COMMISSION H : Waves in Plasmas (Nov. '2001 - Oct. '2004)

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Based on the papers published from November of 2001 to October of 2004, we compiled major achievements in the field of plasma waves and related studies made by Japanese scientists and their collaborators. We categorize the studies into two groups. One is based on observations and experiments, and the other is theories and computer simulations. Studies in each category are further divided into several sections. Each section provides a specific summary of important scientific achievements rather than a comprehensive report of the whole research activities of Japanese Commission H. On the other hand, the reference list attached at the end is intended to be used as a database of all papers we have collected from the Japanese Commission H members.

H1. Space Observation and Experiments of Plasma Waves

H1.1 Hydromagnetic and ULF Wave Phenomena

The four years covered by this report mark the start and growth of the ground-based remote-sensing of the magnetospheric plasma mass density by using ULF waves; from a geomagnetic field-line eigen-frequency, that is identified by applying method(s) in a group of methods called "gradient methods" to the data from two ground magnetometers separated in latitude by about 1 degree, one can estimate the plasma mass density at the equatorial point along the field line that runs through the midpoint of the two magnetometer sites. By applying this procedure to a chain of ground magnetometers, one can remote-sense the L-dependence of the magnetospheric equatorial plasma mass density. Kyushu University, Japan, having CPMN (Circum-pan Pacific Magnetometer Network; previously called 210MM), has been working along this line of research. Kawano et al. [2002] applied an improved method, called the "amplitude-phase gradient method" (APGM), to actually observed data for the first time, and proved its usefulness; they further improved APGM so that it can be applied to a chain of ground stations at once.

There exist papers on Pc pulsations: Matsuoka et al. [2002] studied high-latitude narrow-band Pc3 pulsations by using ground magnetometer arrays, SuperDARN radars, and the GEOTAIL satellite. As a result they found that, at times, there existed high coherence between the pulsations in the dawn magnetosheath and on the ground, from which fact they suggested that the driving source was located in the magnetosheath. Tanaka et al. [2004] statistically examined the longitudinal structures of coherence, amplitude, and phase of the Pc-3 H component by using three longitudinally separated sub-equatorial stations, and reported for the first time a nearly in-phase structure in the 0730-1700 LT sector and a nearly 180-deg phase jump across 0730 LT. Motoba et al. [2002;2003;2004] reported the existence of, and studied, Pc5-range magnetic-field oscillations on the ground that were actually caused by oscillations of a DP2-type current system.

Electric and magnetic field variations inside the plasmasphere associated with sudden commencements (SCs) are analyzed based on the Akebono satellite observations. Shinbori et al. [2004] showed that intense electric field disturbances with a bi-polar waveform associated with SCs are followed by a dumping oscillation with a period of Pc3-4 ranges. The dumping oscillation persisted for about 3-7 minutes in the equatorial region of the plasmasphere. The phase relation of Ex and Bz components of the oscillation reveals that there is a phase lag of about 90 degrees with compression nature. From this result, Shinbori et al. [2004] concluded that the dumping oscillation generated by SC disturbances may be fast mode waves propagating in the plasmasphere.

Many scientists worked on Pi2 pulsations: Yamaguchi et al. [2002] presented a case study in which a bursty bulk flow (BBF) in the plasma sheet started prior to the corresponding ground Pi2 onset, but was preceded by th ecorresponding Pi2 onset at GOES8. From this and another feature they suggested that the BBF was not the cause of the low-latitude Pi2. Shiokawa et al. [2002] examined 10s-resolution ground-observed auroral images at the times of Pi2s, but did not find an oscillation of the auroral luminosity synchronized with the oscillation of Pi2. Higuchi et al. [2002] presented anew method to identify the Pi2 onset time; the method is based on statistical science and uses, e.g., Akaike Information Criterion (AIC). Saka et al. [2002;2004] suggested, mainly based on observations at the synchronous orbit, that impulsive dusk-to-dawn current near the nightside synchronous orbit, which current is closed by field-aligned currents, is a source of Pi2.Nose et al. [2003] investigated a morning-side Pi2 using ground stations andthe ETS-VI and EXOS-D satellites; from the dependence on (L,LT) of the observed waveform, period and phase, they concluded that the Pi2 was caused by the plasmaspheric cavity mode resonance and that its longitudinal structure was rather uniform. Uozumi et al. [2004] investigated propagations of high-latitude Pi2s observed by CPMN ground stations. With the aid of POLAR/UVI auroral images, they found that Pi2 was observed earlier (by about35s) in the polar cap than in the auroral region; thus, Pi2 in the polar capis to be used to determine the substorm onset time. They also found thestarting MLT of Pi2 to be 22.5 hr.

Fujita et al. (2001) numerically calculated how a Pi2 pulsation propagates in magnetosphere-ionosphere system. They also showed its relation with substorm current wedge (Fujita et al., 2002). In recent years, a cavity resonance mode has been widely believed as the main mechanism of low-latitude Pi2 pulsations. Although it has been implicitly assumed that the frequency should be the same throughout different local time zones for cavity resonance mode, Kosaka et al (2002) and Han et al. (2003) found a local time dependence of dominant frequency. To explain their results, Fujita and Itonaga (2003) made a numerical simulation and showed that the frequency can be local time dependent in longitudinally non-uniform plasmasphere. The propagation mechanism of Pi2 pulsations has also been investigated using satellite data by Nose et al. (2003) and Han et al. (2004), and they confirmed that the cavity resonance mode is the most plausible mechanism in low latitudes. The propagation characteristics in high-latitudes (Uozumi et al., 2004) and in low-latitudes on dayside (Han et al., 2004) were also investigated.

As regards Sudden Commencements/Impulses (SC/SI), Takeuchi et al. [2002a]reported that negative SIs are not caused by reverse shocks but by varied structures such as tangential discontinuities at high-low speed stream interaces, front boundaries of interplanetary magnetic clouds, and trailing edges of heliospheric plasma sheets. Takeuchi et al. [2002b] reported that, for an SC with long rise time (30 min), the corresponding interplanetary shock, observed in the solar wind, was as sharp as usual SCs, but its normalwas highly inclined duskward. Araki et al. [2004] statistically analyzed SCs, and reported that the rise time is essentially determined by time for an interplanetary shock to sweep geoeffective magnetopause length L, which they estimated to be about 30 Re.

