Frequency-time hybrid method in exterior and interior domains

Oscar P. Bruno [(1)]

(1) Caltech, Pasadena, CA 91125, USA, https://www.cms.caltech.edu/people/obruno

We present a frequency/time hybrid integral-equation method [1,2] for the time-dependent wave equation in two and three-dimensional spatial domains, possibly including closed cavities.

Relying on Fourier Transformation in time, the method utilizes a fixed (time-independent) number of frequency-domain integral equation solutions to evaluate, with super-algebraically small errors, time-domain solutions for arbitrarily long times. The approach relies on two main elements, namely, 1) A smooth time-windowing methodology that enables smooth time partitioning of incident waves, and 2) A novel Fourier transform approach which, in a time-parallel manner and without causing spurious periodicity effects, delivers numerically dispersionless spectrally accurate solutions. The algorithm can handle dispersive materials, it can tackle complex physical structures and interface conditions (provided a correspondingly capable frequency-domain solver is used), it enables parallelization in time in a straightforward manner, and it allows for time leaping, that is, solution sampling at any given time T at $O(1)$ sampling cost, for arbitrarily large values of T, and without requirement of evaluation of the solution at intermediate times.

The proposed frequency/time hybridization strategy thus provides significant advantages over volumetric discretization and convolution-quadrature approaches. For interior (cavity) problems, for which the resulting frequency-domain problems are not uniquely solvable, a multiple scattering strategy is used that decomposes a given time-domain problem into a sequence of limited-duration time-domain problems of scattering by overlapping open surfaces, each one of which is reduced to a sequence of frequency-domain problems.

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