Effect of Various EFIT NSTX Equilibria on EBW Simulations

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Abstract

Electron Bernstein wave emission (EBWE) is strongly coupled to the magnetic equilibrium. Simulation results for different EFIT equilibria available for National Spherical Torus Experiment (NSTX) are compared. The EBWE intensity is dependent on which version of EFIT is used, whereas the conversion efficiency remains almost unaffected. Simulations indicate that during flat top current discharges the optimal angles for the aiming of the NSTX antennae are quite rugged and basically independent of time.

ECE and electron Bernstein waves on NSTX

- The low magnetic fields and high plasma densities in spherical tokamaks lead to overdense plasma from which one cannot observe the standard O and X mode radiation emitted from the first several electron cyclotron harmonics
- Any measured electron cyclotron emission (ECE) cannot be simply interpreted. On the other hand, electrostatic electron Bernstein waves (EBW) are not subject to a density limit and are strongly emitted/absorbed near the electron cyclotron harmonics.
- On mode converting to electromagnetic waves near the upper hybrid resonance, the emitted cyclotron radiation can be attributable to electron Bernstein wave emission (EBWE) and hence to a local temperature near the cyclotron harmonic.
- On NSTX, there are two new remotely steered antennas [1], which can scan the frequency ranges 8-18 GHz and 18-40 GHz, respectively, as well as in directional angles.
- The significance of determining the frequency dependence of EBWE is that it provides important information on optimal parameters for proposed EBW heating and current drive experiments.

Antennae aiming optimization

- Proper antennae aiming angles are crucial in EBW experiments. Simulations for L-mode 800 kA helium shots were performed to estimate optimal antennae aiming.
- It was found that the most important parameter, which determines the optimum angles for the most intensive EBWE, is the EBW-X-O conversion efficiency.

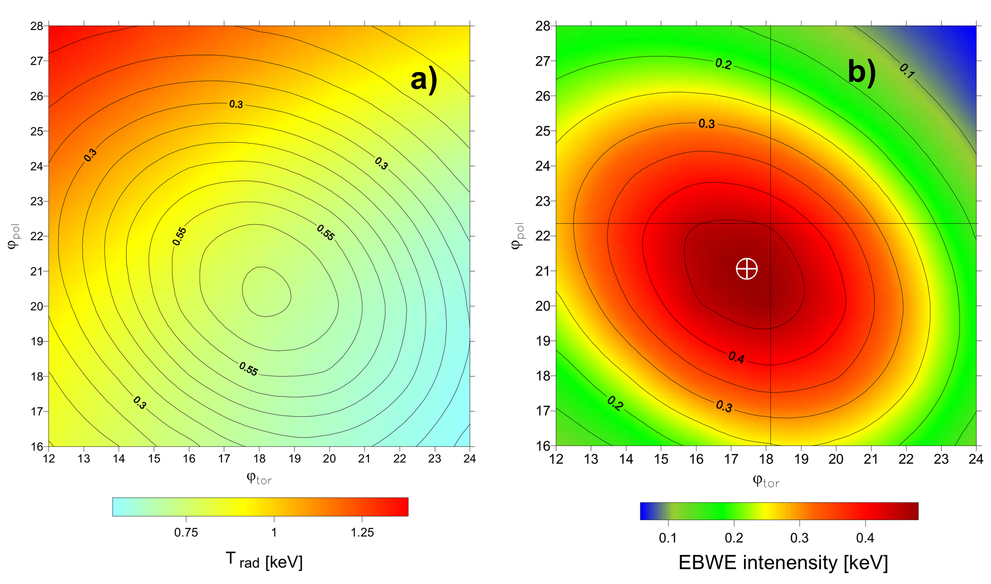

Fig. 1. a) Angular dependence of the antenna beam conversion efficiency (contours) and the EBW beam radiative temperature (colour). b) Angular dependence of the simulated EBWE signal of the high frequency antenna. Both figures for shot 120278, t=0.382, f=29GHz, EFIT02.

