BOUNDARY DETERMINATIONS FROM LOW FREQUENCY MAGNETIC FIELD MEASUREMENTS

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Objects in the interplanetary medium are subject to interactions with the solar wind. As the solar wind encounters magnetized or unmagnetized objects, a shock wave forms upstream of the object and the solar wind field is distorted and draped over the obstacle. For magnetic bodies, this interaction produces three distinct regions of space: the solar wind, the magnetosphere of the body, and the magnetosheath or shocked solar wind between the solar wind and the magnetosphere. Accurate characterization of magnetic bodies therefore depends on identification of crossing from the solar wind or magnetosheath into the magnetosphere of the object. Magnetic measurements in the < 1Hz to 100's Hz range (denoted AC) have proven extremely useful in determining characteristic regions within the Earth's magnetosphere. At low altitudes, magnetic fluctuation levels are particularly useful in identifying field-aligned currents of the ionosphere auroral zones. These currents are a necessary consequence of the solar wind and will occur at other bodies as well, connecting the various altitude regions of magnetospheres. At high altitudes, the AC levels have proven indicative of magnetosheath and magnetopause current layers. Magnetosheath regions are subject to ion cyclotron and mirror mode local instabilities which do not penetrate the magnetopause. Furthermore, the magnetopause boundary for large magnetic shear is the site of intense magnetic noise. Magnetic fluctuation levels may be used to assist in the identification, at various altitudes, of the boundaries between the regions of magnetic influence of the solar wind and interplanetary bodies.

An exciting new discovery of the field-aligned currents is the AC frequency wave power or structure associated with the various large-scale current systems (*Anderson et al.*, 1993). A deflection of the component parallel to the main field is consistent with the associated auroral electrojet and other ionospheric Hall currents (*Zanetti et al.*, 1983). The Freja mission (600 × 1700 km, 63° inclination orbit, launched on October 6, 1992) is a Swedish scientific mission concentrating on auroral physics and involved instruments with which to measure fields and plasma. The Johns Hopkins University Applied Physics Laboratory (JHU/APL) provided the Magnetic Field Experiment.

Figure 1 is a polar plot in magnetic coordinates of the disturbance field transverse to the Earth's IGRF90 model magnetic field on April 4, 1993, interpreted as field-aligned currents. Time series disturbances in magnetic coordinates, north (BN), east (BE) and

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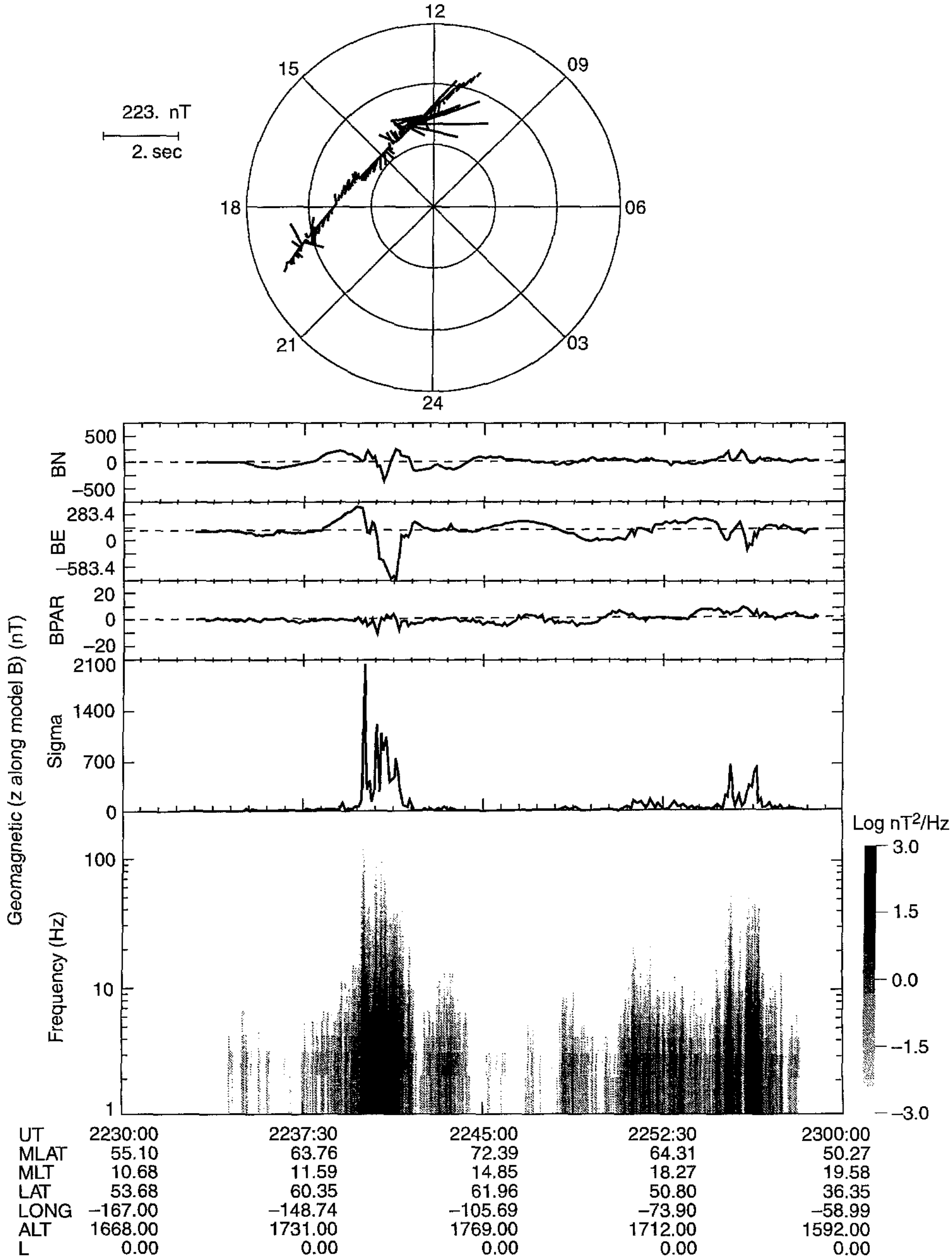

