Comment on "Explanation of the Inverse Doppler Effect Observed in Nonlinear Transmission Lines"

Kozyrev and van der Weide (KvdW) [1] claim that waves with spatial harmonics associated with wave vectors outside of the first Brillouin zone are the source of the anomalous Doppler shift observed by Seddon and Bearpark (SB) [2]. We show that this is incorrect.

KvdW argue with a phase-matching analysis (Eq. 11) that the inverse Doppler effect in their quasicontinuum system could be due to higher spatial harmonics but have not demonstrated that it is due to these higher spatial harmonics. If spatial harmonics are responsible for the effect, then Fig. 1 shows how Eq. 11 of KvdW predicts that other Doppler-shifted signals should be observable, including the "usual" Doppler shift that would be associated with spatial harmonics within the first Brillouin zone (i.e., the $m = 0$ case). KvdW's numerical analysis shows that these spatial harmonics have amplitudes more than 3 times larger than the backward wave spatial harmonics claimed to give rise to the inverse effect and should therefore provide a readily observable peak. However, the usual Doppler shift is not present in the numerical simulations of KvdW (shown in Fig. 1) nor is it observed in the experiments and simulations of SB (0.3 and 0.43 GHz for the first and second reflections from the shock, respectively, in the 0.285 shock speed case).

Furthermore, the inverse Doppler effect has been observed by SB in their simulations of a *discrete* transmission line [2] where spatial harmonics cannot be defined and, therefore, the KdvW explanation does not apply [3]. KvdW state that the discrete model of SB, "...does not allow us to distinguish a particular spatial harmonic due to the discrete nature of the model." A discrete system has no spatial harmonics to distinguish between. The discrete model of SB and the quasicontinuum model of KvdW are not identical physical systems in this regard.

We believe the reason the usual Doppler shift is not observed (and is much smaller than predicted by the KvdW analytical analysis) is related to the unusual nature of the reflecting surface that the shock front represents [3–5]. In our work on shocklike wave propagation in periodic media [3,4], we have found that the shock front does not reflect with a constant phase shift like a metal mirror, as assumed by the KvdW analytical analysis. Instead, the shock front endows reflected radiation with a time-dependent phase shift. Our theory was developed for 1D periodic systems with normal dispersion of the type addressed in the Letter of KvdW. This theory has no requirement for a transmitted wave to exist in the preshock transmission line, as claimed by KvdW. It predicts that the shock front rise time (or thickness) affects the reflected radiation: the normal Doppler shift and other anomalous shifts can be observed when the shock rise distance is much less than 1 lattice unit (a condition that may not be achievable in a nonlinear transmission line), and the inverse Doppler shift will dominate in the limit of a thick shock front. Under the experimental conditions of SB, the shock front rise time is greater than 1 ns and transit time of the shock over each discrete unit is about 0.4 ns, so there are at least 2–3 discrete elements in the shock front at any time. In our work on reversed Doppler effects in shocked photonic crystals [4] we found that similar or greater front thicknesses lead to the domination of the reflected radiation by the inverse Doppler-shifted signal that is observed in the experiments and simulations of SB and the simulations of KvdW.

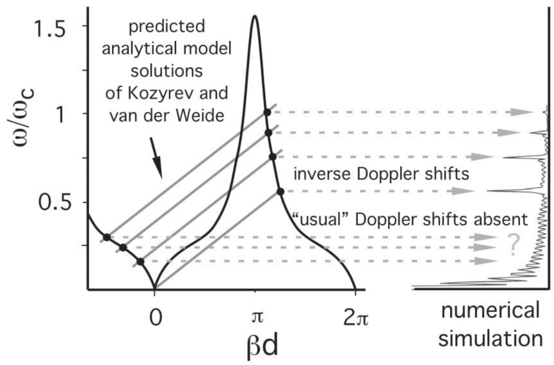

FIG. 1. The KvdW analytical model predicts observable inverse Doppler-shifted signals *and* signals endowed with the usual Doppler shift, but the usual Doppler-shifted signals are not observed in their numerical simulations. Dispersion and simulations are from Kozyrev and van der Weide [1].

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