COMMISSION F : WAVE PROPAGATION AND REMOTE SENSING (Nov. '92 - Oct. '95)

Edited by Yoshio Hosoya

F1. Wave Propagation

F1.1. Wave Propagation in the Atmosphere

Studies on the radio wave propagation in an inhomogeneous atmosphere have been ongoing. Kawaguchi and Oka [1994] have studied the wave propagation properties in the horizontally nonuniform surface ducts using the method of coupled mode analysis.

F1.2. Wave Propagation in the Presence of Hydrometeors and Other Particles

It was found that the ITU-R specific rain attenuation model tends to appreciably underestimate millimeter-wave rain attenuation at frequencies above about 60 GHz, as a result of examination based upon millimeter-wave rain attenuation data measured in the UK [Ihara, 1994]. It was also found that this tendency is very similar to that previously reported for the Japanese experimental data at frequencies up to 245 GHz.

In order to interpret the satellite-to-earth path attenuation at Ka band, a simplified cell model was introduced. Applying this cell model to PPI Radar data, rain attenuation calculations were done and real attenuation coincided almost well with those of the calculations [Otsu, 1993].

Rain attenuation characteristics of quasi millimeter waves have been studied for years in Tokyo area. An outage-free quasi millimeter radio system was proposed based on above results [Manabe and Yoshida, 1993, 1995a, 1995b]. Effectiveness of the transmission power control for quasi millimeter band was also clarified [Manabe et al., 1995c].

The cross-polarization discrimination (XPD) of the Ka-band satellite-to-ground path was continuously observed using the CS-3 beacon signal radiowave (19.45 GHz, RHCP, EL=49.5 degrees) at Neyagawa, Osaka. The effects of ice depolarization were found to largely depend on the background temperature at the heights where ice crystals appear near the cloud top [Maekawa et al., 1993a], and the ratio of ice depolarization to rain depolarization was discussed in light of difference between path lengths of ice and rain regions [Maekawa et al., 1994a] compared with radar observations. The mean cross-polar phases of the rain depolarization show a large variation at each rainfall event possibly due to the raindrop size distribution and may affect a possible improvement of XPD performed by the canceler [Maekawa et al., 1993b]. The mean cross-polar phases were also found to be closely related to the attenuation ratio of Ka-band to Ku-band satellite signals [Maekawa et al., 1994b]. The ice depolarization events were shown to be primarily caused by differential phase shift and to be improved by the canceler about 10 dB in XPD [Meakawa et al., 1993c]. Characteristic of rapid changes in XPD due to thunderclouds were, for the first time, found to be coincide with the cloud-to-ground lightning strokes which primarily occurred to the south side of the earth station within 15 km [Maekawa et al., 1995].

(Y. Karasawa)

F2. Remote Sensing

F2.1. Atmosphere

Recently, detailed observations with various remote sensing techniques such as radars, lidars, and satellites, as well as in-situ measurements with rockets and balloons have clarified characteristics of atmospheric waves propagating in the troposphere (altitude range 0-10 km) and the middle atmosphere (10-100 km). Among atmospheric waves, internal gravity waves have been extensively studied by the middle and upper atmosphere radar (MU radar) located at Shigaraki, Japan (34.85 degree N, 136.10 degree E). A climatological analysis of gravity wave activities and momentum fluxes observed with the MU radar in the troposphere and stratosphere (altitude range 5-25 km) was made by Murayama et al. [1994a], finding strong association of the gravity wave activities with the seasonal variations of the tropopause jet. A series of rocketsonde observations were carried out at Uchinoura, Japan, simultaneously with observations by the MU radar during the DYANA campaign. The vertical wavenumber spectra of the observed horizontal wind profiles (altitude range 20-90 km), which indicate the gravity wave activities, and changes of the background wind and temperature due to a strato-warming and planetary waves were discussed in Murayama et al. [1992]. In the companion paper by Tsuda et al. [1992a], they closely analyzed the vertical scale and the variance of gravity waves, and found that these variations from the stratosphere to the mesosphere suggest the effect of static stability of the atmosphere. Murayama et al. [1994b] described the climatological characteristics of the gravity waves observed by the Rayleigh lidar at Tsukuba, Japan, finding annual variation of the gravity wave activities with a maximum in winter.