Nakagawa et al. [2003] reported left-handed ULF waves with frequency of 0.3-1.1 Hz detected by GEOTAIL at 27 lunar radii upstream of the moon when GEOTAIL was located on field lines that ran through the lunar wake. They explained the observation by polarization-reversal of right-handed, sunward-propagating electron whistler waves with frequencies above 1.4 Hz in the solar wind rest frame, and suggested that the waves were excited by electron beams that had field-aligned-flowed anti-sunward through the lunar wake.

H1.2 Generation and Propagation of ELF/VLF Waves

The Geotail spacecraft has observed Lobe Trapped Continuum Radiation (LTCR) in the Earth's distant magnetotail in the frequency range from several hundreds of Hz up to 8 kHz. Takano et al. [2001, 2004] have estimated the generation region of the LTCR by means of direction finding and 3-d ray tracing analyses. The direction finding analysis with the wave form data of the LTCR has shown that most of the LTCR propagates along the dawn-dusk direction. Comparing this result with the 3-d ray tracing analysis, the generation region of the LTCR has been estimated to be located around the plasma sheet boundary layer and the low latitude boundary layer of the distant magnetotail.

The low latitude boundary layer (LLBL) is a region where solar wind momentum and energy is transferred to the magnetosphere. Enhanced “broadband” electric plasma waves from <5 Hz to 105 Hz and magnetic waves from <5 Hz to the electron cyclotron frequency are characteristic of the LLBL. Tsurutani et al. [2003] reviewed wave-particle interactions, with focus on cross-diffusion rates and the contributions of such interactions toward the formation of the boundary layer and presented a scenario where the global solar wind-magnetosphere interaction is responsible for the auroral zone particle beams, the generation of plasma waves and the formation of the boundary layer.

Shinbori et al. [2002] reported that plasma wave phenomena associated with sudden commencements (SCs) are analyzed by using the Akebono satellite observation data which have been carried out for more than 13 years since March 1989. The 719 cases of SC events showed an enhancement of plasma waves with one-to-one correspondence to the SC onsets measured at Kakioka in the inner magnetosphere, plasmasphere, polar ionosphere. In the middle latitude and in the equatorial region of plasmasphere, electromagnetic whistler, LHR, ion cyclotron mode waves are generated, while in the high latitude region, clear enhancements of electrostatic whistler mode waves with broad-banded spectra are observed.

From time difference between the onset times of SC on the ground and the plasma wave enhancements, Shinbori et al. [2003b] verified that the propagation nature of the SC disturbances deduced from these observations has shown two folding signatures; one route is crossing the equator regions with an average speed of 389.5km/sec, and the other route is passing the polar regions entering from the cusp region and propagating from dayside to nightside polar ionosphere with an average speed of 47km/sec.

Higashi et al. [2004] estimated the impedance of the wire dipole antennas onboard the Akebono satellite by using the electromagnetic field observations for Omega navigational signals. The estimated capacitance and resistance exhibit specific spin variation, which would be caused by the plasma sheath formation around the antenna wires depending on the angle between the antenna direction and the geomagnetic field line.

Imachi et al. [2004] studied the effective lengths of a wire dipole antenna onboard spacecraft and found the frequency dependence from DC (static) to AC (wave) electric fields by a “rheometry” experiment, where a scale model of the antenna is immersed in a water tank with two electrodes creating a quasi-static electric field in it.

The SS-520-2 rocket experiment was carried out over Ny-alesund, Svalbard, Norway, on Dec. 4, 2000, in the dayside polar region. With the onboard Plasma Wave Analyzer (PWA), Ueda et al.

[2003] have observed impulsive packet-like waveforms with frequencies around 3 to 4 kHz as well as auroral hiss emissions. The packet-like waveforms were linearly polarized, and appeared for the duration of 100-500 ms, with their spectral peaks well below the lower cutoff of the auroral hiss emissions. The cross correlation obtained with the PWA interferometry system has estimated the phase velocity of the packet-like waves to be about 60 km/s. With the linear dispersion analysis they have shown that the most plausible wave mode for the packet-like waveforms is the lower hybrid wave excited by electron beams. On the other hand, the Electric Field Detector (EFD) onboard the SS-520-2 rocket was designed to observe DC electric fields and plasma waves with frequencies up to 50 Hz. Miyake et al. [2003] have analyzed EFD data, especially on natural DC electric fields observed in the noon polar region, by eliminating inductive electric fields with estimating several parameters. They have shown that natural DC electric fields were observed around the apogee and descending period of the rocket's trajectory, with their magnitudes of 20-40mV/m, and with almost south-westward directions.

Two large scientific balloons (PPB: Polar Patrol Balloon) were launched on Jan. 13th, 2003 at Syowa Station in the antarctica. The balloons reached the altitude of 33km, and observed important scientific data for about two weeks. Miyake et al. [2004] have participated this project in observing ELF/VLF electromagnetic waves. They developed a wide-band electromagnetic wave receiver EMW (ElectroMagnetic Wave receiver) onboard PPB, which can observe waveforms of ELF waves and power spectra of VLF waves. This EMW receiver worked properly, and succeeded to observe clear electromagnetic wave data.

Singh and Hayakawa [2001, 2003] examined the relative merits of ducted and non-ducted propagation of low-latitude whistler critically in the light of work done mostly in the Asian countries. They found a growing consensus in favor of the non-ducted pro-longitudinal mode of propagation for nighttime whistlers, and ducted propagation for daytime whistlers. Hayakawa and Ohta, [2003] reviewed the direction finding systems and suggested the importance of the use of direction finding in VLF studies with a few experimental examples.

In an attempt to monitor subsurface VLF electric field changes associated with earthquakes, a borehole antenna has been installed at Agra, India. Some preliminary data analysis by Singh et al. [2003] has indicated penetration of ionospheric/magnetospheric VLF signals to large depths in the crustal region and caution for careful identification of seismogenic VLF signals.

Hayakawa and Nickolaenko [2001] reviewed lightning effects onto the mesosphere and lower ionosphere extensively in relation to the generation of sprites and elves and the associated ELF transients. Hobara et al., [2001, 2003] and Hayakawa et al, [2004b] have carried out the observation of sprites for the winter lightning in the Hokuriku area of Japan and found that sprites are really triggered mainly by +CGs whose charge moment change is exceeding the threshold of 200~300

C·km.

Otsuyama et al. [2002, 2003a, 2004a, 2004b] studied the VLF signature of ionospheric perturbations (Trimpis) associated with winter lightning in the Hokuriku area. They found that there is no significant difference in the Trimpi occurrence rate between – and + CGs. Otsuyama et al. [2002] also performed the FDTD computer simulation for VLF scattering in the Earth-ionosphere waveguide.

