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Microwave Scattering Due to Density Fluctuations in the DIII-D Tokamak[1]

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Heat pulse propagation experiments and beam propagation simulations have demonstrated a long-suspected connection between millimeter-scale turbulence and deposition profile broadening of electron cyclotron (EC) waves[1] on the DIII-D tokamak[2]. Over a variety of edge conditions produced in DIII-D experiments, Doppler backscattering measures an order of magnitude variation in density fluctuation level, which correlates linearly with the factor of 1.4-2.7 broadening of EC deposition as compared with equilibrium ray tracing. A self-consistent, profile-driven turbulence model coupled to a full wave rf simulation generates a level of broadening comparable to that seen in these experiments. The EC deposition profile is determined from transport analysis of the electron temperature modulation in response to EC power modulation at 20-70 Hz. Converting the temperature modulation to heat flux modulation and fitting across the harmonic structure to diffusive, convective, and coupled transport terms can resolve the EC deposition width from the temperature perturbation to within 25 percent in each case. The degree of beam broadening by scattering off simulated turbulence and the experimental evaluation of the deposition broadening agree across the full range of conditions studied. Quantifying the effect of edge fluctuation broadening on EC current drive on ITER, which can increase the power requirement for suppression of neoclassical tearing modes, will require 3D full wave codes that can be validated on the current generation of machines. These DIII-D experiments provide a quantitative measure of fluctuation effects, and demonstrate the power of 3D full wave simulations to model phenomena missed by 1D equilibrium beam and ray tracing. [1] A. Kohn et al PPFC 60 (2018) [2] M.W. Brookman et al submitted to PRL (2019)

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