COMMISSION F : WAVE PROPAGATION AND REMOTE SENSING (Nov. '89 - Oct. '92)

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F1. Wave Propagation

F1.1. Wave Propagation in the Atmosphere

An analysis using the geometrical optics theory was attempted to determine the propagation characteristics in a nonuniform air in which the refractive index varies in both height and range due to a small-scale nonuniform air mass occurring in the propagation path [Oka, 1990]. Propagation of electromagnetic waves in the stratified atmosphere with negative gradient of the modified refractive index was analyzed by using wave theory [Kawaguchi, 1992]. The distribution of the modified refractive index for the middle layer in the atmosphere can be approximated by an even power of the height.

Propagation test of air-ground path was carried out on 900MHz band. Atmospheric parameters such as effective radius factor k were studied for estimating air-ground long path propagation characteristics [Akeyama et al., 1990a]. In order to predict the fading occurrence probability on microwave line-of- sight links, the radio meteorological influences on fading occurrence were studied [Sasaki et al., 1990].

Radiative transfer equation was solved for optical waves propagating in the turbulent atmosphere coexistent with fog particles, by combining the small angle and the diffusion approximations. Numerical results were given for the wavelength 0.6328mm and for several turbulence strengths and sizes, to see the relative contributions of turbulence and fog particles to intensity [Zhang et al., 1990].

F1.2. Hydrometeors and Other Particles

A method was presented for obtaining the specific intensity of linearly polarized optical waves propagated in discrete random media [Ito et al., 1989]. Solutions for the specific intensity were obtained for large particles over a wide range of optical depths. A comparison with numerical solutions was made to demonstrate the validity of the present theory. Incoherent wave components generated by multiple scattering of waves in rain were calculated at several wavelengths in the microwave to millimeter region for medium and high rainfall rates [Oguchi, 1991]. The results indicate that the incoherency effect may become a problem in radio communications at frequencies higher than 300 GHz.

Simultaneous propagation experiment at 82 GHz and 350 THz was made on a 1.4 km range in a snowy district. Analysis of the one-year data shows that millimeter wave suffers much less attenuation than optical wave in snow and fog conditions, while suffers larger attenuation in rainy conditions, indicating a usefulness of millimeter and optical wave diversity operation [Awaka et al., 1991].

Propagation characteristics through suspended water and ice particles which makes up haze, fog, or clouds were examined for microwave and millimeter wave frequencies using a newly developed model for the complex permittivity for water and ice [Liebe, et al., 1991]. Experimental data for attenuation and phase delay for a fog event were found to be consistent with this model calculation [Liebe et al., 1989].

Depolarization characteristics of Ka-band satellite-to-ground path were investigated using the CS-2 and CS-3 beacon signal radiowaves (19.45 GHz, RHCP, EL=49.5deg), as concerns both rain and ice effects. The ice depolarization effects were found to largely depend on the rain height in the stratus rainfall events [Maekawa et al., 1990a]. The characteristics of depolarization fluctuations were examined, and the ice effects were also correlated with cross-polarized phase in the low attenuation range due to both rain and ice effects [Maekawa et al., 1990b]. A possible improvement of XPD by phase shifters specific to the ice depolarizations was shown to be approximately estimated by the amplitude of these ice effects [Maekawa et al., 1991a]. On the other hand, nature of rapid changes in depolarization due to thunderclouds was presented, and large canting angles of ice crystals due to both electrostatic and aerodynamic forces were inferred. Also, their impact on linear dual polarization systems was suggested [Maekawa et al., 1992a].

Rain depolarization characteristics were examined in relation to difference of rainfall types primarily caused by raindrop size distributions. The cross-polar phase which is important to estimate a possible improvement of XPD by depolarization canceller was found to be largely affected by the raindrop size distributions rather than rain intensity [Maekawa et al., 1992b; c].

The effect of integration time on various attenuation statistics was discussed by using attenuation time-series data at 19.5GHz with a 1 second measuring interval [Fukuchi, 1992b]. It was found that the difference in cumulative distributions due to integration time was not significant. The integration time effect was significant in duration time statistics. This may be due to the rapidly varying scintillation imposed on the slowly varying rain-induced attenuation.

F1.3. Radio Meteorology

Formulas evaluating one-minute rain rate statistics, required for prediction of rain attenuation, using one-year, one-hour or 10-minute precipitation were presented [Irie, 1989]. They were derived from the measured meteorological data in 18 cities in Japan. Prediction accuracy was assessed in terms of r.m.s. and mean relative errors.

By examining measured one-minute rainrate data reported so far and one-hour rainrate data obtained by AMeDAS in Japan, a simple conversion method of one-hour rain rate data to one-minute rain rate distribution was developed, and its high accuracy was confirmed [Karasawa and Matsudo, 1990b]. Based on the method, a couple of maps of one-minute rain rate statistics such as 0.01% rain rate using AMeDAS data in Japan were developed [Karasawa and Matsudo, 1991].

