Radar studies of ionospheric dust - plasma phenomena

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Dust plasma phenomena occur in the Earth ionosphere in particular in the meteor ablation zone at altitudes ~50-95 km and above where radar meteors form. Radar also detect coherent polar mesospheric radar echoes (PME), i.e. radar echoes that are caused by spatial variations in the plasma refractive index at around 80 to 90 km altitude in the Earth's mesosphere. During summer, PM(S)E form in the presence of ice particles and are linked to the electric surface charge of the particles. Straightforward quantitative descriptions of PME are however still missing as well as the role of turbulence in their formation. In addition, radar can under certain conditions, detect incoherent scatter. Incoherent scatter results from electromagnetic waves scattering at electrons that are coupled to ions and charged dust through plasma oscillations and to the neutral particles through collisions. The contribution of dust to incoherent scatter is small, but possibly an important tool for future studies. When illuminated with electromagnetic waves of frequency ω_0 the waves back scattered from electrons would form a broad distribution around ω_0 due to the Doppler shift caused by the electron thermal motion. If the radar wavelength, λ_{radar} is large in comparison to the plasma Debye length, λ_{Debye} where $\lambda_{Debye} \approx (T_e/n_e q_e)^{1/2}$ the plasma oscillations that couple the electrons to other charged components become important. Resonances occur and in the absence of bulk motion are at frequency shifts corresponding to the frequencies, ω_{wave} of the plasma oscillations $\omega = \omega_0 \pm \omega_{wave}$. The two predominant resonances are from plasma (Langmuir) waves with the plasma frequency ω_p, where $\omega^2_p \approx \omega_e^2 \approx n_e e^2/m_e$ and from ion acoustic waves with frequency ω_{ia}, where $\omega^2_{ia} \approx (T_e + 3\,T_i) / m_i$ with T_e and T_i being electron and ion temperature, respectively and m_i the ion mass. In addition, for $T_i \approx T_e$, which is the case in the lower ionosphere, Landau Damping occurs for the ions and ion acoustic waves and the resonances around $\omega = \omega_0 \pm \omega_{ia}$ smear out toward ω_0 forming a central peak, often denoted as the ion line. Incoherent scatter is observed when $(\lambda_{Debye} / \lambda_{Radar})^2 << 1$ and at a sufficiently large transmit power. As the charged dust acts analogous to the ions but with larger mass, it influences the inner part of the ion line. So far, the dust component could only be reliably derived from the observations in a few cases, because at the altitudes of interest the incoherent scatter signal is weak and in addition influenced by ion-neutral collisions, negative ions and positive molecular ions. The differences in electron, ion and dust temperatures also play a role and the scattering varies with frequency. Based on dust parameters derived from models and observations with rocket instruments the radar signals are estimated.

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