V. I. Ozhogin and M. A. Savchenko. *Exchange-enhanced linear and nonlinear magnetoacoustic effects in antiferromagnets.* The dynamics of the magnetic (spin) subsystem of an antiferromagnetic material has much in common with the dynamics of a ferromagnetic material—with one important exception. Specifically, for a ferromagnetic material in the absence of an external magnetic field H the freqeuncy of a homogeneous resonance $\omega_0 = \gamma H_A$ is determined by the anisotropic field H_A, and the exchange field H_E, which is the cause of ferromagnetic ordering, does not enter into the formula, whereas for an antiferromagnetic material it followed already from the calculations of Kittel[1] that $\omega_0=\gamma\sqrt{2;H_E H_A}$ where H_E is the effective exchange field with which one magnetic sublattice of an antiferromagnetic material acts on the other. Subsequent experimental and theoretical studies showed that by H_A we can understand not only the anisotropy field, but also H_S—the effective field of lattice deformations at an electron, or H_N—the effective field of the nucleus at the electron. The former arises as a consequence of spontaneous deformation of the lattice due to the magnetoelastic interaction,[2,3] and the second arises as the result of the average statistical magnetization of the subsystem of nuclear spins due to the hyperfine interaction.[4]

At the same time it turned out that taking into account the hyperfine or magnetoelastic interactions leads to a renormalization of the dynamics of the corresponding subsystem of nuclear spins[4] or of the elastic continuum,[5] and in this case also the ferromagnetic exchange interaction almost does not come into play (for waves with $a_0k\ll 1$ where a_0 is the lattice constant), while for antiferromagnetic materials, particularly weakly anisotropic ones, H_E greatly enhances the renormalization or, speaking more precisely, it extends the range of the external fields for which the renormalization is significant. In particular, in an antiferromagnetic material with a high Néel temperature T_N such as hematite (α-Fe_2O_3; in it $H_E\approx 10^7$ Oe), this leads to a very strong dependence of the velocity of sound v_s on the magnetic field[6,7] and on the directional compression σ.[7] The magnitude of the latter effect, namely $v_s^{-1}dv_s/d\sigma$, is easily calculated[8] and also as a result of the exchange enhancement turns out to be 100–1000 times greater than the corresponding value for simple solids as the result of anharmonicity of their crystal lattice.

However, by σ we may understand not only external mechanical stresses but also those which are due to deformation in the sound wave itself. This brings to mind that in the materials considered the velocity of sound, which is a deformation wave, should depend strongly on the amplitude of these deformations, i.e., there should be a great anharmonicity of the elastic subsystem (more precisely—an effective anharmonicity, since it is produced by nonlinearities of both the magnetic subsystem itself and of the magnetoelastic coupling with the modulus of B). Subsequent calculations showed that literally all nonlinear dynamical effects involving hypersound[9] and ultrasound[10] in weakly anisotropic antiferromagnetic materials have an enormous value (and for ultrasound one can even say a stupendous value). For example, for $TmFeO_3$ near the spin orientation[11] when the magnetic subsystem becomes soft, and for α-Fe_2O_3 in low fields[12] the effective moduli of the nonlinearity $C_3^{\text{eff}}\approx H_E^2B^3/M_0^2(\omega_0/\gamma)^4$ for the ultrasound region of frequencies 10 . . . 100 MHz can reach values of 10^{17} erg/cm^3, exceeding by a factor of 10^4 the ordinary values for solids. The same thing to an even higher degree applies to C_4^{eff}—the effective moduli of nonlinearity of the next order.[13] As a result many ultrasound analogs of well-known phenomena of nonlinear optics become practically achievable: frequency doubling, stimulated Raman scattering (in other words—parametric excitation of sound by sound), nonlinear self-action of sound waves, self-focusing, and so forth. High-temperature antiferromagnetic materials (i.e., those with large H_E) with a soft magnetic mode (i.e., with a low frequency of antiferromagnetic resonance $\omega_0=f(H,\sigma,T)$) are exceptionally appropriate objects for realization of still other nonlinear ultrasonic effects (including strongly nonlinear ones).

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