3D full wave simulations of microwave interactions with turbulence

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The scattering of microwaves by density fluctuations in magnetised plasmas where the inhomogeneity scale length is comparable to the wavelength is not a fully understood problem. Yet microwaves are used extensively in magnetically confined fusion plasmas not only to provide a wealth of information through diagnostics but for heating and current drive. The largest scattering is expected to occur as the microwave beam propagates through the plasma edge where the turbulence fluctuations are largest. The time averaged effect of instantaneous scattering results in an effective beam broadening. The effect is particularly pronounced over propagation distances that are many vacuum wavelengths as is the case in most current, and certainly, future devices. The broadening of microwave beams can result in a lower than expected heating and current drive efficiency which could make the stabilisation of neoclassical tearing modes more challenging [1].

We present simulation results using the full-wave, cold plasma, finite difference time domain codes EMIT-3D and IPF-FDMC developed independently at York and Stuttgart, respectively. First we present a novel systematic study of the scattering of microwaves through turbulence: we quantified the relationship between the normalised turbulent correlation length and the scattered power. Additionally we found a quadratic relationship between the scattered wave power and the turbulence amplitude [2]. The complexity is then extended by modelling the effect of microwave beam broadening due to edge turbulence in distinct tokamak scenarios L-mode, H-mode and negative triangularity where the modelled propagation distance is large (≈ 40λ₀). The L-mode like simulation shows significant beam broadening of greater than twice that without turbulence. We go on to present results to model the Doppler back-scattering (DBS) of a broad microwave beam from a moving turbulent slab. This second problem is particularly important for interpreting 2D DBS data from the Synthetic Aperture Microwave Imaging (SAMI) diagnostic installed on MAST and now NSTX-U.

References