F1.4. Optical Wave Propagation

The following novel precise angle gauge was proposed [Takano and Yonehara, 1990]. Incoming laser light was fed to the system through two separate condensing lenses. The phase difference between two rays were compensated by a phase modulator to hold a constant interference condition. The angle of the incoming light was measured by the modulation voltage. Owing to advantages for accuracy and configuration, the angle gauge is suitable for navigation using angular information.

The basic research of ISL and a laser radar was conducted [Takano, 1990]. The link analysis of ISL and a laser radar for two missions were given to show the possibility of actual use. Then, a novel precise angle gauge was described. The phase difference between two extracted rays from incoming laser light was compensated by a phase modulation. Instruments using beams tended to suffer from performance degradation due to diffraction phenomena. The method to suppress Fresnel diffraction by spatial filters was studied, theoretically and experimentally.

(Y. Karasawa)

F2. Remote Sensing

F2.1. Atmosphere

Atmospheric water vapor contents measured by the Microwave Scanning Radiometer aboard MOS-1 satellite were found to agree with the ones measured by radiosonde after correcting constant bias errors. Several causes of the bias errors were examined and discussed [Ojima et al., 1990].

The MU (Middle and Upper atmosphere) radar of Kyoto University which is a high-power VHF radar for tropospheric and stratospheric observations revealed a lot of new phenomena in hierarchical structures associated with medium-scale cyclones such as convection cells on the Baiu front primarily based on high resolution vertical wind data, which were never obtained by other instruments [Fukao et al., 1991b].

The Jicamarca VHF radar in Peru, which is one of the largest high-power radars in the world, detected reliable atmospheric echoes in the so-called "gap region" from 30 to 60 km heights. These echoes was, for the first time, discriminated from clutter echoes, using both co-polarized and cross-polarized arrays to monitor the clutter component which may enter the antenna sidelobes [Maekawa et al., 1991b; 1992d].

Radio Acoustic Sounding System (RASS) which combines acoustic and radar techniques is a useful tool for observations of temperature profiles in the troposphere and lower stratosphere. The echo power loss of RASS caused by the distortion of the acoustic wavefront due to the temperature gradient was theoretically analyzed to make clear the limitation in the height coverage [Masuda et al., 1990]. The accuracy of temperature measurement with the RASS using a monochromatic acoustic pulse was found to be strongly affected by the lapse rate of the atmospheric temperature and the ratio between acoustic and radar pulse lengths by using a numerical model. The optimum ratio was determined by a compromise between the practical requirement of the temperature accuracy and the sensitivity in the echo detection [Adachi et al., 1991]. On the other hand, it was found by a numerical simulation that a RASS using a chirped acoustic pulse can correctly measure a wide rage of Doppler shifts and that the accuracy of the temperature measurement was almost independent of the lapse rate of the temperature [Masuda et al., 1992a].

The use of a RASS with the MU radar for tropospheric profiling has an advantage of high time resolution observations of both temperature and vertical wind velocity. Preliminary results of frequency spectra of temperature and vertical wind velocity fluctuations were reported, and heat flux profiles were derived [Tsuda et al., 1991]. A 1.3 GHz pulse Doppler radar aiming at remote wind profiling of lower atmosphere was developed by Communication Research Laboratory (CRL). The initial observation results indicated its usefulness for wind profiling under both fine and rainy weather conditions [Masuda et al., 1992b; 1992c].

The NASA's deep space explorer Voyager-2 brought the first chance of the occultation by Neptune in the summer of 1992. On this occasion, NASA/JPL and ISAS made the collaborating experiment of the occultation using Usuda Deep Space Center of ISAS [Hayashi et al., 1990]. To detect quite slight fluctuations of the phase and amplitude of the radio wave carrier caused by occultation, a high G/T receiving system was realized combining a 64-m antenna and high-performance maser amplifiers. An antenna driving scheme to suppress the gain reduction due to elevation change was developed to keep the phase stable despite the antenna distortion [Takano et al., 1992]. From the radio science data obtained at 2.3 GHz at Usuda, a temperature-pressure profile of the Neptune's atmosphere was retrieved for the pressure levels between about 1 mbar and 2 bars. The resultant profile was compared with the one retrieved from the 8.4 GHz data obtained at Camberra, Australia [Mizuno et al., 1990]. The method of data analysis in which the signal frequency and amplitude were extracted from the Voyager Neptune radio science data was described along with the estimates of possible errors affecting the frequency estimates in [Mizuno et al., 1992].

F2.2. Hydrometeors and Other Particles

A method to estimate raindrop size distribution (DSD) from a spaceborne radar measurement was proposed. This method employs a path-integrated attenuation derived from surface echo and a radar reflectivity profile, and estimates a set of DSD parameters characterizing the precipitation profile along the path. An analysis result of airborne radar data, which demonstrates the validity of this method, was also presented in [Kozu et al., 1990; 1991a; b].

