Commission F : Wave propagation and Remote Sensing

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F1.1 Terrestrial Fixed Radio Systems

Active studies of rain attenuation characteristics are continuing for developing broadband systems above quasi-millimeter wave band. It is based on a trend that the use of microwave band has been changing gradually from the fixed use to the mobile use. Results of those studies will be reflected in developing a multipoint-to-multipoint system, a mesh type wireless network system, a point to multipoint system, and a fixed wireless access system (FWA). In addition to the FWA in a millimeter wave band, FWA systems in UHF band and microwave band have become the object of propagation research.

A. Effects of Rain

Using KIT (Kitami Institute of Technology) databank that contains different integration time rain rate data sets from 54 locations in 23 countries, a new prediction method for the worldwide rain attenuation distribution on terrestrial link is proposed [Ito and Hosoya, 2002, 2004a]. This new method uses the M distribution (simplified Moupfouma distribution) and the rain rate spatial correlation, in which regional climatic parameters such as the thunderstorm ratio are considered. This new method was compared with Rec. ITU-R P.530-8 method that is currently used as the worldwide standard prediction method. From the results, it is shown that significant improvements to existing methods are obtained by this newly proposed prediction method.

Effects of the regional climatic parameters on Lavergnat-Gole Conversion Method were analyzed, and the result was incorporated into the extension of this method for the worldwide application by using KIT databank [Ito and Hosoya, 2004b]. It was found that a good accuracy in worldwide rain rate conversion could be obtained by using regional climatic parameters such as thunderstorm ratio and so on, and it was proved that this model could be expanded to arbitrary integration times and regions. Moreover, the analysis using this method in Japan, along with the data at eight cities across Japan, indicated that good conversion accuracy could be obtained by using a parameter appropriate to Japan.

An investigation of a highly accurate method for estimating the one-minute rain rate distribution for various locations throughout Japan using observed precipitation data collected through the Automated Meteorological Data Acquisition System (AMeDAS) is reported [Akimoto et al., 2003a, 2003b]. The method estimates the one-minute rain rate distribution by supplementing the hourly rainfall data with 10-minute rainfall data and shows quantitatively an improvement in the accuracy over existing estimation methods.

Based on the experimental data of rain attenuation on 3 links at 15 GHz and on 2 links at 22 GHz, and of rain rate at 4 locations in Tokyo urban area, the accumulated number of events of given duration with rain rate or rain fade exceeding specific level are mainly investigated [Ishida et al., 2003]. And these data are compared with RAL model on rain duration and their results obtained in Europe. As the results, new expressions available to Japan are introduced.

For realizing Gigabit millimeter wave broadband wireless access systems using 32 GHz band, propagation tests are conducted on three converging links of about 2km path length and the rain rate are measured at 10 locations in Tokyo. The characteristics of rain attenuation correlation and of the joint probability distribution for rain attenuation between adjacent links, and the spatial correlation of rain rate, to be necessary for realizing the mesh network to possess the routing function are examined [Takahashi, N. et al., 2003]. The specific rain attenuation at this frequency band and the path reduction factor on rain attenuation, to be main factors for guiding the rain attenuation distribution, are investigated. As the results, the specific rain attenuation tends to be a little larger than practical value published in the world. And the simple equation for calculating path reduction factor is newly presented [Ishida et al., 2004].

B. Effects of Vegetation

Experimental results of the attenuation through vegetation by using quasi-millimeter wave band FWA system are reported [Ohmoto and Takahashi, 2004]. Excess losses and bit error rate (BER) are measured through several species of trees. The effect of wind is also examined. The impact of the attenuation through vegetation on the FWA system performance is also considered from the viewpoint of probability distribution of the excess loss.

C. Effects of Multipath (Residential/Urban Environment)

A method of estimating the intensity of delayed components using a radar cross-section σ based on measured delay profiles in 5-GHz and 25-GHz bands in residential area is reported [Yamada, W. et al., 2003]. The relationship between σ and the path length of the delayed component exhibits a less remarkable dependency on the frequency band. Common estimation method can be applied to both the 25-GHz and 5-GHz bands. The arrival probability of the delayed components for the path length is also studied. The results show that the probability density distribution of delayed components on the path length can be assumed as a Rayleigh distribution in both the 5-GHz and 25-GHz bands.

A 2 dimensional multi-building model and a prediction way of path loss and delay spread characteristics in entrance radio links by using ray-tracing calculation method are presented [Taga, 2002a]. As a result, when the clearance factor for the first Fresnel zone along direct path is more than 5m, the path loss can be taken into account as free space loss; smaller clearance values yield average excess loss values of several dB, and the path loss increases strongly at negative clearance values. These results agree very well with the experimental results.

(A.Sato)

F1.2 Satellite Radio System

A. Effects of Rain

Earth-space path in both Ku and Ka band are still important objects for propagation studies. Several propagation measurements have been carried out also in a tropical area in addition to the inland of Japan.

The rain attenuation measurements are simultaneously performed for both up and down links of the Ku-band satellite (Superbird C), which connects the Equatorial Atmospheric Radar (EAR) in Indonesia and Research Institute for Sustainable Humanosphere (RISH), Kyoto University, in Japan, by monitoring the signal levels received at the VSATs in the two locations. In the equatorial region, the frequency scaling characteristics show a slightly larger ratio between up and down satellite links, suggesting rather smaller raindrop size distribution than in Japan [Maekawa et al., 2004a]. Also, a smaller seasonal variation of rain attenuation statistics, such as the worst month statistics, is found in the equatorial region [Maekawa et al., 2004b]. Two-year rain attenuation statistics obtained at EAR in Indonesia is compared with the recent ITU-R predictions. Using the local rainfall rate time percentages obtained at EAR at the same time, a fairly good agreement is found between the observations and the predictions up to the attenuation of about 10 dB. In the attenuation range of more that 10 dB, however, the observed time percentage decreases more rapidly than predictions, indicating so-called “break” which is peculiar to the tropical convective storms possibly localized in a few km area [Fujiwara et al., 2004].