Characteristics of gravity waves in the mesosphere were observed using the MU radar by Nakamura et al. [1993a, 1993b]. The frequency spectra of wind fluctuations and momentum fluxes were analyzed and the contribution of the gravity waves with periods longer than 30 minutes were found to be most significant [Nakamura et al., 1993a]. Horizontal propagation characteristics were summarized in the companion paper [Nakamura et al., 1993b], finding a clear difference between the short-period and long-period gravity waves. A hemispheric comparison of the mesospheric gravity wave activities was described by Nakamura et al. [1993c], using the data obtained at Shigaraki, Japan and at Adelaide, Australia, both located at 35 degree latitudes. A similar comparison between 35 degree N (Shigaraki, Japan) and 52 degree N (Saskatoon, Canada) was presented by Nakamura et al. [1993d], suggesting stronger activities of gravity waves at lower latitudes. Tsuda et al. [1994a] summarized these latitudinal, altitude, and seasonal variations by the radars, rocket sondes and lidars.

Watanabe et al. [1994] observed a rotor circulation near the Baiu front in the lower troposphere with the MU radar in 1990. The temporal and vertical scale of the rotor were ~50 min and ~2 km, and the stratification observed by radiosondes was statically stable. Fukao et al. [1994] computed the vertical eddy diffusivity due to atmospheric turbulence with spatial scales of 1-100 m from the echo power spectral width observed by the MU radar for almost every month from January 1986 to December 1988. The contamination due to beam broadening, vertical shear and transience was removed. Muraoka et al. [1994a] presented a case study on mesospheric IGWs observed with the MU radar on September 1988. A long-period wave motion was dominant only in the horizontal winds, while short-period wave motions are commonly seen in the vertical and horizontal wind components. Muraoka et al. [1994b] made a spectral analysis of the radial (line-of-sight) wind velocity observed in the mesosphere by the

MU radar during the daytime of September and October 1988. The radial velocity was measured every 1 min at 300-m range resolution along the three beam directions of 0 degree, 10 degrees and 20 degrees from the zenith.

Sato et al. [1995a] analyzed temperature and horizontal wind fluctuations with periods shorter than 3 days in the equatorial lower stratosphere by using operational rawinsonde data at Singapore (1 degree N, 104 degree E) during 1978-1993. IGW-like structures having a period of about 2 days and a short vertical wavelength of 5 km had significant energy, separated from Kelvin waves and mixed Rossby-gravity waves. Ogino et al. [1995] investigated meridional variation of the lower stratospheric IGW activity in the western Pacific region (14 degree S-25 degree N) on the basis of vertical wavenumber spectra analyzed from temperature and wind data observed by rawinsondes of the Hakuho-maru J-COARE cruise during November 1 and December 4, 1992. The dominant vertical wavelength of IGWs was ~2.7 km, which was distinguished from that of Kelvin waves (~4 km).

Yamanaka and Fukao [1994] calculated vertical fluxes of momentum and energy through the middle atmosphere by using a simple semi-empirical model of quasi-monochromatic IGWs with dominant vertical wavenumbers. In this model those dominant IGWs were assumed to saturate and break at each observational altitude by an effective critical-layer mechanism.

Wave propagation in the equatorial region was studied by launching radiosondes every 5-7 hours for about a month in an observation campaign conducted in 1990 [Tsuda et al., 1992b]. Equatorial waves and diurnal tides were predominantly detected below 25 km altitudes [Tsuda et al., 1994b], where Kelvin waves were found to modify the tropopause structure. On the other hand, Tsuda et al. [1994c] studied characteristics of gravity waves in the same observation campaign, suggesting that cloud convections are an important source of gravity waves near the equator.

Using the high-power VHF radar at Jicamarca, Peru, Maekawa et al. [1993d] have detected, for the first time, reliable atmospheric echoes in the so-called "gap" region from 30 to 60 km altitudes where the radar echoes are extremely weak. These echoes were discriminated from clutter echoes utilizing both co-polar and cross-polar arrays of the radar to monitor possible contamination via antenna sidelobes.

Mean wind and semidiurnal tides in the lower thermosphere were compared between Japan and Siberia [Kazimirovsky et al., 1993] by LF and meteor radar observations, showing a significant difference between them in winter.

