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Strong electrostatic fluctuations associated with intense electric currents in the plasma sheet of the Earth magnetotail

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Flapping of the Current Sheet (CS) associated with the propagation of the Burst Bulk Flow (BFF) allowed to observe consecutive crossings of the Earth magnetotail Plasma Sheet (PS). Both parallel and perpendicular Intense electric currents up to ~100 nA/m^2 were observed during the interval of interest. Simultaneously, the presence of parallel electron anisotropy of suprathermal population was observed over the entire PS. These ECS are localized and may be observed at any regions of PS. The distribution of intense ECS versus the distance from the neutral plane experiences strong variations from crossing to crossing of the PS demonstrating the transient nature of these currents.

Nonideal electric field ($\mathbf{E'} = \mathbf{E} + [\mathbf{v}_e \times \mathbf{B}]$) leading to violation of the frozen-in condition reached ~100 mV/m during the interval of interest. Typically, such strong fields are observed in the outer PS (B_x~±(10-15) nT). In this event they were observed also near the neutral plane of the CS. This leads to extremely intense energy conversion value ($\mathbf{j}$,$\mathbf{E'}$) up to ~3 nW/m^3, which are typical for the electron diffusion region (EDR). Our analysis shows that the regions with different signs of the ($\mathbf{j}$,$\mathbf{E'}$) appear sporadically throughout the PS. Globally, the probability to observe positive and negative values of the ($\mathbf{j}$,$\mathbf{E'}$) are almost equal over the entire PS. This may reflect the turbulent structure of the BBF, where energy transfers locally from particles to waves and vice versa.

We selected 179 events j>25 nA/m^2 near the neutral plane (B_x<5 nT). In 57 events intense (>10 mV/m) nonideal electric fields were observed inside the ECS. In 13 cases these fields appeared as electrostatic fluctuations, associated with accelerated field-aligned electrons beams. We selected two types of the electrostatic fluctuations: i) with frequencies lower than electron cyclotron frequency $\omega_{c,e}$ and ii) the broadband electrostatic fluctuations which high-frequency range exceeded $\omega_{c,e}$. We assume that the first type can be related to the linearly polarized electrostatic mode of whistler waves. The second one can represent the ensemble of electron solitary waves including the electron cyclotron harmonics.

Electrostatic fluctuations are typically associated with field-aligned beams in the Plasma Sheet Boundary Layer (PSBL), where they propagate along the magnetic separatrix. Also, such fluctuations were reported in the reconnection region. We showed the presence of strong electrostatic fluctuations associated with the intense field-aligned ECS inside the central PS at closed field lines and well outside the reconnection region. These currents were generated by field-aligned electron beams with suprathermal energies. We suggest that these beams are accelerated by induction electric fields generated near the neutral plane due to the transient changes in magnetic configurations of the islands/flux ropes transported by the BBF (e.g. via the electron tearing mode [1,2]). These processes produce the chain of transient acceleration sites distributed along the radial direction near the neutral plane and outside the X-line. They can be responsible for the appearance of field-aligned accelerated electron beams in the central PS at various distances from the neutral plane. Similarly to the field-aligned beams propagating in the PSBL, the electron beams in the central PS can be a source of the strong electrostatic fluctuations and intense energy conversion along the beam pathway.

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