Rain attenuation at three different locations about 100 km far away from each other within Kyushu Island, Japan, are simultaneously measured in Ku-band by utilizing JCSAT-1B and VSAT system. One year measurement of rain attenuation for a small percentage of time was given together with the ITU-R estimate and shown the significant difference among all the locations [Hasanuddin et al., 2002a, 2002b, 2003].

Predicted rain attenuation in the 12-GHz and the 21-GHz bands for Tokyo and Osaka (two big cities in Japan) and measured results of rain attenuation in the 12-GHz band for both areas are presented [Minematsu et al., 2004]. Comparison of predicted rain attenuation by the ITU-R methods with measured data in the 12-GHz band is conducted.

B. Effects of Other Factors

For high-data rate satellite communications, the bit error rate in Ka-band was calculated under the arrival-angle fluctuation caused by the atmosphere turbulence. It was shown that the turbulence increases degree of the bit error at low elevation angles [Yamada, K. et al., 2002a, 2002b, 2003].

The airplane effect on the earth-space path was measured by the VSAT system using JSCAT-1B near Fukuoka Airport. The relation of the bit error and the flight route showed that the route of landing airplanes takes almost the same one all the year around, but in case of takeoff airplane bit error was produced by airplanes which pass a limited area [Fujisaki et al., 2002; Setoguchi et al., 2004].

Satellite link simulator is one of key tools to develop new protocol or improve existing one for high-data rate and efficient satellite communication systems. A bit error generation algorithm was proposed based on statistical characteristics of received signal level, and produced bit errors agreed well with experimental data [Franklin et al., 2004].

(A. Sato)

F1.3 Mobile Radio Systems

A. Street Microcell Systems

In order to characterize the propagation phenomena in environments where the antenna height of base stations is lower than that of the surrounding buildings, experimental and theoretical analyses were conducted. Propagation measurements were made in metropolitan Tokyo at frequencies of 3.35, 8.45, and 15.75 GHz to model the path-loss characteristics in microwave urban line-of-sight (LOS) propagation [Masui et al., 2002]. In their study, the influence of the road traffic to microcell propagation was experimentally and theoretically analyzed and the characteristics were made clear [Shimizu et al., 2002b, 20002c and 2004]. The effect of the traffic was also analyzed by the other approach. Uemura et al. adopted the knife edge approximation to model the shadowing effects by vehicles [Uemura et al., 2003]. The reduction of delay spread by the use of directional antennas in LOS microcells is clarified by experimental and theoretical studies [Taga and Tanaka, 2003]. The necessity of the different expression of the propagation loss in microcells is introduced from that in macrocells [Jinguu et al., 2003].

B. Macrocell/Microcell Systems

Numerous efforts were devoted in order to clarify the propagation mechanism and to develop propagation models for macrocell and microcell mobile radio systems. NLOS and LOS propagations in microwave frequencies were studied through energetic propagation campaign assuming a base station antenna situated above the surrounding buildings. Frequency characteristics for urban path loss in the microwave band were found to observe 21Log(f), nearly the same as conventional characteristics in the UHF band. It was made clear that when applying the behavior to the Sakagami model developed for UHF band and employing mobile-station antenna-height compensation of the Okumura-Hata model, estimated and measured values agreed well [Sakawa et al., 2002a, 2002b, 2002c, 2002d]. Nishi et al. presented the measured results of propagation loss characteristics in UHF-TV band in various environments in Hiroshima, Okayama, and Takamatsu regions in Japan [Nishi et al., 2004]. Frequency band over 2GHz is assumed a candidate spectrum for future generation mobile radio systems. On the other hand, the most of existing propagation models for macro-cellular systems have been studied and established only under 2GHz band. In order to investigate the propagation characteristics over 2GHz and to establish practical propagation models required when the future systems are designed, path loss measurements are conducted using 5GHz band in a suburban town in Japan [Iwai, et al., 2003]. The measured results are used to extend the applicable frequency range of well-known Walfisch-Ikegami propagation model up to 5GHz [Yonezawa, et al., 2004]. In the measurement, delay spread is also measured to investigate the multipath delay characteristics at 5GHz. Significant correlation between path loss and delay spread is shown, as the results of the analysis using the measured data [Takahashi, S. et al., 2004]. A measuring system for line-of-sight (LOS) centerline blocking is developed and the measured results were reported on the path loss when the LOS centerline is blocked in LOS propagation in an urban environment with low base station antenna height [Shimizu et al., 2002a]. XPD (cross polarization discrimination) is also of interest in macrocell environments. A method that uses both vertical and horizontal polarizations at the same time has been proposed. The characteristics of XPD and the correlation coefficient of received levels between the two orthogonal polarizations are clarified using the measurement results of microwave-band in urban and sub-urban areas [Ohta et al., 2004]. Taga developed a method of evaluating the performance of mobile antennas that uses the theoretical expressions of the "Mean Effective Gain (MEG)" and the correlation coefficient between antenna diversity branches. The "Cross polarization Power Ratio (XPR)" measurement method, directional statistical model of wave arrival in azimuth, and a simple method for measuring distribution parameters of wave arrival in indoor environments are also described [Taga, 2002b].

C. Formulation of Mobile Propagations

A new method for predicting the path loss in over-rooftop propagation environments in microwave bands is proposed. In the paper, it is clarified that the path loss due to distance can be divided into three regions where the direct wave, the reflected wave, and the diffracted wave are dominant, respectively. The validity of the model is tested by measuring the path loss at 2.2 GHz and 5.2 GHz (CW) in suburban areas in Tokyo [Kita et al., 2004c]. A height variation model at subscriber station (SS) in the region more than 4 m high, which reflected the dependency on location of SS for FWA/NWA systems in microwave band in suburban areas, is proposed by Kita et al. The validity of the model was tested by measurements of the height variation at SS in 5.2-GHz band carried out in a residential area in Tokyo area [Kita et al., 2004d]. Kitao and Ichitsubo carried out the propagation loss measurements in urban areas at the 400MHz to 8 GHz band.