Studies related to the use of spatial and frequency domain interferometry have continued at the MU radar. Spatial interferometry (SI) is an attempt to use spatial diversity to increase the angular resolution of radar measurements. Typically the angular resolution is determined by the size of the antenna. Frequency domain interferometry (FDI) uses dual transmitter frequencies with the goal of higher radial resolution. FDI measurements using the MU radar first began in 1990, when it was used to "image" turbulent layers in the troposphere and lower stratosphere. Since that time, numerous advancements have been made, including the use of FDI for oblique beams [Palmer et al., 1992]. In this work, the authors mathematically described the behavior of the FDI signals for non-zenith beam directions. Experimental evidence supported their claims. Furthermore, the work showed a connection between thin turbulent layers and aspect sensitivity. Subsequently, Kilburn et al. [1995] used the technique for a more extensive time period than previously attempted. The result was a large improvement in the analysis methods including the calibration of turbulent layer positions. Before this work, the positions of layers were relative to any phase offset between the two transmitter frequencies.

Multiple receiver measurements were first used to estimate the drift speed of scatterers in the

ionosphere. The technique was named spaced antenna (SA) drifts. The cross-correlation between signals from these spaced receivers was used to find the drift speed. In 1992, researchers using data from the MU radar discovered that the same wind measurements could be made using data in the frequency domain. In other words, the cross-spectrum was used to find the drift velocity. A statistical comparison between the results from the two domains was carried by Sheppard et al. [1993], showing that statistically identical horizontal wind estimates could be obtained from either domain. More importantly, however, it was shown that time domain measurements were more easily implemented. Fundamental studies of the SA technique continued at the MU radar, with a focus on the effect of various atmospheric phenomena on the measurements. At VHF wavelengths, aspect sensitivity causes a decrease in returned power for off-zenith beam directions. The effect on SA measurements was studied by Brown et al. [1995] and Chang et al. [1995]. Furthermore, Brown et al. [1995] studied the relationship between the time and frequency domain results as a function of temporal scale. They found that when the temporal scale was small, results from the two domains showed less agreement. Studies of the effects of atmospheric phenomena on SI measurements continued with the work of Chilson et al. [1993, 1995], who presented data from a fortunate precipitation event. The results illustrated the need for SA analysis in the frequency domain since precipitation echoes could be separated from clear-air measurements. In the time domain, the two signals are mixed and cannot be analyzed.

With the flexibility of the MU radar, numerous unique experiments have been conducted, resulting in improved versions of various SA-like wind profiling algorithms. Palmer et al. [1993] presented data from the MU radar showing that synthesized beam steering could be used to obtained wind estimates. Basically, the method uses phased array steering techniques to synthesize beams in numerous directions, which are used for the calculation of the horizontal wind. With a need for robust techniques, Palmer et al. [1995a] refined the imaging Doppler interferometry (IDI) method so that implementation was trivial. In addition, the measurement variance was reduced using the new algorithm. Since any of the multiple receiver measurements relies on the phase difference between the receivers, phase calibration is an important topic. However, a phased array system does not easily lend itself for calibration. Using the radio star Cygnus A, Palmer et al. [1995b] used radio astronomy techniques in order to calibrate the SI system phase of the MU radar.

After a significant upgrade to the MU radar data acquisition system, simultaneous FDI and SI experiments could be performed with the first such experiment carried out by Palmer et al. [1995c]. By combining the information from SI and FDI, they were able to essentially increase the altitude resolution of the wind profiles using the IDI method. In other words, altitude information from FDI was used to refine the profiles from the IDI method.

The RASS (Radio Acoustic Sounding System) technique has been developed at the MU radar to profile atmospheric temperatures in the troposphere and the lower stratosphere with a high time resolution up to a minute. Tsuda et al. [1994d] showed that the MU radar/RASS observation can observe the temperature of 1.5-7 km altitude with height and time resolutions of 300 m and 90 seconds, respectively. Adachi et al. [1993] discussed on the accuracy of the RASS technique for various pulse length of acoustic and radar pulses with both a numerical model and the radar experiment.

A technique to measure temperature fluctuations using meteor echoes has been introduced to the MU radar by Tsutsumi et al. [1994], which was applied to observe temperature fluctuations associated with gravity waves in the mesosphere.

