Calculation of RF current drive in tokamaks

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The toroidal plasma current is a key parameter for controlling MHD stability and fusion performances in tokamaks. Among the various methods for driving a current, the radio-frequency (RF) waves are one of the most flexible and powerful tool. Therefore, their role in the design and optimization of advanced scenarios is considerable. Since the solution of the steady-state problem is highly non-linear, because of the self-consistency between pressure and current profiles, the influence of the current drive models is critical in the simulations. For a realistic description, the numerical codes must consider the possibility to use multiple waves with different frequencies launched at several positions, including possible synergistic effects between them. The power absorption process must also take into account of the complex dynamics of the charged particles in an arbitrary axisymmetric toroidal magnetic configuration, in particular those which are resonantly interacting with the RF waves.

The universal ray-tracing code C3PO coupled with the fully implicit 3-D electron bounce-averaged relativistic Fokker-Planck solver LUKE is an illustration of the present day effort for performing fast and realistic calculations of the current density profile. The underlying physical models are detailed as well as the advanced numerical methods which allow to fully benefit from the available high computing power level. The versatility of C3PO/LUKE is highlighted by several examples of simulations concerning the lower hybrid, the electron cyclotron and electron Bernstein waves. Finally, it is shown that this work opens the route to several new interesting problems for the current drive physics, which are both theoretical and numerical challenges for the coming years.