Scattering of RF waves by edge density fluctuations and blobs in a tokamak

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The edge region of tokamak plasmas is replete with spatially distributed density fluctuations and localized turbulent structures such as blobs. Radio frequency (RF) waves, commonly 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 properties of the waves through reflection, refraction, and diffraction.

We stress the limitations associated with several models in literature which treat scattering as a particle-like (ray-based) collisional process, thus completely ignoring the fact that there cannot be ("collisional") deflection without reflection. In contrast, we have been studying the scattering of RF waves by fluctuations and by blobs using a full-wave theory [1]. We assume that edge plasma is cold. The blobs are taken to be either spherical or cylindrical in shape and are treated differently from fluctuations which are considered to be spatially distributed along planar fronts. At the edges of the fluctuations and the blobs we need to satisfy the electromagnetic boundary conditions that follow from Maxwell's equations. These boundary conditions necessarily require the simultaneous excitation of the two, independent, cold plasma waves. Thus, for example, in the electron cyclotron range of frequencies, if an ordinary wave is coupled to the plasma from an external source, the fluctuations and the blobs will not only scatter the ordinary wave but also couple some of the power to the extraordinary wave.

The theoretical approach that we follow is similar to that for Mie scattering of electromagnetic waves by dielectric particles. The plasma, both inside and outside the blobs, is assumed to be homogeneous with arbitrary densities in either region; thus, we are not limited to small density fluctuations. The anisotropy induced by the magnetic field is such that the propagation characteristics and the polarization of the RF waves depend on the polar angle with respect to the direction of the magnetic field.

The scattering broadens the spectrum of the waves propagating into the core of the plasma. We will present results on the effect of fluctuations and blobs on short wavelength electron cyclotron waves and longer wavelength lower hybrid and ion cyclotron waves.

[1] A. K. Ram, K. Hizanidis, and Y. Kominis, Phys. Plasmas 20, 056110 (2013).

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