectangular-waveguide H-plane discontinuity.

7.2 Planar and Quasi-Planar Waveguides

Tsuji et al. have discovered various leakage phenomena on printed-circuit transmission; a surface-wave-like leaky modes [Tsuji, M. et al., 1999a], a higher-order leaky mode [Tsuji, M.

et al., 2000], a simultaneous propagation between the bound and leaky modes [Tsuji, M. and H. Shigesawa, 2000b], and a quasi-bound mode [modes [Tsuji, M. et al., 1999b, and Shigesawa, H. and M. Tsuji, 2000]. Furthermore, Tsuji, M. and H. Shigesawa [2000a] have found out a mode extinction effect on microstrip lines when the thickness of a conductor with loss is decreased.

On the other hand, a coupled-mode equation has been successfully applied to the analyses for coupled microstrip lines [Watanabe, K. and K. Yasumoto, 2000b], and microstrip lines on ferrite substrates [Matsunaga, M. and K. Yasumoto, 2000]. Hsu, J. P. et al. [1999] have derived the Foster-type equivalent circuit for a strip line right-angle bend with slant-wise corner cut..

7.3 Dielectric and Optical Waveguides

Koshiba et al. have successfully applied a finite element beam-propagation method to the analysis of optical circuits [Yoneta, S. et al., 1999a and 1999b] and then have improved it by adding perfectly matched layer boundary conditions for analyzing 3-D optical waveguides [Koshiba, M. et al., 1999, and Tsuji, Y. and M. Koshiba, 2000b]. Tsuji, Y. and M. Koshiba [1998 and 2000a] have proposed a adaptive mesh generation for the full-wave finite-element analysis of optical waveguides, and also Tsuji, Y. and M. Koshiba [2000c] have presented an imaginary distance beam propagation method based on finite element scheme for analyzing the guideded and leaky modes of lossy optical waveguides.

On the other hand, a combined method of the BPM and the MEPM has been proposed for analyzing a bidirectional optical beam.[Hayata, K. et al., 1998], and also a time domain beam propagation method based on a finite element scheme has been applied to the analyses of optical circuits [Hikari, M., 1998], and photonic crystal circuits [Koshiba, M. et al., 2000].

Shiraishi et al have investigated the efficient coupling between the single-mode fiber and the laser diode by using several types of GI fibers; a parabolic-index fiber tip [Shiraishi, K. et al., 1998], a hemispherically-ended GI fiber [Shiraishi, K. and S. Kuroo, 2000], a GI oval-core fiber [Ogura, A. and K. Shiraishi, 2001], a silica GIO fiber with a highly elliptic core [Ogura, A. et al., 2001], and a wedge-shaped GI fiber [Yoda, H. et al., 2001].

Yasumoto, K. et al. [1999a] have presented a numerical approach for transition problems in optical waveguides, by using the Fourier series expansion method with the PML boundary condition, and also Yasumoto, K. et al. [1999b] have presented a numerical approach for three-dimensional optical waveguides using periodic boundary conditions.

Watanabe, K. et al. [2000] have performed an accurate coupled-mode analysis of a grating-assisted directional coupler with help of the singular perturbation technique and also Xu, S. et al. [1999] have analyzed the radiation effect for the quasi-periodic multi-layer planar dielectric grating by means of the multimode network theory with the mode-matching method.

Jia. H, et al. [2001] have proposed a fast and efficient method for analyzing an inset dielectric guide with help of the Fourier transform technique with a modified perfectly matched boundary.

The finite difference beam propagation method (FDBPM) has been successfully applied to design various optical circuits consisting linear and/or nonlinear materials: a Y branch [Yabu, T. et al., 2001], a three branch [Yabu, T. et al., 1999], a self-switch [Pramono, Y. H. et al., 1999], logic gates [Pramono, Y. H. et al., 2000], and a power limiter [Kitamura, T. et al., 2001a]. An optically controlled nonlinear directional coupler has been analyzed by the coupled mode theory [Rawat, B. S. et al., 1999]. Furthermore, applying a FD-BPM, Asama, K. et al. [2000] examined the effect of wall roughness of an optical waveguide and Kurokawa, H. et al.

[2001] presented a basic design of a Y-branch optical waveguide with a reflecting surface.

7.4 Resonant Modes

Kitamura et al. have investigated three different types of filters consisting of various planar-circuit resonators by using the FDTD method. One of them is a dual plane comb-line filter of conductor-backed coplanar waveguide [Kitamura, T. et al., 2001b]. The others are a slot coupled microstrip filter [Murata, M. et al., 2001] and a triplate strip resonator with a loading capacitor [Kitamura, T. et al. 1998].

Kogami et al. have performed various investigations employing the whispering-gallery mode on a millimeter-wave dielectric disk resonator: a dielectric measurement [Kogami, Y. et al., 2001a], a bandpass filter [Kogami, Y. et al., 2001b], a temperature characteristic measurement [Kogami, Y. and K. Matsumura, 2000], and an analysis by the point matching method [Tomabechi, Y. et al., 2001].

