

NOTICE

The following report on researches appear in the "Review of the Radio Research Laboratories" (Japanese edition) Vol. 24 No. 131 December 1978.

PART I. GENERAL

In the Part I of the special issue on Medium Capacity Communications Satellite for Experimental purpose (CS) and Medium Scale Broadcasting Satellite for Experimental purpose (BSE) projects, general historical background and trend of both communication satellite and broadcasting satellite from global view-point are described.

The summaries of each CS project and BSE project are followed. They include the purpose of project, history, organization, items of experiment, satellite function and its performance, ground station and communication link budget.

PART II. MAIN FIXED EARTH STATION OF CS PROJECT

Main Fixed Earth Station of CS project is located at Kashima Branch of Radio Research Laboratories and acts as the central ground station among the fixed and mobile stations in the organization of CS project.

Following the summary of the function and performance of the facilities of the station, details of each of them are presented. Those are antennas, transmitters and receivers of K band and C band, terminal equipments for communication experiments and satellite control equipments and its softwares.

PART III. MAIN TRANSMIT AND RECEIVE STATION FOR BSE PROJECT

Main Transmit and Receive Station, MTRS, is the key station among various earth terminals used in satellite broadcasting experiments in the program of Medium-scale Broadcasting Satellite for experimental purpose, BSE.

This paragraph presents functions and characteristics of the MTRS. MTRS can transmit and receive two channels of color TV signals simultaneously in FM or PCM-PSK modulation.

The station consists of 13 m antenna, K band transmitters/receivers and TV signal processing terminal equipments. It has also TT&C system and its computers.

PART IV. COMMON FACILITIES

Main Fixed Earth Station for CS and Main Transmit and Receive Station for BSE are at a same building in Kashima Branch. The facilities described in the Part IV are commonly used for CS and for BSE.

Those facilities include experiment data processing and editing system, standard clock, communication networks between facilities in the building and between the laboratories and other organizations.

Rain Radar, building and air-conditioning/power supply are also presented.

PART V. FACILITIES OF THE RADIO WAVE OBSERVATORIES

The Radio Wave Observatories of the Radio Research Laboratories joined the CS and BSE projects and the equipments for the projects were or are being provided.

Wakkanai Radio Wave Observatory located at north end of the Japanese main lands is equipped with 20 GHz receiver for CS signal strength measurement and BSE TV signal receiver.

Single channel per carrier (SCPC) transmitter/receiver and signal strength measuring equipment for CS and BSE TV signal receiver are provided at Yamagawa Radio Wave Observatory located at south end of the main lands.

The following report on researches appear in the "Review of the Radio Research Laboratories" (Japanese edition) Vol. 25 No. 132 March 1979.

THE RELATION BETWEEN NQ AND SNR METHODS FOR THE MEASUREMENT OF SENSITIVITY AND SELECTIVITY IN FM MOBILE COMMUNICATION RECEIVERS

Yoshiaki ICHINO and Wa SHIOBARA

To test the appliance to be registered as a type approval, the NQ method has been applied for measuring the sensitivity and selectivity in FM mobile communication receivers. On the other hand, the change for the SNR method after investigating problems and the conversion method for value measured had been already proposed by Mrs. Takahira and Kawakami.

This paper mainly describes the conversion of measuring value of sensitivity and the investigation of problems therein, in which the values by the NQ method are proved in suitable condition to show the almost same ones by the SNR method. The values of NQ method are apt to be affected by rippling of IF filter than SNR method itself, and this

effects by the degree of modulation are to be negligible in case of modulation of which degree exceeds 50% in its rated value.

THE EXPERIMENTAL RESULTS ON THE SHORTED BOUNDARY EDGE-GUIDED-MODE ISOLATOR

Chihiro MIKI, Kiyomichi ARAKI and Yoshiyuki NAITOH

In the recent communications, according to the demand increased and its variety, the frequency bands used have been extended to the higher frequency region and the circuits in systems tend to be configured by solid state devices. An isolator is one of the indispensable devices in the circuits. The isolators in the past, those of wave guide types with large dimensions and of concentrated constant types with complex structure were to be available. Since irreversible devices based upon the edge guided modes (EGM) on strip lines on ferrites bases was reported by Hines (1970), they have attracted attentions and have been developed by many researchers.

As for the isolators proposed by him, directional characteristics are obtained by using some resistors for the reversely propagating signal. These characteristics are also obtained by the technique of shorting one side of strip lines which is proposed and theoretically clarified by Araki et al. (1974). This technique gives superior characteristics especially in directional one, Comparing with the devices in the past, this device is so simple in the structure and so small in size that it is suitable to be adopted in solid state circuits.

By measuring the distribution of electromagnetic field intensities on the lines when the fields propagates through the shorted boundary type EGM isolators, these devices are ascertained experimentally to perform as isolators. Moreover, by varying the shorted positions, line widths, and shorted line lengths, their effects on the insertion loss, reverse loss, and frequency band width are examined. Since these characteristics are, however, not sufficient for an isolator, deformation of the static magnetic fields applied is attempted to improve frequency characteristics and especially VSWR of the device. Consequently, we obtained the shorted boundary type EGM isolator whose characteristics are of frequency band of 1.3–2.0 GHz, insertion loss of 2.3 dB, reverse loss of 23 dB and VSWR of less than 1.08.

The value of VSWR of which improvement is the principal object, is less than 1.08 over the very wide frequency band and satisfies the target value. This value obtained is incomparatively superior to that of various existing isolators.

There still remains some dissatisfactions in other characteristics of the device, but they will be easily overcome by selecting appropriate materials and developing the manufacturing techniques.

A METHOD OF CONTROLLING ORBITS OF GEOSTATIONARY SATELLITES WITH MINIMUM FUEL CONSUMPTION

Kozo TAKAHASHI

The orbital angular velocity of a stationary satellite is considered to express the perturbation on an orbit of the satellite, and to induce the fact that the minimum variation in direction of this velocity agrees with the minimum fuel consumption to maintain a stationary satellite within allocated bounds. The directional variation of the orbital angular velocity is kept minimum by maintaining the ascending node of the orbit in direction of about the vernal equinox. The direction of the ascending node with minimum fuel consumption to maintain the orbit are given over 18.6 year nodal period of the moon, over which period the inclination variation of the orbit and the angular speed proportional to the necessary amount of fuel to maintain the orbit are also given. The method in this paper is applicable to the geostationary communication satellite, UHF broadcasting satellite, solar power satellite, etc.

A CONFIGURING OF AUDIOBAND CPFSK-DIFFERENTIAL DETECTOR AND THEIR ERROR RATE CHARACTERISTICS COMPARING WITH PSK-COHERENT DETECTION

Ken IWASAKI

An audioband CPFSK-differential detector has been made by assembling a VCO, a BBD, a multiplier, and an active filter.

Three kinds of bandpass filter have been prepared which filter has BT product of 1.34, 0.97, and 0.65, respectively.

As compared with these error rate characteristics, CPFSK with modulation index 0.7 has been about 1 dB superior to that with the index 0.5, but about 2 dB inferior to PSK-coherent detection.

GENERALIZED FORMULA OF THE EFFECTIVE HEIGHT ON VERTICAL RECEIVING-ANTENNAS

Ryosuke INOUE

Being put an electromagnetic field, the linear antenna has following functions: One is re-radiating where terminals are shorted as reflector, director and arbitrary conductor etc. and other is receiving where the terminals have load. Then, those antennas can be called as "Receiving-antennas" generally.

First, the current distributions of Receiving-antennas can be obtained as the solutions of linear wave equation in distributed constant line problem where distributed emf excited by

electrical field practically.

By the terminal and approximate conditions for its solutions, the current distribution in the case of re-radiation can be expressed as the cosine wave distributions which a pedestal, and the current distribution in receiving case as single sine wave distribution.

Second, the generalized formulas of effective height of vertical Receiving-antennas on the ground are obtained by employing those current distributions.

For example, when antenna length equals to odd times of $\lambda/4$, both effective heights have same formula. But in the case that receiving antenna equaling to $\lambda/8$, effective height is about 2 dB (0 dB/1 m) less than that in the case of re-radiating, independently the elevation angle.

In this report, an outline of those analytical results is described together with a few numerical examples.

A TECHNIQUE OF MEAN ATOMIC TIME SCALE GENERATION BY CESIUM CLOCKS

Michito IMAE

This paper presents a technique to generate Atomic Time Scale by several commercial cesium clocks which are continuously operating at Radio Research Laboratories.

There are several technique to generate Atomic Time Scales, which are based on number of clocks, clock modeling, and others.

Our technique is the following: We divide the fluctuation of each clock into two parts, long term part and short term part, and make weighted average of each part, then determine the Atomic Time by the combination of these two weighted averages.

An example of computer simulation of this technique shows comparatively good long term stability. And we applied this technique to the raw clock data. The result of rough estimation of stability of it shows a frequency of $2 - 4 \times 10^{-14}$ for 10-60 day averaging.

IONOSPHERIC PLASMA PROPERTIES AROUND THE SOUTH ATLANTIC GEOMAGNETIC ANOMALY REGION BY THE SATELLITE TAIYO-RPA OBSERVATIONS

Shigeru MIYAZAKI

The aeronomy satellite TAIYO observed the ionospheric plasma in the altitudes 250 km-3100 km in the low latitudes of $\pm 31^\circ$ during a period of minimum solar activity, 1975-76. The observational results indicate that there exist very frequently high energy components in electrons and ions of the ionosphere over the longitude region. $250^\circ\text{E}-0^\circ\text{E}-80^\circ\text{E}$ in the daytime and the nighttime. The altitude range of the region in which there exist non-thermal components of the plasma reaches to about 800 km or more. And this longitude region coincides with the region in which peculiar phenomena are observed by other TAIYO

instruments and many other satellite observations.

The following report on researches appear in the "Review of the Radio Research Laboratories" (Japanese edition) Vol. 25 No. 133 June 1979.

**BROADCASTING ANTENNA FACTORS FOR CORRECTION OF FIELD
STRENGTH OF MF BROADCASTING RADIO WAVES
MEASURED BY A MOBILE EXPERIMENT**

Ryosuke INOUE

In order to measure the night-time MF field strength over long distance, a mobile experiment was carried out on board a ship rounding the Pacific Ocean area, from June through November 1973.

The correction of measured field strength with respect to the broadcasting antenna directivity is very important in the mobile experiment in which the direction of radio ray paths change from time to time with the movement of ship.

Thus the transmitting antenna directivities for 26 broadcasting stations were calculated analytically, and then the antenna correction factor of field strength was derived numerically, and then the antenna correction factor of field strength was derived numerically along propagation paths for each broadcasting station.

This paper describes mainly the outline of derivation of the antenna correction factor, and introduces propagation curves of the night-time field strength thus corrected.

**TRANSIENT IONOSPHERIC RESPONSES TO GEOMAGNETIC
STORM SUDDEN COMMENCEMENTS**

Takashi KIKUCHI

A geomagnetic storm sudden commencement, called SSC, often accompanies a reverse impulse preceding the main increase. This impulse named preliminary reverse impulse (PRI) appears predominantly in the afternoon-side high latitudes and at the dayside dip equator. The possibility of occurrence of PRI due to the transient response of the ionosphere to the magnetic increase incident vertically from the magnetosphere has been examined analytically by assuming that the ionosphere is uniform and the incident magnetic field varies in the form of a step function of time. When the magnetic increase propagates vertically through the ionospheric E-region where the current responsible for the PRI flows, its mode becomes the diffusion under the equatorial condition, and the Schrödinger-type wave under the polar condition. The westward current associated with the diffusion mode in the equatorial E-

region can never be the primary source for the equatorial PRI, but it causes ionospheric screening effects on the incident magnetic increase. In the polar E-region, northward Hall currents are generated, which will be the primary source for the high latitude PRI.

From the viewpoint that the equatorial PRI is caused by the electric field transmitted instantaneously from the polar ionosphere to the equatorial ionosphere, the possible mode for the horizontal transmission has been examined by assuming that the polar electric field is transmitted one-dimensionally in the E-region. When the same solution for the transient response of the uniform E-region is applied, the propagation time of the polar ionospheric electric field impressed suddenly from the magnetosphere requires more than one hour to make observable magnetic effects at the equator, and if the polar electric field varies with time scale of SSC, the propagation loss is so great that the polar electric field can not be transmitted to the equator.

It has been verified that the instantaneous transmission of the polar electric field to the equator is caused by a mode propagating in the Earth-ionosphere waveguide. Two modes, TE (Transverse Electric) and TM (Transverse Magnetic), are excited in the Earth-ionosphere waveguide by the westward polar electric field and by the westward magnetic field due to the northward Hall current generated in the polar E-region, respectively only, the zeroth-order TM (TM_0) mode is instantaneously propagated from the pole to the equator without propagation loss, accompanying the westward electric field in the ionosphere. Consequently, the polar electric field is instantaneously transmitted to the equator by the TM_0 waveguide mode. Since the TM_0 mode has no lower cutoff frequency, both the transient and quasi-static electric fields can be transmitted, which results in occurrence of PRI and DP2 geomagnetic variations at the equator. Even when the hydromagnetic (HM) region above the E-region is taken into consideration, effects of the HM region on the propagation of the TM_0 mode is negligible. It should be noted that the ionospheric electric field transmitted from the polar ionosphere is propagated upward into the HM region along the magnetic lines of force.

The electric field transmitted from the magnetosphere to the polar ionosphere has a small scale compared with the distance from the pole to the equator, allowing for the convergence of the geomagnetic lines of force. The finite scale of the polar field causes geometrical attenuation of the transmitted electric field. Letting the scale of the polar electric fields of the PRI and DP2 be 4000 km and the propagation distance be 10000 km, the intensity of the ionospheric electric field at the equator reaches about 10% of that of the polar field. The disappearance of PRI at low latitudes can be explained in terms of the geometrical attenuation of the transmitted electric field, but the PRI appears at the dayside equator because the dayside ionospheric conductivity is anomalously enhanced in the equatorial region.

