Effects of misaligning the probe beam and magnetic field in Doppler backscattering measurements

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The Doppler Backscattering (DBS) microwave diagnostic enables the non-perturbative characterisation of density fluctuations ($1 \lesssim k_\perp \rho_i \lesssim 10$) and flows, both at the edge and the core of the plasma. The large magnetic pitch angle (up to 35°, compared to 15° in standard tokamaks like JET) and the time-varying magnetic equilibrium make the use of DBS in spherical tokamaks challenging. Due to spatial variation, it is not possible to simultaneously achieve alignment between the probe beam and electric field for all launch frequencies. This misalignment, which affects the backscattered signal, can be empirically optimised with 2D beam steering [1].

However, empirical optimisation is inefficient, requiring repeated pulses with different diagnostic settings, and may not always be possible. Hence, it is important to develop a model to quantitatively account for the effect of the misalignment on the backscattered signal, avoiding the need to optimise empirically.

We used beam tracing [2] and the reciprocity theorem to derive an analytic model for the backscattered power and its dependence on the mismatch angle. Unlike previous work on reciprocity [3], our model works for both the O-mode and X-mode in tokamak geometry. Our more general model can be implemented numerically, allowing the misalignment of DBS measurements to be accounted for. The results are compared to scans of the toroidal launch angle from MAST data. With insight from our model, we also assessed the measurement capabilities for the planned MAST-U DBS system.

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