Commission H (Waves in Plasmas) Activity Report

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Research Topics

GEOTAIL

GEOTAIL spacecraft has been operated since 1992. The Plasma Wave Instrument (PWI) is continuously collecting spectrum data and high time-resolution waveform data. It is expected to be in a good condition at least until the next long eclipse in 2012. The 24 hour plots of the observed wave spectrum data have been opened in the PWI web site http://www.rish.kyoto-u.ac.jp/gtlpwi, and http://www.stp.isas.jaxa.jp/geotail. Furthermore, one can easily also access the PWI 2 hour plots with full time and frequency resolution through the above web page.

BepiColombo

The BepiColombo is the science mission to Mercury. It is the first collaborative science mission between JAXA and ESA. The BepiColombo mission consists of two individual spacecraft called MPO (Mercury Planetary Orbiter) and MMO (Mercury Magnetospheric Orbiter). Scientists in Japan and Europe jointly proposed the plasma wave observation system called PWI (Plasma Wave Investigation). The MMO launch is scheduled in 2014. The Principal Investigator of the PWI is Prof. Yasumasa Kasaba of Tohoku University.

The PWI investigates plasma/radio waves and DC electric field in Mercury magnetosphere. It consists of two components of receivers, two sets of electric field sensors, two kinds of magnetic field sensors, and the antenna impedance measurement system.

The Flight model integration test of the PWI is ongoing in Research Institute for Sustainable Humanosphere of Kyoto University. It will finish in the end of July, 2011 and the system integration test will start in August at ISAS/JAXA.

Business card size waveform receiver. The receiver has the capability to observe 6-components of waveforms up to 100kHz, simultaneously.

<Miniaturized waveform capture receiver>

Fukuhara et al. [2011] succeeded in the development of the very small waveform capture receiver using the analogue ASIC chip. They realized 6channels waveform receivers with the function of the receiver gain inside the chip with the size of 5mm x 5mm. The bandwidth of this receiver is 100 kHz. The upper limit frequency is well defined using the switched-capacitor filter. They also manufactured the Breadboard model using this chip. The size of the board is the business card one. The chip and its peripheral components such as a regulator are installed on the board of the business card size.

Reference

Fukuhara, H., H. Kojima, S. Okada, H. Ikeda, and H. Yamakawa, Waveform receiver on-a chip dedicated

to plasma wave instrument onboard scientific spacecraft, IEEEAC paper #1139, *2011 IEEE Aerospace Conference Proceedings (reviewed),* 2011.

Imachi et.al [2011] have been developing the onboard system software of EWO-WFC/OFA aboard BepiColombo Mercury Magnetospheric Orbiter (MMO) (Fig.1). On the mission of BepiColombo MMO, they aim to investigate the properties of electromagnetic field and plasma wave phenomena at Mercury's magnetosphere and the interplanetary region around Mercury. For the subject they are developing Plasma Wave Instrument (PWI) aboard MMO. EWO is one of components of PWI. It includes Electric Field Detector (EFD), Waveform Capture (WFC) and Onboard Frequency Analyzer (OFA). PWI has two dimensional electric field sensors and three dimensional magnetic field sensors. The measured fields detected by the sensors are converted to digital data by each receiver instrument and processed by Mission Data Processor (MDP) (Fig.2). The transmission rate from the receivers to MDP is up to a few Mbps, however, the bandwidth of telemetry communication from MMO to the earth is up to several ten kbps. To achieve an efficient observation, highly optimized data processing is required, and it largely due to the performance of MDP software.

