SPRINT-A/EXCEED 観測機の検出感度較正
Calibration of detective sensitivity of SPRINT-A/EXCEED

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SPRINT-A/EXCEED は地球周回軌道からの観測を目的としている。観測装置は宇宙サンプル・サンプル・サンプル、2011年3月から観測装置全体の組み上げと較正実験が予定されている。観測装置は空間分解能、波長分解能、感度の較正を極端紫外光で行う必要があり、装置全体が入る容積の大ささの長さ3m、直径2mの真空チャンバーを製作中である。本研究では実状でのEXCEED光学系の較正実験結果を報告する。

キーワード: 極端紫外光、宇宙望遠鏡、惑星プラズマ
Keywords: SPRINT-A, EXCEED, EUV
EUV の波長領域における MPO の性能試験
Performance test of Micro-pore Optics (MPO) in the EUV spectral range

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硝子の透光率が極めて低いために、EUV の観測にはレンズを使うことができない。したがって、EUV の観測には反射光学系を組む必要があった。Micro-pore Optics (MPO) は、縦横比数百倍の微小な正方形のガラス管数万個を数千の細管に組み合わせ、その細管を方形または放射状に並べた薄板である。MPO はこれまでも、X 線の観測でレンズと同等の性能を果たす光学素子として使用されてきた。そこで今回は、焦点距離 35mm の MPO を用意し、EUV での透過率を測定した。その結果、30.4nm から 140.0nm の波長に対して 60%以上の値を示した。本発表では、MPO が EUV の波長領域でもレンズと同様の役割を担い得るかを検証するために、EUV に対する光学的な性能を評価した。

キーワード: 極端紫外線, 大気光, 光学系, 撮像素子
Keywords: EUV, airglow, optics, remote sensing device
Designs of multi-layer coated mirrors for remote sensing of planetary ionospheres

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According to observations of the polar orbital and the geosynchronous satellites the oxygen ions sometimes become the main component, especially during the periods of the southward interplanetary magnetic field and the high geomagnetic activity. Besides the atmosphere of the terrestrial planets has oxygen atoms as the main component, and the process of the oxygen atoms/ions escape is one of most significant issues for the evolution of the planetary atmosphere. One of the powerful tools for this study is an imagery of the oxygen ions.

The concept study of the oxygen ions imagery proposed in 1990’s has been expected to make a progress about the studies on the evolution of the planetary atmosphere and on the plasma structure in the direct interaction region between the solar wind and the planetary ionosphere. However, the observations have never been performed, because a reduction of the noise produced by hydrogen atom resonance emission is too difficult to observe the signal from the oxygen ions. The members of our research team has developed the instrument with the thick indium filter to reduce the hydrogen Lyman alpha emission, and succeeded in observing the oxygen ions emission. The technical methods is adopted to the Upper-atmosphere and Plasma Imager (UPI) on the SELENE(KAGUYA) satellite. The imager is ready for the observation of the oxygen ion distribution in the polar wind and the near-earth magnetosphere.

But we revealed that the intensity of the Lyman beta emission was not negligible. Consequently, a multi-layer coating is designed to keep the reflectivity at the oxygen ions emission and to reduce simultaneously the reflectivities at the Lyman alpha and beta emissions. There are several methods of the noise reduction, but the use of only one multi-layer mirror has an advantage of the compact and light instrument. The measured reflectivity of the preproduction sample mirror is presented, and the optical performance is discussed.

Keywords: planetary ionosphere, plasma remote sensing, soft x-ray and extreme ultraviolet light
Effects of a light reflecting layer to the response of piezoelectric PZT elements

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We have studied responses of piezoelectric PZT elements for measuring cosmic dust. This report is aimed at a theme on effects of a light reflection layer to the response of the PZT element.

The BepiColombo mission that explores Mercury and its environment is progressed as a joint project between JAXA and ESA. Since the measurement of dust ambient Mercury is one of the approved programs, the Mercury Dust Monitor (MDM) has been developed onboard the BepiColombo mission (MPO). Because of restricted resources to the MDM, it comprises piezoelectric PZT elements and electronic circuits.

Since the MDM is to be operated around the Mercury orbit, the thermal flow around the PZT element is estimated using a thermal model. The temperature condition under which the element is operated is crucial, because the piezoelectric character should be maintained. In order to overcome this difficulty, we discussed a layer that reflects thermal flow from the sun. The layer is useful to lower temperature down at which piezoelectricity is retained. On the other hand, this layer would considerably affect the characteristic of the PZT.

