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Multi-point observations of ULF foreshock waves by Cluster and wave mode identification

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Using multipoint measurements from the Cluster mission, wave identification techniques are applied to observations of ULF waves made in the terrestrial foreshock with the aim of identifying the modes and properties of the waves taking into account the effects of a high beta plasma. The wave properties in the spacecraft and plasma rest frames are experimentally derived using Minimum Variance Analysis and Phase-differencing method for case and statistical studies respectively. Two waves dominate the dynamic frequency spectrum with periods of 30 and 3 seconds. Results from the case study indicate that these waves propagate in the fast-magnetosonic and Alfven / Ion Cyclotron modes respectively. Both waves propagate in the upstream direction in the plasma rest frame but are convected downstream in the spacecraft frame. The measured wave properties in the plasma rest frame are in good agreement with those obtained from the theoretical kinetic dispersion relation taking into account the effects of different plasma beta. The dispersion results show a rather significant deviation from fluid model especially for when high beta plasma conditions occur. These experimentally derived foreshock ULF wave properties are in good agreement with previous results but when the effects of a high beta plasma are considered it is not as straight forward to choose the correct wave mode branch. Similar results to the case study are obtained from the statistical analysis.