Numerical solutions of the vector two-frequency radiative transfer equation were obtained to investigate the effects of multiple scattering on pulse propagation in rain. The shape and magnitude of transmitted and reflected pulses were calculated, and the effects of multiple scattering on communication and polarimetric interpretation of radar returns from rain were discussed [Oguchi and Ito., 1990]. A numerical simulation was made, using dual-wavelength radar technique, to retrieve rain rates from radar echoes calculated with and without multiple scattering effects included. The result showed that the retrieved rain rate based on multiple scattering calculation is always smaller than that based on radar equation [Oguchi et al., 1992].

A method to estimate a range profile of raindrop size distribution (DSD) from dual-frequency radar data was proposed in [Meneghini and Kozu, 1991]. This method uses a recursive procedure beginning at the range gate near the surface progressing backwards toward the storm top, and provides 2n+1 parameters of DSD (n: the number of range gates). A test result of this method using a dual-frequency airborne radar data was also presented.

Analyses of dual-frequency airborne radar data were described for testing and evaluating rain retrieval algorithms from space. Those include comparisons of path-averaged rain rates derived from several algorithms, surface cross sections under rain and no-rain conditions, effects of mixed-phase precipitation on the retrieval accuracy, and a method to estimate the raindrop size distribution. Approximate criteria on combining the different retrieval algorithms were also discussed [Meneghini et al., 1990; 1992].

Statical properties of the differential reflectivity Zdr estimated by dual-polarization rain radar were examined by considering the dependence of the correlation between simultaneously measured horizontally and vertically polarized signals on the raindrop incidence angle and the rainfall rate for square law and logarithmic estimators [Ohsaki, 1991]. The effect of polarization switching time on the statistics properties of Zdr was also examined in [Ohsaki, 1992]

A dual polarization radar technique was applied to observe anomalous wintertime thunderclouds in Japan. The differential reflectivity factor of the C-band radar discriminated extremely flat, small ice particles and round and/or rotating, comparatively large ice particles. These corresponded to "ice crystals" and "graupel", respectively, both of which play an important role in thunderstorm electrification [Fukao et al., 1991a; Maekawa et al., 1991c]. The lightning locations were seen along the edge of the cloud center with the echo intensities of about 30 dBZ, where the graupel and ice crystal echoes distributed at short range, suggesting the riming electrification and resulting charge separation between the two kinds of ice particles [Maekawa et al., 1992e]. Calibration of a rain radar for satellite slant path of CS-2 or CS-3 was performed with the aid of ground based rain gauge near the earth station of Osaka Electro-Communication University, and the accuracy of rain measurements was slightly improved by correcting characteristics of the receiving amplifier according to the rainfall rate ranges [Miyazaki et al., 1990].

The measurement of linear depolarization ratio (LDR) at X band was conducted from the airborne multi-parameter rain radar which flew over tropical storms in the western Pacific. Very high value of LDR was obtained in the melting layer which suggested the existence of highly aspherical or irregular shaped hydrometeor particles in this height [Kumagai et al., 1991]. The statistical relation among LDR value in the melting layer, dBZ values both at X band and Ka band, and the difference between the two was studied [Kumagai et al., 1992a]. Also, the radiometer data at X and Ka band taken simultaneously in the experiment were analyzed and compared with the radar data [Kumagai et al., 1992b].

Rain rate estimation properties of multiparameter radar measurements combining radar reflectivity and microwave attenuations were studied through simulations using a disdrometer data set [Kozu and Nakamura, 1991]. For the simulation, the concept of the multiparameter measurements was generalized to combine the radar reflectivity profile with a low spatial resolution path attenuation. The simulation result indicated that this type of measurements improved the rain rate estimation accuracy by a factor of 2 to 4 compared with the conventional single parameter measurement.

Rain rates estimated from brightness temperature measured with Microwave Scanning Radiometer (MSR) on board the Marine Observation Satellite 1 (MOS-1) were compared with a satellite-derived index of precipitation intensity (SI) derived from GMS satellite data. Good correlation between MSR- and SI-derived rain rates validated the rain rate retrieval algorithm [Ohsaki and Fujita., 1992].

An influence of ocean surface roughness on microwave passive measurements of rain from an airborne platform was evaluated in [Fujita, 1991]. A two-scale rough surface model was adopted to characterize the microwave scattering signature from a rough ocean surface. The results of computation showed that the nadir-looking configuration minimized the influence of ocean surface roughness on rain measurements. A comparison between the theoretical results and the measurements was also shown.

Because of the short decorrelation time of surface return signals for spaceborne pulse-compression rain radar, it is important to evaluate the decorrelation effect on the compressed waveform of pulse-compression radars. In [Kozu, 1990; 1991], this decorrelation effect for linear FM pulses was quantitatively evaluated through numerical calculations. It was shown that the transmit pulse width should be shorter than half the time at which the auto-correlation function of scattered signal decreased 0.1, in order to keep the decorrelation effect negligible.

