COMMISSION F : WAVE PROPAGATION AND REMOTE SENSING (Nov. 95 - Oct. 98)

Edited by Ken'ichi Okamoto

F1. Radio Communications

F1.1. Terrestrial Fixed Radio Systems

The probability of simultaneous fading occurring on plural paths in the same route is a fundamental parameter for estimating the outage rate of non-regenerative repeating microwave systems. In-band amplitude dispersion (IAD) is also an important parameter for the system design of digital radio. The cumulative probability used to calculate the outage caused by IAD should consider the accumulation effect.

A new correlation is introduced between the two fading occurrences of two paths. It indicates that the conventional calculation method in which the simultaneity of fading is assumed to be independent underestimates the joint probability of received power variation. This result is obtained from a nation-wide experiment carried out over 30 paths in Japan. A calculation method of IAD with cumulative distortion is newly derived theoretically. A simplified formula in which the cumulative degradation is treated as the modification of the frequency correlation coefficient is proposed [Sato and Ando., 1996].

(A. Sato)

F1.2. Fixed Satellite Radio System

Kyushu University performed Ku-band satellite communication experiments using the VSAT system for JCSAT-1. The VSAT system is located near Fukuoka Airport and the propagation path is almost under the landing route of the airplanes. In addition to rainfall, airplanes flying across the channel have some effects such as signal attenuation on the satellite links. It is suggested that the bit error was caused by landing airplanes that fly across the propagation path between JCSAT-1 and VSAT system at low altitudes of about 300 m. The average of bit error rates was about 0.0355 [Sakamoto et al., 1996].

Tokyo Engineering University carried out continuous measurements of the signal level at 12.6 GHz from Japanese SUPERBIRD-B satellite received at Hachioji, Tokyo, using a 3.6 m diameter antenna. Based on the data obtained at 10 sec intervals, monthly and yearly cumulative distributions of rain attenuation and rainfall rate, the effective rain height against rainfall rate, the correlation between 10-sec and 1-minune rainfall rates and the duration properties of rain attenuation were analyzed. It is clearly seen that the larger the rainfall rate the lower the effective rain height. The 1-minute rainfall rate is found to be sufficient to know the property of the cumulative time distribution. The duration time of rain attenuation is nearly inversely proportional to the number of its occurrence [Yamada and Miura, 1998].

The effects of attenuation and depolarization along the earth-space path on a dual polarized 21 GHz-band digital broadcasting satellite service (BSS) are studied by using both theoretical and measured attenuation and depolarization relations. It is concluded that the effects of rain- and ice-depolarization on bit-error-rate performance in the digital 21 GHz BSS are not significant, including for the power control situation. This indicates that the channel number can be doubled without significantly degrading the system performance [Ohta and Fukuchi, 1998]. As concerns 22 GHz satellite communication systems, quantitative evaluation of site diversity gain was performed using a 3-variate log-normal distribution model. The validity of this model is confirmed for site diversity systems using three locations [Nakayama et al., 1997].

Rain attenuation and cross-polarization discrimination (XPD) of the Ka-band earth-space path were continuously observed using the CS-3 beacon signal (19.45 GHz, RHCP, EL=49.5 deg) at Neyagawa, Osaka. As for rapid XPD changes observed in thunderstorms, the increase of these changes seems to be caused by random orientation of ice crystals as the electric force is released after a lightning discharge. The decrease of the changes may be affected by ice crystals far from the lightning as well as those near the lightning, since depolarization cancelation is possibly induced by the difference between these mean canting angles [Maekawa et al., 1996a]. The rain attenuation at the Ka-band was compared with the one at the Ku-band obtained from the broadcasting satellite (BS), and the ratio of the attenuation is found to be 2.3-3.9, depending on the typical raindrop size distributions (DSD). The equiprobability relationship between Ka- and Ku-band attenuation shows large year-to-year variations, too. The attenuation ratios are correlated with the yearly distribution of the cross polar phase which is also sensitive to the type of DSD rather than rainfall intensity [Maekawa et al., 1996b, 1996c; Karasawa and Maekawa, 1997]. The Ka-band up-link attenuation at 30 GHz band is inferred in a more realistic manner by selecting a relevant DSD for each rainfall event based on the cross-polar phase measurement. Consequently, the time percentages of bidirectional Ka-band up- and down-link attenuation between the Neyagawa (Osaka) and Setagaya (Tokyo) stations are estimated more precisely. The time percentages show a characteristic difference of about 50% according to the transmission directions in each year, while the are nearly the same in long-term statistics during six years [Maekawa 1998a]. The time scale of attenuation fluctuation of Ka-band satellite radiowave is investigated during the passage of each rain front. The correlation time becomes larger as the passage of the fronts is slower. Rain cells of the stationary front that moves along the front line give longer attenuation duration time than those of the cold front that move across the front line [Maekawa 1998b].

(Y. Maekawa)

F1.3. Land Mobile Communication

Propagation studies for land mobile communication systems in Japan are mainly aiming at wider bandwidth and higher frequency band. Concerning the bandwidth, more than 10 MHz is being studied recently. Microwave band and quasi-millimeter wave bands are began to be considered for mobile use.

In order to design a wideband mobile radio system, countermeasure techniques for multipath interference are required. Using measured data obtained in several urban environments makes some statistical approaches. A prediction method for the delay characteristics in line-of-sight microcells is presented and an estimation method of r.m.s. delay spread is formulated [Ichitsubo et al., 1996a]. The channel impulse responses are measured widely to clarify the statistical characteristics for indoor, pedestrian and vehicular environments at 2 GHz band [Ichitsubo et al., 1997].

In contrast to the statistical approach, the behavior of instantaneous delay profiles is studied

[Taira et al., 1998]. Phase fluctuations for each delayed wave are analyzed and categorized for a dynamic modeling of delay characteristics. An idea for measuring the delay profiles and the directions of arrival by using a super resolution algorithm is presented [Sakaguchi et al., 1998].

Ray tracing method is used to characterize the multipath propagation in urban areas. The r.m.s. delay spreads are calculated using optical ray theory, taking into consideration the wedge diffraction on the street corner in a 2 GHz band [Furuno et al., 1996; Taga and Furuno, 1997]. The influence of the noise level is also pointed out when a delay spread is calculated from a measured delay profile. BER estimation with random phase summation applied to ray tracing is studied to reduce the estimation time and its effectiveness is verified [Takahashi et al., 1998a]. Frequency band in consideration is expanded from 2 GHz to 5 GHz and above ray tracing method shows the effect of directional antennas for improving the delay characteristics in a street environment [Taga, 1998].

Propagation loss characteristics for broadband systems are studied for line-of-sight microcells in a 2 GHz band. Cumulative distributions of received signal level are found to be approximated by Nakagami-Rice distributions instead of Rayleigh distributions [Yamaguchi et al., 1997a]. A model of received signal level for wide-band transmission in mobile communications is presented [Seino et al., 1996]. It is shown that the equivalent received bandwidth and the power ratio of the direct wave to non-direct waves are useful parameter for describing received level distribution characteristics. The equivalent transmission-path model for evaluating the wideband digital transmission characteristics is proposed and its theoretical foundation is examined [Iwai and Karasawa, 1996; Karasawa et al., 1997a]. The autocorrelation is studied as an important parameter for wide-band mobile transmission characteristics [Nakabayashi et al., 1998].

