Parameterisation of Microwave Beam Broadening by Plasma Density Turbulence

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High-power microwave beams are used to inject power into fusion plasmas for the purposes of heating and current drive. Turbulence at the plasma edge can broaden these beams significantly, affecting their efficiency [1]. In the turbulent layer, fluctuation levels can exceed 100% of the background density, reaching cut-off densities for the incident microwaves, and turbulence correlation lengths are comparable to the microwave wavelength [2]. In order to accurately predict the broadening effect this turbulence can have on microwave beams, it is often necessary to use full-wave code. However, when a large number of scenarios need to be considered, such as in an optimisation study, this becomes very computationally expensive.

We have developed an empirical formula which predicts microwave beam broadening as a function of plasma and beam parameters. The parameters we investigated were radial and poloidal correlation length, background density, fluctuation level, microwave beam waist, and width of the turbulence layer. We carried out a series of 2D parameter scans in pairwise combinations of these parameters using the full-wave cold plasma code EMIT-2D in order to determine the dependence on each parameter (or combination of parameters in the case where the dependences were not separable). We found that the dependences on the radial and poloidal correlation lengths are not separable from each other, and that ignoring this effect results in a significant over-prediction of the beam broadening in fusion-relevant scenarios. The dependences on background density and fluctuation level are also inseparable, but all other dependences are separable.

We used these results to find an empirical formula to predict the beam broadening based on these parameters, allowing the prediction of beam broadening in a fraction of a second rather than the hours required for full-wave simulations.

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