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Analysis of subprotonospheric whistlers observed by DEMETER ; case study

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Subprotonospheric (SP) whistlers consist of a series of low dispersion echoes that result from repeated reflections between the base of the ionosphere and the altitudes up to ~1000 km. We present new results based on a plane wave analysis of SP whistlers observed onboard the French satellite DEMETER. The analysis is based on the multi-component measurements of the wave electric and magnetic field. The measured wave normal angles and plasma characteristics serve as the input for a three dimensional ray tracing technique. For several SP whistlers we also succeeded in finding the causative lightning, which was usually relatively strong and located at relatively large distances from the satellite foot point along the magnetic field. We show that the reflections and formation of the SP whistlers takes place owing to an oblique propagation, with respect to the magnetic field, in the wave guide formed by a profile of the increasing Lower Hybrid Resonance (LHR) frequency in the upper ionosphere and the base of the ionosphere. We observed propagation across the magnetic meridian planes. We conclude that the individual echoes of the SP whistler propagate along different ray paths. The waves forming these echoes enter the ionosphere at relatively large distances from the satellite foot point and experience a spread of wave normal angles during this entry. Depending on the initial wave normal angle, these waves undergo a different number of reflections before reaching the satellite, thus arriving with different time delays. However, the first trace observed of a SP whistler is formed by waves entering the ionosphere at relatively small distances from the satellite foot point and at relatively small wave normal angles. These waves do not reflect above the satellite, but propagate to the opposite hemisphere.