It is concluded that most of the characteristics of the PRI and the other geomagnetic disturbances characterized by the enhancement in amplitude around the dayside dip equator are interpreted in terms of the polar originated ionospheric electric field transmitted by TM_0 mode in the Earth-ionosphere waveguide. It is suggested that the direct current flows from the magnetospheric source region to the dayside equatorial ionosphere via the polar ionosphere, and that the magnetospheric electric field can penetrate the plasmasphere by way of the Earth-ionosphere waveguide, when a large scale electric field is generated in the magnetosphere.

A NEW STABLEPULSE-SYNCHRONIZATION DEVICE USED IN LONG-TERM RECEPTION OF LORAN-A SIGNALS

Choshiro NEMOTO

In the propagation experiment through long-term reception of Loran-A sky-wave signals, the conventional AFC circuit for synchronized reception shows unsatisfactory response in the presence of strong interference and noise.

This paper describes a new stable pulse-synchronization device including automatic switching circuit, in comparison with the conventional system. Effectiveness of the device is envisaged through evaluation experiments.

The new device is expected to be applicable to the pulse synchronization reception for other purposes as well.

DEVELOPMENT OF THE MULTIPLEXED-DIGITAL-SSRA EQUIPMENT AND ITS APPLICATIONS EXPERIMENTAL PLAN

Mitsuo YOKOYAMA, Hideichi SASAOKA, Naokazu HAMAMOTO
and Shigetoshi YOSHIMOTO

This paper introduces the aim in the development of the new digital-SSRA (Spread Spectrum Random Access) system and its solution of how the aim being implemented to the new SSRA equipments. Experimental plan of the developed SSRA system using the Japanese Medium-capacity Communications Satellite for Experimental Purpose (CS) and its link budget are also introduced.

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AN APPROACH FOR ESTIMATING PHASE ERRORS OF A RADIO INTERFEROMETER DUE TO SECONDARY WAVES

Masaharu FUJITA

A phase error of a radio interferometer due to secondary waves is discussed statistically. As phases of secondary waves at each antenna may vary largely to a certain reference, those can be regarded as random variables. Therefore, these phases are assumed to have a uniform probability over a range of $[0, 2\pi]$ and to be independent of each other at two antennas. Under this assumption, rms values of the phase error are calculated with numerical

technique. With considerations on a probability density of the phase error, not only reducing secondary wave suppression ratios but also equalizing them are important to minimize phase errors due to secondary waves. A case in which the secondary wave can be regarded as a plane wave is also discussed in comparison with the previous case.

A BASIC EXPERIMENT ON THE SYNCHRONIZATION DETECTION OF SPREAD SPECTRUM COMMUNICATIONS

Ken IWASAKI and Yasuo KADOKAWA

In the spread spectrum communication systems, a desired signal must be differentiated from the undesired signals or noises occupied the same frequency band.

For this purpose, synchronization of PN code generated in the receiver is required. In this paper, regarding undesired signals or noises as interference, experimental results on the synchronization detection of receiver are described with relating to the given signal-to-interference ratios (SIR). In this experiment, 4-stage PN signal is added as interference signal at baseband stage.

Results are summarized as follows:

- (1) To make error rates of synchronization detection sufficiently small, SIR larger than -12 dB is necessary when a code length is 511 chips, and required values of SIR vary with code length rating as -3 dB/oct.
- (2) Full length auto-correlation seems to be slightly preferable to the same length partial auto-correlation.

A PREDICTION METHOD FOR SUNSPOT ACTIVITY

Masaru ICHINOSE, Rikio MAEDA and Shoichi ITO

A revised McNish-Lincoln prediction method for the sunspot number has been programmed for computer operation. The optimum prediction coefficients are obtained and used in the revised prediction which estimates the 12-month running means of monthly sunspot numbers. The observed values in the 10 solar cycles since 1855 were used to calculate the prediction coefficients, and those in the current 20th solar cycle were compared with their predicted values. The results show that predicted values agree fairly with observed ones except in the starting and fluctuating epochs of sunspot activity.

CHARACTERISTICS ON E_s PROPAGATION BY OBLIQUE IONOSPHERIC SOUNDING EXPERIMENTS

Ichizo NISHIMUTA and Kenji SINNO

Oblique radio propagation experiments on Iioka-Okinawa (distance 1550 km) and Yamagawa-Okinawa (625 km) by using variable stepped frequencies from 4 to 64 MHz, were carried out during the selected four periods in 1975-1976.

Occurrences of top frequency of E_s mode in oblique ionograms are studied in relation with the vertical ionograms obtained at Yamagawa.

It is found that the top frequency is approximately related to so called the secant law based from vertical soundings, f_oE_s . However, the better relation is introduced by additionally use of f_oE_s instead of only f_oE_s .

INTERFERENCE OF VHF COMMUNICATION SERVICES DUE TO IONOSPHERIC SPORADIC E

Katsumi KITAMURA and Tokuji KOIZUMI

Disturbance records in the broadcasting service collected from a number of stations show that anomalous propagation of the VHF band due to E_s layers causes crucial disturbance to mobile and broadcasting services. In this report some consideration about the relation between these records and E_s layer activity in the middle latitude is presented and also discussion is given for its prediction method.

The following report on researches appear in the "Review of the Radio Research Laboratories" (Japanese edition) Vol. 26 No. 137 March 1980.

EQUIPMENTS AND RESULTS OF IONOSPHERIC MODULATION EXPERIMENT DUE TO LORAN-A RADIO WAVE

Kaoru ISHIZAWA, Shoichi ITO and Rikio MAEDA

In order to survey spatial distributions of electron density, collision, temperature and energy loss in the ionospheric D-layer, ionospheric cross-modulation detectors have been made on trial. Detection objectives are radio wave amplitude and phase modulations due to electron non-linear phenomena in the ionosphere where the cross-modulation is generated on a radio wave passing the D-region heated by another high power radio wave. The radio navigation LORAN-A wave transmitted from Hasaki ($35^{\circ}49'N$, $140^{\circ}47'E$) was regarded as a

heating wave incident obliquely to the ionosphere at which a wanted wave is reflected. On the amplitude modulation experiment in December of 1972, the transmitter and the receiver were located at Koganei ($35^{\circ}42'N$, $139^{\circ}29'E$) and Murayama ($35^{\circ}45'N$, $139^{\circ}24'E$), respectively. The transmitter and receiver, however, were located at Koganei on the phase modulation experiment from August to October of 1976. It was found with the vertical distribution of the cross-modulation that the maximum amplitude and phase modulation coefficients are given at heights of 82 km and 75 km, respectively. These values determined from the observation are consistent with those calculated by means of the probable models of the ionospheric electron density and collision. The ionospheric cross-modulation, especially amplitude modulation was easily measured at a place and a time where radio noises are negligible. It is desirable that detection of the ionospheric cross-modulation will be carried out separately about the amplitude and phase receptions for the ordinary and extraordinary modes.

ON THE DIFFUSION EQUATION DERIVED FROM THE SPACE-TIME TRANSPORT EQUATION (I)

Koichi FURUTSU

The diffusion equation is derived from the ordinary space-time transport equation having a scattering cross section of the form $\sigma(\Omega \cdot \Omega')$, Ω and Ω' being the azimuth vectors of incident and scattered waves, and the condition of applicability is examined in detail. The boundary equations on a surface of medium discontinuity are also derived. These results are compared with those of recent paper on the same subject, and the origin of a few significant differences is shown to be at an extended use of equations beyond the range of validity of approximation in the latter.

ON THE DIFFUSION EQUATION DERIVED FROM THE SPACE-TIME TRANSPORT EQUATION (II)—CASE OF ANISOTROPIC RANDOM MEDIA

Koichi FURUTSU

The diffusion equation is derived from the ordinary space-time transport equation with an arbitrary scattering cross section $\sigma(\Omega | \Omega') \neq \sigma(\Omega' | \Omega)$. After various equations are Fourier transformed with respect to the space-time coordinates, the transport equation is shown to be reduced to an integral equation of Fredholm type with respect to the angle of scattering, while the variables of Fourier transformation are kept to be constant. The solution is then expanded in the eigenfunction series and, under the diffusion condition, its convergence of series is generally good enough to keep only the first term of the series except for the case where the waves are scattered mostly in forward direction, as in turbulent air. The boundary conditions on surface of medium discontinuity are also obtained based on the equation of continuity of each of the eigenfunction components.

REFLECTED AND TRANSMITTED PULSE FORMS OF A PLANE WAVE PULSE INCIDENT UPON A SCATTERERS SLAB—AN APPLICATION OF THE DIFFUSION EQUATION

Shigeo ITO and Koichi FURUTSU

In the previous papers, the diffusion equation was derived from the ordinary space-time transport equation, and the corresponding boundary conditions on a surface of medium discontinuity were also obtained. In this paper, the theory is applied to evaluate the reflected and transmitted wave intensities of a plane wave pulse incident upon a scatterers slab and the pulse shapes are displayed for a wide range of parameters. In both case, the pulse waves are found to decrease exponentially with the time t in the asymptotic domain, even when the scatterers have non-absorption, and this forms a marked contrast to the case of semi-infinite or infinite scattering media where the intensities decrease by the factor $t^{-3/2}$. An expression for average pulse width is obtained analytically for the pulses transmitted through the scatterers slab and is given as a function of the mean cosine of the scattering angle, optical thickness, and absorption cross section. The expression obtained for pulse width, with a reasonable value of absorption cross section, seems to show good agreement with Bucher and Lerner's experimental results concerning optical pulse propagation through thick clouds, as compared with any other recent analytical theories.

DISTORTION EFFECT FOR AN ANTENNA BY ABOVE DECK STRUCTURES

Shingo OHMORI, Atushi IRIMATA, Hisashi MORIKAWA,
Kimio KONDO, Yoshihiro HASE and Shuichi MIURA

The communication between a satellite and a ship may be degraded by the presence of masts, wires and similar obstacles above the deck. Particularly in case of small ships, whose capacity is about 30 tons, on which we have been planning to equip small antennas, whose gain is about 14 dBi, blocking effects caused by above deck structures will not be negligible by the reason that we can not avoid setting the antenna near the obstacles because of narrow space above the deck and that the low gain antenna has a main beam of a broad width.

The blocking effect for the antenna by a mast which is regarded as a typical superstructure is investigated theoretically. Scattering patterns of co-polarization and cross-polarization are calculated in each case of varying the diameters of the mast and the elevation angles.

As a result it has been made clear that the blocking effect caused by a co-polarization component of scattered waves can not be neglected when the obstacle has a diameter comparable with the wave length and the effect depends on a distance between the obstacle and the receiving antenna. For example in the case of a mast which is 30 cm in diameter, about 5 m distance will be required between the mast and the antenna to suppress scattering waves to 10 dB-17 dB down in magnitude with respect to direct waves in the shadow regions behind the mast.

In recent years a technique of ferrite coating to suppress scattering waves has been proposed and the effects have been confirmed experimentally and theoretically only when the diameter of the cylinder is small enough compared with the wave length.

However in the case of thick cylinders we have now considered, it has been made clear that the ferrite coating method has no effect to suppress scattering waves to the forward direction.

SATELLITE SYSTEMS FOR LAND MOBILE COMMUNICATIONS

Takashi IIDA

The satellite for land mobile communications is supposed to have a large antenna and a high power output by the reason of a large number of direct accesses to the satellite by the individual small terminals. Hereupon following two systems are proposed; (i) the independent system, which can accommodate 400 000 mobile radios by using the 8 GHz band, and whose satellite weighs about 2000 kg and has a multibeam 8.7 m dish antenna, and (ii) the complement system to the terrestrial urban mobile radio network, which can accommodate 50000 mobile radios by using the 900 MHz band, and whose satellite weighs about 800 kg and has a 14.5 m dish antenna. These systems are examined by considering the satellite cost as a function of frequency. As a result, the 900 MHz band of the system (ii) establishes minimum satellite cost frequency, but the 8 GHz band of the system (i) is higher frequency than minimum satellite cost frequency. Then parameters of the system (i) are reconsidered and the antenna gain of 6 dB for mobile radios is adopted to realize reasonable satellite cost.

VLBI AND CLOCK SYNCHRONIZATION

Michito IMAE

For VLBI (Very Long Baseline Interferometry) experiments, precise synchronization between local oscillators used at both sites is necessary.

So this paper presents a review of several clock synchronization techniques. Main part of it is about clock synchronization by artificial satellites, including the RRL's present condition.

And a principle of time comparison by VLBI is also described.

The Following report on researches appear in the "Review of the Radio Research Laboratories" (Japanese edition) Vol. 26 No. 138 June 1980.

PROPAGATION EXPERIMENT PROGRAM AT MILLIMETER WAVES

1. Outline of the Program

Yoji FURUHAMA, Katsusuke TOHMA, Katsumi KITAMURA,
Toshio IHARA, Yuji IMAI, and Hiromi YAMAMOTO

This article is concerned with propagation experiment program at frequencies above 40 GHz which has been conducted in RRL since 1977. Outline of propagation characteristics of radio wave through the atmosphere, guiding principle to design experimental systems, and concept of remote sensing in measuring path-averaged raindrop size distribution are introduced.

PROPAGATION EXPERIMENT PROGRAM AT MILLIMETER WAVES

2. Transmitter and Receiver System

Toshio IHARA, Yoji FURUHAMA, Katsusuke TOHMA,
Katsumi KITAMURA, and Yuji IMAI

In order to make clear the propagation characteristics of radio waves above 40 GHz through the atmosphere, especially the effects of precipitation, RRL has conducted the propagation experiment at millimeter and centimeter wave bands, assigned to four frequencies of 81.8 GHz, 34.5 GHz, 11.5 GHz and 1.7 GHz in the "atmospheric windows", since April 1979.

Transmitter and receiver subsystem, basing on a multi-frequency phase lock, is one of five subsystem which configure the whole experimental system. Copolar attenuation, cross polarization discrimination, and phase difference between two frequencies can be measured by this system.

In this paper, the construction, characteristics, and functions of this system are described.