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Figure 1. Freja Magnetic Field, April 4, 1993.

parallel (BPAR) are also plotted. The next panel shows onboard processed standard deviation (nT) of the spin axis 1.5–128 Hz bandpassed channel showing the correlation to the auroral current zone. The bottom panel shows the onboard processed FFT in spectrogram format, 1–256 Hz, versus time; power (log nT^2/Hz) is indicated by greyscale. Details of the broadband wave activity correspond to the structure of the auroral zone currents. The Sigma and the FFT panel show the correlation of fluctuations, or characteristic scale lengths, of the current structure with the large-scale transverse vector disturbances which have traditionally been used to identify the field-aligned currents, which can more simply identify the auroral current zone.

The Active Magnetospheric Particle Tracer Explorers (AMPTE) program consists of three spacecraft (US, Germany, UK) and was launched in August 1984. The JHU/APL Charge Composition Explorer (CCE) was in an equatorial, 8.8 Re apogee, elliptical orbit and entered the magnetosheath and even the solar wind during large compressions of the magnetosphere.

Figure 2 (*Anderson and Fuselier*, 1993) shows AMTPE/CCE magnetic field data on December 13, 1984 from 02:00 UT to 05:00 UT during an exit of the Earth's magnetosphere into the magnetosheath. The magnitude and polar angles are shown in the left panel with the magnetopause (MP) identified. The FFT spectrograms in the right panel show transverse electromagnetic ion cyclotron and compressional mirror waves, both clearly

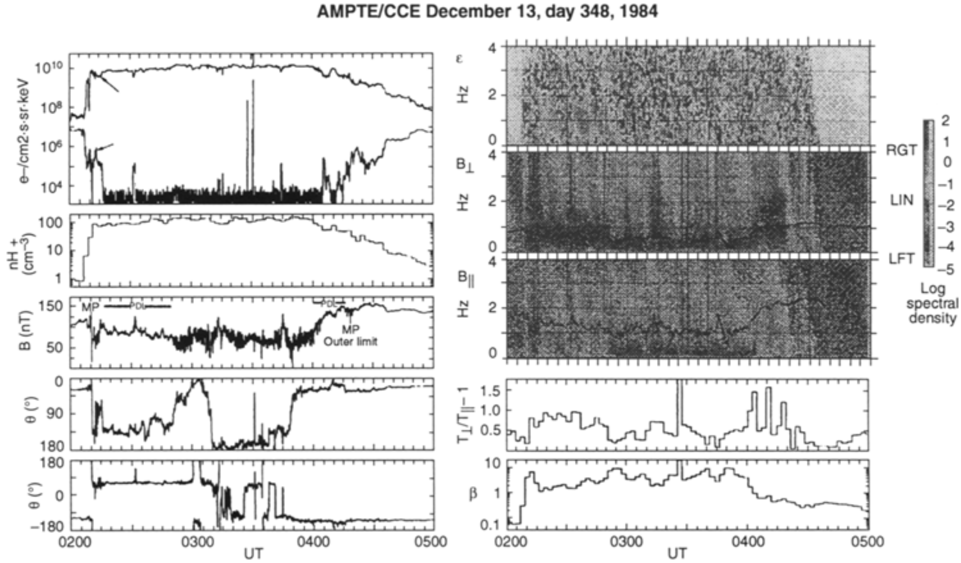

Figure 2. AMPTE/CCE magnetic field data on December 13, 1984, from 0200 UT to 0500 UT during an exit of the Earth's magnetosphere into the magnetosheath. The magnitude and polar angles are shown in the left panel with the magnetopause (MP) identified. The FFT spectrograms in the right panel show transverse electromagnetic ion cyclotron and compressional mirror waves, both clearly identifying the magnetosheath area. The dark, low-power region indicates the quiet magnetosphere.

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Studies of magnetic fluctuation levels have led to much increased understanding of the magnetosheath and magnetopause. The outbound magnetopause crossing occurred at 02:10 UT. The inbound crossing occurs for low magnetic shear but discontinuous changes in the 50–300 eV electrons indicate that the crossing was at 04:17 UT. The background fluctuation level is more intense in the magnetosheath (03:30–04:00 UT) than in the magnetosphere (04:40–05:00 UT). Transverse and compressional band limited signals are also apparent. Lastly, broadband perturbations occur during the high shear magnetopause crossing. As shown, the 50–300 eV electrons display discontinuous changes even during low-shear magnetopause crossings when the current layer is impossible to identify locally in non-AC magnetic field data. The final observation of the magnetopause region is the broadband noise signal which appears to be inherent to the magnetopause current layer. The outbound and inbound magnetopause crossings of Figure 2 illustrate the contrast in fluctuation levels between high and low magnetic shear. *Drake et al.* (1994) have found that current layers are susceptible to an instability in which the current layer degenerates into a turbulent structure of filamentary currents.

In summary, low frequency magnetic field fluctuations can be used to identify boundaries of magnetospheres and solar wind interaction regions due to high altitude magnetopause and the outer magnetosphere magnetic field structure. At low altitudes, high latitude AC structure is due to the current carrying packets, thus making the fluctuation characteristics more reliable than vector field changes to identify the current regions which define magnetospheric boundaries.

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