Shift of the resonance line of a spin system in narrow-band noise fields

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Bonch-Bruevich *et al.*[1] have studied the absorption spectrum of a two-level system in intense nonmonochromatic radiation fields. They studied the change in the weak-radiation absorption spectrum caused by a narrow-band Gaussian noise field in the rf range produced from white noise by linear square filters. The particular system which they studied was an ensemble of Cd^{113} atoms, with a ground-state nuclear spin $I = 1/2$, which were oriented by optical pumping.

One result found in Ref. 1 was a shift of the peak of the absorption line (a shift of the resonance line) under the influence of the narrow-band noise field. This shift was found to depend on the intensity and width of the spectral line of the noise field. This result, shown graphically in Fig. 1 of Ref. 1, demonstrates the clear absence of a limiting transition from the effect of a narrow-band noise field to a monochromatic field as the spectral width is reduced. Bonch-Bruevich *et al.* explained this result by differences in the statistics of these fields.

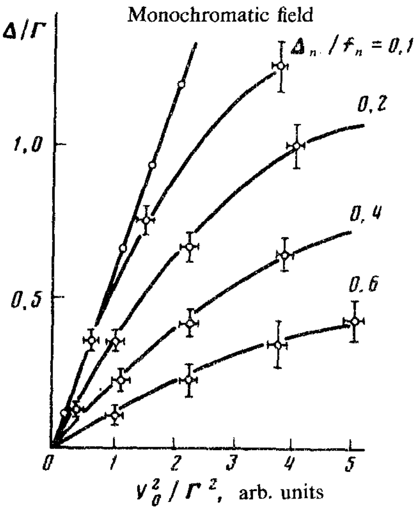

FIG. 1. Dependence of the shift of the parametric resonance line on the power level of the noise field.

In an attempt to reach an understanding of this aspect of Ref. 1, we have carried out a similar experiment with the following changes:

a) We studied an ensemble of Cs^{133} atoms, which exhibit an electron paramagnetism, during transverse optical pumping with circularly polarized resonant light. b) The weak probing radiation was a linearly polarized rf field $H_1 \cos\omega t$ directed along a static magnetic field H_0. As a result, we detected a parametric resonance[2] in the system of Cs^{133} atoms by an optical method. For this resonance, there is no rf line broadening. c) The spectrum of the parametric resonance was recorded by scanning the field H_0 near the value of $H_r = \omega\gamma$, where γ is the gyromagnetic ratio of the Cs^{133} atoms, and $\omega/2\pi = 600$ Hz. d) The experiments were carried out inside a shield to suppress the effects of stray magnetic fields.

Although these changes in the experiment are not fundamental and should not lead to substantially different results, we find that the shift (Δ) of the parametric-resonance line depends on the power of the narrow-band noise field, with various spectral widths Δ_n of this noise, in a way different from that of Ref. 1. Our results are shown in Fig. 1. Qualitatively, the dependence of Δ on the power level of the noise field at Δ_n = const is similar to that described in Ref. 1, but the positions of the curves for the different values of Δ_n are diametrically opposite those of Ref. 1. In other words, the shift Δ increases, rather than decreases, with decreasing width Δ_n of the narrow-band noise spectrum at a constant noise power; in the limit, the shift Δ approaches that induced by a monochromatic field. In the other limiting case[1)] $\Delta_n \gg \Gamma$, where Γ is the width of the resonance line, we observe no line shift at any noise power studied. We thus see a smooth transition in the behavior of the shift of the resonance line as the noise spectrum is contracted from a broad band to a monochromatic spectrum.

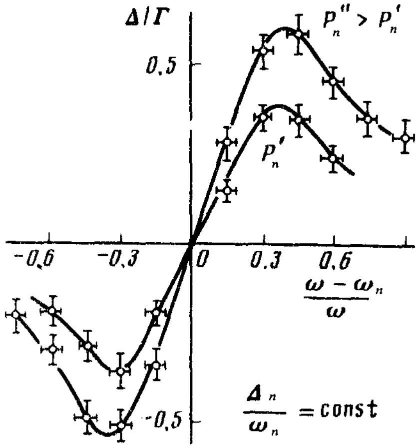

FIG. 2. Dependence of the shift of the parametric-resonance line on the frequency difference $(\omega - \omega_n)/\omega$.

We also studied the dependence of the shift Δ on the frequency difference $\omega - \omega_n$, where ω_n is the central frequency of the spectrum of the narrow-band noise field, for an arbitrarily chosen ratio Δ_n/ω_n and for various power levels of the noise field. These results are shown in Fig. 2. We see that the magnitude and direction of the shift depend on the magnitude and the sign of the difference $\omega - \omega_n$. It should be noted that a similar behavior of the shift of a resonance line has been observed elsewhere[3,4] during the application of a monochromatic rf field to a spin system.

[1)]Under our conditions, this case corresponds to a "broad-band" noise over the frequency range 20 Hz–100 kHz.

[1]A. M. Bonch-Bruevich, S. G. Przhibel'skiĭ, V. A. Khodovoĭ, and N. A. Chigir', Zh. Eksp. Teor. Fiz. **70**, 445 (1976) [Sov. Phys. JETP **43**, 230 (1976)].
[2]E. B. Aleksandrov, O. B. Konstantinov, B. I. Perel', and V. A. Khodovoĭ, Zh. Eksp. Teor. Fiz. **45**, 503 (1963) [Sov. Phys. JETP **18**, 346 (1963)].
[3]L. G. Malyshev and L. N. Novikov, Pis'ma Zh. Eksp. Teor. Fiz. **15**, 129 (1972) [JETP Lett. **15**, 194 (1972)].
[4]L. G. Malyshev and L. N. Novikov, Opt. Spektrosk. **34**, 807 (1973).

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