PROPAGATION EXPERIMENT PROGRAM AT MILLIMETER WAVES

3. Raingauge Network and Meteorological Instruments

Katsumi KITAMURA, Yuji IMAI, Toshio IHARA, Yoji FURUHAMA,
Katsusuke TOHMA, and Hiromi YAMAMOTO

Rapid-response raingauges and their data collection network, and also meteorological instruments are introduced for the millimeter wave propagation experiment. Outline of these systems and their characteristics are briefly reviewed.

PROPAGATION EXPERIMENT PROGRAM AT MILLIMETER WAVES**4. Instruments of Raindrop Size Measurement**

Katsusuke TOHMA, Toshio IHARA, Yoji FURUHAMA,
Katsumi KITAMURA, Yuji IMAI, and Hiromi YAMAMOTO

Various methods of raindrop size measurement are reviewed. A microphonic device sensitive to momenta of falling raindrops is elaborated on together with its calibration methods.

PROPAGATION EXPERIMENT PROGRAM AT MILLIMETER WAVES**5. Data Acquisition and Processing System**

Toshio IHARA, Yoji FURUHAMA, Katsusuke TOHMA,
Katsumi KITAMURA, and Yuji IMAI

Millimeter wave suffers from large attenuation and depolarization on propagating through rain. In order to make clear statistically, the propagation characteristics of radio wave relating to the characteristics of rain, RRL has conducted the propagation experiment at millimeter and centimeter wavelengths, since April 1979.

Data acquisition and processing system is one of five subsystems which the experimental system consists of. The whole experimental data can be automatically collected by this system using minicomputer and are recorded on a digital magnetic tape. These data are analysed easily by means of the main computer system of the RRL.

This paper describes the construction, characteristics, and functions of the data acquisition and processing system, and also describes a problem concerning the data analyses by means of the main computer of the RRL.

DEVELOPMENT OF RADIO ACOUSTIC SOUNDING SYSTEM (RASS)

Madoka FUKUSHIMA, Kin-ichiro AKITA and Yoshihisa MASUDA

A transportable RASS for remote measurement of temperature in the lower atmosphere was developed by the Radio Research Laboratories (RRL). The RRL RASS is composed of a 445 MHz CW Doppler radar with two 3 m ϕ paraboloidal antennas and a tone burst transmitter with a 1.5 m ϕ paraboloidal antenna. By using this system RASS design considerations were clarified and sample data of real-time atmospheric temperature profiles up to the height of several hundred meters, occasionally to 1200 meters were obtained.

SIGNAL ENHANCEMENT OF UHF TV WAVE DUE TO THE OCCURRENCE OF INVERSION LAYERS: A CASE STUDY

Madoka FUKUSHIMA, Kin-ichiro AKITA and Yoshihisa MASUDA

A good agreement was obtained between high radio fields of UHF TV waves on the overland path of 117 km between Choshi and the RRL and the occurrence of the atmospheric temperature inversion layers over the path which were observed by the RRL sodar of movable type. In this radio link, it may safely be deduced that the occasionally high signal is caused by ducting mode propagation through a partial radio-duct occurred over the path.

MUF SHORT-TERM PREDICTION IN JAPAN AREA BY IONOSPHERE SOUNDING SATELLITE DATA

Masaru ICHINOSE, Rikio MAEDA and Shoichi ITO

A short-term prediction of the maximum usable frequency (MUF) has been tried for communication circuits in Japan area where a statistical relationship between the ionospheric and geomagnetic activities was used in prediction calculation. Regression constants of the relation was determined by a minimax method using the data obtained on the topside and bottomside of the ionosphere as to every segment of time and space where Japan area was divided into ten meshes, and was also applied to a diurnal MUF prediction during the coming week. The MUF prediction was successfully made for the Tokyo-Hakodate circuit in the period from May 2 to May 5, 1978 when a large geomagnetic storm occurred.

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PROBABILITY OF COLLISION AND METHODS FOR COLLISION AVOIDANCE OF STATIONARY SATELLITES

Kozo TAKAHASHI

The collisions between stationary satellites, including those of a stationary satellite with abandoned stationary satellites which have the nearly synchronous and relatively large inclination orbit, are discussed. The general formula for calculating the probability of the three dimensional collision is introduced by the use of arguments which are the three dimensional

size of satellites, orbital bounds, number of satellites and time. The numerical calculation shows that the probability is negligibly small in case of the satellites with comparable size to that of existing satellites, whereas that the probability is large enough to collide possibly in case of the satellite with size as huge as a hypothetical gigawatt solar power satellite. The probability would become large if the satellites are continued to be abandoned in the stationary orbit, as at present they are done, over several centuries, even if the size is ordinary, such as several metres. The methods for avoiding the collision are discussed in each case where a satellite collides not only in the stationary orbit with stationary satellites and abandoned satellites but also on the occasion of injection into the stationary orbit.

SEVERE IONOSPHERIC SCINTILLATIONS ASSOCIATED WITH GEOMAGNETIC STORM ON MARCH 22, 1979.

Hisamitsu MINAKOSHI, Kenji SINNO, Miyao KAN,
Hiroshi KURIHARA and Osamu FURUTA

In recent radio observations of several geostationary satellites signals, it has been found that severe scintillations of signals occurred occasionally at mid-latitude during geomagnetic storms.

In this report is shown an example of such severe scintillations observed on March 22-23, 1979 in and around Japan. Although the geomagnetic storm was not very strong (about 170γ in ΔH) in this event, severe scintillations occurred on frequencies from VHF through SHF band; maximum depths reached 18, 10, 15 and 3.5 dB_{p-p} at 136 MHz, 1, 7, 4 and 12 GHz, respectively.

Ionograms obtained at the ionosonde stations in Japan showed not only spread-*F* echoes but also anomalous vertical movement of the *F* layer at the almost same time as scintillation occurrence.

Furthermore it is found that spread-*F* has a tendency to appear in association with downward movement of the *F* layer other than upward movement.

It is inferred from the observation in several places that the disturbed region occurred in the southern small area at midlatitude and apparently moved northward decreasing its speed.

SHORT-TERM PREDICTION OF HF PRORAGATION IN PROMPT USE OF THE *F*-LAYER CRITICAL FREQUENCIES OBSERVED WITH THE IONOSPHERE SOUNDING SATELLITE-b

Yugoro TAKENOSHITA, Shoichi ITO, Rikio MAEDA and Tokuji KOIZUMI

Global maps of the MUF variability were made from the *F*-layer critical frequencies observed with the Ionosphere Sounding Satellite-b from October 1978 to March 1979. The maps were used weekly in a trial to correct the monthly MUF of HF circuits predicted in

advance of three months by the Radio Research Laboratories. The correction was carried out as a weekly prediction with consideration of temporal and spacial characteristics found in the CCIR MUF maps.

An adequacy of the trial was examined, taking into account of HF circuit data obtained at Hiraiso Branch. The trial with the most reliable data succeeded 55 times, failed 6 times and missed 39 times in correction.

DEGRADATION OF THE DELAY-LOCK DISCRIMINATOR CHARACTERISTIC DUE TO THE TRANSMISSION CHANNEL DISTORTION

Mitsuo YOKOYAMA

When a bi-phase shift-keyed signal by a PN code passes through the band-limited channel with delay distortion, this signal comes to be distorted. The cross-correlation between this distorted signal and the locally generated PN code is reduced and it causes the degradation of the delay-lock discriminator (DLD) characteristic. As the DLD is used for the PN tracking purpose, the degradation invites unfavourable effects on the SSRA performance. In this paper the degradation is examined quantitatively. Bandwidth limiting is modeled by the Gaussian filter or the rectangular filter, and the delay distortion effect is examined into the first and the second order, respectively.

As a result, it is verified as follows: bandwidth limiting causes the power loss, the first-order delay dulls the sensitivity of the DLD and the second-order delay shifts the zero crossing point of the DLD.

EFFECT OF DIVERSITY ON FREQUENCY HOPPING TECHNIQUES

Mitsuhiko MIZUNO and Yasuo KADOKAWA

Spread spectrum (SS) systems have been so far investigated from the viewpoint of spectral efficiency to fill the recent growing demand for land mobile communication channels. A definite conclusion has not been reached yet whether the SS mobile system have more channel capacity than the existing FM systems or not.

The system performance of land mobile communication is strongly degraded by fading. And the influence of selective fading should be especially considered in the wideband systems such as SS systems. The frequency hopping (FH) system, however, is capable of reducing the effect of fading by transmitting multiple chips per one data, because in selective fading environment, the frequency diversity technique is available on the basis of low correlation between frequency chips.

This paper presents computer simulation results of frequency diversity combining properties.

And also describes theoretical analysis of the upper bounds of error rate performance on the FH system with FSK (frequency shift keying) incoherent detection. In the computer

simulation, the selective fading is generated by superposition of many waves with different phases, amplitudes, and delay times. The envelope of a hopping signal is approximated to Rayleigh distribution. M-sequence is modified and applied as a hopping pattern.

It is concluded that the error rate performance by frequency diversity is superior to the case of majority decision, and that the bandwidth over a few MHz is required to realize sufficient diversity gain.

NUMERICAL EXPERIMENT OF THE EXCESS PATH LENGTH OBTAINED FROM RADIOSONDE OBSERVATIONS

Kunimasa KOIKE and Nobuyuki KAWANO

In the last few years there has been increasing interest in developing VLBI systems capable of making more accurate measurements of geometrical delay time, which is the difference between arrival times of radio waves at two separated antennas. However, the retardation of propagating radio waves in the atmosphere affects the accuracy in determining the geometrical delay time using VLBI. The delay time due to ionized gases can be exactly estimated by dual-frequency observation in VLBI, but it is difficult to determine the delay time produced by the neutral atmosphere.

The delay time produced by the neutral atmosphere varies in different time, seasons, localities and countries so that it is important to investigate characteristics of the variations for a long term in each observation area.

In this paper, monthly variations of excess path length which corresponds to the propagation delay time multiplied by light velocity in a vacuum are calculated from radiosonde data at Tateno, for three years. We assumed that the excess path length calculated from radiosonde data is "true" one. On the other hand, estimation of the excess path length is derived as a linear combination of the temperature, pressure and humidity measured on the ground. The coefficient for the three elements are determined by minimizing the expected mean-square difference between the estimated excess path length and the "true" one. Furthermore, sky noise temperatures are derived from radiosonde data, and those temperatures are assumed to be real ones. The same estimation is conducted as a linear combination of the sky noise temperature, in addition to the temperature, pressure and humidity measured on the ground.

In the first case, without considering sky noise temperature, the estimation error is about 5 cm in summer season and come to 2 cm in winter season. In the second case, with considering sky noise temperature, it is lesser than 1.5 cm throughout the year.

THE 9-B TYPE IONOSONDE OF THE RADIO RESEARCH LABORATORIES

Teruo KOSEKI, Tetsuo TAKEUCHI, Kaoru ISHIZAWA
Shoichi ITO and Yasukazu KURATANI

This paper describes specifications adopted and adoptable in the 9-B type ionosondes which are in regular operation at the Radio Wave Observatories, Wakkanai, Akita, Kokubunji (Tokyo), Yamagawa and Okinawa in Japan, and also Syowa Station in Antarctica.

It had been looked forward to install a new type ionospheric sounder in the Radio Research Laboratories early in 1970s, because the 8 type ionosondes in commission were remarkably aging through routine ionospheric soundings during 1960s. A new sounder was designed by the ionospheric sounding group of the Radio Research Laboratories, following the principle that main devices except a transmitter are almost made of many semi-conductors instead of vacuum tubes as found in the old type sounders. The new 9-B type ionosonde has been produced as the most reliable analogue sounder with a yearly operational efficiency of 99% or more.

The following report on researches appear in the "Review of the Radio Research Laboratories" (Japanese edition) Vol. 26 No. 140 November 1980.

THE CHARACTERISTICS OF THE ON-BOARD TRANSPONDERS OF THE JAPAN'S MEDIUM CAPACITY COMMUNICATIONS SATELLITE FOR EXPERIMENTAL PURPOSES

Yuichi OTSU, Tadashi SHIOMI, Noriyuki KAWAGUCHI,
Naokazu HAMAMOTO, Masaaki IGUCHI and Kazuhiko HASIMOTO

The Medium Capacity Communications Satellite for Experimental Purposes (CS) of Japan was launched on December 15, 1977 and was successfully put into geo-stationary orbit. The CS is one of spin stabilized satellites having 93 rpm.

After an initial check-up on the mission subsystems by National Space Development Agency (NASDA), the various communication and satellite control experiments were commenced after May 15, 1978 by the Radio Research Laboratories (RRL) and Nippon Telegraph and Telephone Public Corporation (NTT).

The satellite has six K-band transponders and two C-band ones with the bandwidth of 200 MHz. All transponders are equipped with the function of AGC (Automatic Gain Control) except one of the K-band transponders with the function of AGC on and off, and one of the C-band transponders with the function of input step-attenuation from 0 to 10.5 dB in every 1.5 dB.

The check-ups on the functions of the satellite-borne transponders have been carried out periodically every six months, concerning the input and output characteristics, amplitude-

frequency characteristics, delay-frequency characteristics, noise pedestals of all transponders, satellite antenna patterns and other satellite control subsystems. The results of the last three check-ups revealed that no remarkable changes were observed in the characteristics of satellite transponders and other subsystems for one and half year operation.

On the non-linear characteristics of satellite transponders with the function of AGC, new methods of using balanced and unbalanced two tones were applied to obtain the true characteristics of Travelling Wave Tube Amplifier (TWTA) without AGC function.

The measurements of transponder noise figure (NF) were also made by taking C/N (Carrier to Noise Ratio) meter and FM (Frequency Modulation) noise methods. The measured characteristics of NF versus satellite receiving level in those two methods shows noise suppression effects due to transponder non-linearity in the C/N meter method and increase in the noise figure due to AM/PM conversion effects in FM noise method.

Satellite antenna pattern was measured, normally by scanning of satellite antenna in azimuth direction, over several stations scattered in the Japan's main islands. The measurement data of satellite antenna patterns in those last three check-ups shows little changes for one and half years.

The measurement method of spin-axis tilting was also taken to get the two dimensional patterns of the satellite shaped beam antenna with one or a few stations. This method makes use of the hourly changes of relative position between earth stations and satellite antenna boresight direction due to the spin axis tilting of about one degree.