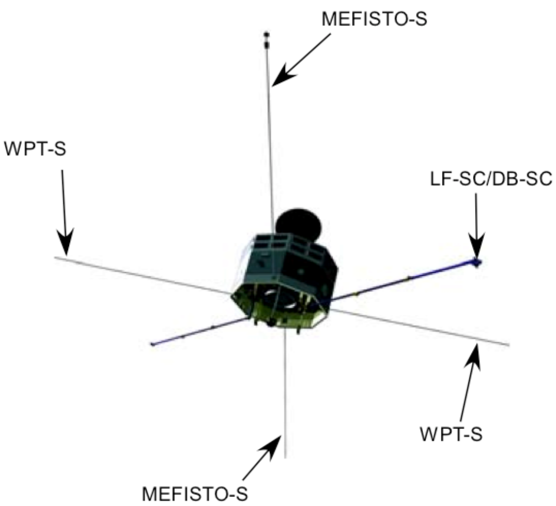

Fig. 1: The sensors aboard MMO for electromagnetic field measurement

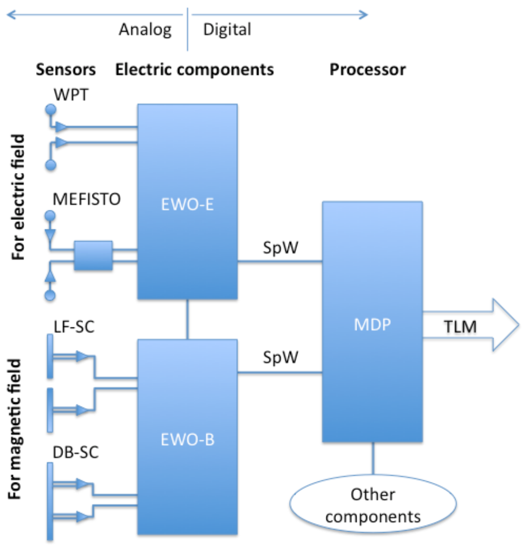

Fig. 2: Overview of EWO block diagram

References

Imachi, T., Y. Kasahara, Y. Goto, Y. Kasaba and H. Kojima, "Software development of EWO-WFC/OFA aboard BepiColombo MMO spacecraft," Proc. XXX URSI General Assembly and Scientific Symposium, Istanbul, Turkey, August 13-20, 2011.

Development of the small sensor node for the sensor network system in space

A sensor network consisting of a number of palm-sized nodes with small electric and magnetic sensors has been proposed to monitor local electromagnetic activities in space plasmas, which is referred to as a "monitor system for space electromagnetic environments (MSEE)." In Yagitani et al. [2011], a compact loop antenna system was designed and fabricated for use in MSEE sensor nodes that can capture magnetic vector fields from ELF to MF frequencies (Fig. 3). The performance of the developed system was shown to be sufficient to allow measurement of the magnetic field activity around artificial structures in addition to intense natural plasma waves in geospace.

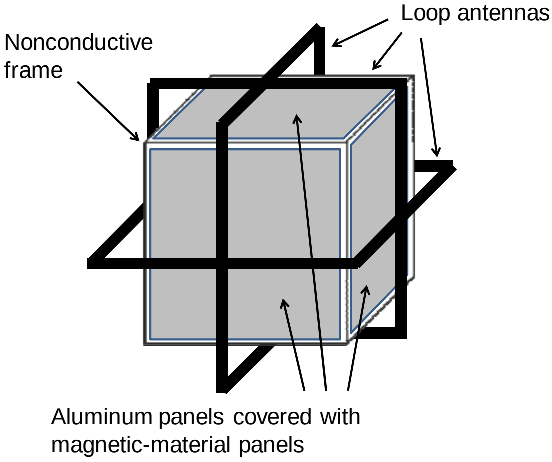

Fig. 3: Configuration of loop antenna system in MSEE node

References

Yagitani, S., M. Ozaki, and H. Kojima, "A compact loop antenna system for monitoring local electromagnetic environments in geospace," IEICE Trans. Commun., Vol.E94-B, No.6, pp.1744-1747, 2011.

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KAGUYA (SELENE)

The Lunar Radar Sounder (LRS) is one of the scientific instruments onboard the KAGUYA main orbiter. The LRS consists of two orthogonal 30 m tip-to-tip antennas and three subsystems; the sounder observation (SDR), the natural plasma wave receiver (NPW), and the waveform capture (WFC). The SDR is designed to investigate the surface and subsurface structures of the moon using an HF radar technique, and the NPW and WFC are designed to measure natural plasma waves around the moon and in interplanetary space.