Propagation loss in a higher frequency band such as microwave band is investigated. Three frequencies, 3.35 GHz, 5.2 GHz, and 8.45 GHz, are used to clarify the dependency on frequency in street cells. A relation between base station antenna height and propagation loss is also obtained [Taira et al., 1996]. Path loss measurements at 3.35 GHz and 15.75 GHz in a street environment are reported [Masui et al., 1998]. In a quasi-millimeter band, two studies are reported. A 19 GHz high-speed transmission system with 23 Mbps is used for mobile transmission trials of digital data and MPEG2 video images [Furuya et al., 1997]. Effectiveness of space diversity reception and possibility of image transmission in mobile systems are investigated experimentally. Simulation results for a wireless ATM in a 20 GHz band are reported [Sato et al., 1997d].

(A.Sato)

F1.4. Indoor Mobile Radio System

Ichitsubo et al., measured the cumulative distributions of r.m.s delay spread in the 2.6-GHz band for different types of rooms and corridors [Ichitsubo et al., 1996b]. They found that the median of the r.m.s. delay spread can be modeled by a simple function of the floor area of the room. Based on their measurement results, they proposed an multipath delay profile model which can be used for indoor multipath propagation simulators. In their model, multipath delayed waves are simulated by a tapped delay line with instantaneously Rayleigh distributed multipath components whose average delay profile is given by an exponential function of excess delay time.

In indoor radio communication systems such as wireless local area networks, shadowing caused by human bodies has a significant effect on transmission characteristics of communication channels. Obayashi and Zander proposed a statistical model for estimating the effects of shadowing by human bodies for given layouts of of walkways in offices [Obayashi and Zander, 1998]. In their model, statistical effects of shadowing on received levels are estimated by two-dimensional multipath ray-tracing calculations in which propagation loss of each multipath component caused by human bodies statistically distributed on walkways are taken into account. They applied their model to predict contour maps and cumulative distributions of transmission losses at 900 MHz and 60 GHz in an office room, and compared a estimated cumulative distribution with measurement results at 900 MHz. Sato and Manabe estimated the propagation-path visibility between base stations and user terminals for indoor millimeter-wave communication systems in which base stations and user terminals are installed on ceiling and desk top, respectively, under shadowing condition by human bodies by assuming a clustering model of desks in office environments [Sato and Manabe, 1998]. They also showed the effectiveness of the selection diversity between two base stations to improve the visibility of base stations. Probability distributions of attenuation under various conditions of shadowing caused by human-body movements were measured in the 1.3-GHz and 2.5-GHz bands in an office environment [Yamada et al., 1997]

Indoor broad-band transmission experiments were made in the 37-GHz band using a QPSK modem operating at a transmission rate of 100 Mbps [Aikawa et al., 1998]. The zone coverage estimated from the measured BER performance were found to be greatly improved by adjusting the receiver position only a few centimeters which indicates the effectiveness of space diversity reception with an antenna spacing of several centimeters.

The effects of antenna directivity and polarization on the multipath propagation characteristics at 60 GHz were investigated by indoor propagation measurements and ray-tracing simulation taking into account the antenna radiation pattern and the complex interior structure of the room [Manabe et al., 1996]. It was found that the use of directional antenna as well as the use of circular polarization is effective to reduce multipath delay spread. Kato et al.,investigated high-speed (64-256 Mbps) BPSK transmission characteristics in conjunction with multipath delay profiles by indoor propagation measurements at 60 GHz in a office room [Kato et al., 1997]. They analyzed the effects of the polarization and the radiation pattern of the base station antenna on multipath and bit-error characteristics for different types of base station antennas.

Reflection and transmission characteristics of construction materials such as concrete [Sato et al., 1996a] and interior structures such as wall, floor, window glass, partitions, and ceiling of a office building [Sato et al., 1997a] were measured at 60 GHz. It was found that the reflection and transmission characteristics of most of the interior structures can be explained by multilayer dielectric models. The effects of tile carpets above the floor and the effects a window shade in front of window glass on the reflection characteristics were also examined at 60 GHz [Sato et al., 1997a].

(T. Manabe)

F1.5. Satellite Mobile Radio Systems

In order to measure LMSS (Land Mobile-Satellite Service) propagation characteristics accurately, a measuring system which receives a transmitted PN-SS signal through a satellite was developed [Arakaki et al., 1998]. Using the system, delay profile measurements of LMSS channel were carried out by receiving 1.5 GHz signal from the ETS-V satellite. The results showed that multipath condition in urban area is more severe than that in suburban and mountainous areas.

By using the ETS-VI satellite, which has a sub-recurrent orbit and 10-20 degrees higher than angle of elevation than a geostationary satellite, propagation characteristics such as shadowing probability and signal fade statistics at very high elevation angles (i.e. 57 - 66.5 degrees) were measured [Yamamoto et al., 1998]. From the experiment, a significant advantage in LMSS at such higher elevation angle conditions was confirmed.

A typical but conceptual propagation environment for LMSS is characterized by a combination of three states appearing one after another based on Markov Process [Karasawa et al., 1997b]. The three states named "states A, B and C" represent the line-of-sight (LOS) condition, slight shadowing by trees and/or small obstacles such as utility poles, and full shadowing by large obstacles such as buildings, respectively. The probability density functions (PDF) for each state, f_A , f_B and f_C, can be represented by the Nakagami-Rice distribution for State A, Loo's for State B and Rayleigh's for State C with the state occurrence probability parameters of p_A, p_B and p_C (where $p_A + p_B + p_C = 1$). Accordingly, the overall PDF is given by "$p_A f_A + p_B f_B + p_C f_C$". The three-state model has proven to be a good representation of LMSS environments such as urban and suburban environments at L-band frequencies.

The three-state model given above has a capability for assessing satellite diversity effects in the case of multi-visibility satellite constellations (i.e. switching to the least impaired path based on the state-by-state selection scheme) [Karasawa et al., 1997]. Based on the calculation, drastic improvement by means of the diversity can be demonstrated particularly in a suburban environment.

(Y. Karasawa)

F2. Remote Sensing

F2.1. Atmosphere

Study of the earth's atmosphere has been intensively carried out using radar and other sensors. Major tendency in recent years is the joint observations with multiple sensors having complementary characteristics, such as vertical profiles with a ground-based radar and horizontal structure by an optical imager, or radar wind measurements with temperature profiles by RASS, and so on. Climatological aspects based on data over a long period is another feature of recent studies. Here we summarize recent advances in this field in the ascending order of the target height region.

The planetary boundary layer is a relatively new region as a target of the atmospheric radar technique. The use of a high frequency band for such a low altitude region enabled the use of much smaller antenna than MST radars. An overview of the L-band boundary layer radar operating in Indonesia is presented by Hashiguchi et al. [1996].