For future systems beyond IMT-2000, they proposed prediction formula based on multiple regression analysis of the measured path loss [Kitao and Ichitsubo, 2004b]. Frequency correlation coefficient characteristics were studied theoretically by Nakabayashi and Kozono. Equations of frequency correlation coefficients in NLOS and LOS propagation paths were derived [Nakabayashi and Kozono, 2002]. The phase difference distribution with and without diversity in multipath propagation was evaluated by computer simulations and theoretical analyses. The distribution was discussed in both time and frequency domains [Kozono and Wang, 2004]. A very simple, general scheme for calculating the irreducible bit-error rate (BER)－namely, the BER floor－due to inter-symbol interference (ISI) in frequency-selective Nakagami-Rice fading environments has been developed. The scheme is called the Equivalent Transmission-Path (ETP) model and a consistent calculation formula for the BER due to ISI is presented. Also an application of the ETP model to the indoor propagation environment is demonstrated [Karasawa, 2002]. To accurately estimate the transmission characteristics of MC-CDMA, an accurate delay profile model well reflecting actual delay profiles is necessary. Sato and Fujii proposed an extremely simple equivalent path model for time-domain code spreading MC-CDMA. It consists of just two paths but its transmission characteristics are reasonable if the delay profile has paths that exceed guard interval [Sato and Fujii, 2004].

D. Indoor Propagation

Numerous experimental and theoretical studies were done, particularly for WLAN and millimeter-wave communications. A new method for measuring the quasi-instantaneous broadband frequency-domain characteristics using an OFDM technique in 5.2-GHz band was introduced and the results of the indoor measurements using the method were presented. A ray trace simulation was also conducted for these rooms to evaluate the measured result [Kita et al., 2002; Itokawa et al., 2002]. The results of an experimental study on the propagation characteristics for broadband wireless access systems in 5.2-GHz band in an underground mall environment were presented by Itokawa et al. It was made clear that the influence of the shadowing caused by passersby can be reflected by an exponential term that includes the density of the passersby. Also it was presented the maximum delay spread value during the rush hours is at most 65 nsec [Itokawa et al., 2003]. Tachikawa et al. presented the optimum tilt and beam width of the terminal antenna for indoor high data-rate wireless communications for establishing a link between terminals by considering the situation in which a partition was placed in the middle of an office, and showed the angle of arrival characteristics of multipath waves. It is revealed that the optimum tilt angle with the HPBW (Half Power Band Width) of 30 degrees is 50 to 60 degrees when the data rate is greater than 10 Mbps in the considered situation [Tachikawa et al., 2001]. The penetration from outdoor to indoor is also of interest. Miura et al. carried out the outdoor-to-indoor propagation loss measurements at 8 GHz and proposed a new propagation model to accurately predict penetration loss [Miura et al., 2002]. On the millimeter-wave communications, experimental results of indoor propagation characteristics in 60GHz, in Japanese style wooden houses, are described. The values of wall-attenuation and an estimation method of the received signal level, and the delay spread in indoor circumstances are discussed [Yoshikawa et al., 2001]. A series of the studies on millimeter-wave wireless adhoc systems were reported since 2002. A strict equation for the Fresnel zone radius was introduced. The applicability of light emission method is presented by the difference angle between light axis and LOS condition without shadowing the first Fresnel zone [Hirose et al., 2002]. A detailed investigation of the propagation loss characteristics along the surface of wooden and metal desk plane at 60 GHz was described. The study assumes a two-ray propagation model, and shows a strong match between the theoretical model and the measured data [Kuribayashi et al., 2002]. RMS delay profile was measured in a wooden house and an office environment in the millimeter-wave band and the measured results were reported [Suzuki, T. et al., 2002]. A detailed investigation of the receiving power time variation characteristics in 70GHz band indoor propagation was described [Kuribayashi et al., 2003]. A propagation experiment was carried out in an exhibition hall and the statistical characteristics of shadowing loss in 70GHZ band was presented [Ohkubo et al., 2003a]. A conventional cafeteria in Japan was selected and measurement on the propagation characteristics in a 70GHz band was executed [Akeyama et al., 2003]. The received signal level and delay spread was measured in outdoor and indoor environment [Ohkubo et al., 2003b]. Ohkubo et al. also carried out a propagation experiment in a hall. In addition to cumulative probability distributions of attenuation level, the variation of averaged shadowing duration was measured. Human movement in typical offices was investigated, and then an estimation equation for total amount of shadowing duration per hour was proposed based on the results of propagation measurement [Ohkubo et al., 2003c]. The 70-GHz band propagation characteristics of two different hot-spot zones for high-speed LAN systems are measured and analyzed: The two types are (1) a transmitter fixed to a ceiling servicing the area

beneath it (type A) and (2) a transmitter fixed to a wall servicing the area in front of it (type B) [Kanazawa and Ogawa, 2004].Complex permittivity of construction materials at 62GHz and 70GHz were also measured and reported [Kanazawa et al., 2004]. A detailed investigation on the propagation characteristics along the surface of a desk plane at 70 GHz was described [Kuribayashi et al., 2004]. The outline of the propagation measurement and the results of mean fade duration due to shadowing were presented. The estimated results of the walking speed and the level variation speed were also shown [Ohkubo et al., 2004]. Analysis on materials of walls and windows of buildings are also an important issue for the development of indoor propagation models. Complex refractive index of soda-lime glass at 30-GHz was measured by transmission method. Also, a simple empirical formula of complex refractive index of soda-lime glass over frequency range from 0.1-GHz to 1000-GHz was derived using the experimental result together with data previously reported in literatures by various researchers [Ihara et al., 2004b].