Ground-based radar systems like a boundary layer radar (BLR) and a meteor radar, in addition to radiosonde equipment and other ground-based meteorological instruments, were brought into the equatorial Indonesia in order to clarify the dynamics of the equatorial atmosphere [Tsuda et

al., 1995]. From continuous observations by BLR since November 1992, Hashiguchi et al. [1995a] found a marked reversal of the wind direction from easterly to westerly at the beginning of the rainy season, which was associated with an eastward movement of the convection center (a super cluster). The striking appearance of a strong echo layer which ascended from below 300 m in altitude (in the morning) to above 3-5 km (in the afternoon) was found in the dry season [Hashiguchi et al., 1995b], and identified with a diurnal variation of the top of the mixing planetary boundary layer [Hashiguchi et al., 1995c].

A 1357-MHz wind profiler has been operated since 1993 at Communications Research Laboratory, Tokyo. Wind vectors below the height of 3 km can be measured continuously using this radar [Ohno et al., 1994a]. The same type profiler was introduced at Bangkok, Thailand and has been operated to study the tropical boundary layer [Ohno et al., 1995].

F2.2. Hydrometeors and Other Particles

Iguchi and Meneghini [1994] reviewed several rain-profile retrieval algorithms at attenuating frequencies from airborne or spaceborne rain radar data. They also proposed a hybrid method that provides a smooth transition between the Hitschfeld-Bordan method, which performs well at low attenuations, and the surface reference method, for which the relative error decreases with increasing path attenuation. A rain profiling algorithm combining both radar and microwave radiometer is proposed for airborne and future spaceborne rain measurements. This method enables to estimate the vertical profile of drop size distribution of rain and then obtain rain profile [Kumagai et al., 1993c].

Iguchi et al. [1992] found experimentally that the effect of multiple scattering to the linear depolarization ratio (LDR) might be significant for 35-GHz rain radar. The effect of multiple scattering on the estimation of rainfall rates using dual-wavelength radar technique is analyzed [Oguchi et al., 1994]. The simulation indicates that the conventional inversion algorithm always underestimates the true rainfall rate.

Rainfall non-uniformity in a radar field-of-view (FOV) can cause a significant bias error in the spaceborne radar rain rate estimation. This error may be relaxed by estimating the variability in the FOV from the measured reflectivity variability of surrounding FOVs [Kozu and Iguchi, 1995].

Results from airborne rain measurements using a dual-frequency radar at X and Ka bands, dual-polarization capability being added to the X band also, were presented. The ratio of radar reflectivity factors between X and Ka bands and the linear depolarization ratio (LDR) at X band provide information about shape and size of hydrometeor in the vertical rain profiles [Kumagai et al., 1993a].

The first spaceborne precipitation radar (PR) is under development for the Tropical Rainfall Measuring Mission (TRMM). The PR is a 13.8 GHz active phased array radar, and will play an important role to achieve quantitative rain mapping from space, especially vertical storm structure measurement [Kawanishi et al., 1993; Kozu, et al., 1994]. Results of conceptual design study and performances of developed key devices of BBM of the 13.8 GHz TRMM radar are presented [Okamoto, 1993]. To confirm the radar design and assess the basic performance, an eight-element of bread-board model of the precipitation radar onboard the TRMM satellite was developed. The radar consists of an active array system with all solid state components [Kumagai et al., 1993b]. The TRMM precipitation radar(PR) algorithms have been studied by the TRMM PR team [Okamoto and Kozu, 1993]. Some rain retrieval algorithms for TRMM PR

are reviewed.

Ohsaki et al. [1993a, 1993b] investigated the standard deviation of the rain echo power of TRMM radar on various signal-to-noise ratio by theory and by computer simulation. Ohsaki and Nakamura [1993, 1994a] proposed a TRMM data processing based on a new concept to reduce a bias error of mean rainfall rate. Ohsaki [1994] obtained a relationship between the standard deviation of rainfall rate and the number of averaging samples by a computer simulation. Ohsaki and Nakamura [1994b] compared to the three rainfall rate estimators of dual-polarization radar. The path averaged rainfall rate estimated from rain attenuation is compared to the point rainfall rate measured with a rain gauge by computer simulation using distrometer [Ohsaki and Kuroiwa, 1994].