Because the moon is basically non-magnetized, the solar wind particles directly hit the lunar surface and a plasma cavity called the "lunar wake" is created behind the moon. Hashimoto et al. (2010) presented observations of electrostatic solitary waves (ESWs) near the Moon in the solar wind and in the lunar wake. They demonstrated that ESWs are categorized into three types depending on different regions of observations: ESWs generated by electrons reflected and accelerated by an electric field in the wake boundary (Type A), strong ESWs generated by bi-streaming electrons mirror-reflected over the magnetic anomaly (Type B), and ESWs generated by reflected electrons when the local magnetic field is connected to the lunar surface (Type C).

The evidence of a lunar ionosphere provided by radio occultation experiments performed by the Soviet spacecraft Luna 19 and 22 has been controversial for the past three decades because the observed large density is difficult to explain theoretically without magnetic shielding from the solar wind. On the other hand, the KAGUYA mission provided an opportunity to investigate the lunar ionosphere with another method. When the NPW and WFC observe auroral kilometric radiations (AKR) propagating from the Earth, the dynamic spectra of the AKR sometimes exhibit a clear interference pattern caused by phase differences between direct waves and waves reflected on a lunar surface or a lunar ionosphere. Goto et al. (2010) proposed a new method to determine the electron density profiles above the lunar surface by comparing the observed interference pattern with the ones theoretically constructed by ray tracing technique using several patterns of electron density model profiles. This method is a kind of model fitting in which candidate density profiles are evaluated and provides a new approach to examining the lunar ionosphere that does not involve the conventional radio occultation technique. They introduced a practical use of the method using the AKR spectrogram observed by the KAGUYA.

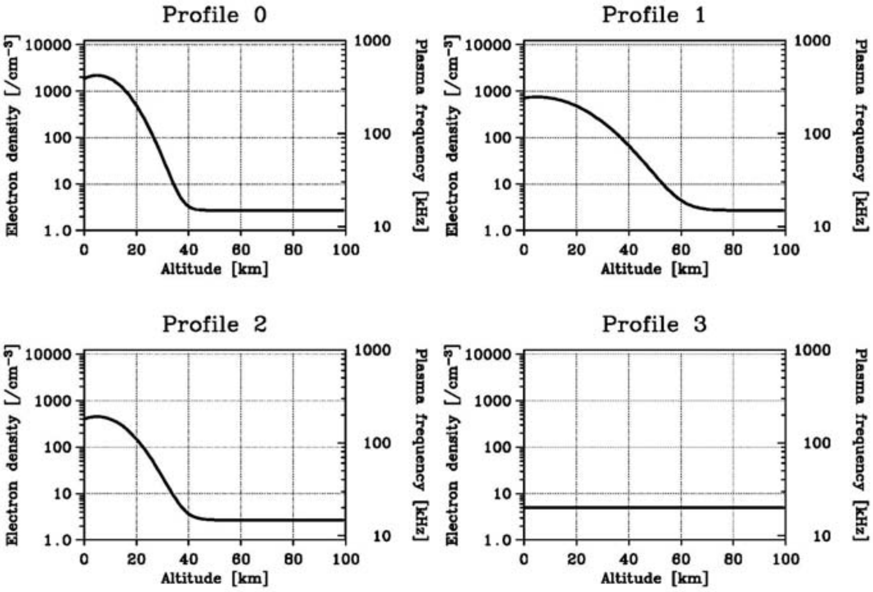

Fig. 1: Electron density model profiles according to Luna 19 and 22 observations (Profile 0, 1 and 2), and a model profile with no ionosphere (Profile 4). [Goto et al., 2011]