Turbulence and gravity waves in the lower and middle atmosphere have been studied in details by MST radars and by combinations of multiple sensors. Tsuda et al. [1997a, b] studied angular dependence of VHF specular reflection echoes in the lower atmosphere. Kurosaki et al. [1996] developed a climatology of vertical eddy diffusivity in the lower and middle atmosphere based on the MU radar observations over 7 years. Horizontal and vertical structures of low-frequency gravity waves and their propagation characteristics have been studied by the MU radar with the aid of radiosonde observations [Sato et al., 1997c, Yamamori and Sato, 1998, and Yamanaka et al., 1996]. Yamamoto et al. [1996] studied the relation of wind velocity and temperature fluctuations associated with the gravity waves by the MU radar-RASS technique.

At the mesospheric heights, Kubo et al. [1997] revealed a seasonal and international variability of mesospheric MU radar echoes based on 10 years of observations. Nakamura et al. [1996a] studied mean wind structure at 60-90 km observed with the MU radar.

Although limited in the covering height range, meteor wind radar also serves as a continuous monitoring tool of the winds at this height region. Tsutsumi et al. [1996] studied wind velocity and temperature fluctuations due to a 2-day wave. Hasebe et al. [1997] used winds derived from meteor radars in validating HRDI MLT winds. Tsuda et al. [1997c] compared diurnal oscillations measured by a meteor wind radar with that by radiosondes in Indonesia.

MF radar is another important technique for measuring winds in the middle atmosphere, and collaborative observations with other radars have been carried out. Igarashi et al. [1996] compared wind measurements by Yamagawa MF radar and the MU radar. Nakamura et al. [1996b] studied mesospheric gravity waves at three largely different latitudes over the globe. Nakamura et al. [1997] found evidence for the interaction between gravity waves and the atmospheric tide based on the low-latitude MF and meteor radar observations.

Optical observations is among the most important complementary sensors providing horizontal coverage, which is hard to obtain with atmospheric radar techniques. Nakamura et al. [1998] used OH CCD images for studying horizontal propagation characteristics of gravity wave patterns. Fujiwara et al. [1998] studied meteor luminosity at 160 km altitude based on TV observations of bright Leonids meteors.

It is planned to install a submillimeter-wave limb-emission sounder for observing stratospheric minor constituents (SMILES) on the Japanese experiment module (JEM) of the international space station (ISS). The outline of the project and its current status is reported by Manabe et al., [1998].

(T. Sato)

F2.2. Hydrometeors and Other Particles

The Tropical Rainfall Measuring Mission (TRMM) is a joint US-Japan space mission to observe tropical and subtropical rainfall. The TRMM satellite was launched to the orbit on November, 1997. The TRMM satellite is equipped with the first spaceborne precipitation radar (PR) and several other sensors [Kummerow et al., 1998]. Early results of TRMM PR data were presented by Okamoto et. al. [1998]. Okamoto et al. [1996b] described outline of the PR algorithms.

For a spaceborne radar having a large foot-print size, the non-uniform beam filling (NUBF) becomes a major error source in the quantitative retrieval of rainfall rate. Kozu and Iguchi [1996] examined a potential usage of the "local" statistical properties of rain to decrease the bias error caused by the NUBF when rain rate estimation is made by a surface reference technique. Ohsaki and Nakamura [1998] studied the NUBF problem by a simulation. Sato et al. [1996b] described a TRMM validation using the high-resolution MU radar, which provides us with the NUBF information and also enables us to examine the vertical variability of the dropsize distribution.

The TRMM PR measures weak rain with a low SNR (signal-to-noise ratio). Ohsaki and Kozu [1997] demonstrated by a simulation that the dynamic range for Rayleigh fading signals can be expanded when the nonlinear input-output characteristics of the actual TRMM receiver is being taken into consideration. Ohsaki and Nakamura [1996a] examined the low SNR problem using three kinds of data processing (truncation, zero rain, and negative rain methods).

A new airborne rain radar named CAMPR (CRL Airborne Multiparameter Precipitation Radar, where CRL stands for the Communications Research Laboratory) was developed for the major purpose of calibrating the TRMM PR. Kumagai et al. [1996] reported system design of CAMPR and preliminary results of flight experiments.

Ohsaki and Kuroiwa [1997] investigated the feasibility of calibrating the TRMM PR by using the path-averaged rainfall rate estimated from path attenuation of a terrestrial link and that of a broadcasting satellite down link.

Fujita and Satake [1997] proposed a new algorithm applicable to rainfall rate profiling with a rain-attenuating-frequency radar for vertical incidence from an air or space platform. The algorithm solves a non-linear equation by the method of nonlinear least squares by linearizing the equation.

Meneghini et al. [1997] examined a complimentary use of radar and radiometer data. Their study begins with the estimation of a two-parameter drop size distribution from dual-wavelength radar data. Defining storm models, the brightness temperature for each model is computed. A storm model or class of storm models is considered optimum if it provides the best reproduction of the radar and radiometer measurements.

Ohsaki and Nakamura [1996b] showed that when the maximum diameter of raindrop is adaptively determined from the differential reflectivity (ZDR) with a dual polarization radar, errors in the estimated rainfall rate can be reduced. Ohsaki and Nakamura [1997] examined a possibility of estimating the rainfall rate using ZDR alone.

Even spherical particles can produce appreciable linear depolarization ratio (LDR) by multiple scattering effects. This was demonstrated by an experiment, the result of which shows a good agreement with a theory [Oguchi et al., 1998].

Nakamura et al. [1996] reported that when rain exists over ocean, the observed echo by a real aperture microwave imaging radar showed short-term fluctuations. They explained that this short-term fluctuations appeared due to an interference between rain and sea surface echoes.

Horie et al. [1998] reported preliminary results of their first cloud observation with a newly built 95 GHz multi-parameter cloud profiling radar on an airplane.

Sonoi et al. [1996] have proposed two types of predictable parameters for the lightning discharge occurrence based on a discrimination method of graupel and ice crystals by the radar reflectivity and ZDR of a dual polarization radar.

Shibagaki et al. [1997] carried out a three-week observation campaign using the MU (Middle and Upper atmosphere) radar and meteorological radars. Based on the observational evidence, they proposed a conceptual model of hierarchical structures of the distributions of vertical velocity fluctuations and precipitating clouds in the Baiu frontal zone.

Awaka and Iguchi [1997] showed that the effect of antenna beam movement on rain observation by a radar, which was opened up by Jameson and Kostinski [1996] ("Non-Rayleigh signal statistics caused by relative motion during measurements," J. Appl. Meteor., vol. 35, pp. 1846-1859) can also be handled by the standard fluctuation theory of Marshall and Hitschfeld.

Nanbu and Tateiba [1996b] calculated the effective dielectric constant of a medium containing many dielectric spheres using their new approach. They concluded that their method is more powerful for the analysis of the dielectric constant than the conventional methods. They also calculated the effective dielectric constant of a medium which contains many dielectric cylinders [Nanbu and Tateiba, 1996a]. Meng and Tateiba [1996] calculated the radar cross section (RCS) of a conducting elliptic cylinder in a strong continuous random medium. Their numerical analysis shows that the spatial coherence of an incident wave on the cylinder has an important effect on the RCS.