The circular depolarization ratio (CDR) of radar returns from rain has been calculated by using the second-order multiple scattering solution [Ito and Oguchi, 1994]. The predicted values are found to give a general trend of the CDR in comparison with numerical solutions. The same approach as used in the CDR has been applied to the evaluation of the linear depolarization ratio (LDR) at X and Ka Bands. A good agreement of the computed LDR values with observations from an air-borne dual polarization radar suggests that multiple scattering processes really exist in the rain cell [Ito et al., 1995].

The wintertime thunderclouds which are not popular in the world except in the region along the coast of the Sea of Japan have been observed, for the first time, by a dual polarization radar. The three dimensional distribution of graupels and ice crystals were determined by using polarimetric informations of the radar [Maekawa et al., 1993e]. It has been found that the product number of graupel and ice crystal echo (GI index) in each 5x5 km^2 area is well correlated with lightning location identified by lightning locating instruments. Based on this result, the authors propose that this number can be used as a good indicator for prediction of possible lightning locations [Maekawa et al., 1993e; Sonoi et al., 1995].

Studies concerning the evaluations of precipitation at Syowa Station, Antarctica by using vertically pointing 9.41GHz meteorological radar data and snow particle size distribution have been ongoing. Relative snow particle size distributions were obtained from VCR image recorded by a specially designed portable video camera set on ground [Hatanaka et al., 1993, 1995]. Using Mie's back scattering cross section based on a snow particle model, the falling speed of the particle, the obtained relative snow particle size distribution and the observed radar Z factor data, precipitation rate at Syowa Station was evaluated [Takeya et al., 1994].

A dual-frequency cloud radar using 94 GHz and 35 GHz bands is proposed for future space mission. The dual-frequency system enables to measure vertical cloud profile accurately for clouds with various density [Kumagai et al., 1994].

F2.3. Ocean and Sea Ice

Studies concerning the remote sensing of ocean waves by HF radar have been ongoing. Two HF ocean radars were developed by the Communications Research Laboratory. These radars enable measurement of ocean current vectors in coastal area. Experimental observations using these radars were made at the Tokara Strait and the Bungo Channel to study coastal ocean currents [Ohno et al., 1993, 1994b]. Two-dimensional ocean current velocities and wave parameters such as wave height, period and direction are estimated from HF radar by Hisaki [1993]. The backscatter of HF radio waves by sea surface is investigated in detail by Hisaki and Tokuda [1994, 1995a, 1995b], and it is shown that bound waves which are generalized Stokes-type

harmonics are detectable from HF radar. The limitation of the perturbation theory of the HF radio backscattering by sea surface is investigated from field observations.

The broadening of first-order echo on Doppler spectra obtained by HF Ocean Surface Radar is investigated with relation to ocean surface current field [Nadai, 1993] and with relation to change of ocean current field [Nadai, 1994a]. The possibility of measuring ocean surface phenomena related to ocean surface current field by using the broadening of the first-order echo is studied in Nadai [1994b]. The reason of the broadening of first-order echo and the possibility of measuring complicatedness of ocean surface current field has been studied in Nadai [1995a]. In Nadai [1995b], the complicatedness of the ocean surface current complicatedness is analyzed by using the broadening of the first-order echo.

Okamoto et al. [1993, 1994a] made experiments to detect intentionally oil polluted areas using the C-band Synthetic Aperture Radar on the European Remote Sensing satellite-1 in November 1991 and in October and November 1992.

Tateiba et al. have successfully carried out the computer simulation of return pulse train in satellite altimetry [1993, 1994] and discussed a method for measuring ocean wavelengths using the pulse train [1995].

An X-band (9.53 GHz) real aperture SLAR system were used to detect pack ice in the Sea of Okhotsk [Okamoto et al., 1994b].