Tropical Rainfall Measuring Mission (TRMM) is the first space mission, bearing the first rain radar in space, dedicated to the measurements of rainfall in the tropics where 60 percent of the global rainfall is concentrated [Okamoto and Tanaka, 1990]. Launch operation, mission operation and data processing as well as the system design and development status of the TRMM were presented in [Kozu et al., 1992a]. Rain radar is a key sensor of the TRMM program to obtain a reliable rainfall data set over the whole tropical area. The radar has the minimum measurable rain rate of 0.5 mm/h with a range resolution of 250 m, a horizontal resolution of 4 km and a swath width of 220 km. The conceptual radar design study was conducted by CRL in cooperation with NASA/GSFC. As a result, the active array radar was selected as a reliable candidate , and development of the key devices has been conducted [Okamoto et al., 1990; 1991a; Ihara et al., 1991a; Kozu et al., 1992b; Takamatsu et al., 1992]. Integration of these key devices to compose an 8-element Bread Board Model was made. The basic electric antenna beam scanning function by the switching of the 5-bit digital phase shifter was confirmed. The preliminary measurements of both the transmitting and receiving pattern of the 8-element active array antenna were also made to show good electric performance [Okamoto et al. 1992].

Two rain rate retrieval algorithms for TRMM rain radar were proposed in [Okamoto et al. 1991b]. One is the backscattering method and the other is the attenuation method. These two methods are complementary in the sense that the backscattering and attenuation based techniques perform best at low and high rain rates, respectively. In the attenuation method, the surface reference technique becomes useful over the ocean.

The effects of sea-surface clutter on rain measurements with a satellite-borne rain radar were quantitatively evaluated for the case of the TRMM rain radar [Manabe et al., 1989].

Attenuation and backscatter properties of bright-band particles were examined by a spherical composite dielectric model and by a concentric spherical model. Computations were made at 13.8 GHz, which was to be used by the TRMM space-borne rain radar. It was found that the scattering properties of bright-band strongly depended on models [Awaka, 1992].

A model of precipitation from stratus was examined using the slant-path attenuation and radar data obtained during the ETS-II satellite experiment, and was used to simulate radar echoes expected to be observed from satellite-borne rain radar such as the TRMM rain radar [Hatanaka et al., 1992].

One-minute rain rate and raindrop size distribution measured by a tipping bucket raingage and a disdrometer at Darwin, Australia, were analyzed to characterize the tropical rainfall. It was found that the raindrop size distribution and associated Z-R relation underwent an abrupt shift between the convective and stratiform portions of tropical squall lines. This shift may have important consequences for radar rainfall measurement [Short et al., 1990].

F2.3. Ocean and Sea Ice

Microwave backscatter from the sea surface were measured with a C-band Doppler radar at extremely low grazing angles. Dependence of the received power, the Doppler bandwidth, and the Doppler shift on the wind speed and the wind direction was examined [Iguchi, 1989].

An HF ocean radar was developed by the Okinawa Radio Observatory of the Communications

Research Laboratory (ORO/CRL). The principles of HF ocean radar measurements of ocean currents, surface wind, and wave height were described. Comparison between ocean parameters deduced by the radar and those deduced by in-situ measurements showed a good agreement [Iguchi et al., 1990; Kuroiwa et al., 1992; Hisaki and Tokuda, 1992]. The difficulties in extracting sea-surface information using the existing scattering theory were pointed out in [Iguchi, 1991a]. The design and configuration of HF ocean radar developed at the ORO/CRL were described in [Nozaki, 1991]. The effects of transmit/receive(T/R) switching waveforms on the received signal in Frequency Modulated, Interrupted Continuous Wave (FMICW) radar were examined. Simple square-wave switching was found to have advantages over random code switching for a ground-wave HF ocean radar [Iguchi et al., 1989; Iguchi, 1991b]. Personal computer programs for the automatic observation and the data processing of the HF ocean radar were developed at the ORO/CRL [Umehara et al., 1991a]. Observations of the ocean currents around Okinawa Main Island and Kume Island were made in 1989. Currents measured by the radar and those measured by a research vessel were compared. Diurnal and semi-diurnal tidal currents were analyzed [Ohno, 1991a; Umehara et al., 1991b]. Kuroshio Current observations by the HF ocean radar were carried out at Yakushima and Tanegashima Islands from October to December in 1990. Changes of the current velocities caused by a passing of the Kuroshio were detected by the ocean radar [Ohno, 1991c; Ohno and Tokuda., 1992]. The first-order echoes of the HF ocean radar were examined statistically, and it was shown that splitting of first-order echoes sometimes occurred due to the inhomogeneity of the current within the radar target cell [Nadai, 1992]. Principles of measurements of the wave height and other wave parameters by the HF ocean radar were described in [Iguchi, 1991c; Hisaki, 1992]. Comparison of the measured wave parameters with those measured by ships and wave-buoys revealed some problems of the method to estimate wave parameters by the radar. Sea-surface wind directions were deduced by the Doppler spectra of the HF ocean radar echoes and a passage of a cold-front on the sea was detected by the radar [Ohno, 1991b].