FM SIGNAL TRANSMISSION EXPERIMENTS VIA THE CS

Hideichi SASAOKA, Toshio CHO and Iwao NISHIYAMA

The Medium Capacity Communications Satellite for Experimental Purposes (CS) of Japan was launched on December 15, 1977 and was successfully put into geo-stationary orbit. The CS is one of spin stabilized satellites having 93 rpm.

This paper describes preliminary results of FM (Frequency Modulation) signal transmission experiment with some discussion.

Experiments were conducted using both C- and K-band links, and basic FDM-FM (Frequency Division Multiplex-FM) telephone transmission characteristics were measured, changing various parameters such as frequency deviation, transmitting power, down-link C/N_0 , emphasis on or off, and receiver BPF (Band Pass Filter) bandwidth. Long term measurements of S/N and C/N_0 were also carried out during the rainy season to estimate the degradation of S/N due to rainfall attenuation in K-band satellite communication.

From the results of the noise loading tests, it was found that 972 channels of FDM-FM telephony signals can be transmitted through any K-band and C-band transponder with signal quality better than 50 dB in $S/(N + D)$. (D means distortion.).

Characteristics of S/N and C/N_0 versus transmitting power were measured to obtain a margin for the up-link rain attenuation, and experimental results showed a good coincidence with the values which were calculated from the CS link parameters. S/N versus C/N_0 characteristics were also measured in the satellite loop-back and modem back-to-back configuration. From these results, the effects of the spin modulation and the transponder nonlinearity

on signal-to-noise power ratio were also investigated.

Concerning the effect of rainfall attenuation in K-band links upon this FM signal transmission, it was found that degradation of S/N could be calculated by the value of down-link rainfall attenuation. Therefore, statistics of S/N degradation can be estimated by the statistics of rainfall attenuation.

Judging from the statistical curve of S/N degradation due to rain, it was found that 972 channels of telephony signals can be transmitted through K-band links with signal quality defined in the CCIR recommendation 335-2.

PSK SIGNAL TRANSMISSION EXPERIMENTS VIA THE CS OF JAPAN

Shigetoshi YOSHIMOTO, Yukio HASHIMOTO, Iwao NISHIYAMA
Masa-aki IGUCHI and Katsuhiko KOSAKA

The Medium Capacity Communications Satellite for Experimental Purposes (CS) was launched on Dec. 15, 1977 and was successfully put into the geo-stationary orbit. The CS is one of spin stabilized satellites.

The spacecraft has two C-band (6/4 GHz) and six K-band (30/20 GHz) transponders. The horn reflector type despun antenna of the CS has a beam pattern shaped to cover the Japan's main islands effectively.

The PSK (Phase Shift Keying) signal transmission experiment is one of the important experiments in the CS project. The PSK experimental equipment was developed to conduct various kinds of transmission experiments and has various functions, in which, for example, we can select the transmission rate of 6, 32, 64, and 96 Mbps with the modulation of 2, 4 and 8 phases for each rate.

This paper reports the preliminary experimental results with short descriptions on the PSK equipment.

First of all, are shown the base band characteristics of PCM-TP (TP: Telephone) and PCM-TV transmission, and then are also shown the BER (Bit Error Rate) performance in C- and K-band links. Finally, effects of spin modulation nonlinearity of a transponder and amplitude-frequency response in a communication band, on BER performances are discussed.

The experimental results are: The apparent degradation of the BER performance is large in the case that the satellite receiving power decreases, because of the transponder nonlinearity and the degradation of the BER performance in a K-band link resulting from spin modulation which is greater than that in a C-band link.

As for the effect of rain attenuation, there was good correlation between BER performance and attenuation. Also, we show the results of sun interferences to PSK signal transmission obtained in both C- and K-band communication channels.

TDMA COMMUNICATION EXPERIMENTS VIA THE CS

**Katsuhiko KOSAKA, Hideichi SASAOKA, Naokazu HAMAMOTO
Shigetoshi YOSHIMOTO and Yukio HASHIMOTO**

The Medium Capacity Communications Satellite for Experimental Purposes (CS) of Japan was launched on December 15, 1977 and was successfully put into geo-stationary orbit. The CS is one of spin stabilized satellites having 93 rpm.

This paper describes preliminary results of TDMA communication experiments via the CS conducted during the first one year for the experiment with some discussions.

The CS has C-band (4/6 GHz) and K-band (20/30 GHz) transponders on board and the experiments have been conducted using those two kinds of transponders. Link parameters for using transponders are investigated and also the effect of transponder nonlinearity on total C/N (Carrier to Noise) ratio is discussed.

Except the case of rainfall attenuation, the most distinctive feature of the K-band links compared with the C-band ones is that the K-band links suffer from the effect of larger spin modulation (receiving level variation due to spin), because of more sharpness of K-band radiation pattern of the CS antenna. Experimental results show that the spin modulation degrades BER (Bit Error Rate) performances by nearly 1 dB in C/N.

Concerning synchronization characteristics, it was found that performances of frame and burst synchronization were satisfactory, and that phase jitters of the recovered clock signals scarcely affect BER performances.

Initial acquisition is conducted by transmitting a low power acquisition signal which measures round trip delay time between the satellite and the earth station. The miss detection probability of acquisition signal at the receiving side was measured as about 1×10^{-4} and also the false detection probability was calculated as less than 1×10^{-30} which is actually impossible to be measured. The interference of the acquisition signal to communication signals is almost to be neglected, if the nominal acquisition signal level is maintained. However, when there are other stations of which up-link power is attenuated by rainfall, its effect on BER performances can not be neglected.

PROPAGATION EXPERIMENTS IN THE CS PROJECT (Measured Results Mainly at the Main and Wakkanai Stations)

**Yuichi OTSU, Hajime FUKUCHI, Tetsuo TAKAHASHI,
Risao HAYASHI, Haruo OHYAMA and Yoji FURUHAMA**

Propagation experiments in the CS project started at the main station on January 1st 1978, using K-band beacon (19.45 GHz). Other stations, including the stations of Nippon Telegraph and Telephone Public Corporation (NTT), also made a start on the propagation experiments after May 1978. These experiments have been conducted since then.

Cumulative distribution curves of rain attenuation at the main station show that the percentages of time in which attenuation exceed 5, 10, 15, and 20 dB become 0.09, 0.017, 0.0075, and 0.0035%, respectively.

Ratio of rain attenuations in the up-link at 29.65 GHz to those in the down-link at 19.45 GHz attains about 2.1. This value can be applied to the derivation of the up-link attenuation statistics. These statistics including up-link attenuation statistics are indispensable for the design of satellite communication system.

Attenuation of the beacon and noise temperature increase at the out-band, measured with the same 13 meter antenna, coincide well with each other for many rain events. This fact shows that the excess noise measurement by radiometer is confirmed to be a good method to know the attenuation along the slant path within limited dynamic range.

At the main station, cross polarization term of the K-band beacon signal shows a diurnal variation, and the degradation of XPD (cross polarization discrimination) due to rain is worse than the predicted one by the theory of OGUCHI. It is considered that this is caused by the ice crystal layer of so called "bright band" in the radar.

In the C-band signal, ionospheric scintillation is often observed within the amplitude of 1 dB, and the percentage of time in which scintillation of 1 dB peak to peak occurs is 0.1%.

At Wakkanai, located at the most northern part of Japan, the field strength meter of K-band beacon was set up on the 15th of November 1978. And in the first winter, the experiment on the effects of snow on the surface of antenna was mainly studied at the station.

SATELLITE CONTROL EXPERIMENTS VIA THE CS

Tadashi SHIOMI, Seiichiro KAWASE, Takanori NISHIGAKI,
Kaoru HAYASAKA and Koichi HIRAI

The Medium Capacity Communications satellite for Experimental Purposes (CS) of Japan was launched on December 15, 1977 and was successfully put into geo-stationary orbit. The CS is spin-stabilized satellite with the spin rate of approximately 93 rpm.

With regards to the Satellite Control Experiments, are described the performance of routine base TT&C operation, which includes monitoring of house keeping data and commanding the satellite for mission experiments, and the results of various researches and experiments for satellite control, especially on the attitude determination, orbit determination, tracking, and despun antenna pointing, which were carried out during the first one and a half year after the launch of CS. These experimental results will be very valuable and useful for the development of space technique and research.

At first, are described the TT&C systems and daily operation procedures at Kashima CS Control Station and the results of monitoring and investigations of spacecraft status under the special events, e.g. lift off, eclipse and initial check-up.

Secondly are described ranging experiments, which have been done in several ways, for example, tone ranging via TT&C channel, via one hop communication channel, and via two hop communication channels by using a small retransmitting station.

And thirdly, were carried out the orbit determinations of the geostationary satellite using one station's ranging data and K-band tracking angle data, in which it is shown that the orbit determination can attain the same accuracy as obtained by using two station's range data.

And also the attitude determination and prediction were performed, the prediction of

the attitude of CS for about 10 days could be realized within an error of 0.01 degree, which is sufficient for planning attitude maneuver.

At last, the pointing error of despun antenna was analyzed concerning the effects of pretty large nutation caused by continuous firing with one axial thruster for north-south keeping of the satellite.

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TRANSMISSION OF OMEGA VLF RADIO WAVE OVER TRANS-EQUATORIAL 11000 km PATH

Takashi KIKUCHI, Yoshiko TERAJIMA and Akira OHTANI

The diurnal variations in the phase and amplitude of OMEGA radio navigation signal (REUNION-10.2, 11.33 and 13.6 kHz) received at Inubo are analysed in terms of the lowest order mode in the isotropic waveguide, in order to establish the propagation model of the OMEGA VLF waves in low latitudes on the basis of a better understanding of behavior of the lower ionosphere. The basic parameters of the propagation, i.e., the day-night differences in the phase (ϕ_{DN}) and amplitude (E_{DN}) and the interference distance (D) in the nighttime waveguide are obtained for the frequency of 13.6 kHz as $\phi_{DN} = 7.8 \mu\text{s/Mm}$, $E_{DN} = 7.1 \text{ dB}$ and $D = 1392 \text{ km}$, while the day-night differences in the phase are obtained for 10.2 and 11.33 kHz as $\phi_{DN} = 10.8 \mu\text{s/Mm}$ and $9.5 \mu\text{s/Mm}$, respectively. These values are interpreted by assuming the propagation in the waveguide with β_D (height gradient of the ionospheric conductivity in the daytime) = 0.3 km^{-1} and h_D (ionospheric reference height in the daytime) = 75 km and β_N (height gradient of the ionospheric conductivity in the nighttime) = 0.5 km^{-1} and h_N (ionospheric reference height in the nighttime) = 88.5 km. It is concluded that the trans-equatorial west-to-east propagation of the OMEGA VLF waves shows normal propagation characteristics same as those obtained at the mid-latitude, although the equatorial anomalies appear clearly on the east-to-west trans-equatorial path. The daytime phase variations of REUNION (13.6 kHz) are correlated to the solar zenith angle, χ , in such a way that $\Delta\phi \propto \Delta \ln(\sec \chi)$. If the Chapman theory is applied to the formation of the reflecting layer, the scale height, H , of the neutral atmosphere to be ionized is obtained as $H = 3.0 \text{ km}$. On the REUNION-Inubo path, the SPA's (Sudden Pahse Anomaly) caused by the solar flare are always positive for the frequencies of 10.2, 11.3 and 13.6 kHz. It is found that all the SES's (Sudden Enhancement of Signal Strength) at 10.2 kHz are negative, while the SES at 13.6 kHz is negative around the local noon (solar zenith angle $\bar{\chi} < 45^\circ$), but positive near the dawn and dusk transition periods ($\bar{\chi} > 45^\circ$).

ROCKET OBSERVATIONS OF ELECTRON DENSITY PROFILES IN THE POLAR IONOSPHERE

Shigeru MIYAZAKI, Tadahiko OGAWA and Hirotaka MORI

In this paper, are described observational results of the ionospheric electron density profiles measured with S-210JA-29 rocket which was fired at 19h15m (LT) on July 12, 1977 in very quiet ionospheric condition as well as with S-310JA-7 rocket which was fired at 22h15m (LT) on March 27, 1978 in a severe auroral disturbed condition, at Syowa Station in Antarctica. The results indicate that the maximum electron densities range $(2\sim 4) \times 10^4 \text{ cm}^{-3}$ in quiet condition and about $1 \times 10^6 \text{ cm}^{-3}$ in a severe disturbed condition. The empirical formulae to infer the nighttime electron density during auroral disturbances are deduced from 30 MHz cosmic noise absorption and geomagnetic disturbance levels. The results also indicate that $\log N_e = 0.362 \Delta x + 4.12$ at the altitude of 90 km and $\log N_e = -0.00118 \Delta H + 4.84$ at 105 km, where N_e is electron density in cm^{-3} , Δx is variation of 30 MHz CNA in dB and ΔH is variation of geomagnetic horizontal component in nT ($= \gamma$).

CORRELATION PROPERTIES OF GOLD CODES IN SPREAD SPECTRUM COMMUNICATIONS

Masashi SHIBATA and Yasuo KADOKAWA

The Gold code is a kind of nonmaximal linear sequences, and it has a large number of different codes.

The Gold code, however, is not always the best spectrum-spreading code in spread spectrum communications having many different users, since the code sometimes shows bad properties in the behavior of both autocorrelation and crosscorrelation in comparison with those of maximal linear sequences (m-sequences).

This paper describes several merits of the Gold code derived from the preferred pair of m-sequences, together with some discussion on both autocorrelation and crosscorrelation of the Gold codes.

It is clarified that the specified pair of Gold codes with 3-values as obtained from the preferred pair of m-sequences gives a smaller upper band of crosscorrelation than the arbitrary pair of Gold codes which are generated by m-sequences at random, and it has also a good autocorrelation properties.

It is found by computer simulation that most of the specified pair of Gold codes have a smaller rms value of crosscorrelation than that of m-sequences.