F2.4. Land, Vegetation and Others

Radiometric calibration of ERS-1 C-band SAR was carried out for NASDA standard products using square trihedrals [Fujita et al., 1993]. To develop an advanced technique for SAR radiometric calibration, an ARC having a frequency shift capability was developed and showed the shift of its ERS-1 SAR image in azimuth relative to its background due to the frequency shift [Satake et al., 1994]. A polarization selective reflector for polarimetric calibration was developed by using the concept of a polarization grid and a dihedral [Fujita and Masuda, 1995]. A preliminary result of the SIR-C polarimetric calibration by using the polarization selective reflectors was reported to show the promising characteristics of the reflectors [Fujita et al., 1995]. Image intensity of SIR-B images over a hilly area was evaluated quantitatively and it was shown that the image intensity was correlated with the local angle of incidence of the radar wave [Satake et al., 1992]. By the observation with ERS-1 C-band SAR over two years, it was shown that the number of days after transplanting, and hence the growing stage of rice crops, was able to estimate from the rice crop backscattering coefficient [Kurosu et al., 1995].

The remote sensing technology has seen a tremendous advancement using a new "polarimetric information". Radar polarimetry, i.e, the full utilization of vector nature of the electromagnetic information has become an indispensable tool for advanced high resolution radar sensing. The polarization theory has been extended and verified using a unique FM-CW radar system together with synthetic aperture technique for detection of objects buried in lossy media such as snow, soil, and air, extensively by Yamaguchi et al. [Yamaguchi and Sengoku, 1993; Yamaguchi et al., 1993a, 1993b; Boerner et al., 1993; Yamaguchi et al., 1994a, 1994b; Ishizuka, et al., 1994; Tanaka et al., 1994b; Boerner et al., 1994; Yamaguchi et al., 1995a; Moriyama et al., 1995]. Radar polarimetry is on its way to expand its potential ability to diverse imaging areas not only for aerial mapping but also for underground sounding, classification, and identification of targets in a complex featured background radar scene.

A bistatic radar using coherent long pulses or a CW wave modulated by PN-PSK signals is proposed for the purpose of space debris monitoring [Takano and Yajima, 1994a]. In this radar, the received radio wave is recorded in a VLBI recorder and processed by a VLBI correlator. A method for monitoring space debris by networking popular large antennas based on a bistatic-radar concept is proposed by Takano et al. [1994]. The use of movable receiving stations in a bistatic or multistatic radar scheme for space-debris monitoring is also proposed [Takano and Yajima, 1994b]. Advantages of the use of movable receiving stations are clarified in comparison with systems with fixed stations for transmission and reception. The applicability is determined by the signal strength extracted from the undesired signals. Assuming appropriate parameters of the system, the performance is analyzed numerically. The results show wide range of applications.

Yokota et al. [1994] are developing a compact laser radar system for space debris measurement that could be installed on many satellites and space stations. This laser radar consists of a Nd:YAG laser with an energy of 4 mJ and a pulse-width of 12 ns at 532 nm, a photomultiplier, and a CCD camera. Prior to the construction of an engineering model, the laser radar system was considered theoretically [Tanaka et al., 1994a]. It is important to know the information on debris in order to evaluate the degradation of spacecraft surface and onboard instruments exposed in space.

Akimoto et al. [1994] and Tazaki et al. [1995] presented the method and equations for determining the complex refractive index using pseudo-Brewster angle method, and applied them to microwave and visible light regions for measuring surface of earth and others.

(T. Manabe)

F3. Radio Communication

Manabe and Furuhama [1994] reviewed recent research activities in Japan on propagation through non-ionized media related to radio communications including land-mobile, indoor-mobile, and mobile-satellite communications, and propagation through the atmosphere and precipitation.

F3.1. Terrestrial Fixed Radio Systems

Two types of non-regenerative repeating digital microwave radio systems are studied in Japan. One is a coherent non-regenerative repeating digital microwave radio system that features non-regenerative transmission of a channel unit. The other is a full frequency band non-regenerative repeating digital microwave radio system that enables non-regenerative transmission of all channels in half of each frequency band [Kagami et al., 1994].

(E. Ogawa)

F3.2. Fixed Satellite Radio Systems

A prediction method on the long-distance site diversity effect up to 1000 km for rain attenuation in satellite communication circuits was proposed by Yamada and Karasawa [1994], using an empirical equation obtained from statistical data of 1-min. rainfall rate simultaneously observed at many places in Japan. Sato et al. [1993] proposed a Time Division Multiple Access (TDMA) system that can compensate rain attenuation by adaptive control of transmission rates and conduct experiments using Japanese CS-3 satellite with Ka-band (20/30 GHz) transponders.