Ground based observation of sea ice by a UHF step-frequency radar was carried out on the sea ice near Syowa Station, Antarctica. This was the first experiment to measure sea ice thickness using a step-frequency radar system. The echoes from snow/ice and ice/water interfaces were clearly detected. The snow depth and ice thickness measured by this radar system showed good agreements with direct measurements [Uratsuka et al. 1989].

A short pulse radar with a pulse width of 1 ns at 4.3 GHz was developed to detect crevasses in front of a snowmobile. A preliminary experiment to measure the distance of plywood boards was made in an anechoic chamber to confirm the fundamental characteristics of the radar. Another experiment to detect a hole dug in the snow pile was made to find out the usefulness of the radar for the crevasse detection [Suitz et al. 1989, Suitz and Uratsuka, 1990].

F2.4. Land, Vegetation and Others

In order to investigate the millimeter-wave scattering properties of various natural and man-made objects, two different types of experimental scatterometers were developed; a 50 GHz cw scatterometer and a 60 GHz polarimetric step-frequency scatterometer [Awaka et al., 1989; Ihara et al., 1991b]. Using the 60 GHz scatterometer, the backscattering coefficients of soil surfaces were measured for different surface roughness conditions. The surface roughness was measured with a laser profile meter. The incidence angle dependence of the measured backscattering coefficient showed distinctive features according to the surface roughness. The results are compared with estimates from a small perturbation theory [Yamasaki et al., 1991; 1992].

An active reflector for SAR calibration, in which the frequency of a received SAR signal was shifted by a certain amount, was proposed. This frequency shift caused a shift of the reflector image in azimuth direction. This function would allow to enhance a signal-to-clutter ratio of the image by moving it onto a radiometrically dark background, and hence it would be possible to use a relatively narrow test site near water surface for SAR calibration [Fujita, 1992].

Dependence of SIR-B image intensity on local incidence angle was investigated to estimate quantitatively topographic effects on SAR imagery. Slope images representing the variation of local incidence angles of a hilly area were compared with the SIR-B images. Based on the topographic effects, backscattering coefficients of the hilly area were estimated and compared with the existing data base [Satake et al., 1992].

(T. Manabe)

F3. Radio Communication

F3.1. Terrestrial Fixed Radio Systems

A new type of passive reflector which can reduce influences of the incident angle fluctuation was presented [Komai, 1991].

The line-of-sight propagation test was carried out on three paths along the seashore in the south part of Ghana using FM microwave radio-relay-link [Yoshikawa et al., 1992].

Several types of diversity systems were examined both theoretically and experimentally. Propagation tests on tilted beam diversity were carried out on several paths. Test results showed its effectiveness on a path with strong reflection [Satoh and Sasaki, 1989].

An prediction method for space diversity improvement was presented. This method was clarified by world wide data [Hosoya, 1990]. A frequency diversity was effective to improve the transmission quality on a path with strong reflection. Its effect in multi-carrier digital radio system was newly clarified [Ichikawa and Murase, 1990]. An estimation formula of the received power space correlation coefficient, which was necessary for designing the space diversity reception system on microwave links, was obtained from amplitude statistics of three rays, path conditions, radio meteorological statistics and so on [Sasaki et al.,1991a]. Multiple diversity reception techniques were summarized including test results of both tilted beam and three antenna diversities [Sasaki et al., 1991b].

A method for estimating the low path visibility is necessary to design a point to multi-point radio communication system which uses mm-wave. The low path visibility can be estimated by using building density, building height distribution and so on [Satoh and Ogawa, 1990].

(E. Ogawa)

F3.2. Fixed Satellite Radio Systems

As for rain attenuation prediction methods, a concept on equivalent slant path was presented and was given by a function of the elevation angle and the point rain rate, and determined using the

CCIR rain attenuation data bank so as to attain the minimum mean-square logarithmic error. The prediction accuracy obtained was comparable to the best one so far presented [Irie, 1990]. Based on the current CCIR data bank on slant path attenuation, a similar formula to the existing CCIR method which covers time percentages of 1.0 to 0.001% was proposed with improved accuracy and expanded application range to 0.0001% [Irie, 1992]. A more improved prediction method characterized by adopting an empirical relation between ratio of rain attenuation for 0.01% of time to that of 0.1% and ratio of rain rate for 0.01% to that for 0.1% was presented [Karasawa and Matsudo, 1990a]. A noticeable improvement of prediction accuracy could be obtained.