- In Fig. 1, we compare the angular dependence of the beam conversion efficiency and the beam radiative temperature ($C_{EBW-X-O}$) with the angular dependence of the simulated EBWE intensity for the high frequency antenna. The radiative temperature of the EBWs increases with angles aimed near the equatorial plane, whereas the conversion efficiency peaks at those optimum angles determined by the magnetic field direction in the conversion region.
- For the tested L-modes during the flat top current phase, the optimal angles are the same (see Fig. 2a) and do not even depend on the magnetic equilibrium model.
- The optimal poloidal and toroidal angles (φ_{pol},φ_{tor}) for the low and high frequency antennae are (-24°,-22°) and (+21°,+17.5°), respectively.

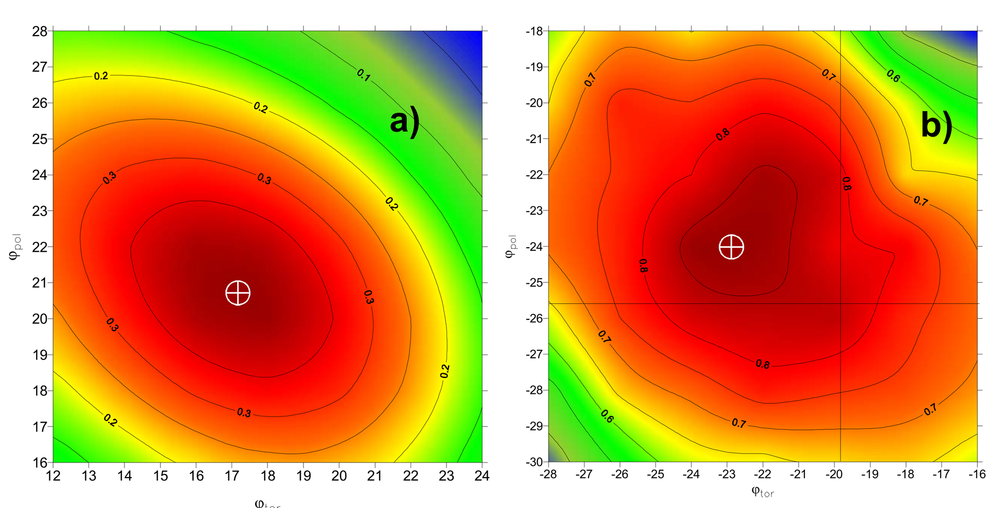

Fig. 2. a) Angular dependence of the simulated EBWE signal of the high frequency antenna. Shot 120271, t=0.398, f=29GHz, EFIT01. b) Same as 1b) for 16 GHz, low frequency antenna.

References

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EBWE simulations using different equilibrium models

- The EBWE simulation model, described in detail in [2,3], uses the magnetic configuration determined by an EFIT code.
- We consider three different EFIT versions [4, 5] for NSTX. The 'Basic' EFIT01 uses only the external magnetic measurements and simple models for plasma current and pressure. The 'Partial kinetic' EFIT02 adds weak pressure constraints, allowing for edge currents and using higher approximations. The more advanced EFIT03 incorporates, in addition to EFIT02, constraints from the MSE measurements.
- The main differences in the equilibria are in the pressure and current profiles, but EBWE is sensitive mainly to the changes in the profiles of the magnetic field magnitude (Fig. 3).
- In the conversion region (usually near the LCFS), however, these magnetic field changes are minimal and thus the conversion efficiency is independent of the equilibrium model (Fig. 4).