Molchanov et al. [2001] investigated the modulation in the amplitude and/or phase of subionospheric VLF propagation. The result indicated the significant power in the frequency range of atmospheric gravity waves.

Hayakawa et al. [2004a] have presented the long-term observational results on the ionospheric Alfven resonance at middle latitudes on the basis of observation at Kamchatka and introduced a lot of resonance properties. Nickolaenko et al. [2004c] suggested an alternative mechanism due to the wave interference in the ionosphere and magnetosphere.

Ando et al. [2002] have theoretically investigated the penetrations of power line harmonics and compared with the previous satellite VLF observation.

Soloviev and Hayakawa [2002, 2004] have proposed an algorithm to study the VLF scattering with taken into account a 3D local ionospheric irregularity over the ground of the solar terminator transition on the basis of a mathematical model, an asymptotic theory and an appropriate numerical method.

Hayakawa and Otsuyama [2002], Otsuyama et al. [2003b] and Otsuyama and Hayakawa[2004] have applied the FDTD method to the global Schumann resonances. They demonstrated that this application is expected to be very useful for the complicated ionospheric models (day/night asymmetry, local ionospheric perturbation etc.).

Ando and Hayakawa [2004] have studied the inverse problem extensively for the Schumann resonance data observed at a few stations in the world and deduced the global distribution of background lightning activity.

Nickolaenko et al., [2004a, 2004b] have developed an algorithm to accelerate the convergence of the time domain formal solution for the natural ELF transient pulses in the Earth-ionosphere waveguide.

H1.3 Electrostatic Waves Excited by Electrons

Electrostatic waves associated with reconnection phenomena in the dayside magnetosphere region, were reported by Matsumoto et al. [2003] using the observation results by Geotail skimmed along the dayside magnetopause. They confirmed the 3-dimensional multiple x-line magnetic reconnections take place in the same time period. The observed electrostatic waves are Electrostatic

Solitary Waves (ESW) and Amplitude Modulated Electrostatic Waves (AMEW). They showed that the enhanced broadband electrostatic emissions associated with reconnection are not random noises but are nonlinear coherent structures which may provide important dissipation in the electron diffusion region during reconnection.

In the auroral zone and polar cap region outside the plasmapause, Shinbori et al. [2002, 2003b] reported that electrostatic whistler mode waves with broad-banded spectra suddenly appear below the local electron cyclotron frequency associated with SC onsets measured at Kakioka in the plasma wave data of the Akebono satellite. The ratio (E/H) of electric and magnetic field intensity of the plasma waves at 17.8 kHz obtained by the VLF instruments onboard the Akebono satellite is much larger than that of electromagnetic waves in vacuum. This result suggested electrostatic nature of the whistler mode waves. From simultaneous observation of low energy electrons by the Akebono satellite, Shinbori et al. [2003b] showed that the electrostatic whistler mode waves are excited by electron beams with an energy range of less than 100 eV.

H1.4 Electromagnetic Waves Excited by Electrons

Umeda et al. [2004] presented particle simulations of electrostatic solitary waves (ESW) observed by the Geotail spacecraft and recent spacecraft in the Earth's magnetosphere. Recent particle simulations have demonstrated that ESW correspond to Bernstein-Greene-Kruskal electron holes formed through nonlinear evolution of electron beam instabilities. Since an electron hole is a coherent electrostatic potential structure, electron beam instabilities were conventionally studied by electrostatic particle simulations. However, the Polar spacecraft and FAST spacecraft observed electromagnetic field signatures associated with ESW. To study interaction between coherent electrostatic potentials and electromagnetic waves, we extend the previous electrostatic particle model to an electromagnetic particle model. In the present two-dimensional simulations of an electron beam instability, electromagnetic field components are enhanced around two-dimensional electron holes. We found that the enhancement of electromagnetic fields is due to a current formed by electrons undergoing the $E \times B_0$ drift, where the electric field is a perpendicular electrostatic field at the edge of a two-dimensional electron hole. An electromagnetic beam mode is excited by the current due to the drifting electrons moving with the electron hole. The amplitude ratio of the electric field to the magnetic field is estimated on the basis of the present simulation result, and it is in agreement with those of the Polar and FAST observations.

Imhof et al. [2004] made comparisons between X-ray (>2 keV) emissions emanating from the Earth's Northern Hemisphere aurora observed on the Polar satellite and auroral kilometric radiation (AKR) plasma wave intensities detected on the Geotail satellite. For this comparison the plasma wave frequencies were divided into a low-frequency (LF-AKR) (30-100 kHz) band and a high-frequency (HF-AKR) (100-800 kHz) band. For the LF-AKR band the correlation coefficients with auroral X-ray emissions are generally high intensities often display slower recovery times than do the LF-AKR. and significantly larger than the corresponding coefficients between X-ray and HF-AKR variations. It is found that short time-scale variations of the LF-AKR activity often correspond to the temporal fine structure of the intensity (5-10 min) of X-ray auroral emissions. HF-AKR intensity enhancements generally precede enhancements of the X-ray emissions, while the LF-AKR intensity enhancements generally lag the X-ray enhancements. This sequence implies that auroral acceleration begins at lower altitudes and then moves to higher altitudes. In addition, the time profiles of the X-ray

A year's worth of observations of kilometric continuum (KC) from the plasma wave instrument (PWI) on GEOTAIL and extreme ultraviolet (EUV) images of the plasmasphere from IMAGE are compared. In the vast majority (94%) of the 87 cases when simultaneous data from both spacecraft were available, KC was observed to be associated with density depletions or notch structures in the plasmasphere. From a careful analysis of 1 month of EUV data comprising 13 notch structures, only one notch structure was found in which no accompanying KC was observed when GEOTAIL was in a low-latitude position and therefore should have observed the emission if it were generated. IMAGE observations from the radio plasma imager (RPI) during passage through a plasmaspheric notch structure found that KC was generated in or very near the magnetic equator at steep gradients in density and associated with emissions in the upper hybrid resonance band as previously reported by others at lower frequencies. Statistical analysis of the KC events associated with plasmaspheric notch structures shows that the typical source region is at an equatorial radial distance of 2.4 RE (Earth radii) in the magnetic equator and produces an emission cone that is 40° in longitude and 20° in latitude. These results show that a density depletion or notch structure in the plasmasphere is typically a critical condition for the generation of KC but that the notch structures do not always provide the conditions necessary for the generation of the emission. (Green et al. [2004])

The propagation characteristics of auroral kilometric radiation (AKR), the propagation mode, power flux as well as propagation direction, have been analyzed by applying the wave distribution function method to the Poynting flux measurement data of the Akebono satellite. Hosotani et al. [2001] showed that the power flux of O-mode waves was about 10% of the X-mode wave intensity in strong AKR emissions. The X-mode AKR waves tend to fill inside the radiation cone of an auroral field line, while the O-mode AKR waves showed two different propagation directions: one was directed to almost 90 degree with respect to the local magnetic field and the other showed the propagation angle of about 40 degree. From the above results, Hosotani et al. [2001] concluded that the source locations of the O-mode AKR waves with the above propagation angle located close to the source of the intense X-mode AKR waves.