(J. Awaka)

F2.3. Ocean and Ice

HF Ocean Radar is a ground based Doppler radar for detecting ocean current and wave vectors. Communications Research Laboratory have been developing the 24.5MHz Ocean radar since 1988. The radar is a FM-CW radar. The current measured by the radar at Okinawa showed a good agreement with the directly measured current by the ocean current meter [Nadai et al., 1997]. Observation using this radar was carried out at several coasts in Japan [Hisaki, 1998]. Hisaki[1996] improved a theory of the ocean radar. Ocean wave estimated by the radar is given as a solution of a non-linear integral equation. He solved the equation numerically without approximation.

Side looking imaging radar is available for the detection of the oil slicks. However, it has not been proved that satellite-borne synthetic aperture radar (SAR) is available for detecting the small oil slicks. Okamoto et al.[1996a] carried out the experiments to detect the artificial oil slicks. The ERS-1 SAR data show clear image of the artificial oil slicks.

Ice radars have been mainly developed to measure the ice thickness of Antarctic ice sheet. Recent works using ice radar tend to investigate ice dynamics. Maeno et al.[1996, 1997] observed the Antarctic ice from the Syowa station to the Dome-F, where exists one of the largest highland in the Antarctica, by 179 MHz radar mounted on the over-snow vehicle. The vertical cross section of ice sheet along 1000 km shows dynamical ice flow through the analysis of internal layered echo. They also found that cross section structure around the summit of the Dome-F was horizontally layered, which suggests very small horizontal ice flow. Maeno et al.[1997] found that the surface ice flow vector has a good agreement with the attenuation anisotropy which was measured by varying the antenna polarizaton. This result suggests a new technique to profile the flow vector of ice sheet by ice-radar.

Another approach to investigate internal ice characteristics by ice-radar was reported by Uratsuka et al.[1996a]. Their observations by airborne 179 MHz radar were carried out at ice shelf (the bottom of which is contacted sea water) and at its source ice sheet. They found the disappearance of internal layered structure near the grounding line, which is defined as a boundary of ice shelf and ice sheet. The disappearance occurred at about 600m inland from grounding line.

Study of the internal layers is usually made by the direct sampling of ice-core, the vertical resolution of which is a few centimeters. However, ice-core sampling can be made only at a few points. On the other hand, radar can observe internal layers widely at a time with rather poor resolution about several 10m. Therefore, it is not easy to compare internal radar echo with ice properties estimated by the core samples. L-band high resolution ice-radar was developed to observe internal layers widely at a time with good resolution [Uratsuka, 1996b]. The vertical resolution of the radar was about 1 m. Observations by this radar were carried out on the Canadian ice caps. Comparison between radar echoes and static conductance profile has good agreement.

On the contrary, for the ice thickness measurements of the temperate glacier, lower frequency (5 to 10 MHz) radars are used sometimes. Usually the impulse-radar is used. Matsuoka et al.[1997] used the 5MHz impulse radar at the ice cap in the Kamchatka, Russia.

(S. Uratsuka)

F2.4. Land, Vegetation, and Others

Full polarimetric radar remote sensing has seen a tremendous growth, from theory to data analysis as shown below, in various areas including land, vegetation, and others, during these three years.

The basic principle of radar polarimetry extended to polarimetric enhancement [Yang, et al., 1997], accurate scattering matrix retrieval from Mueller matrix [Yang, et al., 1998], target classification using three component decomposition of scattering matrix [Yamaguchi, et al., 1997b], polarization averaging method in super-resolution technique[Yamada, et al., 1998].

A superb CRL/NASDA airborne SAR appeared [Kobayashi et al., 1997], showing the high resolution (1.5 by 1.5 m at X-band, 3 by 3 m at L-band) and full polarimetric (HH, HV, VH, and VV, both in the X- and L-bands) capability, and simultaneous interferometric data acquisition function at the X-band. The image acquired with the CRL/NASDA SAR showed top-of-the world quality, and it had a great reputation among radar experts in the world. This is evidenced at the international conferences in PIERS Workshop: advances in radar methods [Satake, et al., 1998a], and in IGARSS meeting [Satake, et al., 1997]. This CRL/NASDA SAR will play the most important role in radar remote sensing in Japan and will provide valuable information also for ALOS-PALSAR satellite system to be launched in 2002.

For laboratory applications, there were several implementations of full polarimetric radar systems. One is an FM-CW SAR which has been developed at Niigata University [Yamaguchi, 1996, 1998]. The system verifies state-of-art principles of radar polarimetry (decomposition, characteristic polarization state imaging, enhancement, etc.). The radar especially showed the effectiveness for subsurface applications, suppressing ground clutter which had been one of the most difficult problems in subsurface radar sensing. Moriyama et al. [1998], devised an equivalent Time Sensitivity Control concept for FM-CW radar and implemented it in the advanced FM-CW POL-SAR system.

The other is a polarimetric borehole radar system for detecting cracks and anomalies within underground structure [S. Ebihara, et al., 1997]. It utilizes circular/conformal array antennas for directional polarimetric scattering matrix measurement. From the scattering matrix information, detailed information on the ground structure was retrieved [Miwa, et al., 1997; Sato, et al., 1998].

For realizations of ideal polarimetric radar, it is necessary to calibrate radiometric radar channel. The calibration target is a key factor in the calibration process. Since polarization isolation of 30dB was achieved by an active calibrator and polarization selective dihedral reflectors developed at CRL, these calibrators were applied to CRL/NASDA SAR [Satake, et al., 1998b].

A unique wire-like calibration target was presented by Kitayama, et al.[1998], which consists of parallel plate waveguides on electromagnetic absorber. It showed large RCS comparable with that of plate and ultra wideband characteristics.

By continuous observations with ERS-1 SAR, it was shown that the growing rate of rice crops could be estimated by the C-band backscattering coefficient [Kurosu et al., 1997]. Soil moisture retrieval and snow water estimation are one of the important applications from SAR data analysis. Koike et al. [1998] pursuits the retrieval of soil moisture from SAR data, and Fukami et al. [1997] tries to estimate snow water equivalent. A unique polarimetric signal processing is devoted for a radar mounted on the front end of tunneling machine [Sato et al., 1997b]. Nagai, et al. [1997] proposed to classify land cover using polarimetric enhancement and the wavelet transform.

(Y. Yamaguchi)

References

Aikawa, S., A. Sato, Y. Nakayama, S. Kurosaki, and T. Yoshida [1998], "Transmission performance and diversity technique of 100 Mbps indoor radio on 37 GHz," IEICE Trans. Commun., vol. E81-B, 4, pp. 798-805.

Arakaki, Y., T. Ikegami, H. Wakana and R. Suzuki [1998], "Multipath measurement in land mobile satellite communication channels," Trans. IEICE, vol. J81-B-II, 5, pp. 391-398 (in Japanese).

Awaka, J., and T. Iguchi [1997], "On averages of radar rain echoes in nonstationary conditions," IEEE Trans. Geosci. Remote Sensing, vol. 35, 5, pp. 1094-1104.

