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Science objectives of the magnetic field experiment onboard Aditya-L1 spacecraft

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Abstract

The Aditya-L1 is first Indian solar mission scheduled to be placed in a halo orbit around the first Lagrangian point (L1) of Sun-Earth system in the year 2018–19. The approved scientific payloads onboard Aditya-L1 spacecraft includes a Fluxgate Digital Magnetometer (FGM) to measure the local magnetic field which is necessary to supplement the outcome of other scientific experiments onboard. The *in-situ* vector magnetic field data at L1 is essential for better understanding of the data provided by the particle and plasma analysis experiments, onboard Aditya-L1 mission. Also, the dynamics of Coronal Mass Ejections (CMEs) can be better understood with the help of *in-situ* magnetic field data at the L1 point region. This data will also serve as crucial input for the short lead-time space weather forecasting models.

The proposed FGM is a dual range magnetic sensor on a 6 m long boom mounted on the Sun viewing panel deck and configured to deploy along the negative roll direction of the spacecraft. Two sets of sensors (tri-axial each) are proposed to be mounted, one at the tip of boom (6 m from the spacecraft) and other, midway (3 m from the spacecraft). The main science objective of this experiment is to measure the magnitude and nature of the interplanetary magnetic field (IMF) locally and to study the disturbed magnetic conditions and extreme solar events by detecting the CME from Sun as a transient event. The proposed secondary science objectives are to study the impact of interplanetary structures and shock solar wind interaction on geo-space environment and to detect low frequency plasma waves emanating from the solar corona at L1 point. This will provide a better understanding on how the Sun affects interplanetary space.

In this paper, we shall give the main scientific objectives of the magnetic field experiment and brief technical details of the FGM onboard Aditya-1 spacecraft.

Keywords: Interplanetary magnetic field; Fluxgate magnetometer; Coronal mass ejection; Alfven waves; Geomagnetic pulsation; L-1 position satellite

1. Introduction

Magnetic field measurements are regularly carried out in space to sample the local general environment around a spacecraft. The FGMs are an integral part of most of the missions irrespective of whether the mission is solar or planetary as they are highly sensitive instruments which measure the feeble magnetic fields in outer space. For deriving space weather information also, magnetic field measurements are vital and essential, whether it is magnetospheric, ionospheric or particle related.

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The first magnetometer sent to measure the IMF at L1 point was onboard ISEE-3 (International Sun Earth Explorer), earlier named as International Cometary Explorer (ICE), and the third spacecraft in the ISEE series which was launched by NASA on August 12, 1978. It had a vector helium magnetometer onboard to make continuous measurements of the IMF at L1 point (Frandsen et al., 1978). The broader scientific objectives of this instrument were to measure the instantaneous direction and polarity of the IMF and its 3-component magnitude and to study the interplanetary shocks/hydromagnetic discontinuities and Alfven waves.

The spacecraft WIND was launched by NASA on November 1, 1994 with a suite of instruments onboard including a fluxgate magnetometer. The WIND magnetometer is a boom mounted dual triaxial sensor to provide measurements to study the structure and fluctuation characteristics of the IMF (Lepping et al., 1995).

On August 25, 1997 NASA launched ACE (Advanced Composition Explorer) which has a similar magnetometer, dual triaxial sensor mounted on a boom, that was onboard WIND to provide continuous measurements of the local magnetic field in the interplanetary (IP) medium. These IMF measurements are necessary for the identification of the source location for solar wind thermal and energetic particle distributions (Smith et al., 1998).

Coronal mass ejections (CME) are huge clouds of solar magnetic flux and plasma ejected from the sun into the IP space. ICMEs which are the interplanetary counterparts of CMEs, propagate in the interplanetary medium at high speed (Schwenn, 2006). The ICME magnetic field structure, strongly varying field of the cloud, plasma density of the sheath region and the IP shock are known to be the main drivers of geomagnetic activity (Farrugia et al., 1997). Besides, it is the strong southward component (B_z) of IMF inside the ICME that is responsible for the high magnitude of the geomagnetic activity. This happens because of efficient coupling of the IMF B_z component with the northward-pointing geomagnetic field, releasing large amount of energy, transferring the mass and momentum of the solar wind into the magnetosphere, ultimately generating a huge geomagnetic storm. Therefore, measurement of the local IMF direction and magnitude at 1 AU upstream of Earth as a function of time assumes importance in order to link the source regions on the Sun with the ICMEs observed at 1 AU.

The L1 orbit resembles a geostationary orbit for a near Earth satellite which gives the opportunity to monitor the region uninterruptedly. This will also give an opportunity to study the microphysics of the solar wind at the vicinity of the L1 point which includes the generation and propagation of linear and nonlinear waves, instabilities, turbulence and shock acceleration processes. Turbulence is a potentially major factor in magnetospheric dynamics and in solar wind-magnetospheric couplings (Bruno et al., 2004). Recent theoretical results have shown that parametric decay of Alfven waves could be a source of coherent structures, like shocks and current sheets, which are created when the instability is active (Valvo et al., 2005). Some of these fluctuations in the solar wind are remnants of those in the Sun's corona while others get affected through an active turbulent cascade of energy between scales (Horbury et al., 2005). Thus the waves and the magnetic turbulence in the ULF frequency range (1–10 mHz) play a vital role in examining the process of energy transfer from the solar wind to the Earth's magnetosphere. It is also understood that these waves are carriers of information of the solar coronal hole conditions. The proposed FGM onboard Aditya – L1 mission will be extensively useful in understanding the generation of various low frequency plasma waves such as ion cyclotron waves, Alfven waves and mirror modes. It has been suggested that mirror modes observed at 1AU might even be an indicator of the presence of ion-cyclotron waves in the solar corona (Russell et al., 2008). Due to their temperature anisotropy at and beyond 0.3 AU, heavy ions in the solar wind may provide reasonable insight into the coronal heating and solar wind acceleration. Theoretical models have predicted the dissipation of ion cyclotron resonant Alfven waves in the extended solar corona (Cranmer, 2000). Ion cyclotron waves generated near the Sun and carried out by super-Alfvenic solar wind have been observed near 0.3 AU by the MESSENGER mission (Jian et al., 2010). The proposed FGM measurements can be further used to analyze the presence of electromagnetic ion cyclotron waves and probe particle heating in the solar wind. It is generally believed that most Alfven waves in the interplanetary medium are likely the undamped remnants of waves generated at or near the sun. In situ observations of the plasma waves will give information about local processes, thereby remote sensing the interplanetary medium. Magnetic field observations at L1 point will be very helpful in examining the radial evolution of these waves.

Space weather deals with the solar wind conditions affecting the near-Earth space resulting in the consequential changes in the magnetosphere, ionosphere and thermosphere (Poppe and Jordan, 2006). It is different from the meteorological weather of the atmosphere (troposphere and stratosphere). This area of research is focused on electromagnetic conditions of near-Earth space plasma environment and practical applications. The term space weather was first coined in the 1950s and became relevant with the advancement in space technology (Cade and Chan-Park, 2015).

Effects of solar wind and IMF on the Earth's environment highly depend on the orientation of interplanetary structures and shocks. The eastward interplanetary electric field, which is the combination of southward IMF B_z and solar wind velocity, is very important in deciding the space weather conditions (Gonzalez et al., 2001). Note that this electric field does not include electrostatic fields (grad ϕ) and contribution from other terms in the generalized Ohm's law (such as Hall term or pressure gradient-driven term). Recently, (Behera et al., 2016) have demonstrated