**OPTIMUM REDUNDANT SATELLITE SYSTEM
—RELIABILITY AND AVAILABILITY OF PARALLEL
OR STANDBY SYSTEMS—**

Kozo TAKAHASHI

In order to find the optimum redundant satellite orbit system, the formulas for reliability and availability are derived in the cases of two parallel, three parallel, one standby, and two parallel and one standby redundant systems, where both the start or switch probability and the necessary delay time for start or switch are assumed to be arbitrary. The calculation by these formulas shows the relation among the reliability and availability of the redundant systems, the launch probability and the preoperation time, where two kinds of numerical value of the parameters are chosen: One is to show clearly the effects of the parameters on reliability and availability, and the other is to show the value in the cases of launches by the conventional rocket and the developing space shuttle.

**THE RESULTS OF LONG-TERM EXPERIMENT OF TRANS-EQUATORIAL
VHF WAVE PROPAGATION**

Kazuo TANOHATA, Isao KURIKI, Masaaki IGUCHI,
Kyoko YAMASHITA and Toshiro SAKAMOTO

During about one decade, experimental investigations into the VHF trans-equatorial propagation have been carried out with frequencies of 32, 48, 72, 88 and 102 MHz, along the path of 4841 km between Yamagawa, Japan and Darwin, Australia.

On the basis of analysis of the experimental data, it is found that the trans-equatorial propagation waves can be received with higher reception rate during several hours after around 20h in local time in spring and autumn, and that the reception rate shows a positive high correlation with the variation of the sunspot number. In the presence of ionospheric spread echoes at higher critical frequencies, the VHF signals can also be received with the higher reception rate.

**CHARACTERISTICS OF THE FIFTH HARMONIC RADIATION
FROM MICROWAVE OVENS
—CONCERNING THE INTERFERENCE ON SATELLITE
BROADCAST RECEPTION—**

Akira SUGIURA, Shuichi UCHIKADO, Toshichika ANDO,
Hajime OHASHI and Kango TOKUSHIGE

The fifth harmonic radiation from microwave ovens, which operate at the fundamental frequency of 2.4–2.5 GHz, lies within the frequency band allocated for the satellite broad-

casting. It is therefore considered that microwave ovens will probably cause unacceptable interference to the reception of satellite broadcasts, especially in Europe. However the characteristics of this harmonic radiation have scarcely been investigated.

Measurements of the fifth harmonic radiation were carried out on six new microwave ovens made by different manufacturers, the RF powers of which were 500–600 watts. The levels and the radiation patterns in the horizontal plane were obtained by using a spectrum analyzer according to the C.I.S.P.R. measuring method (Publ. 11). It was found that the maximum levels of the fifth harmonic of all ovens were high and that three out of six ovens radiated about 30 dB more than the C.I.S.P.R. limit of 57 dBpW, e.r.p. The horizontal radiation patterns showed various directivities different from that of the dipole.

From the measurements of the spectrum and the waveform of the radiation, it is concluded that the fifth harmonic may produce a few horizontal bands of crawling noise on the TV picture, which move in the vertical direction with a period of about 17 ms. This conclusion is based on the assumption that the power line frequency and the TV vertical sweeping frequency are 50 Hz and 59.94 Hz, respectively. In fact, the interference experiments in the satellite broadcast reception were performed and a slowly moving noise band could be observed on the TV picture transmitted from the Japanese Medium-scale Broadcasting Satellite for Experimental purpose.

RECORDING ATMOSPHERIC RADIO NOISE WAVE FOR TESTING 2182 kHz RADIOTELEPHONE AUTO-ALARM RECEIVER

Hiroshi MASUZAWA, Yoshiaki ICHINO, Fumito KUBOTA, Rikio CHINO,
Kuniyasu IMAMURA, Chihiro MIKI, Akio OHTSUKI, Nobuo OJIMA,
Kazuo SHIBUYA and Wa SHIOBARA

The radiotelephone auto-alarm receiver at 2182 kHz has been added in July 1979 to one of the apparatuses legally bounded to be authorized by the type approval test, according to the International Convention for the Safety of Life at Sea (SOLAS), 1974.

At the type approval, it is particularly important to test the performance of this receiver against the atmospheric radio noise, because it can be expected that the receiver would experience the conditions of interference caused by powerful atmospherics. In order to develop its test method, it was necessary to investigate and record the atmospherics as a noise source on the ocean. The investigation was carried out on board ship from Japan to New Zealand for one month in May 1979.

This paper reports the results of this investigation as follows:

1. Tape recording the atmospheric radio noise at 2182 kHz.
2. Measurement of radio noise intensity by Amplitude Probability Distribution (APD) instrument.
3. Practical test of radiotelephone auto-alarm receiver.
4. Recording the wide band atmospheric radio noise.

PREDICTIONS OF GEOMAGNETIC ACTIVITY BY AN INTERPLANETARY SPACECRAFT

Shigeaki WATANABE

The solar wind would be a source of geomagnetic disturbances. The variety and degree of geomagnetic activities can be represented by means of several geomagnetic indices, such as AE, AU, AL, ap, Kp and Dst. Those indices have some high correlation coefficient with a solar wind condition, e.g. the southward component of solar wind magnetic field, the bulk velocity and the variance of magnetic field.

This paper proposes procedures for predicting the geomagnetic activity by using interplanetary spacevehicles. The time delay between changes in the solar wind environment and in geomagnetic activity is known empirically to be about 1 hour. Since it is evident that the time of calculation which is needed for high accuracy prediction of geomagnetic activity indices on the basis of information of solar wind measured by spacecraft is short, we can broadcast the alert of the activity indices to allow the users to take countermeasures for spacecraft charging and other harmful phenomena which may occur on long distance power and pipe lines and on communications by satellites.

The following report on researches appear in the "Review of the Radio Research Laboratories" (Japanese edition) Vol. 27 No. 142 March 1981.

IONOSPHERIC INFLUENCES ON THE GEOSTATIONARY SATELLITE RADIO WAVES —RECENT STUDIES IN JAPAN—

Kenji SINNO, Hisamitsu MINAKOSHI, Masaharu FUJITA, Jun AWAKA,
Tadahiko OGAWA, Syogo KAMISHIKIRYO, Hiroshi KURIHARA and Miyao KAN

Measurements of ionospheric scintillation and TEC by means of mainly Japanese geostationary satellite ETS-II have been carried out at Kokubunji, Kashima, Hiraiso and Yamagawa, RRL since March 1977.

Results of the investigations that have already been reported in eight papers, are briefly reviewed in this paper. The items included are as follows:

- a) Instrumental descriptions,
- b) Occurrence characteristics of scintillation and fluctuation of TEC,
- c) Phenomena associated with sporadic-E and spread-F,
- d) Phenomena associated with geomagnetic storms.

**SOLAR RADIO OBSERVATION AT MILLIMETER WAVELENGTH
—DESCRIPTION ABOUT INSTRUMENTS AND PRELIMINARY
RESULTS OF OBSERVATION—**

Hiroshi KUMAGAI and Susumu ISOZAKI

The solar radio observation at millimeter wavelength using a large steerable antenna has been started at Hiraiso. The observing instruments are characterized by a 10-meter diameter Cassegrain antenna, low noise parametric amplifiers, and a real time data processing system. The whole system is controlled by an online mini-computer. The receiving frequencies are 32 GHz and 4 GHz with beam widths of 0.06° (HPBW) and 0.45° (HPBW), respectively. Two kinds of the antenna driving are possible; one is the two-dimensional scanning of the solar disk and the other is the continuous tracking of an arbitrary spot on the disk. It is shown that these functions are remarkably useful for the precise identification of active regions on the disk and for pursuing their temporal behavior, especially at 32 GHz because of the very sharp beam width which is much narrower than the diameter of the solar disk ($\simeq 0.53^\circ$). Two-dimensional radio maps have been made regularly since April 1980. These maps are also used as the basic data for the radio propagation warning service being conducted at Hiraiso.

Main objective of this paper is to present overall features of the hardware and software systems developed for the observation. In addition, we illustrate examples of observational results and then give a brief discussion about some features of the solar radio maps and of the outburst events at millimeter wavelength.

**THE MEASUREMENT OF RAIN ATTENUATION OF MILLIMETER
WAVES BY FM-CW RADAR METHOD USING LARGE
SCALE RAINFALL FACILITIES**

Takeshi SUITZ

The research on the remote sensing at the Radio Research Laboratories is conducted from the standpoint of effective utilization of radio waves and covers wide range of micro-wave remote sensing. As one of the active remote sensors, FM-CW radars have been developed and tested in order to obtain the radiometric characteristics of various objects which are remote sensed, along with acquiring and developing the technique of CW-radar.

Rain attenuation was measured using a Ka-band FM-CW radar and the large scale rainfall facilities of National Research Center for Disaster Prevention of Science Technology Agency.

Intensity of the artificial rain is variable while the rain-drop size distribution was found to be different from the natural rain. The rain attenuation of millimeter radio waves calculated from the rain-drop size distribution agrees very well with the result measured by using FM-CW radar. It is judged that the artificial rain, which is able to reproduce the same rain conditions, is useful for effective experiments and the FM-CW radar demonstrates the capability for sensing rain intensity remotely.

CORRELATION FUNCTION OF M-SEQUENCE CONTAINING ERRORS

Taiji SARUWATARI

In tests of digital transmission systems, a pulse pattern of M-sequence is used, because the sequence has properties of random and periodicity. Properties of M-sequence have been analyzed, but properties of its erroneous sequence have not been investigated. In this paper, several properties of M-sequence containing errors are described. They are a cross-correlation function between M-sequence containing errors and the original sequence, average and covariance of the cross-correlation function.

The following report on researches appear in the "Review of the Radio Research Laboratories" (Japanese edition) Vol. 27 No. 143 May 1981.

I. PROGRESS AND OUTLINE OF BSE EXPERIMENTS

The medium-scale Broadcasting Satellite for Experimental Purpose "BSE" was launched on April 8, 1978 from the Eastern Test Range of the United States, and put into a geostationary orbit of 110 deg. east longitude. The satellite was named "Yuri" meaning "lily" in Japanese.

Initial checks of the satellite in orbit was performed for about three months to confirm the function and performance of the onboard equipments. The BSE broadcasting satellite experiments were started on July 20, and have been continued smoothly.

The extensive plan of the BSE experiments was formed after careful deliberation by the Radio Regulatory Bureau (RRB), the Radio Research Laboratories (RRL) and the Nippon Hoso Kyokai (NHK; the Japan Broadcasting Corporation).

The BSE experiments will be conducted in accordance with the above plan by RRL and NHK in close cooperation with the National Space Development Agency of Japan (NASDA). The experiments will be continued for three years which is a design life of the BSE. In this issue are described the results of the BSE experiments which were obtained during an initial period of about one year with regard to almost all experimental items.

II. RESULTS OF THE BSE EXPERIMENTS

The BSE experiments have been conducted by RRL and NHK in close cooperation with NASDA, and will be continued for three years. In this chapter are reported the experimental results which were obtained during initial experimental period of about one year. The experiments were conducted with regard to almost all experimental items. They can be classified into three categories which are further divided into specified items as follows.

1. Experiments on fundamental techniques for satellite broadcasting system
 - (1) Experiment on estimation of the service area of the BSE satellite broadcasting
 - (2) Experiment on signal transmission system

- (3) Experiment on radio wave propagation
- (4) Experiment on frequency sharing
- (5) Experiment on measurement of characteristics of earth stations
2. Experiments on Satellite controlling techniques and operational techniques for satellite broadcasting system
 - (1) Experiment on satellite controlling techniques
 - (2) Experiment on operational techniques for satellite broadcasting system
3. Experiment on reception of broadcasting satellite radio waves

With a few exceptions, the experimental results in those items will be described with emphasis on what was performed on the part of RRL.

1.1 EXPERIMENT ON ESTIMATION OF THE SERVICE AREA

Since the attenuation due to rain etc. will occur in the radio wave propagation in the frequency band of 14/12 GHz, it is very important to estimate the service area in the satellite broadcasting system in the above frequency band.

In the BSE experiment plan, therefore, the service area is to be estimated by measuring the received field intensity distribution and its variation with the lapse of time. The measurements are made at many participating earth stations including Receive-Only Stations and Simple Receiving Equipments which are located throughout Japanese mainlands and remote islands.

In this section are given the measurement results obtained in participating stations of RRL. They are the Receive-Only Station in Wakkanai, and Simple Receiving Equipments in Okinawa, Akita and Kokubunji.

Measured items are received field intensity and its variation in the lapse of time, relation between rainfall rate and attenuation of radio-wave, variation of received power corresponding to the longitudinal shift of satellite and so on. Furthermore, descriptions are given to the experimental installations and their measuring systems in the above stations.

1.2 TRANSMISSION CHARACTERISTICS OF BSE EXPERIMENTAL SYSTEM AND SIGNAL TRANSMISSION EXPERIMENTS

In this section, we will discuss the transmission characteristics of BSE mission equipments and Main Transmit and Receive Station (MTRS), and a few kinds of signal transmission experiments carried out for the first one and a half years in the BSE program. The transmission characteristics of BSE transponder have almost coincided with the designed values or measured ones prior to the launch of BSE. No degradation of signal quality due to BSE transponder has been observed in the broadcasting experiment of a standard FM-TV signal.

In addition to the FM-TV signal transmission experiments, interim experimental results on followings are described; digital TV signal transmission where an NTSC-color-TV signal is directly encoded by an High-Order DPCM system and then quaternary phase-shift-keyed, and dissemination of time and frequency standard using a TV-color subcarrier and-synchronizing signal.

1.3 RADIO WAVE PROPAGATION EXPERIMENTS IN THE BSE PROGRAM

Radio wave propagation experiments in the BSE program started at the Main Transmit and Receive Station (MTRS, Kashima) in May 1978, using beacon signal (11.7125 GHz, vertical polarization) from BSE. Other experimental earth stations (Wakkanai, Akita, Koku-bunji, Yamagawa and Okinawa), which are located all over Japan, made their starts of propagation experiments in 1978 or 1979. At these experimental earth stations, the TV signal (12 GHz band) from BSE is received with a Simple Receive Equipment. The data obtained at these stations, received signal level and rainfall rate, are sent to the MTRS for statistical analysis.