Murata et al. [2004a] studied the Auroral kilometric radiation(AKR) occultations in the vicinity of the Earth using two observations by GEOTAIL and POLAR. They compared the dynamic spectra of both satellites for eight months paying attention to times and frequencies at which AKR is observed simultaneously. Then, we carefully examined the AKR illumination regions using the POLAR two-month orbit data. Two distinct regions where the AKR is occulted are found during the period. One is the region on the night side of the Earth, where the AKR does not propagate at frequencies > 400kHz. The other region is in the vicinity of the plasmapause, on both the day and night side of the Earth.

Long-term data analysis results of the seasonal variations of AKR activity by Kumamoto et al. [2001] suggested that field-aligned potential drops varies depending on the seasons. The idea was supported by Kumamoto et al. [2001], which clarified the similar seasonal variations of upflowing ion (UFI) events. Furthermore, Kumamoto et al. [2003a] have discovered the solar cycle dependence of vertical distribution of AKR sources and UFI events: AKR and UFI are quiet during solar maximum while they become active during solar minimum. By Kumamoto et al. [2003b], long-term variations of ambient plasma density in the auroral regions has been derived from whistler wave data, and discussed as a control factor of solar cycle variations of field-aligned potential drops and AKR sources.

Shinbori et al. [2003a] showed that the plasma wave data from 263 satellite passages covering the SC onsets included 85 cases of AKR enhancement within a frequency range from 100 kHz to 1.2 MHz. The start time of the AKR enhancements tended to occur after the SC onsets determined by using the geomagnetic records of the Kakioka Magnetic Observatory within a time range from 3 to 8 minutes. The averaged time is about 5.26 minutes. Based on the delay time feature, the magnetic disturbances associated with SCs were thought to propagate from the dayside magnetosphere to the nightside tail region where they compressed the plasma sheet. Furthermore, Shinbori et al. [2003a] discovered the 19 cases of the data sets indicating an enhancement of terrestrial hectometric radiation (THR) occur 1 to 9 minutes after the SC onsets, with the averaged time of 5.84 minutes.

The second harmonic wave properties of AKR were investigated by using the plasma wave data of the Akebono satellite. The statistical analysis results by Hosotani et al. [2003] showed that the probability of a harmonic event occurrence is more than 60% of all AKR events, whose relationship between the frequencies of the fundamentals and the second harmonics is exactly two times for the upper and lower cut-off frequencies of the spectra as well as the fine structures. Hosotani et al. [2003] showed that the intensity ratio of the second harmonics to the fundamentals exhibits a two-fold nature, with both a linear and a quadratic relationship. Furthermore, the second harmonic waves of the X-mode of AKR are generated from a source which is identical to that of fundamental waves of the O-mode. These data analysis results suggest that possible generation mechanism of AKR harmonic structure should allow the coexistence of different AKR emission processes.

H1.5 Observational and Experimental Techniques

In order to determine the propagation mode of Jovian decametric radiation (DAM), Nakajo et al. [2001] instrumented the long range baseline interferometer and examined the stability of the phase information to the interferometry system. In the long baseline interferometer observation, it has been well known that the observed fringe phases are fluctuated by the temporary variation of TEC (Total Electron Contents). The dual frequency interferometer method is a powerful method to eliminate the influence of TEC; however, the problem caused by the dependence of the linear equations must be considered in the case of the observation of Jovian decametric radiation. Based on a simulation study, Nakajo et al. [2001] also showed that the following conditions are required in order to solve this problem; that is (i) the fringe phases are detected with accuracy under the standard deviation of 6 degree, and (ii) the temporal variation of TEC difference between two observation sites should be smaller than $5.0 \times 10^{15} [1/m^2]$.

S-burst phenomena of DAM are investigated by Oya et al. [2001a], who reported that dynamic spectra of the S-bursts are obtained by using a high time resolution radio spectrograph with a time resolution of 2 ms and a bandwidth of 2 MHz. Within the occurrence feature of 65 S-burst events observed in the period from 1983 to 1999, 26 events have been identified as the S-N burst events, which are characterized by the interaction between the S-burst emissions and the Narrow band emissions.

Oya et al. [2001b] have developed array antenna system and multi-frequency interferometer network to investigate the electromagnetic radiation process in the Jovian magnetosphere. To understand the energy source and the radiation process of DAM with correlation to the Jovian auroras, ionosphere-magnetosphere couplings and interactions with satellite Io, it is important to obtain the information on the source location and the polarization of DAMs. The array antenna system consists of 9 antennas covering a frequency range from 20 MHz to 30 MHz. The new long baseline interferometer system employs the multi-frequency interferometer method by which ionosphere scintillation effect can be largely reduced.

Tsutsui (2002) developed a newly developed system for measuring electromagnetic (EM) environment in the earth, we detected earth-origin electric pulses which were leaking out of the ground. The author reported that intensity of the electric pulses detected above the ground was weaker than those in the earth. Due to the clear lower frequency cutoffs appeared in their spectra he suggested the existence of a kind of horizontal wave-guide in the earth and the propagation of EM waves there. The estimated scale depth of the bottom conductive boundary of the wave-guide is consistent with the result obtained from geomagnetic field investigations.

In the dynamic spectra of the S-N burst, Oya et al. [2002] found the trend of emissions with negative and slower frequency drift named as "Trailing Edge Emission (TEE)", which are often observed shortly after the appearance of the S-burst. Detailed analyses of these phenomena revealed that the TEE is not a manifestation of S-burst with slower drift rate but a variation of N-burst. The results suggested that S-burst and the associated TEE are formed simultaneously started from a common region with different drift rates. Furthermore, Oya et al. [2002] interpreted that the appearance of the S-bursts is not controlled by the geometrical effect between the source region and the observer, but directly reflects the generation of the source region widely distributed in an altitude range from a few thousands km to 30.000 km, along the Io flux tube.