(Y. Karasawa)

F3.3. Land Mobile Communication

In the wideband digital mobile communications, delay characteristics due to multipath propagation significantly affect the system performance. Measurements and researches on channel model are extensively conducted. A propagation model is proposed that can be used to predict delay spread for areas with large delay path [Kozono et al., 1993]. Multipath propagation measurements are carried out in areas surrounded by tall mountains. It shows reflection loss is large and delay spread is small [Kimura et al., 1994]. Especially in CDMA scheme, wideband transmission characteristics are important. For CDMA application, the wideband propagation model has been developed for assessment of wideband mobile propagation characteristics so as to be an analysis and simulation tool for wideband propagation phenomena in mobile communication field [Iwai et al., 1993]. Using the model, wideband fading characteristics has been made clear, and furthermore the performances of the wideband fading suppression systems, which are invented to reduce wideband signal level fluctuation, are quantitatively investigated [Iwai et al., 1992, 1994, 1995].

Recently, microcellular systems are put in practical use to improve the frequency re-use efficiency. In the microcells, low base station antennas are used. Microcellular multipath propagation measurement is carried out in a metropolitan area [Moriyama et al., 1993] as well as residential area [Moriyama, 1994b]. It is clarified that most of delay profile shape for metropolitan area is exponential shape, whereas residential is not exponential one. Advantage introduced by path-diversity is quantified by delay spread, bandwidth product [Moriyama, 1994a] and it is confirmed by multipath measurement. The time delay spread characteristics under a line-of-sight and a non-line-of-sight conditions are examined using a geometrical street model which has a reflecting building wall at one end of the line-of-sight street on which the base station is located [Furuno et al., 1993]. Propagation loss and delay spread characteristics are clarified with a low base station antenna on an urban road. It shows the influence of obstacles and a cross road, and dependence of frequency and distance [Kozono and Taguchi, 1993]. A field experiment of the personal communications system for Japanese new standard, PHS, has been done to evaluate the system performance in urban mobile radio environments [Takeuchi et al., 1995].

The predicting method for propagation characteristics in urban microcellular systems when a base station antenna is mounted below surrounding building heights are presented [Iwama and Mizuno, 1994]. Using this predicting method, the best way of frequency assignment is simulated in microcellular systems. For this purpose, microcell patterns, base station settings [Iwama and Kiyonaga, 1994] and antenna directions [Iwama, 1995] are considered in these simulations. In microcellular environments, line-of-sight conditions would be more practical. A general model for envelope correlation statistics in such conditions has been developed based on theoretical method. The model can also be used for maritime and aeronautical mobile-satellite communications [Karasawa and Iwai, 1994]. A new channel model for line-of-sight street

microcells with low antenna height base sites was proposed [Taga et al., 1995].

Studies on mobile radio channel simulator have been done to enable the simulation using the measured channel impulse responses in urban mobile radio environments [Takeuchi, 1993a]. And the database for the use with the above channel simulator has investigated to reduce the amount of the size of the database without lacking the precision of the simulation [Takeuchi, 1993b, 1994a].

Beam rotating and tilting of base station antenna are examined by theoretical and experimental methods. As a result, the effectiveness in reducing the delay spread is confirmed and the predicted delay spread is well agreed with the measured one [Tanaka et al., 1993a]. Multipath propagation characteristics for the RAKE receiving technique are clarified by experiments carried out in the urban areas. Number of paths, probability distribution of received level and amplitude correlation of each path are reported [Tanaka et al., 1993b; Tanaka, 1994].

The use of adaptive antenna technology for mobile communication is effective in reducing fading in macro and microcellular communications and wireless LAN, and is also effective to control a cell shape by dynamic zone configuration [Mizuno et al., 1992]. The implementation and use of CMA adaptive array antenna technology for mobile communication is described [Ohgane, et al., 1993a]. Using this adaptive array antennas, propagation characteristics and BER performance are measured in central Tokyo [Ohgane, et al., 1992, 1993b]. Simulation results show that spectral efficiency can be greatly improved by adaptive base station antenna [Ohgane, 1994].