Experiment on backscattering at 14 GHz band have been carried out at the MTRS since 1979 intending to make simultaneous measurements of attenuation and rainfall rate along the satellite-to-earth path.

In this paper, an interim report based on the propagation experiments carried out from 1978 to 1979 and preliminary report of experiment on backscattering at 14 GHz are presented.

The statistics of rainfall rate and rain-induced attenuation of the beacon signal or TV signal at each experimental earth station have been obtained. Effective path lengths derived from the statistical results became about 5 km at the MTRS with the elevation angle of 37 degrees.

The relations between up and down-link attenuations due to rain or snow were also obtained. Using these results, the frequency dependency of the attenuation coefficient was derived and the dependency showed an agreement with the theoretical results.

Attenuations of the beacon signal and increases of outband noise temperature measured with the same 13 m receiving antenna show close correlations in many rainfall events. This fact shows that the attenuation measurement by a simple radiometer can be a good method to predict the attenuation along the slant path in a limited dynamic range.

Rate of change of attenuation was also discussed and its cumulative distributions were obtained. The results show that the rates are log-normally distributed, and that the high rates correspond to the large attenuations. The observed rate of change reached to about 6 dB/sec at the maximum value.

Cross-polarization discrimination (XPD) measurements have been carried out by using the beacon signal. It was observed that the degradation of XPD was worse than the predicted one based on theoretical consideration. The analysis using rain-radar echos suggests that it is caused by the ice crystal or melting layer which is so-called bright-band.

At Wakkanai earth station, northern part of Japan, the experiment on the effects of snow accumulation on antenna was mainly studied.

Preliminary experiment of rain backscatter signal reception was done for the purpose of measurement of precipitation along the satellite-to-earth path. In this experiment, 14 GHz up-link signal is used as a FM-radar signal. The results suggest the usefulness of the precipitation measurement with this kind of FM-radar system.

1.4 EXPERIMENTS ON FREQUENCY SHARING

In order to evaluate the characteristics of the interference between broadcasting-satellite-service (BSS) feeder links, and between BSS feeder link and fixed-satellite-service

(FSS) up-link, experiments using the BSE link and laboratory simulated link were carried out. Subjective and objective evaluation of co-channel and adjacent-channel interferences between links mentioned above was performed.

1.5 MEASUREMENTS OF PARTICIPATING EARTH-STATION CHARACTERISTICS

Some measured results of earth-station characteristics are presented in this section. Included are the characteristics of the operation and control subsystem and the antenna subsystem of MTRS (Main Transmit and Receive Station), and the simple receiving systems at Yamagawa Radio Wave Observatory. Some considerations for the TV signal reception, using a simple receive equipment, are also presented here. Antenna gain measurements with radio-star sources and its pattern measurements by "a vibration method" were successfully carried out, in addition to those by using BSE down link signals. Through these measurements it was confirmed that the system reported here had sufficient performances for the BSE experiments.

2.1 SATELLITE CONTROL EXPERIMENTS

At Kashima ground station, the satellite control system enables telemetry, command and ranging of BSE through K-band TTC channel. Using these systems, the communication subsystem of BSE has been operated from Kashima since July 1978, after the two months initial checkout. Besides satellite operation, ranging data have been successfully acquired through K-band TTC link to support orbit determination experiments. Continuous receptions of K-band telemetry signal have also provided good opportunity to investigate various fluctuations of satellite signal level due to attitude control characteristics and thermal deformations of satellite equipments. As is well known, there equipped three TWTs on board BSE. Among them, Bch TWT showed gradual drop in cathode current soon after the beginning of operations and tripped off in June 1979. Ach and Rch TWTs showed no remarkable variations in characteristics seen from telemetry data. Some other experiments concerning the evaluation of satellite subsystems have been carried out by the analysis of telemetry data.

2.2 EXPERIMENTS ON OPERATION AND CONTROL TECHNIQUES OF A SATELLITE BROADCASTING SYSTEM

In this section, we will discuss up-link power control experiment, automatic measurement of TV signal transmission characteristics by means of VITS (Vertical Interval Test Signal), calibration system of transmitting and receiving power at MTRS, and transmission characteristics of order wire channels and their operating situation.

Up-link power control for compensation of rain attenuation is useful to decrease interference to other satellite and terrestrial links by keeping e.i.r.p. at the necessary and minimum value. A preliminary experiment of up-link power control shows that the variation of the up-link receiving power due to rain attenuation is kept within about 1 dB by a simple method.

Automatic measurement system by VITS is useful to monitor the situation of transmission links in operation. It is confirmed that measured values by the automatic system is

sufficiently reliable except a few measurement items.

Order wire channels placed in a TV signal transmission channel of BSE are used in voice communications and data transmission among participating earth stations. Their transmission characteristics are kept in a designed or expected range.

3.1 EXPERIMENTS ON THE RECEPTION OF BROADCASTING SATELLITE SERVICE

In this section, we will discuss the evaluation method of the reception quality of television picture and the effect of solar noise interference.

In order to evaluate the reception quality and reception stability of the BSE television signal, the subjective assessment of picture quality is performed. The method of subjective assessment is described here, and a few problems on the evaluation method are also prepared.

The antenna noise temperature of the ground receiving system of satellite link increases due to radio noise from the sun. The mechanism of occurrence of interference and degradation of reception quality of BSS signal are presented here.

The following report on researches appear in the "Review of the Radio Research Laboratories" (Japanese edition) Vol. 27 No. 144 September 1981.

CALCULATIONS AND MEASUREMENTS OF DIELECTRIC LOSSES DUE TO WATER THIN FILMS INSIDE THE WAVEGUIDE AND REFLECTION LOSSES DUE TO THE ONES ON THE METAL SURFACE

Yuichi OTSU, Tetsuo TAKAHASHI, Yasushi ASANO
and Fumiaki SAGA

At the first step to the exact calculations of the losses due to the water thin films on the surfaces of antennas, the calculations of losses due to the thin films inside the waveguide were done, with the results that losses due to the thin films inside the waveguide increases proportionally as the thickness just over 0.1 mm at 35 GHz and microwave frequencies such as 4 and 6 GHz suffer comparatively larger losses of over 10 dB even at the thicknesses of 0.5 to 1.0 mm, but the losses do not increase so quickly until the thickness of 10 mm.

Reflection coefficients due to the thin films on the surface of metal plates were calculated for the several incident angles at 35 GHz and those coefficients are nearly equal to the values measured by the radiometer method.

AN IONOGRAM REDUCTION SYSTEM USING A DIGITIZER CONNECTED TO A COMPUTER

Yasukazu KURATANI, Rikio MAEDA, Tokuji KOIZUMI
Teruo KOSEKI and Shigeharu HIIDOME

The ionospheric vertical sounding is a widely used technique for obtaining some basic information about the ionosphere. The extraction of ionospheric parameters from ionograms is undoubtedly an indispensable, time-consuming and laborious work without which the ionospheric sounding itself would be meaningless. Several approaches were proposed and tested so far to save time and labor for the reduction of ionograms. None of them, however, has reached ultimate success owing to various kinds of limitation. Under those circumstances, a computer-aided manual reduction system has been proposed as one of promising systems which will be put into practice within a couple of years.

This system is composed of the following components: a film projector, a digitizer, an exclusive computer, a tape puncher and a tape reader terminal connected through a telephone line to a central computer system including a line printer and a plotter. The ionogram reduction proceeds in the form of conversation with the exclusive computer system which is now favorably in regular operation at Kokubunji in Tokyo.

MEASUREMENTS OF MF WAVE FIELD STRENGTHS ALONG THE ROUND SAILING COURSE BETWEEN JAPAN AND ANTARCTIC

Choshiro NEMOTO, Shu FUJII, and Masami OSE

Propagation characteristics of MF waves at night time on several regions have been represented. These are very localized, and not fitting to Asian region.

Some measurements of MF wave field strengths were carried out on board "FUJI", made for the Japanese Antarctic Research Expedition, along the round sailing course between Japan and Antarctic since 1973. The field strength through distance over 11000 kilometer were presented in these measurements. The field strengths together with some values obtained from other measurements in the Southwest Pacific were shifted seasonally beyond 10 dB from those of the N-S Cairo curve, and were considered to be controlled by solar activity. A frequency dependence of FM wave transmission is not found even now in the field strengths of these measurements.

FADING EFFECTS ON ERROR PATTERN ON OVERSEA LINK

**Kimio KONDO, Atsushi IRUMATA, Hisashi MORIKAWA,
Shingo ŌMORI, Yoshihiro HASE and Shuichi MIURA**

Multipath fading is inevitable in the maritime satellite system for the small ships, because of its necessity to use as simple antenna as possible, which widen the directivity. The optimum coding for these channels necessitates the knowledge of the occurrence characteristics of the error, which is available by the measurement of error pattern.

In this article, the principal characteristics of bit error rate and the error pattern for DPSK signal on the slow dB-normal fading channel are given and the effect of fading periodicity on the error pattern is discussed. The results of these discussions are also compared with the experimental results obtained for 4800 bps DPSK signal at Mihama in late 1980. This comparison shows that the error pattern is almost predictable for this channel on the assumption of slow fading. It is however necessary for more precise description and evaluation of the channel quality, to get more experimental data and to discuss the transmission characteristics containing the demodulator characteristics.

MEASUREMENT OF SPURIOUS RESPONSES OF A FM RECEIVER BY MEANS OF INTERFERENCE BEAT

Wa SHIOBARA

In general, it takes a lot of time to make measurement of spurious responses of a FM receiver because the measurement must be made over wide frequency range.

To reduce the measurement time, the new method using frequency sweeping technique was developed in our laboratory. In this method, the frequency swept signal (CW) is applied to the receiver input, superposing on the reference signal (CW) whose frequency is set in the pass band of the receiver. Spurious response can be easily observed by detecting beat output resulted from interference between reference and spurious signals appearing in the IF amplifier stage.

This method is characterized by high speed measurement and can be used for automatic measurement device.

HILBERT AND DISCRETE HILBERT TRANSFORM OF A BAND-LIMITED SIGNAL

Yoshiaki ICHINO and Hiroshi MIYAKAWA

The discrete-Hilbert-transformed function is expressible in an infinite series. In order to express this series in finite terms, a suitable approximate method is required. At the beginning of this paper, Hilbert transform of a band-limited signal is examined and an approx-

imate method of discrete Hilbert transform is derived. This method is based on the reduction of a square error in the objective band. Proposed method is compared with customary methods and its effectiveness is confirmed. Furthermore, discrete Hilbert transform of a general periodic signal is derived and correctional comments are given on an insufficient description of V. Čížec paper.

The following report on researches appear in the "Review of the Radio Research Laboratories" (Japanese edition) Vol. 28 No. 146 June 1982.

**OPERATION AND EXPERIMENTAL RESULTS OF IONOSPHERE
SOUNDING SATELLITE-b (ISS-b, UME-2)
OUTLINE OF ISS-b PROJECT**

By
Yukio HAKURA

The project of ISS (Ionosphere Sounding Satellite) has been promoted under the cooperation of the Radio Research Laboratories (RRL), Ministry of Posts and Telecommunications, and the National Space Development Agency of Japan (NASDA). The main objective of the satellite is to carry out observations of the worldwide distributions of ionospheric parameters and radio noises in conjunction with the global survey of radio environment necessary for improvement of efficiency on radio communications.

The first ISS (1976-019A; Ume) was launched on February 29, 1976, but it was put out of commission about one month after the launch because of a malfunction of the main power supply system. The improved backup flight model ISS-b (1978-018A; Ume-2) was launched on February 16, 1978 from Tanegashima Space Center of NASDA by an N-type rocket into a circular orbit of altitude of about 1100 km, inclination angle of about 70 degrees, and revolution period of about 107 minutes.

The spacecraft installs the following four mission apparatus, (1) a digital swept frequency sounder for sounding of the topside ionosphere (TOP), (2) narrow band HF receivers for radio noise measurement (RAN), (3) a retarding potential trap for plasma measurement (RPT), and (4) the Bennett type ion-mass spectrometers for detecting positive ion composition (PIC). In observation modes, the four missions are executed sequentially in every 64 sec.

The regular stage of ISS-b observation has been carried out by the RRL since April 24, 1978. With the routine observation performed for almost three years, a great deal of data over the entire global regions have been accumulated. The present issue summarizes the operational status and the experimental results of this most successful environmental monitoring satellite.

CHARACTERISTICS OF THE RADIO NOISE RECEIVING EQUIPMENT

Chuuka KATOH, Isao KURIKI, Minoru KOTAKI and Hidetoshi SUGIUCHI

We describe the characteristics of the radio noise measurement equipment on-board the Ionosphere Sounding Satellite, ISS-b, which was launched on Feb. 16, 1978 into a semi-circular orbit at an altitude of about 1100 km.

The radio measurement equipment is composed of four HF receivers of which center frequencies are, in order to avoid interferences, fixed in the guard bands of the standard frequency transmission of 2.5, 5, 10, and 25 MHz, respectively.

Each receivers adopted a straight type amplifier, instead of conventional frequency conversion type, so as to exclude non-linear distortion. The band width of the receiver is limited to about 1 kHz by using the monolithic crystal filter. The overall dynamic range of the receiver covers more than 60 dB and it can be in response to the violent change of field strength of radio waves radiated from lightning discharges.

THE ISS-b RETARDING POTENTIAL ANALYZER

Hirota MORI, Shigeru MIYAZAKI, Eiichi SAGAWA and Tadahiko OGAWA

A retarding potential analyzer with spherical electrodes is mounted on the ISS-b. The primary objective is to measure the electron and ion densities and the electron and ion temperatures in the ionosphere. This paper gives the instrumental description of the retarding potential analyzer.

ION MASS SPECTROMETER ON IONOSPHERE SOUNDING SATELLITE (ISS-b)

Iwao IWAMOTO, Nobuyoshi FUGONO and Takeshi SUITZ

An ion mass spectrometer was flown on the Ionosphere Sounding Satellite (ISS-b), which was put into a nearly circular orbit with an inclination of 70 degrees and an altitude of about 1100 km. The observations of global distribution of the positive ions are assured by two identical Bennett spectrometer tubes which are mounted at the top- and bottom-covers of the spacecraft. The Bennett tube is constructed from fifteen planar grids and works as a RF linear accelerator. The mass scan range is 1 to 20 AMU and major positive ion such as H^+ , O^+ and He^+ can be observed. The absolute densities of the positive ions are deduced by in-flight calibration method. In addition to detailed description of the instrument, brief accounts of the observational results are also given. Physical interpretation of the results is presented in accompanying paper.