E. Spatio-Temporal Channel Modeling and Measurement Method

The importance of the spatio-temporal propagation study has become great as the bandwidth of the wireless systems has become broad. A spatio-temporal channel characterization of a suburban non line-of-sight microcellular environment was studied. In the study azimuth-delay profiles obtained by the experiment are compared with ray-tracing simulation. The results are statistically treated in step by step to extract model parameters in order to characterize the spatio-temporal channel [Takada et al., 2002]. Oda and Taga proposed a clustering mechanism of multipath components in urban environments. Vector channel measurements at 5 GHz in an urban area verified the proposed clustering mechanism [Oda and Taga, 2002]. Ichitsubo et al. proposed a multipath propagation model for microcells in urban areas. The proposed model is a statistical geometric model that explains the propagation characteristics for propagation loss, the power delay profiles, and power azimuth spectra [Ichitsubo et al., 2002]. Imai and Taga proposed a stochastic scatter model in an urban area. The main feature of the model is that an ellipse expresses the effective scattering area. The major axis of the ellipse runs parallel along the street in which the mobile station is located [Imai and Taga, 2003]. Kitao and Ichitsubo proposed an angle profile model observed at base station in urban areas. Angle profile model was investigated to clarify the stochastic characteristics of the difference between the received levels of the sector antenna in order to control handover appropriately [Kitao and Ichitsubo, 2004a]. Okamoto proposed a model of arrival wave distribution for evaluating adaptive array antenna at mobile station. The 3-dimensional measurements were carried out in suburban area to confirm the proposed model [Okamoto, H., 2004]. A time-space path model especially suitable for position determination was proposed. The model explains well actual propagation environments [Omote and Fujii, 2002a]. Omote and Fujii also proposed a new time-space path model, which was an extension of the previous model, taking the arrangement of buildings in the city part into account. And it was also shown that the analysis using the proposed model agrees well with the field measurement results [Omote and Fujii, 2002b and 2003a]. The precision of proposed methods by using the time-space path model was estimated quantitatively [Omote and Fujii, 2003b]. Mathematical foundation of the time-space path model was established through theoretical analyses [Fujii and Omote, 2004; Fujii, 2004].

F. MIMO Channel Modeling and Measurement Method

Effect of multipath fading and its countermeasure for radio communication systems have been of interest for a long time. In recent years, using adaptive array antennas both at the base station (or access point) and user terminal, MIMO (Multiple-Input Multiple-Output) has been popular research field of next-generation mobile communication systems. The increase of system capacity without increasing the transmission power or frequency bandwidth has made the MIMO system unique and efficient in data transmission. Karasawa dealt with MIMO propagation channel modeling which might be one of the important study areas realizing effective MIMO communication systems having higher channel capacities. After tutorial description of a propagation channel model for Rayleigh fading, two recent propagation-related topics on MIMO system, i) MIMO utilizing dual and triple polarization diversity branches and ii) Tx/Rx weight mismatch problem for open-loop control system such as eigen-beamforming data transmission system, are highlighted [Karasawa, 2004; Das et al., 2004a and 2004b]. Based on indoor radio channel measurements, it was shown that the performance of MIMO-SDM in line-of-sight environments is better than that in nonline-of-sight environments. It was also shown that the performance of line-of-sight environments tends to change largely depending on the configuration of antennas [Nishimoto et al., 2004a, 2004b]. The suitability of a complex MIMO channel matrix for spatial multiplexing was verified experimentally in 5.2-GHz band in terms of the Demmel condition number. The instantaneous 2 x 2 MIMO-OFDM channel measurements in several indoor environments indicate the location dependency of the condition number. Wideband frequency

characteristics were also analyzed to evaluate the applicability of spatial multiplexing [Kita et al., 2004a, 2004b]. Tachikawa et al. investigated the frequency correlation characteristics of the channel capacity for broadband MIMO channels in NLOS indoor environments. In the paper, the dependency of the element spacing on the frequency correlation characteristics was particularly focused. The calculation results agree well with the measured results in NLOS indoor environments [Tachikawa et al., 2004]. Simulation and experimental evaluation results of a circular and linear polarized antenna array applied to the MIMO system in an indoor environment were presented. A ray-trace simulation is used for the theoretical analysis. Measurements are carried out using a newly developed 2x2 MIMO-OFDM channel measurement system. The analysis results in terms of OFDM sub-carriers were also presented [Yamada, W. et al., 2004a]. Yamada et al. also presented frequency correlation of a MIMO-OFDM channel matrix in a real indoor environment. The eigenvector correlation of the wideband MIMO-OFDM channel matrix obtained from an actual indoor environment was used as an evaluation parameter of the frequency correlation characteristic. The knowledge of the frequency correlation of a MIMO-OFDM channel enables to reduce the calculation of MIMO channel matrix for each OFDM sub-carrier [Yamada, W. et al., 2004b].

G. Ultra Wideband

UWB is also one of the latest interests in the propagation field. Kobayashi and Kouya summarized the features of ultra wideband technologies, their origins, and the recent progress of the research and development, including UWB propagation studies [Kobayashi and Kouya, 2003; Kobayashi, 2003]. Sato and Kobayashi proposed a new UWB line-of-sight path loss formula based on the narrowband two-path (direct and ground reflected waves) model, taking into account the bandwidth of signals. Indoor experimental results verified the validity of this new formula [Sato and Kobayashi, 2004]. Short-range propagation measurements were carried out using UWB (3.1 to 10.6 GHz) and continuous wave (CW) signals on a rectangular metal plate simulating typical desks with and without a low vertical metal partition panels. With the partition panel, the CW reception level showed approximately a 36-dB spatial variation, induced by the interference between the direct and the reflected waves, but the UWB reception level had no particular plunges. They also measured the additional losses when the propagation paths were blocked with a human arm and when the antenna was covered with a human palm [Suzuki and Kobayashi, 2003]. Results of experiments in an anechoic chamber that assessed the reliability of UWB channel sounding system based on a deterministic approach with SAGE algorithm was presented. The system could resolve and detect 10 [deg] separated waves in angle domain, which was near the resolution limit. In the delay domain, 0.67 [ns] separated waves could be resolved where the relation between the bandwidth of subband and spectrum estimation was discovered [Haneda et al., 2004a]. Spatio-temporal analyses of LOS and NLOS home environments based on the deterministic approach were presented. The paths estimated with a SAGE algorithm were classified into several clusters by a heuristic approach. The identified clusters were determined from the physical structures of the environments, i.e. room height, specular directions, and size of scatterers in both the LOS and NLOS environments. The results imply that the spatial and temporal channel characteristics are highly correlated [Haneda et al., 2004b]. Haneda et al. also presented the results from double directional channel measurements in a typical home environment with ultra wideband signal. 100 ray paths were extracted using the SAGE algorithm at the both sides of radio link and they are regarded as dominant propagation phenomena. Then the paths were identified to the real environment, in which clusterization analyses were examined [Haneda et al., 2004c, 2004d]. Another study on UWB propagations was by Suzuki and Kobayashi. The paper described the development and experimental verification of the UWB spatio-temporal channel sounding system with use of a UWB monopulse antenna [Suzuki and Kobayashi, 2004].

