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Scattering of waves by blobs in tokamak plasmas: venturing beyond geometric optics[1]

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The edge region of tokamak plasmas is replete with density fluctuations that manifest themselves 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 blobs modify the propagation properties of the waves through reflection, refraction, and diffraction. There are two basic approaches to studying the effects of density fluctuations on RF waves. The first is the geometric optics approach in which the effect of fluctuations is to refract the RF beam or rays. There are two subsequent consequences–diffusion in real space leading to a spatial deflection of the rays, and diffusion in wave vector space leading to the broadening of the launched spectrum. The geometric optics approach is limited to small density fluctuations of order 10% or less. However, in experiments, larger amplitude fluctuations are generally observed. The second approach to scattering is through a full wave analysis which extends the range of validity well beyond that of geometric optics. Such an analysis is theoretically and computationally much more challenging. The full-wave description includes reflection, refraction, and diffraction of the RF waves by blobs. A full-wave model for the scattering by a density blob has been developed for RF waves in any frequency range. A detailed analysis provides insight into the scattering by blobs and shows that power from the incident RF wave can couple to other plasma waves and to surface waves. The scattering depends on the ratio of the RF wavelength to the spatial scale of the fluctuations. When the ratio is large, as would be the case for electron cyclotron waves, there is an enhancement of the electric fields near the edge of the blobs. Additionally, wave fields propagating along the ambient magnetic field are excited which take power away from the primary wave propagating to the core. When the ratio is of order one or less, as in the case of lower hybrid and ion cyclotron waves, diffractive scattering is prominent and the spectrum of the waves is broadened. The theoretical model for the scattering, along with numerical results and experimental consequences, will be discussed.

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