The effects of the layer on the characteristic responses were experimentally studied by bombarding hypervelocity microparticles with the PZT element. The microparticles were supplied by the Van de Graff accelerator at MPI-K, HIT of University of Tokyo, and the GUN at ISAS.

The PZT element was a square of a 40 x 40 mm2 and its thickness of 2mm. One side of the element was covered with a ~5 um thick silver layer over the entire surface. At the rear side a 5 x 5 mm2 and ~5 um thick silver layer was embedded as a collector of induced signal. Thus then, the surface of the silver layer was painted with a paint up to ~100 um thick. The paint was produced by Ube Kosan C.o. (PETI-330m, high heat resistance material composition polyimide resin). Hereafter we call this paint layer as a white paint.

Output signal from the collector was processed with a charge sensitive amplifier and measured with an oscilloscope. A photo-multiplier was set near the element to observe light flashes immediately after collision. The PZT element was bombarded with microparticles at room temperature. The observed signal forms measured and recorded by the scope were processed in offline analysis. A first one cycle of the signal form was interested in analysis.

The amplitude was plotted against the momentum of the incident particle. Here, let define the sensitivity of the PZT element as the ratio of the increment of amplitude dA to that of momentum dp; dA/dp. Thereby, the sensitivity clustered into three groups. The first group corresponded to the case in which the sensitivity of the PZT element overlapped with that of PZT elements without covering the white paint. There existed the second group that its sensitivity is approximately expressed as a sum of dA/dp and a certain offset. The third group clustered in a region different from those of the first and second groups, and the dA/dp values are considerably small.
At present, it is unclear why the three groups coexist. Except for the first group, the effect of the white paint to the response of PZT element is significant. As an intermediate result, we are interested in the second group that is considered to be significantly influenced by the white paint. Therefore, the present results could be worth reporting, since there are very few reports that the effects of the white paint to the system comprised white paint and the PZT element has been quantitatively discussed.

キーワード: 宇宙塵, ベピコロンボ, 水星, PZT 検出器
Keywords: cosmic dust, dust, BepiColombo, PZT
Development of lightweight loop antenna for future space missions

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In space plasma physics, the polarization and wave normal direction provide key information to identify the modes and origins of plasma turbulences. Such broad-band measurements have been made by loop antennas, from 0.1 to 1000 kHz. Okada et al. developed a loop antenna system aboard the Akebono satellite (EXOS-D) launched in 1989. The loop was square-shaped with an area of 0.36 m² (0.6 x 0.6 m) and the mass of about 2 kg. The major part of its mass was due to antenna frames.

We have examined lighter loop antennas with CFRP technologies since 2007. It has an area of 0.36 m², which is the same as that of the Akebono antenna. The TWF-CFRP tubes are used as antenna frames. Since the CFRP tube is conductive, it is also used as an electrostatic shield of the loop element. The antenna element is rectangular (0.6 x 0.6 m) open coil with 10 turns each. The weight of the loop antenna was 438 g (frame: 72 g, wire element: 135 g, joint parts: 231g), 1/4 of the original Akebono design. As the next step, we will use CFRP joint parts. In that case, the mass will become half. The folding method of the loop antenna was examined in parallel. Then it will be tested by a model with realistic size. We expect to adopt the new loop antenna system to small-sized space missions for magnetospheric and ionospheric studies. It is also expected in landing missions, as a light sensor to detect radio waves from atmospheric discharges, subsurface radar echo, etc.

Reference
Okada et al., Tras. IEICE, Vol. E70, No. 6, 550-561, 1987

Keywords: lightweight loop antenna, ionosphere, magnetosphere, radio wave receiver
SCOPE 衛星搭載に向けた高精度磁力計の開発
Development of high-resolution digital fluxgate magnetometer for the SCOPE mission

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kysuke Iguchi 1*, Ayako Matsuoka 2, Akiko Fujimoto 2

1. SCOPE 計画
地球磁気圏内外における宇宙プラズマのスケール間結合の解明を目的として、JAXA は Canadian Space Agency と協力して地球磁気圏観測衛星群「SCOPE」プロジェクトの実施を計画している。SCOPE 計画では電子スケールの観測を行うため、10 msec 以下の高時間分解能かつ高精度な電磁場、粒子観測が要求されている。