7.5 Miscellaneous

Koshiba, M. and Y. Tsuji [2000] have proposed a unified approach using curvilinear hybrid edge/nodal elements with triangular shape for guided problems, and also Koshiba, M. et al. [2001] have newly developed a high-performance absorbing boundary conditions for photonic crystal waveguide simulations.

(M. Tsuji)

B8. Antenna Theory and Analysis

A problem of a finite gap of a cylindrical dipole antenna has been still given attention and Wu et al. [1999] analyzed the above problem using Hallen type integral equation, instead of Pocklington type. Full wave analysis on monopole antenna with conducting flat disc over the earth was conducted by the same research group and Yuasa et al. [1999] presented useful result to design this kind of antennas. Miyashita et al. [1999a] also presented a useful formula using a product of far field patterns for evaluating antenna coupling. As a figure of merit of a small antenna, Ida [2001b] proposed the efficiency-fractional bandwidth product [EB] and discussed the effectiveness of EB. Some extensive analysis results of complex antennas were reported. Maruyama et al. [1999] showed the transient EM field of a multi-sector monopole Yagi-Uda array antenna. A full wave analysis of a radial slot antenna based on a rigorous model was also carried out by Yamamoto et al. [1999].

8.2 Antenna Elements

Various antenna elements were developed and designed to achieve both electrical and mechanical system requirements or to enhance performances by modifying the original configurations, although these elements can be principally categorized to conventional antennas, such as wire antennas, slot antennas or microstrip antennas.

Size reduction of antennas is always important for system designers and some proposals for small antennas compatible with other requirements, such as wide bandwidth, circular polarization and so forth. Small circular polarization antennas were presented by Nebiya et al. [1999] and Tajima et al. [2000]. Small or low profile antennas with wide bandwidth were reported by Noguchi et al. [1999], and Taguchi et al. [2000a], [2000b].

Circular polarization antennas with simple feeding mechanism were also proposed by Hirose et al. [2000], Nakamura and Honjo [2001], and Hirose and Wada [2001]. Kawano and

Nakano[2000] reported circular polarization array with “C” shape parasitic elements in front of a grid array.

From the view point of applications, antennas for rectennas were presented by Miura et al. [1999], Fujino and Mizuguchi[2001] and Syahrial et al. [2001], and those for ground penetrating radars were presented by Wakita et al. [2000], Miwa et al. [2000] and Nishioka and Uno [2000]. Beam tilt antennas for mobile communications by impedance loading were reported by Tanaka et al. [1999], [2001]. A leaky-wave antenna consisting of an image NRD guide was proposed by Yamamoto and Itoh [2000] and investigated by Chirwa and et al. [2000]. A linear high directivity antenna by a slot array was also investigated by Yamamoto et al. [2000a], [2000b]. A self-diplexing antenna using a patch antenna with a hole was also practical and reported by Rikuta and Arai [2000]. Basic researches on patch antennas were continued and Fujimoto, T. et al. [1999], [2000] presented the formulation of the wall admittance of a circular patch and the analysis of an elliptical patch with a circular slot, respectively.

8.3 Array and Adaptive Array

In the field of phased arrays, techniques for precisely adjusting or diagnosing hardware were developed. Ohtsuka et al. [1999] proposed analysis methods of beam direction accuracy in monopulse phased array antenna and Yonezawa et al. [1999] proposed the beam correction method for a deployable phased array antenna.

Researches and developments on adaptive antennas greatly advanced in this period and many interesting papers were published. Now, adaptive antennas seem to be required to realize and enhance the next generation mobile systems. A new trend in adaptive antennas is to develop the hardwares. Okamura et al. [1999] proposed the real-time calibration method of weights for transmitting digital beam forming. Nishimori et al. [2001a], [2001b] showed other novel calibrating method for a transmitting beam. Obayashi et al. [2001] realized a hardware of an adaptively steering beam antenna using IF local signal phase shifters. Ohira and Gyoda [2000] presented a compact steerable beam antenna called “ESPAR”.

Some application proposals to enhance wireless systems were presented by Matsuoka et al. [1999], Nishimori et al. [2000], Sekiguchi and Karasawa [2000] and Hirata et al. [2001]. Proposals for improving algorithm were also reported by Kasami et al. [2001], Fujimoto, M. et al. [1999], [2000] and Okamura et al. [2000]. Since space-temporal adaptive equalizations are effective in multi-path environments such as encountered in mobile communications, new configurations were proposed by Takatori et al. [2000], Denno and Ohira [2001] and Ichikawa et al. [2001].