Moreover, a countermeasure of rain attenuation by means of onboard resource sharing (ORS) based on dynamic rain information obtained by the AMeDAS data was proposed. Quantitative evaluation of effective rain attenuation effect was conducted a computer simulation [Matsudo et al., 1992]. The effect of the cross-band frequency diversity was evaluated by considering a joint outage probability based on the rain attenuation [Ogawa, 1989]. A method was proposed for the mitigation of attenuation effect on satellite broadcasting systems that use higher frequency bands, by using the time-diversity method. In this method, all of or part of the information was transmitted several times, with certain time delay between each transmission. In order to evaluate the diversity effect, attenuation data at 19.5GHz measured in Japan were statistically analyzed [Fukuchi, 1992a].

Since a continuous measurement system of G/T for a long period is needed to examine the performance of BS receiving systems due to the weather effects, the whole measurement parameters must be measured, controlled and processed by a computer automatically. The development of such measurement system which can measure one or more receiving systems was performed by using a noise estimation method [Purwanto et al., 1992a; b].

In the case of earth-space paths, it was found that there is poor correlation between measured attenuation and XPD because of ice depolarization. This implies XPD prediction error if the theoretical relationship between rain attenuation and XPD is used. A new method of predicting cumulative distributions of XPD taking the ice effect into account by using the factor of 'ice depolarization ratio' was proposed [Fukuchi, 1990]. The applicability of this method was verified by the experimental results. Testing of XPD prediction methods proposed so far was carried out, and quantitative accuracy evaluations were conducted [Yamada and Karasawa, 1990]. The effect of XPD compensation at 4 and 6 GHz through a long-term measurement by using the Intelsat-V satellite was analyzed [Yamada et al., 1990].

(Y. Karasawa)

F3.3. Land Mobile Radio System

A small-section median field strength was measured on the line-of-sight paths in mountaineous area using 280 MHz band. Field strength was around 2 dB-13 dB lower than that of free space [Morita and Nakano, 1989a]. A 280 MHz band regression equation in the mountainous area was given from the relation between measured data and calculation results with knife-edge diffraction model. Mountain diffraction losses were also calculated [Morita and Nakano, 1989b].

A prediction method for mobile propagation loss in urban environments was derived from experiments in Tokyo area. This method was applicable from 450MHz to 2200MHz band [Sakagami and Akeyama, 1991]. By using statistical simulation, formulas for estimating mean propagation loss in terms of base station antenna height, mobile station antenna height, mean building height, mean distance between adjacent buildings and propagation path length were obtained for frequencies of 400, 900, 1500, and 2000 MHz bands [Morita et al., 1991].

Delay profiles were measured in Koganei city, which included both urban and rural areas, and the characteristics of the incident angle of the delayed waves were evaluated by using Doppler spectrum analysis [Ohgane et al., 1991]. The results showed the difference between urban and rural areas. Measurement of delay profile characteristics in the 1.5 GHz band were carried out within a 2 x 1.5 km area in the Tokyo metropolitan area. Measurements in the 775 MHz and 2.3 GHz bands were carried out for comparison with those of the 1.5 GHz band. In the experimental results, the influence of obstacles on the average excess delay was almost the same in the three frequency bands. For the 1.5 GHz band, the mean value of delay spread was 3.0 ms, and in 90 percent of the area it did not exceed 3.9 ms [Sekizawa et al., 1991]. Microcellular multipath characteristics was measured in dense urban [Moriyama et al., 1991], residential [Moriyama et al., 1992c], and indoor environment [Moriyama et al., 1992d]. For dense urban environment, delay spread in microcellular was smaller than for high base station antenna height case. Delay profile shapes observed in most of line of sight area was well fit to the exponential model in dense urban and indoor case, whereas residential, hence echos come from distant building made a ray having large excess delay, the exponential model was not valid.

Measurements for urban microcellular systems when the base-station antenna was mounted below surrounding building heights were made at 1.5 GHz and 2.6 GHz. To determine the dominant rays of line-of-sight propagation characteristics, simple theoretical estimation using geometrical techniques was reported [Iwama et al., 1992]. The total predicting method for propagation characteristics was ale reported. A prediction model were based on a direct ray, specularly reflected rays, diffracted rays and successive combination of reflected and diffracted rays. First, diffracted rays were calculated by knife-edge diffraction theory [Iwama et al., 1990]. Recently, diffracted rays were calculated by geometrical theory of diffraction (GTD) [Iwama and Mizuno, 1992].

A modified classification of variations of indoor propagation was proposed based on the feasible diversity techniques, and propagation characteristics using amplitude distributions were considered [Mizuno et al., 1990]. As a result, short fading, whose period off variation was less than 1.5 wavelength was caused by multipath only, while long fading, whose period was longer than 1.5 wavelength was caused by both multipath and shadowing.