Ebihara, S., M. Sato, and H. Niitsuma [1997], "Estimation of source location for a borehole radar with a circular array by the MUSIC algorithm," Trans. IEICE, vol. J79-B-II ,9, pp. 69-77 (in Japanese).

Fukami, K., H. Kodama, and M. Kaneki [1998], "Potential of snow water equivalent estimation using satellite remote sensing, application of synthetic aperture radar (SAR)," Civil Engineering Journal, vol. 40, 2, pp. 20-25, (in Japanese).

Fujita, M., and M. Satake [1997], "Rainfall rate profiling with attenuating-frequency radar using nonlinear LMS technique under a constraint on path-integrated rainfall rate," Int. J. Remote Sensing, 18, pp. 1137-1147.

Fujiwara, Y., M. Ueda, Y.Shiba, M. Sugimoto, M. Kinoshita, C. Shimoda, and T. Nakamura [1998], "Meteor luminosity at 160 km altitude from TV observations for bright Leonids meteors," Geophys. Res. Lett., vol. 25, pp. 285-289.

Furuno, T., and T. Taga [1996], "Time delay spread in microcellular environment for personal communication systems," IEICE Trans. Commun., vol. E79-B, 9, pp. 1199-1204.

Furuya, N., T. Mizukawa, K. Munakata, A. Sato, and F. Ohkubo [1997], "Field, and laboratory measurements for 25Mbps multimedia communications in 20GHz band," EPMCC'97, pp. 189-194.

Hasebe, F., T. Tsuda, T. Nakamura, and M. D. Burrage [1997], "Validation of HRDI MLT winds with meteor radars," Ann. Geophys., vol. 15, pp. 1142-1157.

Hashiguchi, H., S. Fukao, T. Tsuda, M. D. Yamanaka, S. W. B. Harijono, and H. Wiryosumarto [1996], "An overview of the planetary boundary layer observations over equatorial Indonesia with an L-band clear-air Doppler radar," Beitr. Phys. Atmosph., vol. 69, pp. 13-25.

Hisaki, Y. [1996], "Nonlinear inversion of the integral equation to estimate ocean wave spectra from HF radar," Radio Sci., vol. 31. 1. pp. 25-39.

Hisaki, Y. [1998], "Measurement of ocean currents in Tsushima Channel and waves in Japan Sea by HF ocean radar," Gekkan Kaiyo, vol. 30. 8. pp. 461-466 (in Japanese).

Horie, H., H. Hanado, Y. Ohsaki, T. Iguchi, and H. Kumagai [1997], "Preliminary results of cloud observation with millimeter wave multi-parameter cloud profiling radar (SPIDER)," Proc. IGARSS'96, pp. 512-514.

Ichitsubo, S., T. Furuno, T. Nagato, T. Taga, and R. Kawasaki [1996a], "Multipath propagation model for line-of-sight street microcells in urban areas," IEEE, ICUPC'97 Conference Record, vol. 2, pp. 837-841.

Ichitsubo, S., T. Furuno, H. Okamoto, and R. Kawasaki [1996b], "Indoor multipath propagation characteristics and a delay profile for simulator equipment," IEICE Trans. Commun., vol. J79-B-II, 12, pp. 1048-1050 (in Japanese).

Ichitsubo, S., T. Furuno, and R. Kawasaki [1997], "A delay profile model for microcell multipath propagation in urban areas," IEICE Trans. Commun., vol. J80-B-II, 8, pp. 707-713 (in Japanese).

Igarashi, K., I. Nishimuta, Y. Murayama, T. Tsuda, T. Nakamura, and M. Tsutsumi [1996], "Comparison of wind measurements between Yamagawa MF radar and the MU radar," Geophys. Res. Lett., vol. 23, pp. 3341-3344.

Iwai, H., and Y. Karasawa [1996], "The theoretical foundation of the equivalent transmission-path model for assessing wideband digital transmission characteristics in Nakagami-Rice fading environments," IEICE Trans. Commun., vol. E79-B, 9, pp. 1205-1214.

Karasawa, Y. and Y. Maekawa [1997], "Ka-band Earth-Space Propagation Research In Japan," Proc. IEEE, vol. 85, 6, pp. 821-842.

Karasawa, Y., K. Kimura and K. Minamisono [1997b], "Analysis of availability improvement in LMSS by means of satellite diversity based on three-state propagation channel model," IEEE Trans. Vehicul. Technol., vol. 46, 4, pp. 1047-1057.

Karasawa, Y., T. Kuroda, and H. Iwai [1997a], "The equivalent transmission-pa th model: -Atool for analysing error floor characteristics due to intersymb ol interference in Nakagami-Rice fading environments," IEEE Trans. Vehicular Technol., vol. 46, 1, pp. 194-202.

Kato, K., T. Manabe, Y. Miura, K. Sato, and T. Ihara [1997], "Measurements of millimeter wave indoor propagation and high-speed digital transmission characteristics at 60 GHz," in Proc. 8th IEEE International Symposium on Personal, Indoor and Mobile Communications (PIMRC '97), Helsinki, Finland, pp. 149-154.

Kitayama, K., Y. Takayanagi, Y. Yamaguchi, and H. Yamada [1998], "Polariemtric calibration using a corrugated parallel plate target," Trans. IEICE, vol. J81-B-II, no.10, pp. 914-921 (in Japanese).

Kobayashi, T., M. Satake, H. Masuko, T. Umehara, and M. Shimada [1997], "The airborne X/L-band SAR system of CRL/NASDA: system description and preliminary results," in Proc. of IGARSS'97, Singapore, pp. 1389-1391.

Koike, T., Y. Iijima, T. Tadono, K. Igasaki, and K. Fukami [1998], "Aircraft-ground synchronous experiment for development of soil moisture algorithm dedicated to satellite remote sensing," Proc. of the Workshop on Remote Sensing of Hydrological Processes & Applications, NASDA of Japan, pp. 19-26, (in Japanese)

Kozu, T., and T. Iguchi [1996], "A preliminary study of non-uniform beam filling correction for spaceborne radar rainfall measurement," IEICE Trans. Commun., E79-B, pp. 763-769.

Kubo, K., T. Sugiyama, T. Nakamura and S. Fukao [1997], "Seasonal and international variability of mesospheric echoes observed with the middle and upper atmospheric radar during 1986-1995," Geophys. Res. Lett., vol. 24, pp. 1211-1214.

Kumagai, H., K. Nakamura, H. Hanado, K. Okamoto, N. Hosaka, N. Miyano, T. Kozu, N. Takahasi, T. Iguchi, and H. Miyauchi [1996], "CRL Airborne Multiparameter Precipitation Radar (CAMPR): System description and preliminary results," IEICE Trans. Commun., E79-B, pp. 770-778.

Kummerow, C., W. Barnes, T. Kozu, J. Shiue, and J. Simpson [1998], "The Tropical Rainfall Measuring Mission (TRMM) sensor package," J. Atmos. Oceanic Technol., 15, pp. 809-817.

