New vision of spin nutation

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It is shown that the Torrey nutation theory based on the Bloch equations for the magnetization vector, in principle, cannot be used to describe the "nutation" of interacting spins (including the splitting of spin energy levels in a zero magnetic field). The Bloch equations assume that the vector of the magnetic moment of the spins completely sets the state of the spins. But this is true only for non-interacting particles with spin S=1/2. Using the example of the simplest system with spin S = 1, a systematic consideration of the response Using the example of the simplest system with spin S = 1, a systematic consideration of the response (“nutation”) of spins to the sudden activation of an alternating magnetic field was carried out. A detailed analysis of the dependence of “nutation” is carried out on the spin-spin interaction and the nature of the excitation of spins by an alternating field. Under conditions when spin-spin interactions are comparable to the energy of interaction of spins with an alternating field, the motion of spin magnetization is described as the sum of contributions oscillating with different frequencies, which are equal to the frequencies of transitions between the spin-Hamiltonian eigenstates in a rotating coordinate system.

For the first time, Heisenberg's mathematical apparatus was used to describe the “nutation” of spins. In this approach, the equations of motion are written directly for the quantities measured in the experiment. For spins, the complete orthogonal set of quantities is the dipole moment and multipole polarizations. To demonstrate the potential of this description of “nutation”, a specific case of paramagnetic particles with spin S=1 is considered. Taking into account the splitting energy in a zero magnetic field, the associated equations of motion for the dipole and quadrupole moments are obtained. They can be called generalized equations of magnetic polarization of spins. These equations show that in the presence of spin-spin interactions, a reversible mutual transformation of dipole and quadrupole moments occurs. This leads to oscillations of the length of the spin magnetization vector, the projections of which are usually observed in the experiment. Therefore, the oscillations of the magnetization projections observed in the experiment reflect both the nutation of the magnetization vector and the modulation of the length of this vector due to the mutual transformation of the observed dipole polarization and the quadrupole polarization not observed in conventional experiments.