我々は、この SCOPE 衛星への搭載を目指してフラックスゲート磁力計の開発を行っている。フラックスゲート磁力計は DC から低周波の磁場を高精度で計測できる。加えて、小型、軽量、省電力であることから、多くの科学衛星に搭載されてきた実績がある。フラックスゲート磁力計の主な性能諸元は以下のとおりである。以下の性能諸元は SCOPE 衛星のミッション要求を満たすために設定されている。

磁场测定範囲：約 ±4000 nT
測定周波数帯域：DC から 60 Hz までの変動磁場
分解能：20 ビット（8 pT に相当）

現在は SCOPE 衛星搭載用の磁力計を開発するために、性能検証として観測ロケット S310-40 号機に搭載する磁力計を開発している。観測ロケット用には、以下の性能を満たす磁力計を開発する。

磁场测定範囲：約 ±65000 nT
測定周波数帯域：DC から 60 Hz までの変動磁場
分解能：16 ビット（2 nT）

SCOPE 計画における磁場測定範囲は観測ロケットの場合に比べて狭いため、同じ分解能でも磁場分解能が向上する。したがって、SCOPE 衛星搭載用の磁力計では分解能 16 ビットが 128 pT に相当することがわかる。本講演では観測ロケット搭載磁力計の性能評価結果を報告する。ロケット実験終了後は磁場分解能 20 ビットを目指して開発を進めていく。

2. フラックスゲート磁力計
SCOPE 衛星および観測ロケット S310-40 号機搭載用のフラックスゲート磁力計にはセンサからの検出信号をディジタルプロセッサで処理するディジタル方式を採用している。国際的にはディジタル方式は 1990 年以降開発が進み、従来の方式比べて小型、軽量化がなされ、経年変化や温度特性も改善されたという特徴を持つ。

しかし、測定精度と線形性の向上は未だ課題である。ディジタル方式の磁場分解能は電気回路部のディジタル-アナログ変換器（DAC : Digital-to-Analog Converter）の分解能に強く依存する。宇宙機用として承認されている DAC の分解能は 12 ビットまでしかないため、これまではディジタル方式の高磁場分解能化は困難であった。

そこで、我々は宇宙機に搭載できる部品だけを使い、デルタ-シグマ変調方式を用いた高分解能 DAC を開発した。デルタ-シグマ DAC はデルタ-シグマ変調器を散後段にあるフィルタで構成され、それらの性能がデルタ-シグマ DAC の分解能を決定する。まずはシミュレーションによって 16 ビットを満足するように DAC を設計した。その結果、2 次型デルタ-シグマ変調器散後段フィルタに 4 次型アナログローバスフィルタを採用した。デルタ-シグマ DAC の性能指標であるオーバーサンプリング比を 676 とすることにより 16 ビットの性能を満足することがわかった。次に、この設計に基づいてデルタ-シグマ DAC を製作し、各種性能評価試験を行った。結果は以下のとおりである。

ノイズレベル：16 ビット
線形性：0.006 %F.S.

周波数応答測定：67 Hz @ 40000nT レンジ
以上の結果から、分解能 16 ビットの性能が実現したことを確認した。次のステップとして、このデルタ-シグマ DAC をディジタル磁力計の電気回路に組み込んで、観測ロケット搭載ディジタル磁力計を開発した。

キーワード: SCOPE, 磁力計, デジタル・フラックスゲート, デルタ・シグマ変調方式, デジタル・アナログ変換器
Keywords: SCOPE, magnetometer, digital fluxgate, sigma-delta modulation technique, Digital-to-Analog Converter
Residual magnetism measurements needed for magnetometers onboard QSAT-EOS

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Keywords: residual magnetism, QSAT-EOS, Science Magneto Sensors, MAGDAS magnetometer, measurements of Earth’s magnetic field, Field Aligned Current (FAC)
インピーダンスプローブ計測における共振のQ値の特性
What does determine the resonance Q-factors in impedance probe measurements?

The impedance probe is a powerful tool realizing highly-accurate measurements of the electron density. Detection of the upper hybrid resonance (UHR) frequency from the impedance curve provides the electron density with high accuracy. The frequency response of the antenna impedance also reflects various physical quantities and properties of a plasma in addition to the electron density. Interpretations of the antenna impedance are therefore essential for space plasma diagnostics. This paper reports on the characteristics of the “quality factors (Q-factors)” of the UHR and sheath resonance (SHR) in impedance probe measurements.