ON THE STRUCTURE AND FUNCTIONS OF THE ISS-b SATELLITE CONTROL SYSTEMS

Kohji MURANAGA, Makoto URATSUKA and Motokazu SHIKATANI

The construction of Satellite Control Systems and Center building for ISS-b at Kashima Branch RRL, started in July 1970 and was completed in July 1975. All the sub-systems in the Satellite Control Center are controlled by the computer and so they conduct automatically relevant operation like satellite tracking, telemetry data reception and command transmission according to operational pass schedule. As a result of this computer system CSSC, Computer System for Satellite Control, it could be realized to obtain accurately and efficiently the observational data from ISS-b and also to reduce manpower to some extent.

In this paper, the outline of the structure and functions of ISS-b Satellite Control System at Kashima station is described, especially in the facilities based on the process computer control systems.

SCHEDULING OF ISS-b OPERATIONS

Toshiyuki IDE and Kazuhiro AIKYO

The ISS-b spacecraft is capable of storing the observed data with the aid of an on-board tape recorder with maximum recording time slightly longer than the satellite revolutionary period. In addition to this recording capability, the delay command function controlling the start time of data recording enables to choose satellite passes so that the observational points distribute over the earth as uniformly as possible, having successfully achieved worldwide observations of the ionospheric parameters and radio noises. The stored data are telemetered to a ground station through a fast playback mode at the speed of 26 times of the recording.

This paper describes the operational scheduling for ISS-b and the computer algorithm used for actual operations at Kashima and Ottawa ground stations. The basic policy of the scheduling, in general, can be applied to the mapping purposes with the limited number of satellites and TT&C (Telemetry, Tracking and Command) stations.

OPERATIONS OF ISS-b AT KASHIMA STATION AND THEIR RESULT

Makoto URATSUKA, Tomio YANAGIYA, Eiji KAWAI and Sachihito IGUCHI

It was most active period as regards obtaining the experimental data from the ISS-b for the first two years since the beginning of the regular stage operation of ISS-b at Kashima station RRL in April 1978.

This paper states some operation modes and processes to control the ISS-b as the tracking, telemetry and command. Also it discusses the matters and characteristics variations we encountered in the real operations until now, example solar cell's electric power, battery

voltage, sun spin angle, temperature of equipments on board and others.

ORBIT AND ATTITUDE OF ISS-b

Shin-ichi YAMAMOTO and Fumitake SAWADA

Accurate determination of the position and the attitude of ISS-b is necessary for the operation and analysis of the data obtained. Attempts to determine the orbit and the attitude of ISS-b were successfully made at Kashima Station. The attitude determination algorithm has been used on a routine basis. This paper describes the outline of the methods. Some features of long-term variations in the orbit and attitude determined by the methods are also discussed.

OPERATION OF PRIMARY PROCESSING AND DATA ANALYSIS SYSTEM FOR ISS

Mikitoshi NAGAYAMA, Seiji IGI and Mitsuo YAMANISHI

Satellite Operation Planning and Data Analysis System (SODAS) completed in 1976 has been utilized favorably for the operation of ISS-b and for the subsequent data processing and analysis.

The four subsystems included in SODAS prepared for the purposes of carrying out the primary processing and analysis of the ISS-b data were described in this paper.

They are Data Communication System for the satellite data transmission in real time basis and for exchanging informations via 7 GHz micro wave link between the headquarter of RRL and the Earth Station at Kashima, Satellite Data Monitoring System to acquire information of the four missions and the condition of the electric power and the attitude immediately, Satellite Data Processing System to make digital data tapes for experimenters' effectual utilization, and On-line Ionogram Analysis System to scale critical frequency (f_oF2) and resonance frequencies, and to get $N(h)$ profiles from the satellite data.

ON THE APPLICATION OF HOUSEKEEPING DATA TO ISS-b OPERATIONS

Ryo NISHIZAKI, Akira TAKAHIRA and Toshiyuki IDE

Since the attitude of the ISS-b is solely governed by spin stabilization, the satellite conditions such as thermal structure and power supply vary in a complicated manner. Hence, predictions of the satellite conditions are necessary so as to make the satellite operations under optimum scheduling. By using the HK data acquired after injection into the orbit, the

empirical equations were obtained for expressing the long term variations of the sun-spin angle, the ecliptic ratio, the generated power and the temperatures of various parts of the spacecraft equipments including the battery and the magnetic tape recorder as functions of the revolution number or the date. These equations have been used to predict the satellite conditions which must be taken into consideration in the scheduling of the satellite operations.

AUTOMATION OF SATELLITE CONTROL SYSTEM AND ITS EFFECTIVENESS IN ACTUAL OPERATION

Takashi IIDA, Makoto URATSUKA and Kazuaki SAWAJI

This paper describes purposes and outlines of the full-automated system for Ionosphere Sounding Satellite ISS-b control and shows that the automation increases the successful pass rate from 88% to 97% and it can reduce the number of operators from two to one, comparing with the semiautomated system.

GLOBAL DISTRIBUTION OF THE IONOSPHERIC F-LAYER CRITICAL FREQUENCY f_oF2

Nobuo MATUURA, Kazuhiro AIKYO, Ryo NISHIZAKI, Takanobu OGATA, Seiji IGI,
Takashi MARUYAMA, Hisashi YABUUMA, Mitsuo YAMANISHI
and Toshiyuki IDE

The critical frequency of the ionospheric F-layer f_oF2 , one of the basic parameters of the ionosphere, was derived from the topside sounding data obtained by the digital type swept-frequency sounder on-board the ISS-b. The measurements of f_oF2 were carried out on a routine basis with three or four observational revolutions operated in a day, where the values of f_oF2 at about 100 data points were obtained from each revolution. Global mapping analysis was performed with respect to each data group of the world-wide f_oF2 data collected from those observed within each four-months period between August 1978 and June 1979 and also within the time interval of ± 1 hr around each hour of UT. The mapping analysis was carried out in the manner as determining the coefficients of the functional form of the spherical surface harmonic expansion to make it best fit to the global data of the observed f_oF2 . This paper describes the global observation by ISS-b in Section 2, the global mapping analysis of f_oF2 in Section 3, the comparison of the results with those from ground based observations including CCIR model in Section 4, and some characteristics of the global distribution of f_oF2 in Section 5.

ESTIMATION OF f_oF2 FROM INTERFERENCES APPEARING ON AGC DATA OF ISS-b TOPSIDE SOUNDER

Seiji IGI and Nobuo MATUURA

This work is concerned with a method for estimation of f_oF2 from the lowest frequency of the interferences appearing on automatic gain control (AGC) data of the topside sounder on-board ISS-b. For frequencies below f_oF2 , the AGC output is mainly caused by the background noises from cosmic origin revealing a monotonous frequency distribution, while for frequencies above f_oF2 , the AGC output is mainly caused by the interferences from the ground radio origin exhibiting rather complex frequency structures with high intensity levels. Such a change in the frequency distribution of the sounder AGC data provides us a possibility for estimation of f_oF2 values by detecting the lowest frequency of the interferences, f_i . In order to investigate validity of the method for f_oF2 estimation, a statistical comparison was made with respect to about 47,000 ionograms from ISS-b between the f_oF2 values scaled from the echo traces on the topside ionograms and the f_i values determined from the sounder AGC data with the aid of computer processing. The results show that the value of f_i provides a fairly accurate estimation of f_oF2 value over the regions where the intensity of man-made noises is high, while the accuracy is influenced by the D-region absorption of the ground noises during daytime and by existence of the ionospheric irregularities.

GLOBAL DISTRIBUTION OF TOPSIDE SPREAD F

Takashi MARUYAMA and Nobuo MATUURA

The global distribution of the occurrence probability of topside spread F is investigated through the analysis of topside ionograms recorded by the ISS-b satellite for the period from April 1978 to June 1980. The latitudinal distribution of the spread F shows two distinct high occurrence regions, mid to higher latitudes and equatorial latitudes, with relatively low occurrence regions at around 30° in magnetic latitude between the two in both the northern and southern hemispheres. Spread F at the equatorial latitudes (ESF), which is nighttime phenomenon, exhibits clear longitudinal-seasonal variation in the occurrence; for the northern winter and for the northern summer seasons high occurrence of ESF observed at the Atlantic longitudes and at the Pacific longitudes, respectively. Spread F at mid to higher latitudes appears throughout all the local time, and the occurrence probability of that increases with latitudes. Longitudinal dependence of the spread F occurrence in the nighttime is also found at mid latitudes in the winter hemisphere.

LONG-DISTANCE HF PROPAGATION MODES DEDUCED FROM THE SIMULTANEOUS OBSERVATION BY CHIRP SOUNDER AND ISS-b

Masaru ICHINOSE, Shiyu FUJII, Kenrou NOZAKI and Seiji IGI

The propagation modes on 9200 km circuit from Federal Republic of Germany to Japan were identified based on the chirp oblique sounding data and also the ionospheric data along the circuit which were obtained by Ionosphere Sounding Satellite-b (ISS-b).

The oblique sounding ionograms for the circuit were obtained every hour during the period from November 1978 to May 1979 by the chirp-sounder operated with the swept frequency range from 4 to 30 MHz. The ionospheric condition along the circuit was observed by ISS-b of which orbital path could be fairly close to the circuit on some occasions. The propagation time on the circuit were calculated for every frequency steps by substituting the ionospheric factor of the control points to the analytical formulas which were introduced for the parabolic model of the F2 layer. The traces for the oblique ionogram were simulated by plotting these calculated propagation time against the frequency. The simulated traces for 3- to 5-hop propagation modes were compared with those obtained from observations. The results show that the MOF is greater than the theoretical MUF by about 1 MHz.

SHORT-TERM PREDICTION OF HF PROPAGATION

Yugoro TAKENOSHITA, Shoichi ITO, Rikio MAEDA and Tokuji KOIZUMI

Global maps of the MUF variability were made from the *F*-layer critical frequencies observed with the Ionosphere Sounding Satellite-b from October 1978 to March 1979. The maps were used weekly in a trial to correct the monthly MUF of HF circuits predicted in advance of three months by the Radio Research Laboratories. The correction was carried out as a weekly prediction with consideration of temporal and spacial characteristics found in the CCIR MUF maps.

An adequacy of the trial was examined, taking into account of HF circuit data obtained at Hiraiso Branch. The trial with the most reliable data succeeded 55 times, failed 6 times and missed 39 times in correction.

THE GLOBAL DISTRIBUTION OF THUNDERSTORM ACTIVITY OBSERVED BY THE IONOSPHERE SOUNDING SATELLITE (ISS-b)

Minoru KOTAKI, Isao KURIKI, Chuuka KATOH and Hidetoshi SUGIUCHI

Observation of the global distribution of atmospheric, especially lightning discharges has been made by means of four channel HF receivers on board the Ionosphere Sounding Satellite-b. The operational frequencies of the receivers are set in the guard band of the

standard frequency transmission at 2.5, 5, 10 and 25 MHz so as to avoid interference from terrestrial radio transmitters.

The count of lightning discharges which were observed was accumulated in each geographic bin ($10^\circ \times 10^\circ$ in both longitude and latitude) and normalized by the observation time for the area. Based on the data obtained during the period from June, 1978 to May, 1980, the active regions of lightning were mapped out in the form of global distribution divided into every four hours in universal time, 22-02, 02-06, 06-10, 10-14, 14-18, and 18-22 hr of a day for the four seasons.

We estimate the global lightning frequency to be 64 sec^{-1} for the northern spring, 55 sec^{-1} for the summer, 80 sec^{-1} for the fall, and 54 sec^{-1} for the winter. The peak lightning frequency occurs at $10^\circ - 20^\circ \text{S}$ during the northern winter and at $10^\circ - 20^\circ \text{N}$ during the summer. The diurnal variation of global lightning frequency has a peak at 12 hr UT.

COSMIC NOISE OBSERVATIONS AT HIGH RADIO FREQUENCIES

Minoru KOTAKI, Isao KURIKI, Chuuka KATOH and Hidetoshi SUGIUCHI

Using the equipments on-board, the average galactic radio noise has been obtained at the frequencies of 5, 10 and 25 MHz, and the noise powers from the galactic centre and anti-centre at 2.5, 5, 10, and 25 MHz. Generally, the antenna used for receiving on space vehicle has so wide aperture in most cases, it becomes difficult to distinguish the direction of coming radio waves. Since ISS-b has the circular orbit of about 1100 km altitude, the strength of the galactic noise from the centre and anti-centre can be distinguished by the reason that the galactic centre is occulted by the earth at a certain position on an orbit.

The average temperatures of the galactic radio noise at the frequencies of 5, 10 and 25 MHz have the values of $(1.71 + 0.48) \cdot 10^6 \text{K}$, $(4.15 + 1.05) \cdot 10^5 \text{K}$, and $(3.47 + 1.07) \cdot 10^4 \text{K}$, respectively. The radiated power coming from the direction of the galactic centre is higher than that of the anticentre by 2.2-3.5 dB at high frequency range.

THE EFFECTS OF THE IONOSPHERE ON THE EXTENT OF THE RADIO HORIZON AT HIGH FREQUENCY BAND

Minoru KOTAKI, Isao KURIKI, Chuuka KATOH and Hidetoshi SUGIUCHI

In order to estimate the size of radio window viewed from the satellite with high frequency radio waves, the computational study of three dimensional ray trajectories in anisotropic and inhomogeneous ionospheres has been made. The size of radio window changes with frequency of emitted radio waves and the properties of the ionosphere such as the electron density, the thickness and gradient of the layer.

The study clarifies the relations between the size of radio window and the characteristics of the ionized media. The calculated results are supported experimentally by observations of the Ionosphere Sounding Satellite (ISS-b).

