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Physics of simultaneous excitation of electrostatic slow mode and fast waves

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The significance of parasitic coupling to the undesired slow waves for helicon wave excitation was quantified using the high-resolution state-of-art full wave simulation code. RF current drive is expected to be a crucial current drive actuator in a fusion power plant and particularly useful for current profile control needed for an advanced tokamak reactor. In particular, helicon waves are thought to be promising since it can penetrate into reactor-grade high density core and drive off-axis current at higher efficiency. To explore this attractive current drive concept, high power heating and current drive experiments are being prepared in KSTAR and DIII-D. In this intermediate frequency regime ~ 500 MHz, both slow electrostatic and fast electromagnetic waves can coexist. In this presentation, we summarize the result of modeling effort to support the on-going experiments. To handle the physics of simultaneous excitation of slow and fast waves, the state-of-the-art rf modeling codes with realistic antenna and plasma geometry were utilized to handle the waves with very different wavelength and polarization [1, 2].

The slow waves can be excited when the alignment angle (ϕ) between the Faraday screen and the local magnetic field is larger than 10 degrees [3, 4]. Despite the difference in polarization between the two wave modes at the edge of the plasma, the slow-wave mode has a low cutoff density than the helicon waves. Hence, while the slow-wave modes can propagate from the antenna to the higher magnetic field/density region, helicon waves generally have an evanescent layer between the antenna and the edge plasma.

Recent two-dimensional full-wave simulations [5] showed that the slow wave can be excited even for lower misalignment angle (ϕ ~ 5), as shown in Figure 1, and propagate into the SOL. Furthermore, SOL power losses due to slow waves significantly increase as ϕ increases when density in front of the antenna (n_{ant}) is low (~ $10^{18}m^{-3}$). For higher n_{ant} cases, slow modes become negligible, and the SOL power losses smoothly vary with realistic vacuum vessel boundary, which shows good agreement with 2D full-wave simulations of high harmonic fast waves in NSTX/NSTX-U [6]. For unrealistic rectangular vacuum vessel boundaries, SOL power losses increase with n_{ant}. In particular, when n_{ant} reaches the critical density, which allows fast waves to propagate into the SOL, SOL power losses suddenly jump [7,8].

However, since the misalignment angle between the Faraday screen and the ambient magnetic field is one of the critical parameters for parasitic excitation of slow modes, oversimplified antenna configurations in 2D full-wave simulations is not enough to describe wave excitation at the antenna.

We also plan to present results from the realistic 3D antenna geometry with SOL configurations in the Petra-M code for the helicon and slow wave excitation and propagation in the KSTAR and DIII-D experimental geometries. Helicon and slow mode wave properties in a 3D SOL and core plasma, and SOL power losses with various SOL density and magnetic field configurations will be discussed.

References

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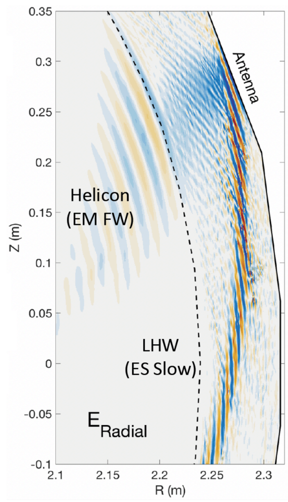

Figure 1. 2D full-wave solution of fast and slow waves using Petr-M in KSTAR. Solid and dotted lines represent the outer boundary and last closed flux surface, respectively. While long-wavelength helicon waves reach the core plasma, short wavelength slow mode only propagate into the SOL.