Waveforms for Dispersive SAR Imaging

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When an electromagnetic pulse propagates through a lossy, dispersive material, frequencies below the absorption band(s) of the material experience the least amount of attenuation and hence, become the dominant contribution to the field at large propagation distances. In causal dielectrics, the low-frequency contribution, known as the Brillouin precursor, has a peak amplitude with an effective decay rate of $z^{-1/2}$, where z is the propagation distance (Oughstun, Opt. Exp., **23**, 247567, 2015). It has been suggested that near-optimal pulse penetration and radar imaging is possible by using the Brillouin precursor as the transmit pulse (Oughstun, IEEE Trans. Ant. Prop., **53**, 1582–1590, 2005).

In radar and imaging applications through dispersive material, such as foliage and ground penetrating radar, the low frequencies required to penetrate the absorptive material along with frequency-dependent travel times create significant complications. Such aspects were considered by (Varslot, Morales, Cheney, SIAM J. Appl. Math., **71**, 1780–1800, 2011) when formulating an optimal waveform for dispersive SAR imaging. The spectra of their numerically-determined optimal waveform "closely resembles the precursor which is generate from a one-cycle sinusoid." This elicited the conclusion that "under certain conditions, precursors may indeed be useful as transmit waveforms in SAR imaging."

Here, we derive what we call a *scattering precursor* waveform for imaging isotropic point scatterers embedded in a dielectric material. This scattering precursor is derived by asymptotic methods on the integral representation of the scattered field due to an impulse response evaluated at some distance d into the material and is expressed in terms of modified Weber functions. This scattering precursor pulse consists of higher frequencies than in the Brillouin pulse of Oughstun and its peak amplitude decays with propagation distance as $z^{-3/2}$.

We compare our scattered precursor with the optimal waveform given by Varslot et al. by analyzing propagation characteristics and the imaging results. We find that the scattering precursor exhibits better propagation characteristics in that it has less decay in the peak amplitude and pulse energy, however the two pulses produce comparable images.