An estimation formula of the median field strength was proposed for the frequency band of 300 to 3000 MHz, using parameters such as base station antenna height, antenna beam width and beam-tilt angle, mean building height and others [Morita et al., 1993]. The reduction of attenuation of radio wave in tunnels has been studied [Yamaguchi et al., 1995b].

Yoshida and Mizuno [1993] described the truth and false of the relation between propagation and system design in the field of mobile/portable radio communications. It is not well recognized that multipath propagation can be a desirable phenomenon if a sophisticated communication system uses adaptive equalization, anti-multipath modulation, or spread spectrum communication, for example.

F3.4. Indoor Mobile Radio Systems

In 1992, Communications Research Laboratory of Ministry of Posts and Telecommunications has commenced a research project to explore the millimeter-wave indoor-propagation characteristics in modern office rooms in the 60-GHz band for the development of high-speed indoor communication systems such as wireless local area networks [Manabe and Ihara, 1994; Ihara, et al., 1995]. Effectiveness of the use of circular polarization instead of linear polarization for suppressing the effects of multipath propagation was experimentally verified at 60 GHz [Manabe et al., 1993, 1994]. The effects of the antenna directivity on indoor multipath propagation characteristics were also investigated at 60 GHz [Manabe et al., 1995a, 1995b]. Along with these propagation experiments, the dielectric properties and the reflection characteristics of concrete [Sato et al., 1995b] and other indoor construction materials [Sato et al., 1995c] were measured at 60 GHz.

In order to realize a high capacity radio transmission system of more than 100 Mb/s, digital transmission characteristics in a multipath environment where the delay time is larger then the

symbol duration are studied [Yoshida et al., 1994; Nakayama et al., 1994].

Studies on high-performance indoor channel sounder have been done [Takeuchi et al., 1992] and the possibility of the delay profile measurement with 1 ns delay resolution was presented [Takeuchi, 1994b]. It is shown that the delay profile as well as cumulative distribution of the delay spread in a shielded building can be simulated based on multiple reflection model using Fresnel's formula [Moriyama, 1994c].

(E. Ogawa)

F3.5. Mobile Satellite Radio System

A geostationary satellite called Engineering Test Satellite Five (ETS-V) was launched in 1987 as the world's first experimental satellite to provide all-round capability for maritime, aeronautical and land-mobile satellite communications experiments at L-band (1.5/1.6 GHz). Wakana [1994] outlined the field experiments using a fishery training ship, an B-747F freighter plane, a test van, hybrid terminals for communication and positioning, and a portable message terminal.

Propagation studies have been carried out with ETS-V satellite. Propagation measurements along most Japanese expressways (total distance 3500 km) were carried out using a low-profile phased array antenna. Results showed that when the fading margin is 5 dB, communication services are available for 90 to 97 % of the total distance along expressways, even though tunnels are included [Obara, et al., 1993]. A multipath measurement system with spread spectrum technique was proposed and developed for mobile satellite radio channels [Arakaki, et al., 1992, 1993]. Multipath delay profiles were measured in various environments including Tokyo metropolis and Sapporo City with ETS-V satellite at 1.5 GHz. Results showed that the maximum excess delay is within 1 microsec and the maximum delay spread is 0.2 microsec at elevation angles of 40 to 47 degrees [Ikegami, et al., 1993].

In the near future, mobile communication systems are expected to play an important role in realizing Universal Personal Telecommunications (UPT), and those days are called "Mobile ISDN era". In the era where mobile communication systems will be incorporated in the global ISDN system, signal quality should be specified so as to keep commonality for both fixed and mobile communication systems. In this respect, various propagation impairments for mobile-satellite systems (such as MMSS, AMSS and LMSS) were reviewed from a viewpoint of the available and unavailable time defined by the CCITT (now ITU-T) Recommendation G821, following which typical characteristics of unavailability caused by those propagation impairments were clarified [Karasawa et al. 1994a].

A prediction model of signal degradation in LMSS environments was proposed [Matsudo et al. 1993]. In order to examine the validity of this model, measurement of satellite visibility by using a radiometer was carried out. A propagation channel model for LMSS was introduced based on a three-state model [Karasawa et al. 1994b]. The model presented has capability for the assessment of system availability for both environments in vehicular service (LMSS-V) and personal communication use (LMSS-P).

(Y. Karasawa)

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