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Scattering of Radio Frequency Waves by Density Fluctuations in Tokamak Plasmas

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In tokamak fusion plasmas, coherent, intermittent, fluctuations in the form of blobs or filaments and incoherent fluctuations due to turbulence are routinely observed in the scrape-off layer. Radio frequency (RF) electromagnetic waves, commonly used for heating the plasma and for providing non-inductive plasma current, are excited by antenna structures placed near the wall of a tokamak. These waves have to propagate through the scrape-off layer before reaching the core of the plasma. While the effect of fluctuations on RF waves has not been quantified experimentally, there are telltale signs, arising from differences between results from simulations and from experiments, that fluctuations can modify the spectrum of RF waves. We have pursued pioneering theoretical studies and complementary computer simulations so as to elucidate the impact of fluctuations on RF waves. These studies, using the full complement of Maxwell's equations for cold, magnetized plasmas, show that the Poynting flux in the wake of a filament, or a blob, develops spatial structure due to diffraction and shadowing. The uniformity of power flow into the plasma is affected by modifications to the wave spectrum as a result of side-scattering, and the coupling of power to plasma waves different from the incident RF wave. For propagation through turbulent fluctuations, Snell's law and Fresnel equations have been formulated within the context of stratified, magnetized plasmas. The corresponding theory is distinctly different from its counterpart in scalar dielectric media, and reveals new and salient physical insight into the scattering of RF waves. All of these studies apply to the scattering of RF waves in any frequency range and for arbitrary variations in plasma density. In the International Thermonuclear Experimental Reactor, electron cyclotron waves will be used to stabilize the deleterious neoclassical tearing mode by providing current in the island region. In order to ensure that the waves provide plasma current with high efficiency within the appropriate spatial locations, it is imperative to understand the spatial and spectral effects of fluctuations on the propagation of electron cyclotron waves. The studies reported in this paper are a requisite and critical advances in that particular direction.

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