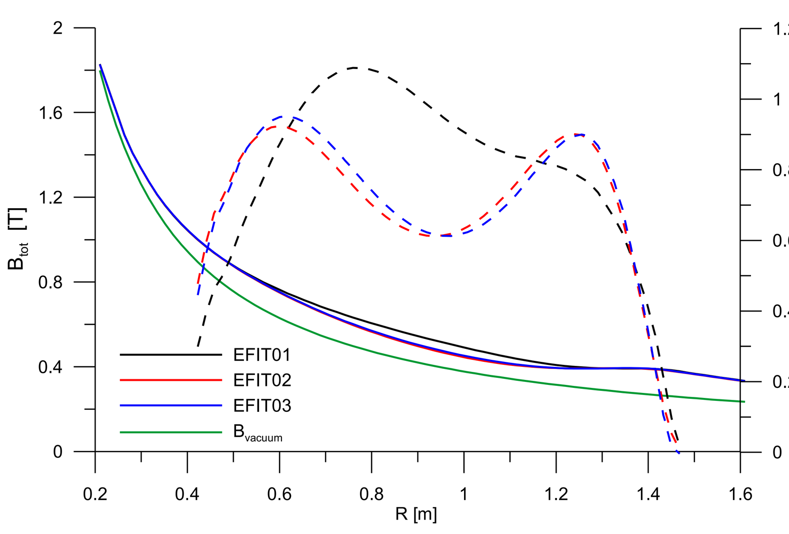

Fig. 3. Magnitude of total magnetic field (solid curves) and toroidal current density (dashed) vs. R in the equatorial plane for different EFIT versions, shot #119685, t=0.348 s.

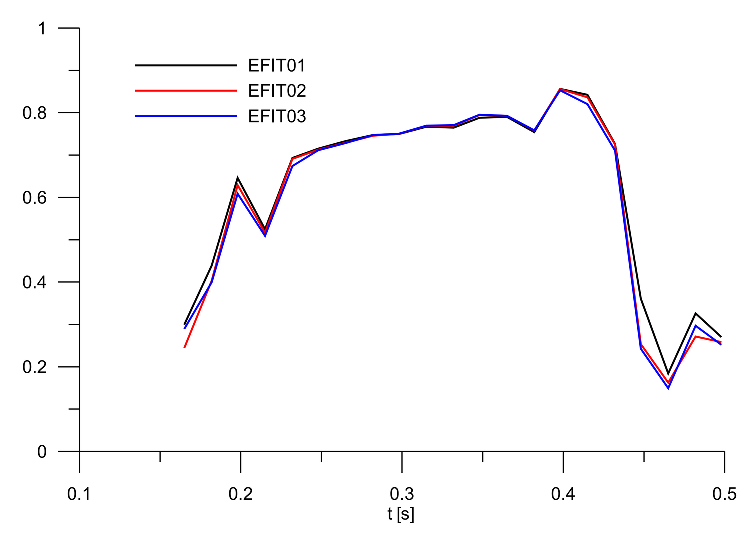

Fig 4. Conversion efficiency of whole beam (summed for both polarizations), f=29 GHz, φ_{pol}=22°,φ_{tor}=18°, shot #119685, t=0.348 s.

- On other hand, the radiative temperature depends on the equilibrium model, with EBWs being radiated from the EC harmonics - see Fig. 5.
- The higher intensity of the 37 GHz wave (3rd harmonic emission) corresponds to the lower magnetic field predicted by EFIT02/03 (Fig. 6).
- The 16 GHz wave (1st harmonic emission) intensity is weaker for EFIT02/03 because they are emitted away from the plasma centre.

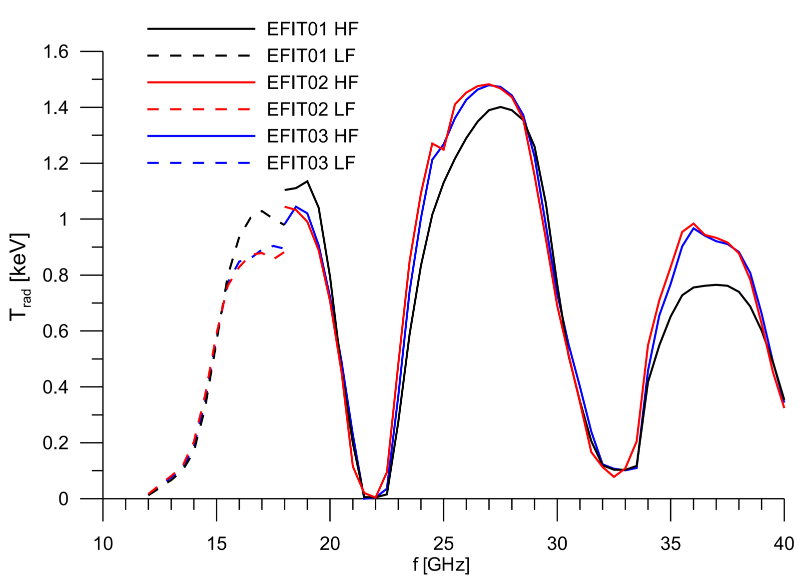

Fig. 5. EBWE, spectrum at t=0.365 s, #119685. Dotted lines correspond to the LF antenna (φ_{pol}=-24°,φ_{tor}=-22°), full lines correspond to the HF antenna (φ_{pol}=22°,φ_{tor}=18°).