Oya and Iizima [2003] proposed a new method for detecting the phase difference of cesium frequency standards facilitated at coupling stations of an interferometer of 100km range baselines for observations of decameter wavelength radio waves. In this method, the Earth's rotation is utilized. That is, a time-depending variation of the phase differences of arriving radio waves from a given source forms a so-called fringe function due to the Earth's rotation. The feasibility of the proposed method has been verified by applying the method to observations of a 100km range baseline interferometer for decameter wavelength radio waves at Tohoku University selecting the radio-wave sources in the Cassiopeia A supernova remnant as the objective. The results of the analyzed correlation values averaged for the observation data of 30hr, at 22.158MHz, are determined being scattered around average values with a distribution of less than 25%; this distribution corresponds to a phase determination error of for the cesium frequency standards of the interferometer at 10MHz.

Hashimoto et al., (2003) developed a software wave receiver utilizing a programmable down converter (HSP50214B) and a digital data processor (TMS320C31) to obtain the spectra and waveform of plasma waves in wide frequency ranges of ELF, VLF and LF bands with high frequency and time resolution. They reported the successful flight test by using the SS520-2 rocket experiment on Dec. 2000 launched from Ny-Alesund in Svalbard in Norway. The result of the rocket experiment provided the verification of digital receiver system on-board the SELENE spacecraft.

Hashimoto et al. [2003] developed a software wave receiver and was installed aboard the SS-520-2 rocket as a part of the Plasma Wave Analyzer (PWA). This receiver consists of a waveform receiver using real-time data compression and a spectral receiver with high time and frequency resolution using a Programmable Down Converter (PDC). They reported the first flight test of the new plasma wave receiver to be used for future planet explorers and space observation missions. Every 0.5 seconds, spectra of a 3MHz signal with 0.3kHz resolution are obtained and the data compression of waveforms with the bandwidth of 15 kHz are performed. Although the sweep time was occassionally affected if the data were not compressed enough, no data were lost during the flight.

H2. Theory and Computer Experiments on Plasma Waves

H2.1 Wave Instabilities

Kasaba et al. [2004] studied several topics related to the 2fp radiation generated in the terrestrial electron foreshock. Our investigation started from the macroscopic geometry of the radio source, and is expanding to the microscopic processes. In this paper, we present a summary of latter studies, especially about the generation mechanism of electrostatic and electromagnetic 2fp waves and the electron acceleration at the quasi-perpendicular shcok.

Omura et al. (2003) have studied the response of thermal plasmas to an induction electric field via one-dimensional particle simulations. The induction electric field is assumed to be uniform in space and constant in time. Because of acceleration of electrons and ions in the opposite directions, there arise counter streaming electrons and ions that cause the Buneman instability. Depending on the ratio of the ion temperature T_i to the electron temperature T_e, responses to the electric field are different. For a case with hot ions ($T_i \gg T_e$) the Buneman instability leads to formation of large isolated electrostatic potentials which trap some electrons to move with ions. For a case with colder ions ($T_i \ll T_e$) the Buneman instability is taken over by excitation of ion acoustic waves, which diffuse the low-energy part of the accelerated electrons to stabilize the instability. However, a substantial part of the electrons are grouped together at the high-energy part, forming a distinct bump in the electron distribution. In the present simulations we have found that the induction electric field can form an electron beam along the magnetic field line. Since the electron beam leaves the region of the induction electric field and moves into an unperturbed plasma, the accelerated electrons can cause a bump-on-tail instability. This can lead to formation of electrostatic solitary waves as frequently observed by the GEOTAIL spacecraft in the plasma sheet boundary layer (PSBL). The persistent observation of the electrostatic solitary waves indicates their association with the induction electric field that results from meandering motion of the current sheet in the magnetotail.

Krasovsky et al. (2002) studied the dynamics of high energy electrons in gyroresonance with a quasi-monochromatic circularly polarized whistler mode tracing a geomagnetic field line are studied numerically. The wavenumber and amplitude of the whistler wave are assumed to be slowly varying functions due to the weak longitudinal inhomogeneity of the geomagnetic field. The space-time dependence of the electromagnetic field manifests itself in the existence of an approximate invariant of the electron motion. Under the conditions characteristic of the magnetosphere, this invariant is found to be conserved with very high accuracy even in the process of resonant wave-particle interaction, whereas the constancy of the electron magnetic moment is strongly violated in the resonance. The availability of the approximate constant of the motion allows one to describe the gyroresonant wave-particle interaction with the aid of simpler equations averaged over the fast Larmor gyration.

Matsukiyo et al. [2004] succeeded in reproducing the high-frequency electric wave spectra observed in the auroral upward current region by one-dimensional particle-in-cell simulations. Using distribution functions suggested by the measurements, they found that in the nonlinear state, ion acoustic waves and electron two-stream (Langmuir) waves dominate the spectrum. In the absence of cold electrons, electron acoustic waves are not excited initially but appear only at a late time. This is due to the result of the formation of a two-temperature electron plasma by nonlinear interactions when all other instabilities have saturated. However, owing to the weakness of these electron acoustic waves, they are less important for the formation of electron holes and affect the particle dynamics much less than the two-stream instability.

The formation process of ESW were studied by Umeda et al. [2002]. They conducted one- and two-dimensional electrostatic particle simulations with open boundaries. They inject a weak electron beam from an open boundary into the background plasma to study spatial and temporal development of a bump-on-tail instability from a localized source. In the open system, spatial structures of electron holes vary depending on the distance from the source of the electron beam. They showed the following scenario of the time and spatial evolution of ESW potentilas: In an early phase of the simulation run, electron holes that are initially uniform in the direction perpendicular to the magnetic field become twisted through modulation by oblique electron beam modes. As the electron holes propagate along the magnetic field, they are aligned in the perpendicular direction through coalescence. Spatial structures of electron holes in a distant region from the source become one-dimensional. In a long-time evolution of the instability, ion dynamics becomes important in determining spatial structures of electron holes. A lower hybrid mode is excited locally in the region close to the source of the electron beam through coupling with electron holes at the same parallel phase velocity. The lower hybrid mode modulates electron holes excited in later phases, resulting in formation of modulated one-dimensional potentials.

