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ABSTRACT

We estimated the characteristic amplitudes and frequencies of different kinds of waves in the Solar wind on the characteristic distance of the order of 0.2 AU that corresponds to the orbit of the Solar Orbiter. These estimates are based on the measurements of Helios 1 and 2 satellites. On this basis we have evaluated the experimental requirements for the magnetic field sensors onboard of the Solar Orbiter. We present the characteristics of the search coil magnetometers that are developed in the LPCE. In addition to traditional search coils we present the new magnetic loop antenna characteristics that can be used for the high frequency wide band magnetic field fluctuations measurements in the range 10 kHz-20 MHz.

INTRODUCTION

Although much is known concerning the waves which exist in the solar wind near the orbit of the Earth, many questions remain concerning the waves which occur much closer to the Sun. At the present time the closest measurements to the Sun have been obtained from the Helios 1 and 2 spacecraft at approximately 0.3 AU. Based on these observations, hereafter is a short presentation of the characteristics of the plasma waves expected to be present at 0.2 AU.

ELF/VLF waves & turbulence:

The wave measurements onboard of the Solar Orbiter have to account for several scientific objectives. Recent studies of the old data of particle distributions onboard of the Helios (Tu and Marsch, 2001) have evidenced the process of pitch angle diffusion of protons. It takes place in the solar wind on the characteristic distances of the supposed orbit of the Solar Orbiter. This results to the conclusion that the Alfvén turbulence and Ion-Cyclotron Waves play an essential role in heating and acceleration of the solar wind. Though these characteristics are implicit they give strong argument that the process of the plasma heating due to the wave activity continues to be effective on quite large distances from the Sun. To study the problem of plasma heating one should have the measurements of the wave activity of low frequency waves. These waves are generated below and at the local proton gyrofrequency, respectively. At 0.2 AU the value of the proton cyclotron frequency (Ω^+) can be estimated to be about 1 Hz (Gurnett, D.A., 1978). Actually the corresponding frequencies observed in the spacecraft frame can be Doppler shifted up to the kilohertz range. The maximum strength for Alfvèn waves and ion-cyclotron waves should be of the order of 10^{-2} nT/(Hz)$^{1/2}$.

The radio-emissions registered on the Earth are those whose traces come to the Earth. There can exist many types of emissions that we can not observed from the Earth. Between those are all the waves reflected or damped while propagating from the Sun to the Earth: in particular modes like slow extraordinary, whistlers, in addition to electron and ion cyclotron harmonics.

Above the proton gyrofrequency, the next resonant frequency to be encountered is the electron gyrofrequency ($\Omega^- \approx 2$ kHz at 0.2 AU). For frequencies between Ω^+ and Ω^- the only electromagnetic mode which can propagate is the right-hand polarized whistler mode. Measurements from Helios have shown that a whistler turbulence is

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present in the solar wind at frequencies up to $\Omega^{\cdot}$. The intensity of such waves can be comparable or even stronger than the wave intensity in the solar wind observed by WIND and ULYSSES satellites on the distances of the order of 1 AU. Helios observations stressed the trend for most solar wind wave modes to increase in intensity at smaller heliocentric distances. In particular this is the case for ion-acoustic waves, and whistler mode waves. Based on these trends one can roughly estimate the whistler mode emissions at 0.2 AU to extend from 10^{-5} nT/(Hz)$^{1/2}$ up to 10^{-1} nT/(Hz)$^{1/2}$ (see Gurnett, 1991).

Ion-Acoustic Waves & Solar Radio waves:

Sensitive electric field measurements with the Helios spacecraft revealed the occurrence of ion-acoustic-like electrostatic waves in the solar wind at frequencies between the electron and ion plasma frequencies (at 0.2 AU, f_{pi} = 4 kHz and f_{pe} = 200 kHz). Although the ion-acoustic mode propagates at frequencies below f_{pi} the observed wave frequencies are mainly determined by the Doppler shift which is much larger than the ion plasma frequency. From Helios observations one can estimate that a sensitivity equal to 10^{-6} nT/(Hz)$^{1/2}$ will be required at 0.2 AU to identify without ambiguity whether the observed waves are electromagnetic or electrostatic.

The importance of the magnetic field measurements was pointed out by Kellogg et al. (1999), who have shown that in many cases the wave modes observed onboard the WIND satellite in the solar wind that were supposed to be electrostatic actually belonged to the electromagnetic extraordinary mode. The estimate of the amplitude of the magnetic field component amplitude is large enough (several units 10^{-4} nT/(Hz)$^{1/2}$) and they can be easily registered by the instrument we propose (see Table 1).

At and above the electron plasma frequency intense electron plasma oscillations and solar radio waves are expected. Helios observations show that wave intensities associated with type III burst increase very rapidly with decreasing radial distance from the Sun. Intense emission could extend up to 10^{-4} nT/(Hz)$^{1/2}$.

One important aspect of the mission is related with the possibility to carry out systematic study of the waves in the frequency range that cannot penetrate through the ionosphere. This range comes up to 20 MHz. To cover this frequency band we propose to use very sensitive magnetic loop developed in LPCE that allows to perform the measurements of the magnetic field component of these emissions.