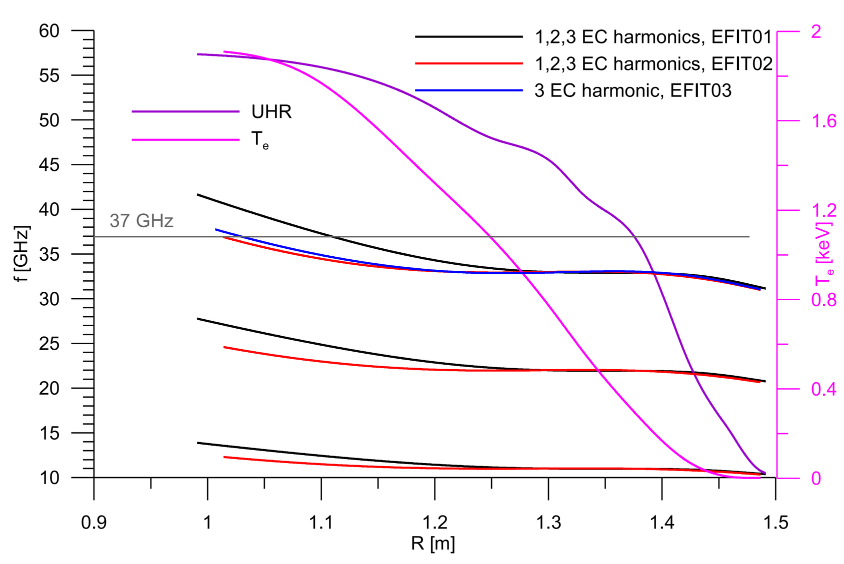

Fig 6. Radial profiles of the characteristic resonances and the electron temperature for different models of magnetic equilibria.

- The time development of the 29 GHz EBWE demonstrates again the stronger magnetic field of EFIT01 - the emission takes place closer to the plasma center (at the HFS), i.e. with higher temperatures - Fig. 7.

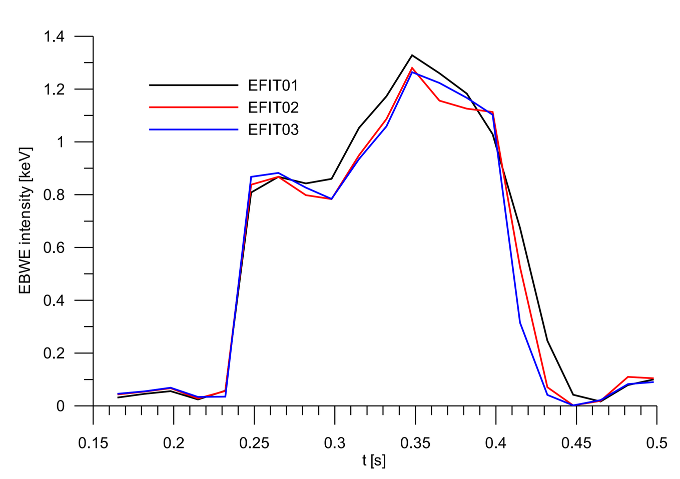

Fig. 7. EBWE time evolution, f=29 GHz, shot #119685, different EFIT versions.

Summary

- EBWE simulations are sensitive to the magnetic equilibrium model.
- The standard EFIT01 predicts usually higher magnetic field than the more rigorous EFIT02 and EFIT03. As a consequence, predicted EBWE intensities are different, particularly for the 3rd harmonic.
- Since there is an insignificant difference at the EBW-X-O conversion region, the conversion efficiency does not depend on the EFIT version. Thus, the antenna aiming studies can be performed with all of the tested equilibria.
- Comparison to experimental results will be available in the near future. We expect better agreement with EFIT02 or EFIT03.

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