Shin et al. [2004] showed the waveforms of the intense electrostatic waves observed in the downstream region are quasi-monochromatic. They named their waves Electrostatic Quasi-Monochromatic (EQM) waves. By comparing the plasma wave data with electron data, they found the good correlation of the observations of EQM waves with beam-like cold electrons. They suggested that the EQM waves are electron acoustic mode waves based on the preliminary linear dispersion analyses.

Deng et al. [2004] have provided possible evidence of multiple X lines collisionless reconnection in the magnetotail at the microscopic level by combining the observations of plasma, magnetic field, particles, and waves. On 11 December 1994 the Geotail spacecraft encountered an active reconnection diffusion region around the X line in the Earth's magnetotail. Three interesting features were observed. One is quadrupole pattern of the out-of-plane By magnetic field component during the passage of magnetic islands and the crossing of the neutral sheet. The second is a direction reversal of the electron beams in the vicinity of the separatrix of the magnetic topology of reconnection. The third is a clear plasma flow reversal.

H2.2 Wave Propagations

Hikishima et al. [2004] investigated the cyclotron resonance and pitch-angle diffusion of resonant electrons by means of theoretical analysis and particle simulation involved in the generation and propagation of chorus emissions in the Earth's magnetosphere. The results indicate that the resonant electrons with initially large pitch-angle anisotropy are rapidly pitch-angle diffused by a generated whistler mode wave, and the subsequent anisotropy decrease saturates the wave growth.

H2.3 Shocks and Particle Acceleration

Nishimura et al. [2004] studied the acceleration and heating of electrons at quasi-parallel shock waves by means of a one-dimensional full particle computer simulation. Our simulation shows that the ion beam instability due to the anomalous cyclotron resonance excites whistler mode waves in the upstream region. When the Mach number becomes large beyond a critical value, the whistler wave packets do not appear. The electron acceleration parallel to the magnetic field results from the parallel electric fields caused by both the whistler mode waves and the electrostatic shock potential. The potential concerning the parallel electric field increases with Mach number below the critical Mach number but is relatively independent of the Mach number beyond the critical Mach number. This verifies that the contribution of the whistler waves to the parallel acceleration is as important as that of the electrostatic shock potential below the critical Mach number. Also, the spatial profile of the potential concerning the parallel electric field is clearly correlated with the magnetic field profile. Downstream, the electron temperature is anisotropic such that the parallel temperature is larger than the perpendicular temperature. The Mach number dependence of the electron parallel temperature can be evaluated from the viewpoint of a wave-particle interaction (current-driven instability).

Nishimura et al. [2003] investigated the properties of reformation in perpendicular collisionless shocks by means of a one-dimensional particle-in-cell simulation. Reformation is associated with ion reflection at the shock ramp and subsequent ion gyromotion in the upstream region. However, if ions are reflected continuously at the ramp, why does the shock reform intermittently at sufficiently high Mach number? The simulations show that the shock potential changes dramatically through the re-formation cycle, so that it is this potential variation which leads to the intermittent response of the shock.

Katoh et al. [2003, 2005] studied particle acceleration processes due to wave particle interactions by employing numerical simulations based on a hybrid algorithm in order to investigate the merging process of cometary oxygen ions into the solar wind and verify a elementary process of energizing mechanism of relativistic electrons in the outer radiation belt during a geomagnetic storm recovery phase. Katoh et al. [2003] carried out one-dimensional hybrid simulation, whose results revealed that a spatial extent of interaction region surrounding comet nucleus is deeply related to the ion beam instability driven by a field aligned motion of picked-up ions. By utilizing a newly developed simulation scheme named as ‘electron hybrid code’, Katoh et al. [2005] investigated pitch angle and energy diffusion processes of relativistic electrons through the resonant interaction by comparing results of the numerical experiment and the quasi-linear theory under the same condition of the interaction between whistler mode waves and high energy electrons. The difference between their results suggests the importance of the verification of the theory under the realistic plasma condition corresponding to the observed parameters in the real magnetosphere.

Nishimura et al. [2002] studied the acceleration and heating of electrons at quasi-parallel shock waves by means of a one-dimensional full particle computer simulation. Their simulation shows that the ion beam instability due to the anomalous cyclotron resonance excites whistler mode waves in the upstream region. The electron acceleration parallel to the magnetic field results from the parallel electric fields caused by both the whistler mode waves and the electrostatic shock potential. They found that the contribution of the whistler waves to the parallel acceleration is as important as that of the electrostatic shock potential below the critical Mach number.

The properties of reformation in perpendicular collisionless shocks were investigated by Nishimura et al. [2003] using one-dimensional particle-in-cell simulation. The reformation is known to be associated with ion reflection at the shock ramp and subsequent ion gyromotion in the upstream region. However, it is also known that the shock reforms intermittently at sufficiently high Mach number if ions are reflected continuously at the ramp. The simulations were performed to investigate this issue and they found that the shock potential changes dramatically through the re-formation cycle, so that the potential variation leads to the intermittent response of the shock.

Hada et al. [2003] analyzed the shock front nonstationarity of perpendicular shocks in super-critical regime by examining the coupling between "incoming" and "reflected" ion populations. For a given set of parameters including the upstream Mach number and the fraction alpha of reflected to incoming ions, a self-consistent, time-stationary solution of the coupling between ion streams and the electromagnetic field was sought. The analytic results were in good agreement with full particle simulations for low beta case.

Futaana et al. [2003] studied the nonthermal ions which were measured by Particle Spectrum Analyzer/Ion Spectrum Analyzer (PSA/ISA) on board the Nozomi when the spacecraft was very close to the Moon. It was found that the nonthermal ions were protons and had a partial ring structure in the phase space. By conducting particle tracing calculation, their source location was found to be the dayside of the Moon, and the nonthermal ions seem to have large velocities when they were generated. It was proposed that the electromagnetic field in the vicinity of the Moon must have a dynamic structure, possibly a miniature bow shock associated with a local magnetic anomaly, where some of the solar wind protons are deflected to forms a partial ring structure in the velocity phase space.

Cross field diffusion of energetic particles (cosmic rays) in a two-dimensional static magnetic field turbulence is studied by Otsuka and Hada [2003] by performing test particle simulations. Qualitatively different diffusion processes were observed depending on the ratio of Larmor radius to the correlation length of the magnetic field fluctuations. The diffusion was found to be composed of several regimes with distinct statistical properties, which can be characterized using Levy statistics.

Lembege et al. [2004] published a review to address a subset of unresolved problems in collisionless shock physics from a theoretical and/or numerical modeling point of view. The topics are the nonstationarity of the shock front, the heating and dynamics of electrons through the shock layer, particle diffusion in turbulent electric and magnetic fields, particle acceleration, and the interaction of pickup ions with collisionless shocks.