A simple calculation method for worst delay spread caused by reflection obstacles such as building, tower and mountain was derived by considering 2-ray model in mobile propagation [Ooi et al. 1990]. The propagation model and delay profile classification were proposed in order to predict delay spread [Tanaka and Akeyama, 1990]. A propagation model was proposed that can be used to predict delay spread for mountain cities bordered by tall mountains [Tanaka et al., 1990]. Considering the generation mechanism of the fading in land mobile multipath channels, and two kinds of fading (flat fading and frequency selective fading) were distinguished by phenomenon [Ohgane and Sekizawa, 1991].

An experiment showed that the delay spread was effectively reduced by base station antenna beam tilting in urban areas [Kozono and Takeuchi, 1991]. Propagation test results which showed effects of the delay spread on p/4-shift QPSK were reported [Oyama et al., 1992]. Narrowing and tilting of base station antenna beam were examined by theoretical and experimental methods. As a result, the effectiveness in reducing the delay spread was confirmed [Tanaka et al., 1992].

In digital mobile-radio communication systems, to understand the effect of frequency selective fading is very important for assessment of digital transmission characteristics in terms of delay profile, delay spread and correlation bandwidth. For this purpose, a general model for correlation analysis in Nakagami-Rice fading conditions which include Rayleigh fading was developed [Karasawa et al., 1992]. Using this model, the frequency correlation characteristics in typical line-of-sight environments were analyzed. As a multiple access system in future mobile communications, CDMA (code division multiple access) was attracted. For the analysis of near-far problem of CDMA, a wideband fading model characterized by its algorithm applicable to computer simulation was developed [Iwai et al., 1992].

Compared results between wide band and narrow band signals were reported. It showed the received level distribution dependence on band width [Kozono et al., 1990]. Correlation bandwidth in urban mobile radio path was measured and the relation between the bandwidth and propagation parameters was clarified [Sakagami and Kuboi, 1991a]. Recent propagation studies on land mobile radio in Japan was summarized. It also includes propagation studies on land mobile satellite communication systems [Kozono et al., 1991].

In mobile radio environments, the mean effective gain of mobile antennas was analyzed and verified by measurements in actual urban areas [Taga, 1990a]. A measurement method of cross polarization power ratio was proposed. Estimation of the measurement error showed that the method had high accuracy [Taga, 1990b]. Considering the cross polarization power, the correlation characteristics of antenna diversity was analyzed. Measured results in urban areas were agreed well with the calculated ones [Taga, 1990c].

Spatial correlation characteristics of mobile base station antennas was studied by measuring the angle-of-arrival in urban areas [Akeyama et al., 1990b]. A dual antenna experiment was conducted in a Tokyo area to estimate the angular distribution of received waves in the mobile radio environment as a function of position and delay time at 2.3 GHz [Thomas et al., 1992]. The results showed that the proposed algorithm was applied to real propagation situation.

The relationship between the bit error rate and multipath was studied only when the excess delay of the multipath was enough smaller than the bit length of transmission signal. In the evaluation of bit error rate for the case when the excess delay of multipath fading was larger than the bit length, the power of the delayed wave must be considered in addition to the delay spread [Sekizawa et al., 1992].

A method to improve the delay resolution of delay profiles measured by the PN correlation method was proposed [Manabe and Takai, 1992], and was applied to the analysis of indoor radio propagation at 900 MHz and 2.3 GHz [Takai and Manabe, 1991]. Using the high resolition method, delay profile and directional dependence were measured in indoor multipath environments[Matsui, 1992]. Design and implementation of macro cell multipath measurement and reproduction equipments for land mobile radio was developed. With the help of antenna switching controller, the equipment can store data measured by multiple antennas on vertical and horizontal [Moriyama et al., 1992a]. Microcellular multipath measurement equipment having a time resolution of 40 ns was developed. For noise reduction of wideband received signal, real-time averaging by coherent addition was implemented [Moriyama et al., 1992b].

Vehicle positions in multipath environments were estimated from the angle of arrival of waves received by multibeam antennas installed at two base stations. The estimated root mean square position error was about 350m [Sakagami et al., 1992].

In Japan, a project to explore the millimeter-wave high-speed indoor communication system has recently started. The project includes studies on indoor multipath propagation, anti-multipath techniques, and integrated antenna technology at millimeter-wave band. At its first stage, a 60-GHz wideband channel sounder with a delay-time resolution of about 2 ns was developed [Ihara et al., 1992]. The complex refractive index of soda-lime glass which was commonly used as window glass was measured at 60 GHz by a free-space reflection method [Manabe et al., 1992].

A platform, powered by microwaves beamed from the earth, carrying radio equipment and flying in the stratosphere, could be used for radio relay like satellite communications, terrestrial microwave radio relay, land mobile base stations. In the Communications Research Laboratory, applications of the high altitude radio platform (HARP) to telecommunications and remote sensing were studied. Features of mobile radio using the HARP, service coverage of the HARP and cellular configurations were described [Saruwatari, 1990].

