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Multi-spacecraft analysis of the structure of low Mach number, low beta, quasi-perpendicular shocks

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Observational, theoretical studies as well simulations have shown that interplanetary (IP) shocks are associated with different types of waves that can exist in their upstream and downstream regions. A nature of upstream and downstream wave packets depends upon the shock strength and geometry expressed by the Mach number, and the angle between the shock normal and the upstream magnetic field. Low-Mach number weak shocks are the result of a balance between the nonlinear steepening and either dissipation due to some anomalous processes or wave dispersion. High-frequency (several Hz) wave packets in the upstream region of quasiperpendicular shocks are observed in fast magnetic field data and provided a strong evidence that these shocks have magnetosonic-whistler precursors with frequencies up to 7 Hz. On the other hand, low-frequency waves (up to 1 Hz) are more frequently registered in the downstream region behind the shock. Our previous analysis of downstream waves has shown that their wavelengths are directly proportional to the shock ramp thickness that is controlled by the ion thermal gyroradius, and they can be classified as magnetosonic waves. In this paper, we compare fast plasma observations onboard Spektr-R/DSCOVR with Wind/DSCOVR magnetic field measurements and discuss a nature and properties of waves associated with low-Mach numbers, propagating in a low-beta environment.