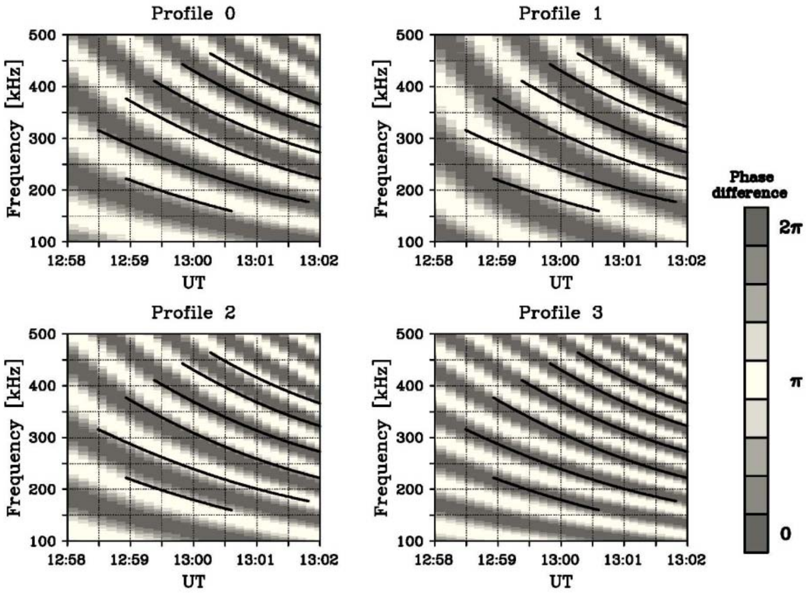

Fig. 2: Observed patterns (black line) and theoretically reconstructed phase patterns (tone) for Profiles 0, 1, 2 and 3. [Goto et al., 2011]

Oike et al. (2011) evaluated the performance of an operation mode named "automatic filter selection (SELECT)" implemented for the WFC-L on the onboard software. In this mode, the onboard software evaluates maximum amplitudes or averaged powers at each frequency band to determine whether to select an intermittent measurement covering higher frequency range with a lower duty ratio or a semi-continuous measurement in the lower frequency range. Because the waveform observation is generally more important in the lower frequency range from a scientific point of view, signals in the higher frequency range weaker than the threshold level are automatically eliminated by the above mentioned optional decimation filters in the DSP and the decimated waveform data is packed into mission packets. This operation mode makes it possible to downlink the significant waveform to the ground in shorter time duration and to capture new series of waveform data with higher duty ratio. Oike et al. (2011) demonstrated that the automatic selection process was successfully operated under the adequate parameters.

References:

Goto, Y., T. Fujimoto, Y. Kasahara, A. Kumamoto, and T. Ono, Lunar Ionosphere Exploration Method Using Auroral Kilometric Radiation, *Earth, Planets and Space*, 63(1), 47-56, doi:10.5047/eps.2011.01.005, 2011.

Hashimoto, K., M. Hashitani, Y. Kasahara, Y. Omura, M. N. Nishino, Y. Saito, S. Yokota, T. Ono, H. Tsunakawa, H. Shibuya, M. Matsushima, H. Shimizu, and F. Takahashi, Electrostatic solitary waves associated with magnetic anomalies and wake boundary of the Moon observed by KAGUYA, *Geophys. Res. Lett.*, 37(L19204), doi:10.1029/2010GL044529, 2010.

Oike, Y., Y. Kasahara, and Y. Goto, Evaluation of data selection algorithm implemented on the LRS/WFC onboard KAGUYA, *IEICE Trans. Commun.*, J94-B(8), (in press), 2011 (in Japanese).