Using the method of moment and the wire-grid model, a thin planer antenna performances for a card-sized paging receiver, for example, the polarization switching system, the radiation efficiency versus antenna height, and so on [Ishii and Itoh, 1991] and the wire-grid model performance for the wire radii and grid geometry were estimated [Ishii and Itoh, 1992].

It was shown that the parallel-plate waveguide modes supported by the slot and the reflector had a harmful influence on antenna characteristics such as drastical changes of the radiation efficiency, and input impedance due to the generation of higher harmonic parallel-plate waveguide modes, by using Galerkin's method in spectral-domain [Katsurahara et al., 1992]. The superresolution technique for the time-domain measurements was proposed. Experimental results of the semirigid cable with a dummy illustrate that it has much better capability of resolving signals and analyzing parameters (e.g. reflection coefficient) comparing with the FFT and gating technique [Ogawa et al., 1990]. Especially, the MUSIC (MUltiple SIgnal Classification) - MSSP (Modified Spatial Smoothing Preprocessing) reveals outstanding performance. And it is mentioned the effect of frequency dependent reflections and distributed reflections [Yamada et al., 1991]. This technique can be used for the antenna measurements and scattering studies [Ogawa et al., 1991]. The generalized matrix formula for scattering mechanism extraction was derived for diffraction coefficient estimation of each scattering center with narrow frequency bandwidth data [Yamada et al. 1992]. Furthermore, the MUSIC algorithm accompanied with the FFT and gating techniques for improving signal-to-noise ratio can saves the number of snapshots, then it can be useful especially for antenna pattern measurements [Ogawa et al., 1992b].

It reviewed four basic adaptive antenna theories, an LMS adaptive antenna reduced the interference signals by minimizing the square error. A DCMP adaptive antenna and a Howells-Applebaum adaptive antenna were used when the arrival direction of the desired signal was known at a receiver. A power inversion adaptive antenna can be used for cancelling very strong interference signals [Ogawa and Kikuma, 1992]. Complex weights were determined by a sample matrix inverse method. Namely, a correlation matrix and correlation vector estimate using training symbols, and then the optimum complex weights obtained directly solving simultaneous equations. This method solved the convergence problem inherent in the adaptive array based on the conventional gradient techniques [Ogawa et al., 1992c]. Training codes used for the reference signal which was known at a receiver. After the training period, detected codes use for the reference signal. It showed the proper behavior of the LMS adaptive array with the above reference signal generator in computer simulations. In addition to the multipath fading reduction, we can improve a signal-to-noise ratio by the diversity technique [Ogawa et al., 1992a].

Recently, a new architecture for adaptive array antenna was proposed. The basic function was formulated as a recursive least squares minimization operation under the condition of the linear direction constraint. This algorithm can be implemented using a pipelined architecture in the form of a triangular systolic array processor (SAP). This paper presented interference and multipath suppressions of adaptive array antenna with SAP in several signal environments using numerical simulation and then discusses them [Ohmiya et al., 1992a; b].

(E. Ogawa)

F3.4. Mobile Satellite Radio Systems

As for multipath fading due to sea surface reflection in maritime mobile satellite systems (MMSS), a new model for analysis of frequency correlation statistics was presented [Karasawa, 1989]. Using this model, various transmission path models such as three- and four-path models were proposed. Various kinds of diversity techniques for multipath fading reduction were examined taking the correlation characteristics, such as space correlation and frequency correlation, into account [Yasunaga et al. 1989]. Effects of 1.5GHz multipath propagation over the sea and land in aeronautical mobile-satellite systems (AMSS) were analyzed [Karasawa et al., 1990]. For some parameters, validity of theoretical estimates was examined through comparison with experimental data obtained aboard a helicopter. A simple prediction method of multipath fading due to sea surface scattering for MMSS and AMSS for engineering application was developed [Yasunaga and Karasawa, 1990]. The method was evaluated by the theory and measured data reported so far, and the good accuracy over wide range of parameters was identified. A new fading reduction scheme for sea surface reflection applicable to Inmarsat-C was proposed [Iwai et al., 1991]. This method combined with an open-loop space diversity, forward error correction scheme (FEC) and an interleaver overcomes disadvantages generally associated with a conventional diversity system.

Concerning inter-satellite interference evaluation, effect of propagation when both wanted wave and unwanted wave are affected by multipath fading must be very important. For this purpose, a rigorous theoretical method for predicting C/I and C/(N+I) where both C and I are in Nakagami-Rice fading conditions was presented [Karasawa and Yasunaga, 1992]. An alternative simple prediction method which is more suitable for engineering application was then proposed. Prediction errors of the simple method was evaluated by using the ETS-V experimental data.

In land mobile satellite communications, signals to and from a satellite are affected by surrounding features such as buildings, trees, terrains and so on. Experimental and theoretical discussions on amplitude and phase variations of received signals when a land vehicles passing near a utility pole were presented [Tanaka et al., 1990].

(Y. Karasawa)

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