Kurosaki, S., M. D. Yamanaka, H. Hashiguchi, T. Sato, and S. Fukao [1996], "Vertical eddy diffusivity in the lower and middle atmosphere: A climatology based on the MU radar observations during 1986-1992," J. Atmos. Terr. Phys., vol. 58, no. 6, pp. 727-734.

Kurosu, T., M. Fujita, and K. Chiba [1997], "The indentification of rice fields using multi-temporal ERS-1 C-band SAR data," International Journal of Remote Sensing, Vol. 18, 14, pp. 2953-2965.

Le Toan, T., F. Ribbes, L.F. Wang, N. Floury, K.H. Ding, J.A. Kong, M. Fujita, and T. Kurosu [1997], "Rice crop mapping and monitoring using ERS-1 data based on experiment and modeling results," IEEE Trans. Geosci. Remote Sensing, Vol. 35, 1, pp. 41-56.

Maekawa, Y., N. S. Chang, A. Miyazaki, and T. Kojima [1996a], "Increase and decrease in depolarization of Ka-band satellite beacon signal in thunderstorm events," 1996 IEEE AP-S International Symposium Digest, vol. 3, pp. 1876-1879.

Maekawa, Y., N. S. Chang, A. Miyazaki, and T. Kojima [1996b], "Observations of depolarization due to rain and ice using the Ka-band satellite signals in Japan," XXVth General Assembly of the International Union of Radio Science, Lille, France.

Maekawa, Y., N. S. Chang, A. Miyazaki and T. Kojima [1996c], "Observation of rain attenuation of Ku-band and Ka-band satellite signals and the depolarization due to rain and ice," USNC/URSI Radio Science Meeting, Baltimore, Maryland, USA.

Maekawa, Y. [1998a], "A study on up-link (30 GHz) rain attenuation characteristics and up-and down-link available time percentages in Ka-band satellite communication," Trans. IEICE Japan, vol. J81-B-II, 5, pp. 365-372 (in Japanese).

Maekawa, Y. [1998b], "Characteristics of rain attenuation fluctuation on Ka-band Earth-space path related to rain front passage," URSI Commission F International Triennial Open

Symposium on Wave Propagation and Remote Sensing, Aveiro, Portugal.

Maeno, H., S. Uratsuka, K. Okamoto, and O. Watanabe [1996], "Subsurface survey of the antarctic ice sheet using a mobile radio echo sounder," J. Commun. Res. Lab,, vol 43 No.2, pp. 139-149.

Maeno, H., S. Uratsuka, K. Kamiyama, T. Furukawa, and O. Watanabe [1997], "Bedrock topography and internal structures of ice sheet in the Shirase Glacier drainage area revealed from radio-echo soundings," J. of the Japanese Soc. of Snow and Ice, vol. 59, 5, pp. 331-339 (in Japanese).

Manabe, T., Y. Miura, and T. Ihara [1996], "Effects of antenna directivity and polarization on indoor multipath propagation characteristics at 60 GHz," IEEE J. Sel. Areas Commun., vol. 14, 3, pp. 441-448.

Manabe, T., M. Seta, S. Ochiai, Y. Irimajiri, H. Masuko, J. Inatani, Y. Iida, N. Ikeda, and T. Noguchi [1998], "Space-station borne submillimeter-wave limb-emission sounder for observing stratospheric minor constituents," Proc. URSI Commission F Triennial Open Symposium on Wave Propagation and Remote Sensing, Aveiro, Portugal.

Masui, H., K. Takahashi, K. Kage, Y. Yamada, and S. Takahashi [1998], "Difference of path-loss characteristics due to reception antenna heights in an urban LOS environment," IEEE APS 1998 Digest, vol. 3, pp. 1672-1675.

Matsuoka, K., T. Shirasawa, S. Uratsuka, M. Ohi, H. Maeno, S. Yamaguchi,Y. D. Muravyev, R. Naruse, and S. Mae [1997], "Radio-echo sounding of the Ushkovsky Ice Cap, Kamchatka, Russia," J. of the Japanese Soc. of Snow and Ice, vol. 59, 4, pp. 257-262.

Meneghini, R., H. Kumagai, R.J. Wang, T. Iguchi, and T. Kozu [1997], "Microphysical retrievals over stratiform rain using measurement from an airborne dual-wavelength radar-radiometer," IEEE Trans. Geosci. Remote Sensing, 35, pp. 487-506.

Meng, Z., and M. Tateiba [1996], "Radar cross sections of conducting elliptic cylinders embedded in strong continuous random media," Waves in Random Media, 6, pp. 335-345.

Miwa, T., M. Sato, and H. Niitsuma [1997], "Characterization of fracture surface by polarimetric borehole radar," Proc. IEEE APS Int. Symposium, Canada, pp. 818-821.

Moriyama, T., H. Kasahara, Y. Yamaguchi, and H. Yamada [1998], "Advanced polarimetric subsurface FM-CW radar," IEEE Trans. Geosci. Remote Sensing, vol. 36, 3, pp. 725-731.

Nadai, A., H. Kuroiwa, M. Mizutori, and S. Sakai [1997], "Measurement of ocean surface currents by CRL HF Ocean Surface Radar of the FMCW type. Part 1. Radial current velocity", J. Oceanography, vol. 53, pp. 325-342.

Nakabayashi, H., and S. Kozono [1998], "Autocorrelation characteristics for received signal-level in a wide-band mobile radio channel," IEICE Trans. vol. J81-B-II, no. 2, pp. 155-161 (in Japanese).

Nagai, T., Y. Yamaguchi, and H. Yamada [1997], "Use of multi-polarimetric enhanced images in SIR-C/X-SAR land-cover classification," IEICE Trans. Commun., vol. E80-B, 11, pp. 1696-1702.

Nakamura, K., T. Kozu, and S. Uratsuka [1996], "Interference of sea surface echo and rain echo observed by real aperture airborne imaging radar," IEICE Trans. Commun., E79-B, pp. 786-792.

Nakamura, T., T. Tsuda, and S. Fukao [1996a], "Mean winds at 60-90 km observed with the MU radar (35deg N)," J. Atmos. Terr. Phys., vol. 58, pp. 655-660.

Nakamura, T., T. Tsuda, S. Fukao, A. H. Manson, C. E. Meek, R. A. Vincent, and I. M. Reid [1996b], "Mesospheric gravity waves at Saskatoon (52 deg N), Kyoto (35 deg N) and Adelaide (35 deg S)," J. Geophys. Res., vol. 101, pp. 7005-7012.

Nakamura, T., D. C. Fritts, J. R. Isler, T. Tsuda, R. A. Vincent and I. M. Reid [1997], "Short period fluctuations of the diurnal tide observed with low-latitude MF and meteor radars during CADRE: Evidence for gravity wave/Tidal interactions," J. Geophys. Res., vol. 102, pp. 26225-26239.

Nakamura, T., T. Tsuda, H. Miyagawa, Y. Matsushita, H. Fukunishi, Y. Takahashi, and Y. Yamada [1998], "Propagation directions of gravity wave patterns observed in OH CCD images during the SEEK campaign," Geophys. Res. Lett., vol. 25, pp. 1793-1796.