SCOPE

The SCOPE is a Japanese future mission to investigate the multi-scale plasma physics using multiple satellites. In the SCOPE mission, formation flying will be made up of a mother satellite, a daughter satellite in the near distance, and two or three daughter satellites in the long distance from the mother. In the fields of solar-terrestrial measurements, it is well known that there is a severe limitation of in-situ observation using a single satellite. This is because it is quite difficult to distinguish between spatial and temporal variation of plasma environment in the magnetosphere by single satellite. Therefore, a simultaneous multi-point observation using multi-satellite are very important to understand the spatial and temporal variety of the geo-space environment. In formation-flying magnetospheric exploration mission, it is necessary to implement an autonomous control system onboard the satellites. Furthermore, inter-satellite communication will be effective for such system. Takenaka et al. (2011) introduced some decision making algorithm for optimum observation mode by accumulating status reports from daughter satellites using inter-communication system to be implemented in the future mission such as SCOPE. They also developed a system using LAN-connected PCs in order to simulate inter-communication among satellites and onboard data processing functions. On the simulator, they simulate co-operational observation under the direction of mother satellite according to the observational reports from daughter satellites. Observation data from the waveform capture (WFC) onboard the KAGUYA spacecraft were used in order to simulate co-operational observation functions under realistic condition. They studied some patterns of decision algorithm and evaluated the performance of co-operational observation.

References:

Takenaka, S., Y. Kasahara, H. Kojima, and T. Imachi, Development of a co-operational observation simulator for formation-flying mission, *IEICE Trans. Commun.*, J94-B(7), (in press), 2011 (in Japanese).

Ionospheric Radio Wave study by Sounding Rocket Experiments

S-310-40 sounding rocket will be launched at Uchinoura Space Center (USC) by ISAS/JAXA in winter, 2011. The purpose of this experiment is the investigation of characteristics of radio wave propagation in the ionosphere and the estimation of electron density structure in the lower ionosphere, when the intensity of radio wave measured on the ground will be attenuate at nighttime. In order to measure the radio waves, a LF/MF band radio receiver (LMR) is installed on the sounding rocket. The LMR measures the propagation characteristics of four radio waves at frequencies of 60 kHz (JJY signal from Haganeyama radio station), 405 kHz (NDB station from Minami-Daitojima), 666 kHz (NHK Osaka broadcasting station) and 873 kHz (NHK Kumamoto broadcasting station) in the region from the ground to the lower ionosphere. The transmitting position is shown by Figure. We will obtain the 3-dimensional structure of electron density in the lower ionosphere by measuring the intensity of radio waves that propagate from the three different directions (see Figure). And we will investigation of unusual propagation characteristics of radio waves in the ionosphere at winter nighttime (Report by K. Ishisaka).

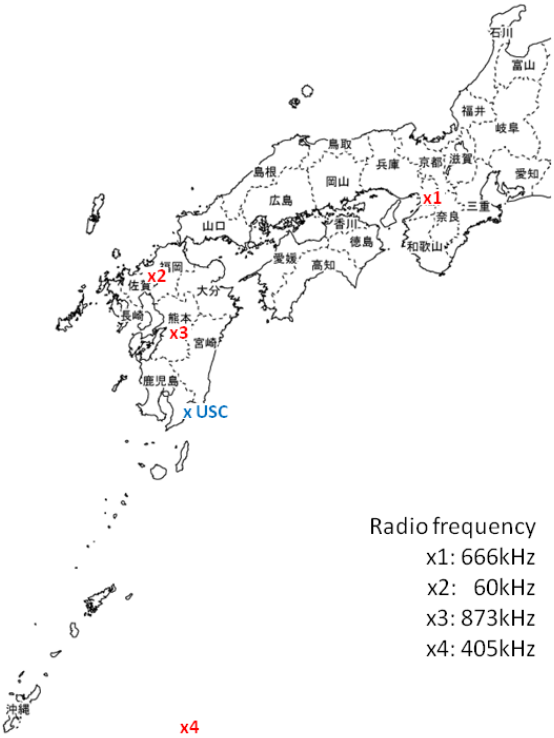

Figure 1. The sites of radio transmitter.

Lightning-generated sferics observations

Ozaki et al. [2011a, b] have evaluated the distance finding technique for a single-site lightning location system by using theoretical sferics. The calculated ionospheric reflection coefficients are stable at smaller incident angles, while they exhibit a poor reflection at larger incident angles around 70 degrees. The distance finding accuracy is improved when the 1st reflected pulse of the sferic having the largest incident angle is excluded in the estimation. The errors of the improved distance finding technique become less than 5%, while those of the previous technique using the 1st reflected pulse were 20%.

