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Instrumental modeling of Mutual Impedance experiments and validation tests in plasma chamber

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ABSTRACT

Mutual impedance experiments are in situ space plasma diagnostic techniques for the determination of characteristic plasma parameters, such as the plasma density and electron temperature. These experiments consist of a set of emitting and receiving antennas. The emitting antennas perturb the in situ plasma environment via the emission of successive sinusoidal signal, at fixed amplitude and given frequencies. The receiving antennas measure, at this same frequencies, the electric oscillation amplitudes in the plasma, from which the mutual impedance power spectrum is built. The plasma density and electron temperature are determined from these power spectra, which typically exhibit resonant signatures at the characteristic frequencies of the probed plasma. For this determination process, typical mutual impedance models usually assume (i) linear plasma responses to active electric excitations of mutual impedance instruments, (ii) homogeneous plasma in the surroundings of the emitting electric antennas.

These two assumptions are often broken during practical mutual impedance applications. (i) As mutual impedance instruments probe cold plasma regions (e.g. RPC-MPI probing the cold inner coma of comet CG/67P with the Rosetta mission, RPWI/MIME experiments that will investigate Ganymede ionosphere with the JUICE mission), finite emission amplitude signals might easily exceed the thermal electron energy, resulting in major perturbations of the plasma dielectric, thus perturbing mutual impedance measurements. (ii) Emitting and receiving electric antennas immersed in plasma are always surrounded by local inhomogeneous plasma regions (plasma sheath) which might modify the characteristics of mutual impedance emission signals, therefore perturbing the plasma density and electron temperature diagnostic performance.

In this context, we aim at assessing the modifications of mutual impedance diagnostic performance, in the case of (i) significant finite emission amplitudes for energy emissions up to the electron energy of the probed plasma, (ii) inhomogeneous plasmas in the vicinity of the emitting antennas.

For this purpose, we use a numerical 1D-1V full-kinetic electrostatic Vlasov-Poisson model to, first, simulate mutual impedance measurements and, second, assess the mutual impedance

diagnostic performance both for (i) strong finite emission amplitudes and (ii) inhomogeneous plasmas.

While the present study is focused on extending the modelling of mutual impedance measurements, with future investigations we plan to extend our understanding of mutual impedance experiments. In particular, we will focus on the optimization of mutual impedance experiments, by coupling the investigation of the experiment, via numerical Vlasov-Poisson simulations, to practical validation of the simulations, via tests in plasma chamber. Promising ongoing work showed the possibility to improve the time resolution of mutual impedance experiments by several folds.