Meteoroid plasma density, mass and velocity determination using a new 3D full-wave scattering method applied to head echoes

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Large-aperture radars have the ability to detect the high-density plasma that forms in the vicinity of the meteoroid and moves with the meteoroid's velocity; reflections from these plasmas are called head echoes. To determine the head echo plasma density and configuration, we have modeled the interaction of a radar wave with the head echo plasma without assumptions relating to wavelength or plasma density; this solution is referred to as the "full-wave" scattering method. This presentation contains the results of a 3D full-wave scattering method applied to head echo data detected by ALTAIR at both VHF and UHF during the Leonid 1998 storm. Head echoes are modeled as reflections from sphere-like plasmas with frequencies near the radar frequency and radii that scale with the atmospheric mean free path. The head echo plasma density was determined by applying the full-wave solution to each head echo's radar-cross-section (RCS), and indicates that head echo RCS will be maximized when the head echo plasma achieves the best balance between plasma density and size. Head echo plasma density is highly dependent upon meteoroid velocity, mass and detection altitude and will be maximized at low altitudes, where densities can exceed 10^{17} el/m^3.

We used three methods to validate our full-wave method. First, we used the 3D method to compare VHF plasma densities with UHF plasma densities. Second, we converted the maximum plasma density from each VHF head echo to electron line density and compared these values with those obtained from a meteoroid ablation model. Finally, we calculated the electron line density at each frequency from a single head echo detected simultaneously at VHF and UHF in order to compare its meteoroid mass at both frequencies. Our results indicate that the full-wave method produces consistent results across frequencies and agrees remarkably well with the ablation model.