8.4 Reflectors, Lenses and Radomes

Satellite-borne antennas are required to have high performances in both electrical and mechanical aspects. Naito et al. [1998] presented a novel patterning method of polarization grids on a curved reflector surface. Influences due to pillow deformation of a mesh reflector were analyzed by Kurihara et al. [1998]. A new shaped beam design using plane wave synthesis was developed by Aoki et al. [1999c] and they applied their method to a horn-reflector antenna on board. Feeding networks designs for scanning beam reflector antennas or multi-beam antennas were presented by some authors, Kira et al. [1999], Kira and Hori [2001] and Tokunaga et al. [1999], [2000]. Compatibility of high cross-polarization discrimination and arbitrary aperture distribution can be said to be ideal goal in an off-set reflector antenna design and Aoki et al. showed a novel design method using geometrical optics [1999a],[1999b] and Furuno et al. [2000] developed more rigorous design method taking into account EM wave propagation phenomena. As for a beam-waveguide design, Miyahara et al. [1999] investigated the influence of the displacement of the beam-waveguide mirrors to the aperture distribution of a main reflector. Interesting reports were presented concerning lens antennas, one of which is a plate Luneberg lens with the permittivity distribution controlled by hole density by Sato and Ujiie [2001] and the other is a film Fresnel lens antenna for applying to a large radio telescope by Ujihara et al. [2001]. Influences of a radome to the wide angle radiation pattern were investigated by Deguchi et al. [2000] and the degradation of DBS reception antennas due to snow fall were measured by Hu et al. [1999].

8.5 Millimeter-wave Antennas and Optical Antennas

Researches on millimeter wave antennas and optical technologies related antennas are increasing for applying to vehicle radar systems, wireless LAN's (Local Area Network) and broad band wireless access systems.

Kobayashi and Yasuoka [1999a], [1999b], [1999c] presented receiving properties of a slot antenna and an extended hemispherical lens coupled slot antenna at 94GHz. Sakakibara et al. [2001] developed a millimeter-wave slotted waveguide array for automobile radar systems. Array antennas controlled by an optical signal processing were reported by Akiyama et al. [2001a], [2001b] and a technology for an adaptive antenna control from a remote station through optical transmission were presented by Seto et al. [2001].

8.6 Mobile Antennas

Owing to the growth of mobile communication services, researches and developments on mobile communication antennas have been increasing. As for the mobile terminal antennas, Kumon and Tsukiji proposed double folded monopole antennas [1998] and a Z-shaped modified transmission line antenna[2000]. Kim et al. [2001] presented a folded loop antenna, which can reduce the induced current on the hand-set case. Sasamori [2001] developed a normal mode helical antenna with matching circuit composed of a sleeve and an inductor. A loop antenna for a wrist-watch phone is presented by Saito et al. [2001] and they compared the characteristics of the loop to a PIFA or a normal mode helical. Amano et al. [1999] developed a duel band internal hand-set antenna using a quarter-wavelength shorted microstrip antenna with a slot. Extensive analyses of the diversity characteristics were carried out for the hand-set phone. Odachi et al. [2001] cleared the terminating impedance condition to enhance the diversity reception characteristics and Sekine et al. [2001] presented the method to reduce the coupling between diversity antenna elements. Meksamoot et al. [2001] presented the analysis results of polarization diversity for a hand-set phone using PIFAs. Coupling between a hand-set antenna and a strip line inside the hand-set box were quantitatively analyzed by Fukasawa et al. [2000]. Performances of hand-set antennas considering a human body were investigated by Ogawa and Takada at 800MHz [2000] and Ogawa et al. at 150MHz [2001]. Saito et al. [2000] measured and evaluated the change of radiation pattern due to a human body.

As for base station antennas, some multi-frequency operation antennas were developed. Kijima et al. [1999] presented a duel frequency base station antenna and Fukasawa et al. [2001] presented a triple-bands array antenna for cellular base stations. Miyashita et al. [1999] presented a rigorous analysis of an electromagnetically coupled coaxial dipole array and Cho et al. [2001] reported a linear array antenna with a bidirectional radiation pattern for PHS.

Extensive measurement results of a polarization diversity antenna for cellular base stations were reported by Nakano et al. [2000].

In addition to cellular mobile systems, wireless LAN systems are becoming important for access links to personal terminals. Seki and Hori [2001] developed a multi-sector antenna with self-selecting switch circuit for a wireless LAN terminal. Cheng et al. [2001] proposed a beamforming antenna controlled by reactance load, which is named “ESPAR”.

8.7 Measurement

A new measurement technology is sometimes required to assure the precise characteristics of antennas. Ida et al. developed an accurate method of measuring low value of an input resistance [1999] and a method of reducing a drift error of a network analyzer at a measurement of a small antenna [2001a]. Nishizawa et al. [2000] developed a precise far field pattern measurement method eliminating the reflections of the antenna surroundings. Superresolution techniques are also important in the field of antenna measurement, and Hirata et al. [1999], Okamura et al. [1999a] contributed to improve measurement performances and Nakazawa et al. [2001] presented measurement method of a direction of arrival using a nonuniform array.

(K. Kagoshima)

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