H. Others

The research on adaptive array processing, DOA (Direction of Arrival) estimation and their implementations in beamformer circuits using FPGA (Field Programmable Gate Array) have intensively been made at Yokohama National University. The simple MRC (Maximal Ratio Combine) beam-former with FPGA was presented for real-time signal processing and verified its practical realization in the next generation mobile communications [Kim, M. et al., 2001]. Inoue et al. clarified the cause of error for DOA estimation by MUSIC and ESPRIT algorithm [Inoue et al., 2002]. Properties and drawbacks of representative DOA estimation algorithms were studied such as MUSIC, Root-MUSIC, and Unitary-ESPRIT by investigating the influence of quantization errors in digital operations for various cases [Shinagawa et al., 2002]. The ‘T’ character-type array antenna system was proposed which estimated the DOA by the virtual uniform rectangular arrays [Hirota et al., 2002]. Ichige et al. discussed a fast approach

for the eigenproblems of correlation matrices used in direction-of-arrival(DOA) estimation algorithms, especially for the case that the number of arriving waves was a few [Ichige et al., 2002,2003]. The EVD using a Jacobi-type method was computed, where the vector rotations and the angles of the rotations were obtained by CORDIC (COordinate Rotation DIgital Computer) [Kim, M. et al., 2002]. The hardware implementation of CMA(Constant Modulus Algorithm) adaptive array algorithms was presented as a technique for compensating multi-path fading in mobile communication [Suzuki, S. et al., 2002]. Implementation of RLS (Recursive Least Square) algorithm on FPGA with fixed-point operation was presented. It was used in 4-elements MMSE (Minimum Mean Square Error) adaptive array antenna [Matsumoto et al., 2003]. A method of direction of arrival estimation using T-type array antenna in a mobile communication at 900 MHz band was proposed and the valuation of the performance of the proposed method was also reported by simulations and experiments [Hirota et al., 2003]. The practical implementation of DOA estimation system using FPGA was proposed. That is a key technique in the realization of the DOA-based adaptive array antenna for cellular wireless basestation [Kim, M. et al., 2003a]. In addition, the real hardware basestation testbed system of DOA-based adaptive array antenna was also presented [Kim, M. et al., 2003b]. A hardware architecture for smart antenna was presented. It includes multi-channel calibrated transceiver, AD/DA converter and digital processing unit together with its optimum DOA and beam forming algorism [Arai and Kim, 2003]. An accurate and fast DOA estimation method using modified fast EM algorithm was presented [Hayashi et al., 2003]. A real time signal discrimination method based on the estimation of signal correlation using an array antenna was presented [Inoue et al., 2004]. The method of DOA estimation using pilot signal was proposed. DOA could be estimated by using the virtual planar array created from the original 'T' character-type array [Hirota et al., 2004]. A practical hardware implementation of uplink smart antenna system useful for macrocellular base stations was described [Kim, M. et al., 2004a]. Kim also presented a practical implementation of FPGA based fast DOA estimator for wireless cellular basestation. This system incorporates spectral unitary MUSIC algorithm [Kim, M. et al., 2004b]. Their results also include an automatic recognition algorithm of analogue modulated signals provided that jamming signals exist near the carrier frequency of a target signal [Matsuzaki et al., 2003].

Propagation research in millimeter-wave band was made particularly for ITS, Intelligent Transportation System, applications. Propagation loss characteristics for inter vehicle communication system was measured in NLOS condition at 60GHz [Yamamoto et al., 2002]. Millimeter-wave path loss between two cars was also measured by Takahashi et al. to obtain the general applicable distance for inter-vehicle communication systems in real environments [Takahashi, S. et al., 2003]. The path loss measurements were carried out using 60-GHz CW radiowaves with standard horn antennas on metropolitan highways and regular roads. Fading characteristics of 60GHz inter-vehicle communications were also studied [Kawakami et al., 2002]. Kawakami demonstrated the data transmission between the two running vehicles, and the cumulative distribution of received power and fade durations average level crossing rate were measured at the experiment. Transmission loss of windshield and effect of rain drop on windshield surface were measured in the 60 GHz band [Sato and Fujise, 2002]. The transmission loss by the windshield is around 2-5dB and the attenuation by rain drop on windshield is about 5 dB. A Radio-On-Fiber system using millimeter-wave transmission has great potential for future road-vehicle communication. However, very intense fading occurs in the interference region because the same frequency is used for different cells. The availability of diversity to solve this problem is discussed [Sato and Fujise, 2004].

Studies for the reception of mobile satellite systems were also made. A performance of a satellite tracking control system for mobile DBS reception was presented. In order to improve the tracking speed and the stability of this system, a directional sensor function is added to a conventional left-right tracking algorithm [Kim, D. et al., 2002].

Imai proposed a prediction method of propagation loss characteristics in tunnels using ray-tracing method. The prediction effectiveness and accuracy in ray-tracing method was discussed based on the comparison made between the results of ray-tracing and of the actual measurement [Imai, 2002].

(H.Iwai)

F2 Remote Sensing

F2.1 Atmosphere

In this section, remote sensing of atmosphere from the ground to the altitude of about 100 km is reviewed.

A. GPS Meteorology

GPS (Global Positioning System) meteorology is a sounding technique of the atmosphere, by measuring propagation delay time of radio waves transmitted by GPS satellites. It provides us with information of electron density in the ionosphere, temperature in the stratosphere and humidity (water vapor) in the troposphere. The receiver could be located either on the ground or on board of LEO (low earth orbit) satellite. Experiments with receivers at the top of the mountain or on board aircrafts are also on going (down-looking GPS measurement).

The LEO measurement with CHAMP and SAC-C satellites revealed structure and atmospheric waves such as Kelvin waves and gravity waves in the troposphere and stratosphere [Tsai et al., 2004; de la Torre et al., 2004; Tsuda and Hocke, 2004; Ratnam et al., 2004]. Ground based GPS receiver network measurements has been applied to derive tri-dimensional structure of the water vapor in the troposphere [Noguchi et al., 2004]. The down-looking GPS measurement for tropospheric water vapor measurements are being developed by both analysis technique [Mousa and Tsuda, 2004], and experiment [Aoyama et al., 2004].

