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High-resolution population density imaging of random scatterers through cross-spectral coherence in matched filter variance

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The matched filter enables imaging with high spatial resolution and high signal-to-noise ratio by coherent correlation with the expected field from what is assumed to be a discrete scatterer. In many imaging systems, however, returns from large numbers of scatterers are received together and the coherent or expected field vanishes. This is the case when imaging schools of fish, other groups of marine life, or other diffuse scatterers in sonar or ultrasound applications. Here we show that despite the absence of an expected field, cross spectral coherence in the matched filter variance retains a pulse compression property that enables high-resolution imaging of scatterer population density. Both analytic and numerical models are developed for active imaging systems. We show the conditions for when the coherent intensity can be neglected. The model is implemented for several scenarios where single scattering dominates and also for cases where multiple scattering is important. It can applied to imaging in both free space and waveguide environments.