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# Whistler waves at the Earth bow shock

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The Magnetospheric Multiscale (MMS) spacecraft, with their state-of-the-art plasma and field instruments on-board, allow us to investigate electromagnetic waves at the bow shock and their association with small-scale disturbances in the shocked plasmas. Understanding these waves could improve our knowledge on the heating of electrons and ions across the shock ramp and the energy dissipation of supercritical shocks. We have found broad-band and narrow band waves across the shock ramp and slightly downstream. The broad-band waves propagate obliquely to the magnetic field direction and have frequencies up to the electron cyclotron frequency. Simultaneously, the electrons have quite disturbed velocities and are anisotropic in velocity space, leading to multiple possible instabilities, such as kinetic cross-field streaming instability, low-hybrid drift instability, etc. In the same region with the broad-band wave, there are narrow-band waves at a few hundred Hertz with durations under a second. These waves are right-handed circularly polarized and propagate along the magnetic field lines. The broad-band waves are only observed at the shock ramp, but the narrow-band waves are observed more frequently further downstream in the magnetosheath. Both wave types are likely to be whistler mode with different generation mechanisms. In this paper, we examine the electric and magnetic fields of these waves, as well as the plasma observations to understand the wave generation and their effects on the shock and magnetosheath plasmas.