Nakayama, T., A. Tsuzuku, S. Kuroki, and H. Fukuchi [1997], " Quantitative evaluation of site diversity gain using 3-variate log-normal distribution model," Trans. IEICE, vol. J80-B-II, 11, pp. 1009-1010 (in Japanese).

Nambu Y., and M. Tateiba [1996a], "Polarization effects on the effective dielectric constant of a medium containing randomly distributed dielectric cylinders," IEICE Trans. Electron., E-79C, pp. 1334-1337.

Nambu Y., and M. Tateiba [1996b], "A comparative study of the effective dielectric constant of a medium containing randomly distributed dielectric spheres embedded in a homogeneous background medium," Waves in Random Media, 6, pp. 347-360.

Obayashi S., and J. Zander [1998], "A body-shadowing model for indoor radio communication environments," IEEE Trans. Antennas Propagat., vol. 46, 6, pp. 920-927.

Oguchi, T., S. Ishii, S. Ito, and T. Manabe [1998], "Laboratory measurements of radar depolarization signatures in microwave pulse transmission through randomly distributed spherical scatterers," IEEE Trans. Geosci. Remote Sensing, 36, pp. 1011-1015.

Ohsaki, Y., and T. Kozu [1997], "A software-based dynamic range expansion of the TRMM radar receiving system," J. Remote Sensing Soc. Japan, 17, pp. 65-69.

Ohsaki, Y., and H. Kuroiwa [1997], "Simulation-based error analysis for the path-averaged rainfall rate estimated from the rain attenuation," IEICE Trans. Commun., E80-B, pp. 176-181.

Ohsaki, Y., and K. Nakamura [1996a], "A simulation study of the bias error analysis of mean rainfall rate measured with spaceborne radar," J. Atmos. Oceanic Technol., 13, pp. 762-768.

Ohsaki, Y., and K. Nakamura [1996b], "Adaptive determination of maximum diameter of raindrop from ZDR," IEICE Trans. Commun., E79-B, pp. 793-796.

Ohsaki, Y., and K. Nakamura [1997], "Possibility of rainfall rate estimation using ZDR alone measured by a Ku-band dual-polarization radar," J. Meteor. Soc. Japan, 75, 95-99.

Ohsaki, Y., and K. Nakamura [1998], "Simulation-based analysis of the error caused by non-uniform beam filling and signal fluctuation in rainfall rate measurement with a spaceborne radar," J. Meteor. Soc. Japan, 76, pp. 205-216.

Ohta, H., and H. Fukuchi [1998], "Effect of rain- and ice-induced depolarisation on dual polarised 21GHz-band digital satellite broadcasting systems," Electon. Lett., vol. 34, 4, pp. 330-332.

Okamoto, K., T. Kobayashi, H. Masuko, S. Ochiai, H. Horie, H. Kumagai, K. Nakamura, and M. Shimada [1996a], "Results of the experiments using synthetic aperture radar onboard the European Remote Sensing Satellite 1, -4. artificial oil pollution detection-," J. of the Communications Research Laboratory, Vol. 43, 3, pp. 327-344.

Okamoto, K., T. Iguchi, J. Awaka, H. Kumagai, R. Meneghini, M. Satake, and T. Kozu [1996b], "Outline of the TRMM precipitation radar data processing and analysis algorithms," Rev. Communications Res. Lab., 42, pp. 305-315 (in Japanese).

Okamoto, K., T. Iguchi, T. Kozu, H. Kumagai, J. Awaka, and R. Meneghini [1998], "Early results from the precipitation radar on the Tropical Rainfall Measuring Mission," Proc. URSI Commission F Open Symposium on Climate Patterns in Radiowave Propagation and Precipitation, pp. 45-52.

Sakaguchi, K., J. Takada and K. Araki [1998], "On measuring the delay profile and the direction of arrival by using super resolution algorithm," 1998 IEEE Vehicular Technology Conference, pp. 154-158.

Sakamoto, M., K. Fujisaki, Y. Ohsako, and M. Tateiba [1996], "Experimental research on the effects of rainfall and airplanes on a VSAT satellite communication system," Proc. 1996 International Symposium on Antennas and Propagation, pp. 569-572.

Satake, M., T. Kobayashi, H. Masuko, and M. Shimada [1997], "Calibration experiments of the CRL/NASDA X/L-band Airborne Synthetic Aperture Radar," in Proc. of IGARSS'97, Singapore, pp. 570-572.

Satake, M., T. Kobayashi, T. Manabe, H. Masuko, and M. Shimada [1998a], "CRL/NASDA Airborne SAR: Its development, preliminary results, and operation plan," p. 42, PIERS Workshop, Ispra, Italy.

Satake, M., T. Kobayashi, T. Manabe, and H. Masuko [1998b], "Polarimetric calibration of X-band airborne synthetic aperture radar using corner reflectors and an active radar calibrator," in Proc. IGARSS'98.

Sato, A., and F. Ando [1996], "System design and propagation characteristics of a non-regenerative repeating digital radio," Proc. of the 5th European Conference on Fixed Radio Systems and Networks, pp. 143-148.

Sato, K., T. Manabe, J. Polivka, T. Ihara, Y. Kasashima, and K. Yamaki [1996a], "Measurement of the complex refractive index of concrete at 57.5 GHz," IEEE Trans. Antennas Propagat., vol. 44, 1, pp. 35-40.

Sato, A., N. Omura, M. Ito, and T. Ito [1997], "Broad band ATM wireless transmission characteristics in a 20 GHz band," ICC'97 Conference Record, vol. 3, pp. 1549-1553.

Sato, K., T. Manabe, T. Ihara, H. Saito, S. Ito, T. Tanaka, K. Sugai, N. Ohmi, Y. Murakami, M. Shibayama, Y. Konishi, and T. Kimura [1997a], "Measurements of reflection and transmission characteristics of interior structures of office building in the 60 GHz band," IEEE Trans. Antennas Propagat., vol. 45, 12, pp. 1783-1792.

Sato, K., D. J. O'Sullivan, and T. J. Dunkerton [1997c], "Low-frequency inertia-gravity waves in the stratosphere revealed by three-week continuous observation with the MU radar," Geophys. Res. Lett., vol. 24, pp. 1739-1742.

Sato, K., and T. Manabe [1998], "Estimation of propagation path visibility for indoor wireless LAN systems under shadowing conditions by human bodies," in Proc. 1998 IEEE Vehicular Technology Conference (VTC '98), Ottawa, Canada, pp. 2109-2113.

Sato, M., M. Takeshita, T. Miwa, and H. Niitsuma [1998], "Polarimetric borehole radar applied to geophysical exploration," Proc. the 7th Int. Conference on Ground Penetrating Radar, Lawrence, Kansas, USA, pp. 7-12.

Sato, T., T. Teraoka, and I. Kimura [1996b], "Validation and ground truth for TRMM precipitation radar using the MU radar," IEICE Trans. Commun., vol. E79-B, no. 6, pp. 744-750.

