# Summary

Time domain integral equations (TDIEs) are widely used in the simulation of transient electromagnetic fields scattered by perfectly electrically conducting (PEC) objects. Like their frequency-domain counterparts, the spatial discretization of these equations is often performed using the boundary element method. The time discretization, however, can be tackled in different ways. A popular approach leverages time basis functions either within a marching-on-in-time (MOT) scheme or within a marching-on-in-order procedure. This work focuses on a third alternative to handle time discretization, the convolution quadrature method (CQM) yielding an MOT scheme. The latter uses implicit schemes (e.g. Runge Kutta methods) instead of explicit time basis functions, which favorably impact the stability of the simulation.

Lamentably, the discretized equations are plagued by at least one of the following limitations: ill-conditioned systems and instabilities. The ill-conditioning has multifactorial origins; it can come from the discretization (spatial or temporal) or the continuous formulation used. In this work, we will focus on two of them, the large time step breakdown and dense mesh breakdown yielding the condition number of the MOT matrices growing quadratically with the time step and with the inverse of the average mesh edge length, respectively. Consequently, fast algorithms based on iterative solvers require more iterations to converge and slow down the computation time and, in the worst cases, return the wrong solution. In addition to the ill-conditioning problems, the time domain integral operators can have nullspaces. As a result, their discretizations suffer from instabilities in which spurious currents appear and degrade the solutions. We can distinguish two of them, the direct current instability (dc instability) resulting from static nullspace, and the resonances resulting from the frequency resonant modes of the operators.

This thesis proposes several time domain integral formulations to fix some of the above-mentioned limitations. They have been derived from frequency-domain technologies that precondition the resulting matrix systems. We mention the Calderón-like preconditioning, the quasi-Helmholtz projectors, and the dual-surface strategies. The resulting formulations offer alternative and adaptive approaches in which the solution cannot be found without. In addition to their previously mentioned advantages, these regularization techniques are compatible with fast solvers at the

additional cost of increasing the number of matrix/vector products.