ABSOLUTE AC ELECTRIC FIELD MEASUREMENTS IN SPACE PLASMA

I. Nagano, S. Yagitani

Kanazawa University, 2-40-20 Kodatsuno, Kanazawa 920-8667, Japan

E-mail : nagano@is.t.kanazawa-u.ac.jp

ABSTRACT

Very long (several tens of meters) wire dipoles have been used to observe low-frequency ($\leq$ MHz) AC electric field onboard spacecraft. Accurate measurements of the field require the accurate evaluation of the pick-up factor and effective length of a wire dipole immersed in space plasmas. In-situ observations with GEOTAIL and AKEBONO demonstrate that the pick-up factor depends on ambient plasma density and temperature, while the effective length is almost a half of the dipole's tip-to-tip length at ELF/VLF frequencies. A model rheometry experiment shows that the effective length approaches to the tip-to-tip length for lower frequencies.

INTRODUCTION

To pick up the low frequency ($\leq$ MHz) AC electric field with sufficient sensitivity in space plasma, we often extend a long (several tens of meters) wire dipole antenna from a spacecraft. It is usually difficult to know the completely accurate amplitude and phase of the electric field in space plasma only from the measured voltage induced at the base of the antenna. This is partly because of an electron or ion sheath formed around the antenna, which alters the antenna impedance and the antenna pick-up factor. Another problem is the effective length of a long wire antenna. So far there have been very few quantitative studies on the effective length of spacecraft-borne long dipole wires in space plasma, which has been usually assumed simply as half of the antenna's tip-to-tip length, much shorter than the wavelength of the waves of interest. In this study, we evaluate the characteristics of wire dipole antennas onboard GEOTAIL and AKEBONO spacecraft, on the basis of in situ observations of electromagnetic waves and a model rheometry experiment in laboratory.

CHARACTERISTICS OF WIRE ANTENNAS ONBOARD GEOTAIL AND AKEBONO

Direct in-situ measurements of the antenna impedance in space plasma have been realized by the plasma wave receivers onboard GEOTAIL [1] and AKEBONO [2]. The antenna impedance consisting of a resistance and a capacitance seems dependent on the ambient plasma density and temperature.

To estimate the effective lengths of long wire antennas on spacecraft, we make use of the waveform observations of electromagnetic fields of VLF whistler mode waves in the magnetosphere [3]. For a whistler mode wave in a cold plasma, its electric field vector waveforms can be theoretically calculated from its magnetic field vector waveforms observed. By comparing such calculated values with actually observed electric fields, we can determine the actual effective lengths of the wire dipoles onboard spacecraft. For the case of GEOTAIL, we use the ELF chorus emissions (several hundred Hz to a few kHz) in the dayside outer magnetosphere to evaluate separately the effective lengths of the two types of wire antennas (a wire dipole and a top-hat dipole). For AKEBONO, Omega navigation signals (around 10 kHz) are used to evaluate its two sets of identical wire antennas. Results show that the effective length of each dipole antenna is estimated to be almost half (50 m for GEOTAIL and 30 m for AKEBONO) of the antenna's tip-to-tip length, as assumed so far.

RHEOMETRY EXPERIMENT

On the other hand, we conduct the "rheometry experiment" [4], where a small scale-model of a spacecraft-borne wire antenna is immersed in a water tank with a uniform AC electric field. By measuring the output voltage from the model antenna we can measure the antenna effective length and its frequency responses. For a wire dipole with its tips conductive to the ambient water, the effective length is about half of its whole length at the frequencies higher than the ELF/VLF range, while for lower frequencies the effective length becomes almost the same as its tip-to-tip length because of conductive coupling. Such frequency characteristics should be considered when interpreting the low frequency wave data observed by the wire antennas on spacecraft.

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