One of the important aspects of impedance probe measurements is the “clarity” of the resonance. The sharpness of the resonance is evaluated by the Q-factor. Sufficient insight on the Q-factor is important for evaluating the lower threshold of the electron density measurement range. Besides, the phase of the probe capacitance measured in plasma chamber indicated that characteristics of the resonance Q-factor should be examined in order to realize automatic detection of the UHR frequency. The Q-factor also has a potential to provide the electron-neutral collision frequency, which is a key parameter of the ionospheric science. However, the effect of the collision frequency on the Q-factor has not been examined. We therefore tried to evaluate the Q-factor experimentally.

We confirmed that the Q-factors of the UHR and the SHR have a clear boundary at $f_{pe}/f_{ce} = 1$. The Q-factor indicated lower values when $f_{pe} < f_{ce}$, while the Q-factor showed clear increases with the electron density when $f_{pe} > f_{ce}$. This tendency was already expressed by Balmain and Oksiutik (1969). However, we also found characteristics which were not pointed out in previous works: the Q-factors were also characterized by the second harmonics of the cyclotron frequency. The effects of a hot plasma (e.g., Suzuki et al., 2009) should affects on the impedance probe measurements.

The effects of the collision frequency on the Q-factor were also examined. The impedance curves measured in the ionosphere were compared with the impedance curves measured in the plasma chamber. Contrary to expectations, the impedance curves measured in the ionosphere and in the chamber showed similar signatures in spite of the difference of 3 order magnitudes of the collision frequency. The result suggested that the mean free path is essential for evaluating the Q-factor. Careful treatments are required both for the measurements and for the numerical calculations in order to estimate the collision frequency from impedance curves.

The present study pointed out that the detailed understandings of the resonance Q-factor are necessary for further improvements of the impedance probe measurements in plasma.
The amount of raw data from the plasma wave instrument is increasing as the scientific objectives require covering a wide frequency ranges with high time and frequency resolution. Furthermore a variety of operation modes are needed to meet these scientific objectives. However, it is inevitable to reduce the amount of telemetry data because it is too huge to downlink all measured data to the ground. Onboard software plays a very important role because many kinds of operational modes can be implemented without changing the hardware configuration. We have developed several software receivers for spacecraft such as NOZOMI, KAGUY A and MMO and implemented lots of intelligent functions in them making use of digital signal processing technique.

In the present study, we investigated a signal processing method to derive polarization of plasma wave using onboard software. We evaluated computation load as well as accuracy of polarization parameters under severe restrictions on telemetry and computation resources in order to find a solution for implementation to onboard software. In the presentation, we introduce the evaluation results using the waveform data obtained by the AKEBONO and KAGUYA spacecraft.

Keywords: Plasma wave instruments, Polarization analysis, Onboard software, Magnetosphere, Signal Processing
Evaluation of co-operational observation strategy for formation-flying satellites using a magnetosphere model

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Recently multi-satellite mission is a mainstream of in-situ measurement method of the Earth’s magnetosphere, because it is quite difficult to distinguish between spatial and temporal variation of plasma environment in the magnetosphere by single satellite. So far four Cluster satellites launched in 2000 and five THEMIS probes launched in 2007 are in operation, and MMS mission is in the planning stage.

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.

Because it is obviously impossible to transmit all raw data measured by onboard instruments because of limitation of downlink capacity, we need to make an operation plan predicting a forthcoming observation region in order to optimize observation parameters for the purpose of data reduction.

To achieve a co-operational observation efficiently with formation-flying satellites, we developed a system using LAN-connected PCs in order to simulate inter-communication among satellites and onboard data processing functions. On the simulator, we assume that each satellite has a function of event detection such as boundary crossing in the magnetosphere, and the mother satellite makes an autonomous decision as a multi-satellite federation to grasp temporal and spatial variation of the target region.

In the present study, we introduced a magnetosphere model in the simulator and studied appropriate parameters to select the best observation mode. In the presentation, we show some experimental results under some conditions of observation configuration and discuss the performance of co-operational observation.

Keywords: Formation-flying satellite, Inter-satellite communication, Co-operative observation, Magnetosphere, Simultaneous multi-point observation