H2.4 Nonlinear Effects

Usui et al. [2002] studied a three-wave coupling process occurring in an active experiment of microwave power transmission in the ionospheric plasma by performing one-dimensional electromagnetic particle simulations. In the simulations, low-frequency electrostatic bursts are discontinuously observed in space. The discontinuity of the electrostatic bursts is accounted for by the local electron heating due to the bursts and the associated modification of the wave dispersion relation. They found that the character of the electrostatic bursts essentially differ for cases in which pump wave propagates either parallel or perpendicular to the geomagnetic field.

Krasovsky et al. [2003] considered the electrostatic pulses recorded by the Geotail spacecraft and labeled electrostatic solitary waves (ESW) within the framework of Bernstein-Greene-Kruskal (BGK) solitons. The general approach developed in the article applies to arbitrary particle distributions of the background plasma, velocities of the BGK solitons and wide variety of the recorded ESW waveforms. The new models and physical interrelations reveal universal features of the BGK soliton structure and allow a direct juxtaposition with the observations. The established interconnections between the physical characteristics of the waves agree well with the Geotail data on ESW waveforms

Generation of electrostatic multiple harmonic Langmuir modes during beam-plasma interaction process has been observed in laboratory and spaceborne active experiments, as well as in computer simulation experiments. Despite earlier efforts, such a phenomenon has not been completely characterized both theoretically and in terms of numerical simulations. Yoon et al. [2003] found analytic expressions for harmonic Langmuir mode dispersion relations and compared their results with numerical simulation results.

Gaelzer et al. [2003] developed generalized weak turbulence theory in which multiharmonic Langmuir modes were included and the self-consistent particle and wave kinetic equations were solved. The result shows that harmonic Langmuir mode spectra exhibit a quasi-power-law feature, implying multiscale structure in both frequency and wave number space spanning several orders of magnitude.

The generation of harmonic Langmuir modes during beam plasma interaction was studied by Umeda et al. [2003] with nonlinear theoretical calculations and computer simulations. In their Vlasov simulation code, multiple harmonic Langmuir modes up to 12th harmonics can be included in contrast to previously available simulations which were restricted to the second harmonic only. The frequency-wave-number spectrum obtained by taking the Fourier transformation of simulated electric field both in time and space showed an excellent agreement with the theoretical nonlinear dispersion relations for harmonic Langmuir waves. The saturated wave amplitude features a quasi-power-law spectrum which reveals that the harmonic generation process is an integral part of the Langmuir turbulence.

Krasovsky et al. [2004] studied the electrostatic pulses observed by satellites in space plasmas with the concept of electron phase density holes to clarify the qualitative differences between the actual three-dimensional (3-D) perturbations and the well-known 1-D Bernstein-Greene-Kruskal (BGK) modes of the electron hole type. They showed that the anisotropy caused by the geomagnetic field is a decisive factor and the hole-like structures is closely connected with the quasi-one-dimensional nature of the electron motion, predominantly along the external magnetic field.

A linear analysis and 2-1/2dimensional electromagnetic full-particle simulations were performed by Fujimoto and Machida [2003] to investigate mechanisms of an electron heating due to an intense Hall current, which is caused by a large velocity difference between electrons and ions in the outflow region inside the diffusion region of the magnetic reconnection. The numerical solution of the kinetic dispersion relation predicted an unstable mode varies according to the electron-ion relative velocity Vd; the kinetic cross-field streaming instability (KCSI) is dominant when Vd is under the substantial fraction of the electron thermal velocity ve, while the electron cyclotron drift instability (ECDI) is first excited for the case where Vd exceeds the critical velocity. It was shown that electrons are heated parallel to the ambient magnetic field due to the KCSI and perpendicularly due to the ECDI. In particular, electrons are very quickly heated up to a high temperature when the ECDI is dominant. However, the electron heating is ineffective when $Vd/ve < 1$.

Shklyar and Matsumoto [2002] studied the initial problem of plasma wave dynamics in the presence of a sharp density jump that divides the space into transparent and opaque regions. A wave packet was assumed to be initially localized in the transparent region. The transient process of field penetration beyond the density barrier during the wave packet reflection from the density jump was investigated. Signal velocity beyond the barrier was defined as the speed at which some small, but finite, value of the field amplitude appearing in the evanescent region. This velocity was determined analytically for the case of quasi-Gaussian wave packet. Also insight into the field dynamics in opaque region was gained by considering a steplike initial wave packet.

In order to self-consistently study the kinetic processes at the Venus ionopause, Terada et al. [2002] calculated the Venus ionopause-solar wind interaction region kinetically, including the ionosphere, ionopause transition layer, magnetosheath, and solar wind, by applying boundary-fitted coordinates to the particle-in-cell code. They found that the distribution of ionopause surface waves generated by the Kelvin-Helmholtz (K-H) instability exhibits a clear asymmetry between hemispheres of upward and downward solar wind motional electric fields. Accordingly, the asymmetrical momentum transport across the ionopause yields an asymmetrical convection pattern of the ionosphere.

Terada et al. [2004] extended their work to study a viscous process associated with the K-H instability around the ionopause, which is less well understood compared to the pickup process of exsospheric ions and electrons. They studied the relative importance of the escape processes for the case of low solar wind dynamic pressure as well as for the high dynamic pressure case, and showed the viscous removal process occurring at the ionopause plays a significant role in the ion escape from Venus. Their model also suggests the asymmetrical appearance of "disappearing nightside ionosphere".

A merging process of cometary oxygen ions into the solar wind particle was studied by Katoh et al. [2003] employing numerical simulations based on a hybrid algorithm. The results of one-dimensional hybrid simulation shows that a spatial extent of interaction region surrounding comet nucleus is deeply related to the ion beam instability driven by a field aligned motion of picked-up ions.

Katoh et al. [2005] investigated pitch angle and energy diffusion processes of relativistic electrons through the resonant interaction by comparing results of the numerical experiment and the quasi-linear theory under the same condition of the interaction between whistler mode waves and high energy electrons. The difference between their results suggests the importance of the verification of the theory under the realistic plasma condition corresponding to the observed parameters in the real magnetosphere.