B. Various Techniques of Observation in Atmosphere with MST (Mesosphere Stratosphere Troposphere) and Other Radars

It is common for the ST/MST radars to use bi-phase pulse-code compression in order to obtain a better signal to noise ratio and obtain a better height and time resolution as well as height coverage. New pulse compression codes which show better suppression of the radio interference has been proposed and used in the MU (middle and upper atmosphere) radar [Ghebrebrhan et al., 2004]. Structure-function analysis has been applied to the MU radar spaced antenna observation in the troposphere and variances of horizontal turbulent velocity components and horizontal momentum flux [Praskovsky et al., 2004]. The many beam method has clarified detailed horizontal structure of the tropospheric scatterer [Hirono et al., 2004].

In south India, a boundary layer radar (BLR) has been operated for several years. The wind vector estimated from the BLR has been compared with the Indian MST radar, showing good agreement [Reddy et al., 2001]. This system has also been used for precipitating cloud systems. It was shown that convective rain is most frequent in the summer monsoon, while stratiform rain is predominant in the winter monsoon [Reddy et al.,2002]. A 3 GHz BLR on board a vehicle has been developed and used for the mobile observation [Yamamoto, M.K., et al., 2002].

An atmospheric radar (wind profiler) for lower tropospheric observations (Lower Troposphere Radar: LTR), as an extension of the 1357.5-MHz boundary layer radar (BLR) has been developed. System gain of this radar is improved due to newly developed large-sized active phased-array antenna, active transmitting modules with higher output power, and pulse compression technique (an antenna gain of 33 dBi with a 4 m x 4 m active phased array antenna, and a peak output power of 2 kW) [Hashiguchi et al., 2004]. This radar has been applied to various interesting and important weather disturbances such as tropical typhoon [Teshiba et al., 2004a] and orographic rain band in Baiu season [Umemoto et al., 2004]. It should also be noted that this radar has now been distributed over Japan as an windprofiler network of Japanese Meteorological Agency (called WINDAS) and the results are utilized for weather forecast.

A 35 GHz radar to observe smaller particles such a as clouds and fogs has been developed and applied to the observation of fog, which was difficult to detect by radars before [Hamazu et al., 2003; Teshiba et al., 2004b].

A low elevation sidelobe suppression algorithm based on the uniform physical theory of diffraction (PTD) is developed to simulate ground clutter prevention fences for boundary layer radars [Rao et al., 2004]. Calibration method of the interferometers in meteor radars has been developed by a statistical approach [Holdsworth et al., 2004].

C. Mesosphere and Lower Thermosphere (MLT) Region

Mesosphere and lower thermosphere region exhibits special interests because it is a transient region between the neutral and ionized atmospheres, and eddy diffusive and molecular diffusive atmospheres. Variability of this region has been studied intensively by using observations, modelings and theoretical works.

As for the observational study, combined radio and optical techniques has contributed significantly. The wind observation using meteor echoes with the MU radar is the most sensitive meteor radar observation in the world and has revealed horizontal structure of the wind field in the MLT region and clarified its effect on the airglow imaging and wave breaking [Nakamura, T., et al., 2002]. Ejiri et al.[2002] used two airglow imagers near the MU radar site and measured the height of small-scale ripple structure in the airglow for

the first time. In the rocket campaign of airglow structure in the MLT region (WAVE 2000 campaign), observations by ground-based airglow imaging observations as well as the MU and an MF radar wind observation has revealed the tri-dimensional structure of the airglow [Iwagami et al., 2002]. The local-time height variation of the airglow layer has now been understood as one of the reason of the difference of radar derived and optically derived wind velocity, which has been an issue discussed for a long time [Fujii, J., et al., 2004]. Temperature obtained by O2 airglow at around 90 km has been used to discuss the atmospheric density variation by a combined observation with the MU radar [Takahashi, H., et al. 2004].

D. Equatorial Atmosphere Radar (EAR) and CPEA (Coupling Processes in the Equatorial Atmosphere)

The Equatorial Atmosphere Radar is a VHF atmosphere radar at 47 MHz with 100kW output equipped with an active phased array antenna. It is located at Kototabang, West Sumatra (100.3 deg E, 0.2 deg S) and started observation in 2001 [Fukao et al., 2003], and has been very successfully used for the study of equatorial atmosphere dynamics, which is very important study in order to understand the drive source of the whole global atmosphere as well as the environmental change of the earth's atmosphere. A project for studying the coupling processes in the equatorial atmosphere using the EAR and related instruments developed and installed in Indonesia has started as a six year project in 2001, which is on-going now (CPEA: Coupling Processes in the Equatorial Atmosphere).

The tropopause variations due to breaking of Kelvin waves and associated turbulences have been observed in detail with the EAR [Fujiwara, M., et al., 2002]. A tilted echo layer and Kelvin-Helmholtz instability around the equatorial tropopause have been investigated by the EAR observations [Yamamoto, M.K., et al., 2003]. Intraseasonal oscillation in the zonal wind with periods of 20 - 50 days in the mesosphere and its association with the tropical convection and tides have been clarified by a long term meteor and MF radar observation in the equatorial region [Isoda et al., 2004]. Atmospheric wave generation and its propagation have been studied in the DAWEX (Darwin Area Wave Experiment) campaign [Tsuda et al., 2004].

F2.2 Hydrometeors and Other Particles

In this section, recent research activities in Japan are reviewed in regard of both ground-based and space-based remoter sensing techniques and observation results.

A. Ground-based Remote Sensing Studies

To study the vertical structure of tropical rainfall, the melting layer model and the vertical drop size distribution (DSD) model both used for TRMM PR algorithm were compared with the zenith-pointing Doppler rain radar observation. It was shown that there existed the agreement between the model and the observation in stratiform rain. However, vertical structure of convective rains is more variable and cannot be explained in the current DSD model [Thurai et al., 2003b].

