Scattering of radio frequency waves by density filaments and fluctuations

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The edge region of tokamak plasmas is replete with spatially distributed density fluctuations and localized turbulent structures such as filaments and blobs. Radio frequency (RF) waves, used for heating and for current profile control, have to propagate from the excitation structures to the core of the plasma through this active region. The fluctuations modify the propagation of the waves through reflection, refraction, and diffraction. A description of this scattering process for large amplitude, experimentally observed, fluctuations is beyond the geometric optics approximation.

A full-wave analytical theory has been formulated for RF scattering off a cylindrical filament or a spherical blob, and off spatially distributed fluctuations along planar fronts. In the boundary layer separating a localized structure from the background plasma, electromagnetic boundary conditions require the simultaneous excitation of the two, independent, cold plasma waves. Thus, for example, for electron cyclotron waves, if an ordinary wave is coupled from an external source, the localized structure will not only scatter the ordinary wave but also couple some of the power to the extraordinary wave. In the full-wave model, the plasma, within and outside these structures, is assumed to be homogeneous, cold, and with arbitrary densities. The primary effect of the filaments, blobs, and fluctuations is to broaden the spectrum of the RF waves, and to change the index of refraction parallel to the magnetic field. The electric fields in the transition region, between the background plasma and these structures, are enhanced and could lead to nonlinear parametric processes. The structures behave like dipole antennas and couple power to wave modes propagating in all directions with respect to the magnetic field. They also tend to focus the electric fields in their wake. The theory applies to waves in the ion cyclotron, lower hybrid, and electron cyclotron range of frequencies.