Matsukiyo and Hada [2002] studied a long time evolution of cyclotron maser instability at null wave number (k=0) which is destabilized by relativistic ring distribution of plasma through the cyclotron resonance. They performed particle simulations using a plasma which consists of relativistic ring electrons, background positrons, and background electrons. The linear and nonlinear stages of the system evolution were examined for both gyrotropic and nongyrotropic ring distributions. The linear theory predicts that, when the initial ring energy is strongly relativistic, there appears a critical initial ring momentum at which the system is marginally stable. Numerical simulations show, however, that the system is nonlinearly unstable even when the initial ring momentum exceeds the critical momentum. The final saturation level of the wave energy was obtained analytically.

Matsukiyo and Hada [2003] examined the dispersion relation and nonlinear evolution of the parametric instabilities of circularly polarized Alfven waves in a relativistic electron-positron plasma. First, the nonlinear dispersion was solved in a nonrelativistic limit, then the weakly relativistic effect was examined. The one-dimensional full particle simulation and bicoherence analysis of the simulation result suggest that successive decay via the interaction between the parallel propagating Langmuir-like wave and antiparallel propagating Alfven-like wave can efficiently generate a continuum of low frequency electromagnetic waves, which can interact with energetic particles.

H2.5 Active Experiment and Spacecraft-Environment Interaction

Using topside sounder data obtained by the Ohzora (EXOS-C) satellite, Uemoto et al. [2004] investigated the structure and dynamics of the ionization ledge in the equatorial topside ionosphere. They found that the ionization ledge observed in the local noon time period shows similar nature as it has been theoretically predicted for the F3 layer. Also they indicated that the seasonal dependence of the occurrence probability of the ionization ledge has a tendency contrary to that of the F3 layer.

Usui et al. [2004a, 2004b] for the first time applied electromagnetic PIC (Particle-In-Cell) computer simulations to analyze the antenna characteristics in magnetized plasma. They particularly examined the electron kinetic effects on the antenna impedance. It is confirmed that the most obvious resonance point is the local Upper Hybrid Resonance frequency. As the electron temperature increases, the resonance frequency also increases in accordance with the modification of dispersion relation for the UHR branch. They also examined the electromagnetic environment of the sheath region created at the antenna surface by performing EM-PIC simulations. They could basically confirm the sheath waves propagating along the metal-plasma interface at the frequencies lower than those of normal wave modes for uniform plasma with no external magnetic field. In magnetized plasma, They also could observe the sheath waves below the Upper Hybrid Resonance frequency. They could also confirm unidirectional waves propagating below the UHR frequency.

Numerical simulations on active perturbation of space environment by microwave power transmission (MPT) and plasma beam emission for the spacecraft charging control have been performed. Usui et al.[2002] studied a three-wave coupling process occurring in an active experiment of MPT in the ionospheric plasma by performing one dimensional electromagnetic PIC (Particle-In-Cell) simulations. Continuous emission of intense electromagnetic waves from an antenna located at a simulation boundary excites a low-frequency electrostatic wave as the result of a nonlinear three-wave coupling. They also found that the low-frequency electrostatic bursts are discontinuously observed in space. The discontinuity of the electrostatic bursts is accounted for by the local electron heating due to the bursts and the associated modification of the wave dispersion relation. Usui et al. [2004c] also studied the basic process of the spacecraft charging and its neutralization using dense plasma emission by performing PIC simulations. They particularly examined the electron/ion flux to the charged body and the corresponding potential variation. It is shown that the negatively charged body is neutralized mainly by the enhancement of ion flux of the emitted plasma In the transient process of the charge neutralization, they found very turbulent current variation at the emitted plasma cloud region, which may cause electromagnetic perturbation in the vicinity of the body.

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similar nature as it has been theoretically predicted for the F3 layer. Also they indicated that the seasonal dependence of the occurrence probability of the ionization ledge has a tendency contrary to that of the F3 layer.

H2.6 Techniques of Data Analysis and Computer Experiments

Akimoto et al. [2003] developed a new general-purpose computational technique for classifying the plasma waves in a systematic way from database of scientific satellite. Firstly, we propose a two-step cluster analysis for the classification. Applying this cluster analysis to the key parameters of the Akebono wave data, we could make some representative classes of wave phenomena with a small amount of calculation time. In order to determine the suitable number of representative class, we propose an evaluation function with AIC. Finally, we discriminated to the representative classes and exception.

Kasahara et al. [2002] introduced new computational techniques for extracting the attributes and/or characteristics of the plasma waves and particles from the enormous scientific database. These techniques enable us to represent the characteristics of complicated phenomena using a few key-parameters, and also to analyze large amount of datasets in a systematic way. These techniques are applied to the observational data of the ion heating/acceleration phenomena in the auroral region obtained by the Akebono satellite. Finally we evaluate our algorithms through some correlation analyses between waves and particles and demonstrate their availability.

Tanaka et al. [2004] developed a general-purpose system which manages and provides various kinds of information accumulated in our university. One of the most important points in the design of the system is management of the enormous amount of data, which comes up to several tera-bytes in the field of natural science in some cases. In the present study, we constructed a database system on the geospace radio environment obtained by the Akebono satellite. This is a model case of enormous database systems especially in natural science because there are huge and variety kinds of data on the space environment measurement. In the paper, we introduced the system and evaluated the performance.

The lunar radar sounder (LRS) experiment onboard SELENE (SELenological and ENgineering Explorer) has been planned for observation of the lunar surface and subsurface structures. The computer simulation of the LRS observations and development of data analysis method have been performed by Kobayashi et al. [2002a] using newly developed simulation code, Kirchhoff approximation sounder simulation (KiSS) code. It has been shown by the simulation that the subsurface echoes are detectable by using data stacking technique. Kobayashi et al. [2002b] has also performed the simulation of the LRS observations in the lunar highland regions, where subsurface echoes are severely masked by confusing surface echoes. The application of the synthetic aperture radar (SAR) method for subsurface echo analysis in the lunar highland region has been proposed based on the simulation results.

One of the most important methods for the studies of plasma waves observed by spacecraft is to compare them with other observations either with same spacecraft or with other spacecraft. Simultaneous ground-based observations also help our understandings of the plasma wave generation mechanisms. Murata [2003] and Murata et al. [2002a] have constructed a software system (STARS) to gather observation data files individually managed at several organizations. It also provides a variety of functions to plot and analyze the data. For 3-dimensional data analyses of the observation data, a virtual Earth's magnetosphere system (VEMS) is produced by Murata et al. [2004b].

Murata et al. [2002b], Murata et al. [2002c], Murata [2002d] and Murata et al. [2002e] have developed systems to achieve high-performance computing and to support computer simulations for plasma particle simulations.

References

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