The millimeter-wave radar observations of wintertime thunderstorms are compared with the C-band radar observations at Mikuni, Fukui, Japan. The comparatively lower values of the millimeter-wave radar for the intense echo range seem to be effective to discriminate the increase of graupel particles in the cloud core that may produce lightning strokes [Maekawa et al., 2002]. Also, the disturbance index shows a very high correlation coefficient with the convergence of horizontal velocity, being indicative of convective air motion as well [Sonoi et al., 2003]. The core of the radar echoes that produced a number of positive-current cloud-to-ground discharges in a few minutes tends to be found near a comparatively lower cloud top of 2-3 km heights, suggesting that the lightning strokes directly come from the cloud top to the ground [Ogata et al., 2002]. The amount of these positive-currents is less than 50 kA, being not so large as positive-currents coming from higher cloud tops, which have occurred more intermittently, and sometimes reached more than 100kA in other cases [Maekawa et al., 2003].

B. Space-based Remote Sensing Studies

The Precipitation Radar (PR) of the Tropical Rainfall Measuring Mission (TRMM) and its six-year observation results are summarized [Okamoto, K., 2003, 2004; Okamoto, K., et al., 2004]. The averaged heights of the bright-band are calculated by using 4 year TRMM PR data [Thurai et al. 2003a]. Results of external calibration of the TRMM PR are summarized [Takahashi, N. et al., 2003]. A surface elevation map is generated using the PR data, for the purpose of improving the rejection of ground clutter in the rain observation by a radar from space [Awaka and Takahashi, 2004]. Studies to improve the PR retrieval algorithms were made [Thurai et al, 2003b], [Meneghini et al., 2004]. Correction of the PR beam mismatch

after an orbit change was reported [Takahashi and Iguchi, 2004]. Studies on the precipitation radar to be boarded in the Global Precipitation Mission (GPM) have also been made [Kobayashi and Iguchi, 2003; Mardiana et al., 2004a, 2004b].

C. Others

Multiple scattering properties of random particles at 30 GHz band at the scattering angles in the vicinity of zero degree were investigated in a controlled laboratory measurement using a mirror image technique [Ihara et al., 2004a]. The measurement gave quantitative results on the backscattering enhancement due to random particles in the millimeter-wave band. The scattering angle dependence of scattered power showed its clear peak in the close vicinity of backward scattering direction for both VV and VH polarizations.

F2.3 Ocean and Ice

Methods for measuring characteristics of ocean waves using satellite altimetry were studied, and it was shown, by a simulation study, that there existed a relation between the significant ocean wavelength and pulse-to-pulse correlation coefficient [Fujisaki et al., 2001, 2003].

A technique to detect ships using synthetic aperture radar (SAR) data was studied [Ouchi et al., 2004]. The technique detects ships from the coherence images produced by cross-correlating multilook images of sea surface. Using this processing algorithm, ships that are not clearly visible in radar images can be detected. The principal theory and experimental results using the JERS-1 L-band and RADARSAT-1 C-band SAR data are reported. Analysis of SAR images of ships in pitching motion was also reported [Ouchi et al., 2002a]. It is shown theoretically and experimentally, on the SAR images, that when ships are in pitching motion the image of the hull is not aligned with the direction of propagation, but displaced in a non-linear manner facing different directions.

Method for deriving of sea ice thickness from SAR image data is one of the major topics in remote sensing of ice. As an attempt to develop an algorithm for deriving the sea ice thickness from SAR data, thickness of a salinity lake was examined and successfully retrieved from the multi-incidence angle data of the RADRASAT [Nakamura et al., 2002]. The results showed very good correspondences in the whole lake to the bore-hole measurements. More parametrical study for the sea ice thickness was carried out by using dual-bands (X and L) polarimetric airborne SAR (Pi-SAR) [Matsuoka, T. et al., 2002; Wakabayashi et al., 2004]. The study resulted in the finding of an algorithm which can infer the ice thickness using the VV and HH ratio, being applied to the real sea ice in the Sea of Okhotsk where all of the ices are first-year ice and 0-5m in thickness.

Semi-automatic detection method of sea ice motion, using the RADARSAT-1 satellite SAR images observed at two-day interval, was proposed [Enomoto, et al., 2003]. Motion detection algorithm was commonly proposed for the arctic sea ice, but the algorithm is not applicable to detection of the ice movement in the Okhotsk sea area because of its quick movement. A newly developed ice-radar system with three frequencies (30, 60, 179 MHz) was applied to investigation of the Antarctic ice sheet. The radar observation shows the physical properties of ice in the ice sheet which is influenced by the glaciological ice movement [Matsuoka, K. et al., 2002, 2003]. The glaciological ice property was investigated using a 60-MHz ice-radar system [Fujita, S. et al., 2002, 2003; Maeno et al., 2003]. The radar observation indicated a lot of horizontal structural echoes in the ice sheet, and it was suggested that the anisotropic distribution of ice crystal orientations (fabric) is the caused of the echoes observed.

F2.4 Land, Vegetation, Subsurface Objects, Landmine and Others

A. Land and Vegetation

Fully polarimetric synthetic aperture radar (SAR) sensing has been attracting attention from theory to data analysis, in various areas including land, vegetation, and others.

Polarimetric indices for extracting scattering characteristics of trees were investigated to show that the correlation coefficient in the circular polarization basis best serves to classify conifer trees and broad leaf trees [Murase et al., 2001]. Characteristic polarization states of a scattering object via equi-power curves on the Poincare sphere were derived, and the property of scattering matrix was examined mathematically to derive the periodicity of scattering matrix nature that is applied to classify the targets [Yang et al., 2002a, 2002b]. The image simulations of the spaceborne ALOS-PALSAR to be equipped with fully polarimetric data take function were carried out using airborne Pi-SAR polarimetric data taking into account of radar resolutions, and comparison was made between image data acquired with AIRSAR (JPL) and that with Pi-SAR (CRL/NASDA) during the Pacific-Rim flight campaign [Yamaguchi et al., 2002a, 2002b].

