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Physics-based signal processing methodologies for separating target echoes into their constituent elastic and geometric components

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Echoes from even simple canonical symmetric shapes such as solid elastic spheres are highly complex, consisting of a superposition of specular, elastic, and geometric diffractive components closely spaced in time and frequency. Although measurement of the individual elastic and geometric components is important for analysis of scattering physics and object identification, in practice individual components are often hard to measure because of mutual interference between components. When an object interacts with a boundary, such as the sea floor, additional interfering echoes make the object signature even more complicated to interpret. Motivated by this problem, a frequency-domain technique is developed for separating an echo into its constituent elastic and geometric components, and for isolating specular reflections from a possibly interacting boundary. It is based on modelling the echo components in the frequency domain as amplitude-modulated piecewise-linear chirps, utilizing physically-inspired group delay models and constraints, and then using a modified Costas' residual signal analysis (RSA) algorithm in combination with chirp transform analysis to decompose the echo. The RSA scheme is demonstrated on actual echoes collected in the NURC EVA-06 sea trial from spherical and cylindrical target shapes and is shown to work well with the separated components verified against modelling predictions.