References

Ozaki, M., S. Yagitani, K. Miyazaki, I. Nagano, “Lightning location technique considering the effect of the ionospheric reflection of VLF sferics,” Proceedings of the 2011 IEICE General Conference, March 14-17, 2011a. (in Japanese)

Ozaki, M., S. Yagitani, K. Miyazaki, I. Nagano, “Error evaluation of single-site lightning location technique by theoretical sferics,” IEICE Trans. Commun. (Japanese Edition), vol.J94-B, no.4, pp.577-588, 2011b.

Polar Region Experiments

Ozaki et al. [2010] analyzed a valuable event of successful simultaneous ground-satellite (Akebono) observations of natural VLF whistler mode waves in Antarctica. During one-year observation, in most cases when the Akebono satellite was just above Antarctic ground stations, the satellite received strong

VLF waves, but the ground stations did not see any specific signal enhancements. They have fortunately obtained a simultaneous observation example. They have analyzed the observation result by theoretical calculation. The natural VLF whistler mode waves received by the satellite had their k-vector directions within the transmission cone angle, and the observed wave attenuation due to the ionospheric penetration was consistent with that obtained by the theoretical calculation.

References

Ozaki, M., S. Yagitani, I. Nagano, Y. Kasahara, H. Yamagishi, N. Sato, and A. Kadokura, "Simultaneous ground-based and satellite observations of natural VLF waves in Antarctica: A case study of downward ionospheric penetration of whistler-mode waves," Polar Science, Vol.4, pp.431-441, 2010.12.

ULF Waves

Nomura et al. investigated Pc 1 pulsations observed by induction magnetometers at three low-latitude stations (Paratunka (PTK), Moshiri (MSR), and Sata (STA), L=1.2--2.1). A detailed polarization analysis showed that polarization parameters (angle of polarization ellipse orientation, Ψ, and polarization sense, ε) of individual Pc 1 bands depend on the frequency at all the three stations. The maxima of seasonal and diurnal variations of the occurrence rate were in winter and during the nighttime, as reported previously, indicating that the transmission of observed Pc 1 pulsations to lower latitudes is controlled by the density of the F layer plasma. They suggested that Pc 1 waves at high latitudes propagated in the ionospheric duct, which caused the frequency dependence of the polarization parameters at low latitudes. They also suggested that the Pc 1 pearl structure with a repetition period of 5−30s observed at low latitudes is a beat of high-latitude waves with slightly different frequencies.

Fujita et al. studied the nature of magnetospheric Pc 5 ULF waves driven by periodic variations of solar-wind dynamic pressure by using a global MHD simulation. They showed that the magnetospheric ULF wave induced by the periodic variation has a harmonic structure due to nonlinear response of the magnetosphere to the solar wind variations. For a ULF wave with a period of 10 min, the inertia current is significant in the magnetosphere when the magnetospheric pressure is depressed under the northward IMF condition, whereas the diamagnetic current is dominant when the pressure is enhanced under the southward IMF condition.

References

Nomura, R., K. Shiokawa, V. Pilipenko, and B. Shevtsov (2011), Frequency-dependent polarization characteristics of Pc1 geomagnetic pulsations observed by multipoint ground stations at low latitudes, J. Geophys. Res., 116, A01204, doi:10.1029/2010JA015684, Jan. 13, 2011.

Fujita, S, T. Tanaka, and T. Motoba, Long-Period ULF Waves Driven by Periodic Solar Wind Disturbances, The Dynamic Magnetosphere, ed. W. Liu and M. Fujimoto, 10.1007/978-94-007-0501-2_3, June 21, 2011,

Conferences and Meetings

The third MESSENGER-BEPICOLOMBO Joint Workshop, Inamori Hall in Shiran-kaikan, Kyoto University, Sept. 5^{th}-6^{th}, 2011.

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