SOLAR ORBITER MAGNETIC FIELD SENSORS

Two set of sensors are necessary to cover the frequency band between 1 Hz and 10 MHz. Within the ELF/VLF frequency range, the three components of the fluctuating magnetic field can be easily measured with a 3-axial search coil magnetometer arranged in a compact configuration and mounted on a short boom which should also point into the anti-solar direction. This boom is required for magnetic cleanliness reasons and could be shared with the magnetometer as long as a minimum distance between the two sensors is respected. There is a strong heritage at LPCE and CETP for the 3-axial Search Coil instrument from GEOS, AUREOL 3, INTERBALL 2, and Cluster satellites (Lefeuvre et al., 1998; Cornilleau-Wehrlin et al., 1997). Antenna and preamplifier design will benefit of the work done for the DEMETER and Solar probe missions to reduce the mass. See Figure 1 for a description of the 3-axial search coil. Two designs are considered. The first one is based on an existing individual sensor available at LPCE. The second option is based on a smaller and lighter sensor to be developed. The total mass of the corresponding 3-axial search coil is estimated to be 500 g or 380 g depending on which option is chosen.

Above 10 kHz, due to the constraints of the mission, we propose to measure one component only. The loop antenna is based on a technique developed by Cavoit et al. (1976). The characteristic parameters are derived from Szeremeta (2001). See Figure 2 for a description of the HF magnetic loop.

The characteristic parameters of both instruments are given in Table 1.

	3-axial Search coil	Magnetic loop
Bandwidth	1 Hz – 10 kHz	10 kHz–10 MHz
Sensitivity nT/(Hz)$^{1/2}$	10^{-5} at 1 kHz	10^{-6} at 1 MHz
Size (individual sensor)	a) l=18cm; ⌀=0.2cm or b) l=10cm; ⌀=0.14cm	⌀ = 20 cm
Mass	sensors: a) 3×100g b) 3×60g preamp: 200g	sensor: 400 g preamp: 200 g
Power	200 mW	200 mW

Table 1 : Instruments characteristics

The associated electronic box must include a system for waveform capture below a few hundreds of Hz, and a spectrum analyzer for higher frequencies. The data processing can be performed in the same way as it was done for the Cluster mission (Woolliscroft et al., 1997).

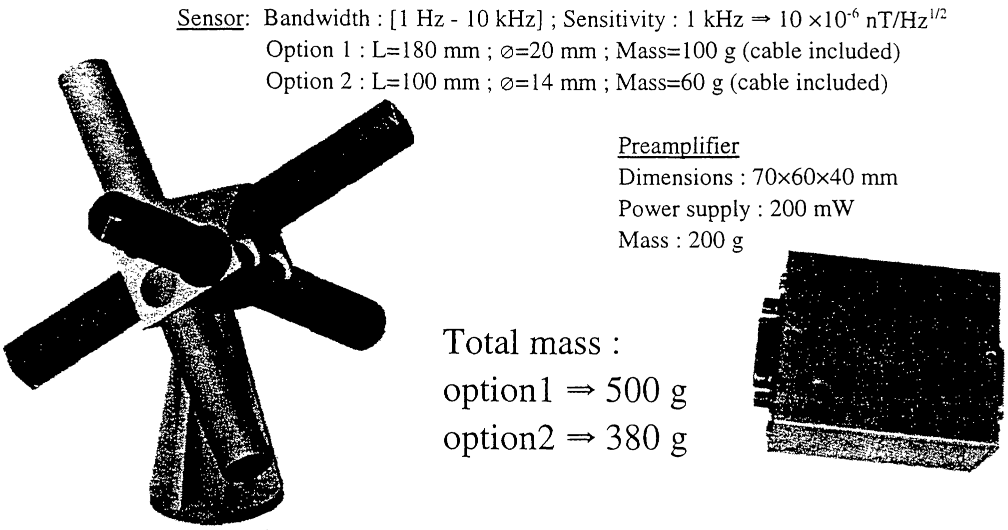

Figure 1: SOLAR ORBITER 3-axial Search Coil + Preamplifier

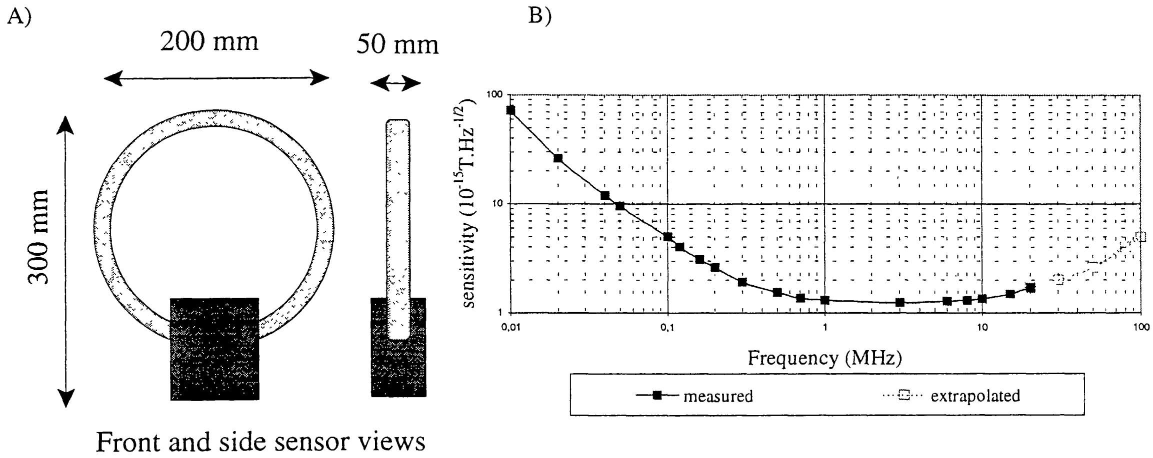

Figure 2: HF magnetic loop. A) Front and side sensor views. B) sensitivity.

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