Sato, T., K. Takeda, T. Nagamatsu, T. Wakayama, I. Kimura, and T. Shinbo [1997b], "Automatic signal processing of front monitor radar for tunnelling machines," IEEE Trans. Geosci. Remote Sens., vol. 35, no. 2, pp. 354-359.

Seino, S., A. Yamaguchi, and S. Kozono [1996], "A study on received signal-level distribution in wide-band mobile transmission," IEICE Trans. vol. J79-B-II, no. 8, pp. 504-506 (in Japanese).

Shibagaki, K., M.D. Yamanaka, H. Hashiguchi, A. Watanabe, H. Ueda, Y. Maekawa, and S. Fukao [1997], "Hierarchical structures of vertical velocity variations and precipitating clouds near the Baiu frontal cyclone center observed by the MU and meteorological radars," J. Meteor. Soc. Japan, vol. 75, 2, pp. 569-596.

Sonoi, Y., Y. Maekawa, Z. Kawasaki, T. Ikawa, K. Fukami, and S. Fukao [1996], "Discussion about the discriminating function of the precipitation particles of the dual polarization radar and the predictable parameters of lightning discharge", Trans. IEE Japan, vol. 166-B, 4, pp. 444-452 (in Japanese).

Takahashi, S., Y. Yamada, and Koji Ogura [1998], "BER estimation with random phase summation applied to ray tracing," 48th IEEE Vehicular Technology Conference (VTC '98), vol. 2, pp. 855-859.

Taga, T., and T. Furuno [1997], "Multipath delay mechanism in low antenna height line-of-sight microcells," IEICE Trans. Commun., vol. J80-B-II, 10, pp. 848-861 (in Japanese).

Taga, T. [1998], "Coverage prediction for 5-GHz-band high-speed digital signal transmission in urban street microcells," VTC'98 Conference Record, vol. 1, pp. 596-600.

Taira, K., S. Sekizawa, G. Wu, H. Harada, and Y. Hase [1996], "Propagation loss characteristics for microcellular mobile communications in microwave band," Conference Record of 5th IEEE International Conference on Universal Personal Communications (ICUPC'96), vol. 2, pp. 842-846.

Taira, K., S. Sekizawa, and Y. Hase [1998], "Wideband channel modeling for line-of-sight microcellular environment with low base-station-antenna-height," Conference Record of 48th IEEE Vehicular Technology Conference (VTC'98), vol. 1, pp. 149-153.

Tsuda, T., T. E. VanZandt, and H. Saito [1997a], "Zenith-angle dependence of VHF specular reflection echoes in the lower atmosphere," J. Atmos. terr. Phys., vol. 59, pp. 761-775.

Tsuda, T., W. E. Gordon, and H. Saito [1997b], "Azimuth angle variations of specular reflection echoes in the lower atmosphere observed with the MU radar," J. Atmos. Terr. Phys., vol. 59, pp. 777-784.

Tsuda, T., T. Nakamura, A. Shimizu, T.Yoshino, S.W.B. Harijono, T. Sribimawati, and H. Wiryosumarto [1997c], "Observations of diurnal oscillations with a meteor wind radar and radiosondes in Indonesia," J. Geophys. Res., vol. 102, pp. 26217-26224.

Tsutsumi, M., Toshitaka Tsuda, Takuji Nakamura, and Shoichiro Fukao [1996], "Wind velocity and temperature fluctuations due to a 2-day wave observed with radio meteor echoes," J. Geophys. Res., vol. 101, pp. 9425-9432.

Uratsuka, S., F. Nishio, and S. Mae[1996a], "Internal and basal ice changes near the grounding line derived from radio-echo sounding," Journal of Glaciology, vol. 42, 140, pp. 103-109.

Uratsuka, S., H. Maeno, T. Suitz, D. A. Fisher, K. Goto-Azuma, and S. Mae [1996b], "Internal layering detected by microwave ice-radar in the arctic ice cap," Memoirs of NIPR, Spec. Issue, no. 51, pp. 387-394.

Yamada, H., T. Yamakura, and Y. Yamaguchi [1998], "Resolution improvement of superresolution techniques using polarization averaging preprocessings," Trans. IEICE, vol. J81-B-II, no3, pp 200-207 (in Japanese).

Yamada, M., J. Yoshida, and M. Takaoka [1997], "Statistical characteristics of signal level variations due to shadowing by human bodies in wireless LAN," in Proc. APCC'97, Sydney, Australia, pp. 1408-1412.

Yamada, M., and Y. Miura [1998], "Rain attenuation characteristics at 12 GHz on an earth-space path," Proc. ICMMT'98, Beijing.

Yamaguchi, A., K. Suwa, and R. Kawasaki [1997a], "Received signal level characteristics for radio channels up to 30 MHz bandwidth in line-of-sight microcells," IEICE Trans. Commun., vol. E80-B, 2, pp. 386-388.

Yamaguchi, Y., and T. Moriyama [1996], "Polarimetric detection of objects buried in snowpack by a synthetic aperture FM-CW radar," IEEE Trans. Geosci. Remote Sensing, vol. 34, 1, pp. 45-51

Yamaguchi, Y., M. Nakamura, and H. Yamada [1997b], "Decomposition of radar target based on the scattering matrix obtained by FM-CW radar," IEICE Trans. Commun., vol. E80-B, 10, pp. 1564-1569.

Yamaguchi, Y. [1998], "Fundamentals of polarimetric radar and its applications," Realize Inc. Japan (in Japanese).

Yamamori, M., and K. Sato [1998], "A quasi-geostrophic analysis on medium-scale waves near the midlatitude tropopause and their relation to the background state," J. Met. Soc. Japan, vol. 76, pp. 879-888.

Yamamoto, S., E. Okamoto, N. Yoshimura, T. Ikegami and H. Wakana [1998], "Propagation measurements for land mobile satellite communications at high angle of elevation with the ETS-VI satellite," Trans. IEICE, vol. J81-B-II, 5, pp. 381-390 (in Japanese).

Yamamoto, Y., T. Tsuda, and T. Adachi [1996], "Frequency spectra of wind velocity and temperature fluctuations observed with the MU radar-RASS," Geophys. Res. Lett., vol. 23, pp. 3647-3650.

Yamanaka, M. D., S. Ogino, S. Kondo, T. Shimomai, S. Fukao, Y. Shibagaki, Y. Maekawa, and I. Takayabu [1996], "Inertio-gravity waves and subtropical multiple tropopauses: Vertical wavenumber spectra of wind and temperature observed by the MU radar, radiosondes and operational rawinsonde network," J. Atmos. Terr. Phys., vol. 58, pp. 785-805.

Yang, J., Y. Yamaguchi, H. Yamada, and S. Lin [1997], "The formulae of the characteristic polarization states in the co-pol channel and the optimal polarization state for contrast enhancement," IEICE Trans. Commun., vol. E80-B, 10, pp. 1570-1575.

Yang, J., Y. Yamaguchi, H. Yamada, M. Sengoku, and S. Lin [1998], "Stable decomposition of mueller matrix," IEICE Trans. Commun. vol. E81-B, no. 6, pp. 1261-1268.