GLOBAL DISTRIBUTION OF ATMOSPHERIC RADIO NOISE DERIVED FROM THE GLOBAL DISTRIBUTION OF LIGHTNING ACTIVITY

Minoru KOTAKI and Chuuka KATOH

Based on global maps of thunderstorm activity measured by the Ionosphere Sounding Satellite-b, the atmospheric radio noise levels over the world were calculated. Global distribution maps of atmospheric radio noise were made for frequencies of 2.5, 5, 10, and 20 MHz, for every four hours in universal time during autumn.

The calculated results agree better with world-wide measurements than those given by CCIR Report No. 322, and moreover, some characteristics of the atmospheric radio noise can be well explained by the present method.

OBSERVATIONS OF THE THERMAL PLASMA IN THE TOPSIDE IONOSPHERE BY RPT MISSION OF ISS-b: ELECTRON DENSITY, TEMPERATURE AND MEAN ION MASS

Eiichi SAGAWA, Shigeru MIYAZAKI, Hiroataka MORI and Tadahiko OGAWA

Procedures and results of analysis of the electron data (Langmuir curves) obtained by RPT mission of ISS-b are presented. The electron density (N_e), electron temperature (T_e), and mean ion mass (\bar{M}_i) are deduced from a Langmuir curve of the RPT data by means of a technique of nonlinear least squares fit. Latitudinal and local time dependences of these quantities are in good agreement with previous observations by other satellites.

Their long term variations are examined from the data obtained from August 1978 to November 1979. Annual variation of T_e at the middle latitude is consistent with that by the incoherent scatter observations, but there is an asymmetry between the northern and southern hemispheres. The results also indicate that the annual variation has comparable amplitude to that of the semiannual variation around the magnetic equator.

Global maps of observed quantities are depicted by using the spherical surface harmonic expansion method. Longitudinal dependences of these quantities in addition to latitudinal ones are evident in these maps. The distributions of T_e and M_i in low latitudes are related to each other, and they can be interpreted by the effects of the field-aligned interhemispheric plasma flows caused by atmospheric winds.

OBSERVATIONAL RESULTS OF THE NIGHTTIME ION TEMPERATURES IN THE TOPSIDE IONOSPHERE BY ISS-b

Shigeru MIYAZAKI, Eiichi SAGAWA, Hiroataka MORI and Tadahiko OGAWA

Global distributions of the nighttime ion temperatures in the topside ionosphere were obtained from Ionosphere Sounding Satellite (ISS-b) during August to December 1978.

First, computer processing method for analysis of the ion temperature from ion current of the retarding potential analyzer was described, secondly the observational results of the ion temperatures were described. The results indicate that ion temperatures at low latitudes are lower than that at high latitudes in general, but these latitudinal dependencies vary with longitudes. The ion temperatures near equator are high over the Pacific region comparing with other region. The nighttime ion temperatures in the low latitudes are gradually decreasing with time.

CHARACTERISTICS OF SEASONAL VARIATIONS OF O⁺ ION DENSITY TROUGHS IN THE NIGHTTIME TOPSIDE IONOSPHERE

Shigeru MIYAZAKI, Iwao IWAMOTO, Hirotaka MORI,
Eiichi SAGAWA, Takeshi SUITZ and Tadahiko OGAWA

Proton, helium ion and oxygen ion densities at about 1100 km in the topside ionosphere were observed by the Bennett type ion mass spectrometer on ISS-b during the maximum solar activity period from August 1978 to November 1979. Their global characteristics for seasonal and local time variations were studied by using the spherical surface harmonic expansion method.

The results show that there exist distinguished O⁺ ion density trough regions, and that the centers of main trough are located around the longitudes 0°E and 180°E respectively in northern summer and in northern winter, and around the latitudes 35°-70° in the winter hemisphere. The main trough region changes its location with respect to the seasons by almost 180° in longitude and by moving toward the opposite hemisphere in winter, during rather short term around equinox conditions. The regions of relatively high and low O⁺ ion density show good correlation with the regions of the eastward and westward declination of the earth's magnetic field in connection with the seasons.

A theoretical interpretation is examined such that the O⁺ ion density trough is enhanced by the field-aligned plasma flow induced from neutral air wind pattern coupled with the earth's magnetic field. The seasonal variation of O⁺ ion density can be explained by the changes in the direction of the vertical plasma flow depending on the seasonal changes in the neutral air wind system.

OBSERVATION OF THE ION COMPOSITION BY IONOSPHERE SOUNDING SATELLITE

Iwao IWAMOTO, Eiichi SAGAWA and Takeshi SUITZ

Fairly complete latitudinal, diurnal and seasonal variations of the ion composition have been obtained from the observation by a Bennett ion mass spectrometer aboard Ionosphere Sounding Satellite (ISS-b). The data used in this study were taken during the periods between Aug. 1978 and Dec. 1979, which correspond solar maximum condition.

The latitudinal profiles of the light ions, H^+ and He^+ , almost always show the mid-latitude trough structure. The trough is deeper in the nighttime than in the daytime. The distributions of He^+ have a marked depression at the geomagnetic equator. The equatorial depression of He^+ is also deeper in the nighttime. The seasonal variations of He^+ clearly show the winter bulge structure in the daytime but it disappears in the nighttime. The cause of the disappearance is attributed to the increased loss of He^+ in the winter night. Dependence of the mid-latitude trough position on K_p -index has been derived statistically from the invariant-latitudinal profiles of He^+ .

MEASUREMENT OF TOTAL ELECTRON CONTENT BY SIMULTANEOUS RECEPTION OF ISS-b TELEMETRY SIGNALS

Kazuhiro AIKYO, Takashi MARUYAKA and Minoru KOTAKI

The ISS-b carries two telemetry transmitters with frequencies in VHF (136.810 MHz) and UHF (400.900 MHz) bands. The both telemetry signals are PCM-modulated by the identical data with the bit rate of 26.624 kbps for the dump-mode and of 1.024 kbps for the realtime-mode. The measurement of the differential time-delay between two signals by time comparison of the decoded waveforms enables to reduce the total electron content (TEC) of the ionosphere along the ray path between the spacecraft and the ground station.

This paper deals with the principle, the measuring implement, evaluation of the errors in measured time delay and the method of calibration. A comparison is also made between the TEC measured above Kashima and the first order mid-latitude TEC model derived by Klobuchar and Allen (1970).

Consequently, it is confirmed that this method gives columnar TEC data in good accuracy even for oblique propagation except in case of the large horizontal gradient in electron density.

The following report on researches appear in the "Review of the Radio Research Laboratories" (Japanese edition) Vol. 28 No. 147 September 1982.

**A PERFORMANCE TEST OF A MICROPHONIC RAINDROP-SIZEMETER
BY ARTIFICIAL WATERDROPS AND PHOTOGRAPHING
OF THE DROP SHAPES**

Katsusuka TOHMA, Toshio IHARA, Hiromi YAMAMOTO, Takeshi MANABE,
Yoji FURUHAMA, Katsumi KITAMURA and Yuji IMAI

A microphonic measuring system of the raindrop size distribution and the shape of raindrops are discussed in connection with the millimeter wave attenuation caused by the rainfall. A moving coil microphone with strong damping measures the raindrop size by sensing the momentum of drops falling onto its vibration cone. It has shown remarkable performance in the broad region of the drop size in drop-by-drop experiments, whereas in natural rain experiments shown rather reduced accuracy for small drops because of the shock absorbing role of the thick water film made on the vibration cone.

Waterdrops falling in stagnant air have been photographed, and they have proved to be of the shapes of the Pruppacher-Pitter type.

**A STUDY OF GLOBAL STRUCTURES OF THE IONOSPHERE
BY MODELLING METHODS**

Takashi TANAKA

Diurnal variations of the thermosphere and the ionosphere are calculated by solving simultaneous time-dependent continuity equations for O^+ , H^+ , O_2^+ and NO^+ ions, equations of motions for ions and neutrals, the heat conduction equations for electrons and ions, and photoelectron transport equations. Equations are solved in the region from 120 km altitude to the equatorial plane along the field line, therefore coupling processes between the ionosphere and the protonosphere are fairly taken into account. In addition, micro-processes controlling the energy flow in the thermosphere are treated precisely to evaluate the heating efficiency of EUV radiations. It is shown that the calculated results for the structure of the ionosphere based on MSIS (mass spectrometer and incoherent scatter data) atmospheric model show good agreements with observations.

**PROPAGATION EXPERIMENT AT 140 GHz THROUGH
SIMULATED RAINFALL**

Takeshi MANABE, Toshio IHARA, Katsumi KITAMURA,
Yuji IMAI, Katsusuke TOHMA, and Yoji FURUHAMA

Measurements of rainfall attenuation of a millimeter wave at 140 GHz were conducted through simulated rain using a large scale rainfall installation. By this installation, rainfalls with different drop-size distributions were realized without varying the rainfall rate. It was

experimentally verified that the rainfall attenuation at the millimeter wave band is strongly affected by the raindrop size distribution. A method of inference of the raindrop size distribution from the simultaneous measurements of the attenuation and the rainfall rate was newly proposed. This method was applied to those experimental results. The inferred drop-size distribution showed fairly good agreement with those measured directly. The polarization dependence of attenuation and the depolarization were also measured. The effects of raindrop distortion from spherical shapes were found to be too small to be detected by our experimental system.

20-GHz BANDS RECEIVING FACILITIES AT SUB-EARTH-STATION FOR CS SITE DIVERSITY SWITCHING EXPERIMENTS

Hiroshi KUMAGAI, Shigeru KIMURA, Takahiro KATO, Hideo KOMURO,
Choshichi OUCHI, Kouji OHBU, Takeshi ISOBE, Eiji OUCHI,
Tokuo NISHINO, and Toshihiro HORI

Site diversity switching experiments using CS (Medium-capacity Communications Satellite for Experimental Purposes) were programmed. The satellite communication facilities used in the experiments both at the main- and the sub-earth-station have been constructed in the ECS project. In addition, receiving facilities at 20-GHz bands of CS down-link were newly installed at the sub-earth-station. They were composed of an antenna feed, a low-noise receiver, and a down converter. In the present paper, the outline and the performance of the facilities added at the sub-earth-station are described. The performance of these facilities has proved to be good enough to carry out the experiments.

IN-ORBIT MEASUREMENT OF NOISE FIGURE OF ON-BOARD TRANSPONDER —INVESTIGATION OF MEASUREMENT METHOD—

Hideichi SASAOKA

This paper deals with measurement methods of a transponder noise figure of an in-orbit satellite. Some measurement methods used for ground test are investigated from a viewpoint of suitability for an in-orbit measurement. As a result of the investigation, conventional methods that are the signal generator and Y factor methods are not suitable for an in-orbit measurement. The former is apt to increase the measurement error over an acceptable value. The latter is difficult to connect the input of transponder with noise sources at known temperature. Therefore, a new method which produces less measurement error as compared with the others is proposed. In this method, the noise figure is obtained from the measured values of signal power at a transponder input and of signal-to-noise power ratio at a transponder output. This method is applicable for a transponder which has an AGC function or an input-to-output nonlinearity. However, in case of a nonlinear transponder, a measured signal-to-

noise power ratio is affected with nonlinearity. From the analysis of this effect, it is found that a few corrections are necessary and that the correction factor is expressed as functions of AM-AM and AM-PM conversion factors.

AN EFFECTIVE LENGTH OF RECEIVING VERTICAL ANTENNA ON AND OVER THE GROUND

Yugoro TAKENOSHITA

An effective length of receiving vertical antenna on and over the ground is evaluated by a method of transmission line approximation. The effective length is derived from the induced voltage at the open terminal of antenna output when a sky wave arrived with unit field strength. It is a function of nine parameters (frequency, dielectric constant and conductivity of ground, earth impedance between the bottom of antenna and ground, top height, output height and bottom height of antenna, radius of antenna element, and elevation angle of sky wave).

The following results from analytical studies and evaluations of the function of antenna effective length are obtained:

- (1) Principles of similarity exist between wave length and other parameters with dimension of length, and between earth impedance and characteristic impedance.
- (2) An antenna effective length is not affected by the radius of antenna element, when the earth impedance is zero or infinity.
- (3) Variations of earth impedance are not effective for the effective length, because the earth impedance is usually too small as compared with characteristic impedance.
- (4) Variations of ground conductivity are effective for the effective length in the case where a wave length is long and the ground is wet, and variations of ground dielectric constant are effective in the case where a wave length is rather short and the ground is dry.
- (5) As an antenna is ascending and the top of antenna becomes higher than the height of half wave length, a sidelobe appears. The more the ground is wet, the more the sidelobe is great.
- (6) As a top of earthed antenna is extending, sidelobes appear when the top height is between $(N\lambda/2)$ and $(N\lambda/2+\lambda/4)$.

AIR TRAFFIC CONTROL AND COLLISION AVOIDANCE SYSTEM AND THEIR APPLICATION TO SHIPS

Kimio KONDO and Shuichi MIURA

Air traffic control system, collision avoidance systems and ARPA (CAS for ships) are reviewed. Radar beacon technique is the key to these systems. Application of this technique to ships is useful but has some problems to be solved. Brief description of these problems is also given.

CONSTRUCTION OF A HIGH DENSITY PLASMA DEVICE FOR THE EXPERIMENT OF MICROWAVE-PLASMA INTERACTIONS

Hirota~~ka~~ MORI, Iwao IWAMOTO, Eiichi SAGAWA,
Takeshi SUITZ and Shin YOSHIKADO

A multi-dipole type plasma device was made to perform simulation experiments concerning the propagation of electromagnetic waves in the ionosphere. The device has a shape of a rectangular parallelepiped, the size of which is 60 cm in height, 60 cm in width, and 120 cm in length.

In its early experiments, it was confirmed that very homogeneous and quiescent plasmas could be generated. A typical value of the electron density of the plasma is $3 \times 10^{10} \text{ cm}^{-3}$ under the condition that the emission current from the tungsten filaments is 2 A and the argon gas pressure is 4×10^{-2} Pa.

As a next step, we are going to construct a powerful microwave beam transmitter and its receiving system to observe the interaction between the microwave beam and the high density plasma.