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Electron Density Measurement on JUICE Mission by Mutual Impedance Technique: MIME Instrument as a Part of RPWI Consortium

J. L. Rauch (1), P. Henri (1), J. E. Wahlund (2), O. Le Duff (1), O. Sene (1), F. Colin (1), T. Hachemi (1), D. Lagoutte (1), N. Gilet (1), L. Ahlen (2), J. Bergman (2), R. Gill (2), W. Puccio (2)

(1) CNRS-LPC2E, Orleans Cedex 2, France (jlrauch@cnrs-orleans.fr) com / Fax: +33-238631234)

(2) Swedish Institute of Space Physics, Uppsala, Sweden

Abstract

Mutual Impedance MEasurements (MIME) instrument is a part of the Radio Wave Plasma Investigation ((RPWI) consortium which has been selected by European Space Agency (ESA) on the nest planetary mission JJUpiter ICy moons Exploer (JUICE) for a launch in 2022. The goals are to explore Jupiter and its potentially habitable icy moons and to study its plasma environment.

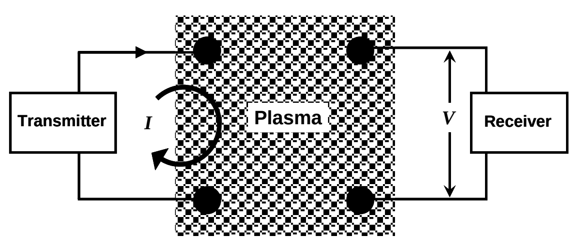
Impedance probes, which are well known in geophysical prospection, in particular for ground permittivity investigations, have been successfully transposed to space plasmas diagnostic. Transmitting and receiving electrodes are used for measuring on open circuit the dynamic impedance of the system at several fixed frequencies over a range that includes characteristic frequencies of the ambient plasma. The measurements are then interpreted using a suitable theory and the values of plasma parameters, such as the electron density and possibly the temperature of the plasma can be deduced. To show how powerful this technique is, results obtained in the Earth's plasmasphere by the mutual impedance probe onboard ROSETTA are presented as example. MIME instrument proposal is then described and its ability to make valuable measurements in the Jupiter space environment and in particular around Europe, Callisto and Ganymede is investigated..

1. MIME instrument features

MIME instrument is dedicated to measure the electron density in the plasma environment of Jupiter and, in particular, around its three Galilean moons : Europe, Callisto and Ganymede. Density measurement is done by mutual impedance technique. Plasma density is derived from the plasma frequency which is determined by a measurement of the frequency response in regard to AC electrostatic field excitation. The low power level below the thermal energy minimizes the plasma disturbance. Moreover, this way using frequency domain allows us to obtain an absolute value of the electron density. And, the density range is mainly set by the geometrical dimension between two electric antennae. Typically, the antennae distance must be between 2 up to 40 Debye lengths.

1.1 Principle of measurement

MIME takes advantage of existing electric antennae of the RPWI consortium in using a particular functioning mode. The principle is to evaluate the mutual impedance between two electric antennae that is strongly depending, especially at resonances, of the surrounding plasma permittivity. This method gives us an evaluation of the plasma permittivity as a function of the frequency.



Schema showing how the mutual impedance

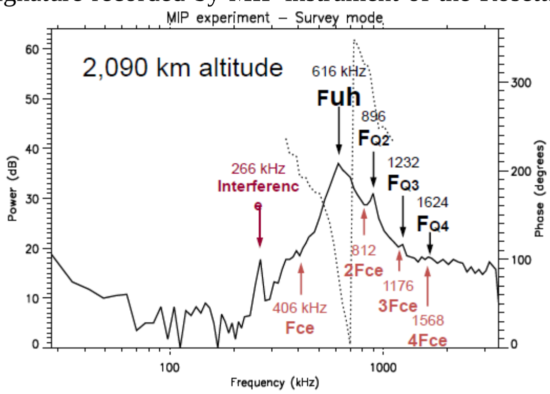
Z = V/I of a quadripole probe is determined.

RPWI consortium owns two antennae sets that allow MIME to sweep two frequencies bandwidths. One is dedicated to Low Frequency (LP/LP mode) investigation [3 kHz- 1.6 MHz], and use four Langmuir probes (LPW) as couple of transmitting/receiving antennae in monopole or dipole configuration. Another set provides High Frequency (LP/RWI mode) recording [80kHz - 3 MHz] range. MIME configuration uses LPW monople/dipole as transmitting antenna and the three RWI dipoles as receiving antennae.

The technique consists to use two-antennae systems, one as a transmitting and the second as a receiver. The antennae system can be double probes (LP/LP probes) or wire antennae (RWI). If only one probe is used, the AC current is injected in it and the voltage is measured between the probe and the spacecraft body. The transmitting electrodes are excited from a sinusoidal signal generator, while the receiving electrodes are connected to a voltmeter whose input impedance is very high compared to the self-impedance of the plasma between the receiving electrodes. Providing that the internal impedance of the current source is very large compared to the self-impedance of the transmitting electrodes, the current may be considered as known and constant.

2. Example of frequency response

Similar instruments have been already included in the previous space satellites payload and have worked with successfully results in space plasma like earth magnetosphere or comet environment (Rosetta). Below figure shows an example of spectrum signature recorded by MIP instrument of the Rosetta



mission during an earth crossing. We can notice strong peaks corresponding to plasma resonances which are interpreted on ground to extract the electron density.

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