Polarimetric filtering technique to detect objects buried in the underground, using null state to eliminate the surface clutter was also presented [Yamaguchi et al., 2002c]. Generalized optimization (generalized eigenvalue problem) of polarimetric contrast enhancement method was developed to find specific target over the clutter in fully polarimetric SAR image [Yang et al., 2004]. It was attempted to classify terrain target using polarimetric entropy, alpha angle, and total power [Kimura et al., 2004a]. Based on unsupervised maximum likelihood method, it is shown that the method is effective for classification in complex environment. It is shown that the phase of the correlation coefficient in the circular polarization basis is effective for detection of man-made targets such as buildings and building blocks not parallel to SAR flight path [Kimura et al., 2004b]. The correlation coefficients in the various polarization bases were examined and it was shown that the phase in the circular polarization correlation coefficient is effective for feature extraction [Moriyama et al., 2004]. The analysis of SIR-C data was made using a target decomposition method and the scattering mechanisms and their dependence on radar parameters as well as the season of observation were characterized [Fujita and Nakamura, 2003]. Pi-SAR polarimetric data were used for classification of trees, based on the alpha-entropy methods, to discriminate conifer and broad leaf trees [Sato and Iribe, 2003], and for land use classification [Amarsaikhan and Sato, 2004]. It was found that the phase component of the circular polarization of the Pi-SAR data shows a unique behavior that may be closely related to the azimuth orientation of the radar target and can be used for quantitative classification [Iribe and Sato, 2004].

An alternative approach for polarimetric SAR interferometry based on the ESPRIT technique was proposed [Yamada, H. et al., 2002]. The approach has a feature to detect local scattering centers corresponding to the canopy top and the ground and can detect three local scattering centers in the forest at the maximum with fully polarimetric data sets. This feature is applied to improve the tree height estimation [Sato, K. et al., 2003]. It is also shown that strong volume scattering causes the bias in the estimated tree height, so that careful evaluation of the results is necessary for the dense forest analysis [Yamada, H. et al., 2003].

An X-band scatterometer was applied to monitor wheat chlorophyll, to show that polarimetric power ratio varies with wheat growing stage [Singh et al., 2003].

Algorithms of classifying rice paddies and their applications to monitoring growth of rice plants are presented. The algorithms were applied to the airborne Pi-SAR data over the Kojima test fields, Okayama, Japan to show good agreement with the ground-truth measurements [Ouchi et al., 2003; Ishituka et al., 2004]. New algorithms of segmentation and classification of rice paddies from multi-temporal RADARSAT-1 SAR and NASA/JPL AIRSAR data are developed. Speckle reduction by the pixel-based region merging and maximum likelihood algorithms are used. Comparison of the result with ground-truth showed 84% of measurement accuracy [Ouchi et al., 2002b; Davidson et al., 2002; Davidson and Ouchi, 2003].

SAR techniques were used for a ground-based (GB) system. A prototype of GB-SAR was tested and used for 3-D imaging of trees. Radar polarimetry was also applied for interpretation [Zhou et al., 2004]. GB-SAR was used for detection of small deformation of radar target by interferometry. Deformation of the order of 1cm of a wall of a wooden house was detected [Hamasaki et al., 2004].

Theoretical study of microwave sensing of soil moisture was carried out [Matsuoka and Tateiba, 2003]. In the study, a moist soil was assumed to be three layers of random medium and a radiative transfer theory was applied to evaluate the scattered power. The polarization ratio is useful for estimate of water contents near surface. Diurnal change of backscattering coefficients of Amazon rain forest at Ku-band was studied with the TRMM PR, to find larger backscattering in the morning [Satake and Hanado, 2004].

B. Subsurface Objects

Low frequency induction is used for deep geological exploration for oil and mineral resources. A novel directional induction logging sensor was proposed [Cheryauka and Sato, 2002]. Radar polarimetry was applied to a borehole radar in a deep drilled borehole and it was tested for evaluation of subsurface fractures [Sato and Takeshita, 2002]. The theoretical principle and numerical simulation of a polarimetric borehole radar for subsurface fracture characterization were demonstrated [Sato, 2004]. Sub-grid FDTD method was applied to the simulation of radar scattering of a borehole radar system [Liu et al., 2004]. Small migration of ground water level was determined quantitatively and the vertical profile of ground water content could be estimated by Ground Penetrating Radar (GPR) [Lu and Sato, 2002]. Lu and Sato [2004] also demonstrated the quantitative GPR measurement can estimate the hydraulic parameters of soil, which will leads to the production estimation of grounds water.

C. Landmine Detection

A stepped-frequency radar with wide bandwidth (10MHz-6GHz) and thereby with very high resolution was developed for the use of landmine detection [Sato, M. et al., 2003]. Bistatic ground penetrating radar (GPR) system using a passive optical electric field sensor was also proposed for landmine detection [Sato, M., 2003]. Wide band GPR using an array Vivaldi antenna, that is called SAR-GPR with SAR imaging algorithm incorporated, was demonstrated to show a good performance for landmine detection [Sato, M. et al., 2004].

D. Others

An earthquake detection system which uses satellites to receive microwaves was proposed [Takano et al., 2004]. The mechanism of the microwave generation in relation to an earthquake is explained on the basis of the experiment of rock-crash in a laboratory. The sensitivity of the satellite sensor and the coverage by a receiving antenna are discussed and clarified.

Microwave emission due to hypervelocity impacts on metallic plates has been found, in the experiment with aluminum plates of various thicknesses and the projectile made of a nylon cylinder with a metal. A heterodyne receiver detected the microwave, a random sequence of pulses with several nanosecond width, at 22 GHz. Since the phenomenon seems to be dependent on the extent of target destruction through the formation of impact craters or penetration, it could be used to better understand the mechanical destruction process [Takano, et al. 2002]. The dependence of emitted frequency (22 GHz and 2 GHz), the time sequence of the signal generation, the correlation with the light emission and the emitted energy was investigated [Maki et al. 2002]. The emission characteristics are studied for several kinds of targets of aluminum, an alumina ceramic, a red brick and a polyurethane rubber. The strength of the emission has correlation to the electric conductivity, the fragility and the density of the targets [Maki et al. 2003]. To understand the features of the phenomena and to clarify the mechanism of the radio-wave generation, the simultaneous observation of the phenomena by the micro-wave detection and the optical imaging method to compare the both methods was carried out [Maki et al., 2004].

The scattered patterns of light-wave from several materials have been measured. Acrylic plastic has Lambertian pattern due to strong internal scattering and a reflection pattern from the surface [Toyoshima, et al. 2004].

(M.Satake)

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