ITER reflectometry diagnostics operation limitations caused by strong back and small angle scattering

E.Z. Gusakov[1], S. Heuraux[2], A.Yu. Popov[1]

[1] *Ioffe Institute, St.Petersburg, Russia*

[2] *LPMIA, UMR-CNRS 7040, Vandoeuvre CEDEX, France*

The microwave reflectometry is considered nowadays as key diagnostics in ITER, for plasma positioning, density profile reconstruction, and also able to provide measurements on turbulence. Both O-mode and X-mode reflectometers launching probing wave from high and low magnetic field are developed [1]. On ITER, the fast frequency sweep reflectometer [1] should be able to diagnose very flat density profiles, which correspond to long probing wave paths (several meters). Under these unfavorable conditions the reflectometers can suffer from destructive influence of plasma turbulence which may lead on one hand to multiple small angle scattering or strong phase modulation and on the other hand to a strong Bragg backscattering (BBS) or to an anomalous reflection. In the first case the probing beam looses coherence and therefore the standard approaches to characterize the turbulence are no more applicable, whereas in the second – the wave reflection occurs far from the cut-off position thus complicating the density profile reconstruction.

In this paper the turbulence level thresholds for strong phase modulation and strong BBS are derived for different probing modes and frequencies. Relativistic corrections to the plasma permittivity due to the high electron temperature were included, which induces a spatial shift of the O-mode and X-mode cut-off positions [3]. Two scenarios one with a rather flat density profile, $n_0 = 1.2 \cdot 10^{20} m^{-3}$, $n_{edge} = 0.8 \cdot 10^{20} m^{-3}$, $B_0 = 5\ T$ and the other with the absolutely flat density profile shown in [2], $n_0 = n_{edge} = 1 \cdot 10^{20} m^{-3}$, $B_0 = 5\ T$ are discussed in detail. For both cases with the considered reflectometers, it is shown that the scattering transition into the non-linear regime occurs at the level of turbulent density perturbation comparable or below that found in the present day tokamak experiments. The threshold of strong phase modulation is given by $\delta n/n_0 \sim 0.05 \div 0.5\%$, whereas the threshold of strong BBS is estimated as $\delta n/n_0 \sim 0.5 \div 3\%$ depending on the mode used and the frequency. A new approach to turbulence diagnostics based on radial correlation reflectometry useful in the case of strong phase modulation is introduced. The possibility of local monitoring of turbulence behavior in this case is discussed.

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