The Two-Frequency Nuclear Quadrupole Resonance for Explosives Detection

G. V. Mozjoukhine

Department of Quantum Radiophysics, Kaliningrad State University, Kaliningrad, Russian Federation

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Abstract. The two-frequency nuclear quadrupole resonance (NQR) of $^{14}$N nuclei is described for purposes of explosives detection. Two applications are known: two-frequency NQR for increasing the signal intensity, two-frequency NQR for improved reliability of explosives detection. The two-frequency experiments were carried out in hexahydro-1,3,5-trinitro-s-triazine $C_3H_6N_6O_6$ and sodium nitrite $NaNO_2$ as a substitute for octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocycine $C_4H_8N_8O_8$. The two-frequency sequences for NQR are proposed for increasing the amplitude of NQR signal and improvement of detection condition.

1 Introduction

Nuclear quadrupole resonance (NQR) may be effectively used for detection of several types of explosives, such as hexahydro-1,3,5-trinitro-s-triazine $C_3H_6N_6O_6$ (RDX), octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocycine $C_4H_8N_8O_8$ (HMX) [1], trinitrotoluene $C_7H_5N_3O_6$ (TNT) [2]. The presence of such explosives is determined by the NQR of nitrogen nuclei $^{14}$N. However, NQR of nitrogen nuclei $^{14}$N has a weak physical effect. Exterior interference and inner noises may suppress the signals produced by NQR completely. There are other effects which lead to mistakes as well.

The usual methods in increasing the sensitivity of the NQR method are based on the use of multiple averaging of NQR signals in multipulse sequences and digital methods of signals processing [3]. However, the intensity of signals may be increased by physical methods.

The lines of NQR spectra of RDX, HMX, and TNT are in the range from 0.6 to 5.3 MHz. That is the reason why the search for methods of increasing the intensity of spectral lines is a matter of great importance. One of such methods is the use of two-frequency NQR excitation on nitrogen $^{14}$N nuclei.
The other advantage of two-frequency NQR is the possibility to increase the reliability of detection of NQR signals in explosives. The use of pulse sequences induces several interfering effects, such as induction and echo signal superposition [4], piezoelectric resonance emerging from the surrounding of explosives [5]. As a rule, the two-frequency method is used in order to assign complicated lines in a spectrum [3]. However, reception of signals of the whole spectrum of NQR of nitrogen $^{14}$N diminishes the probability of false explosives detection. Besides, the multiple frequency influence over the NQR spectrum allows one to change the conditions under which signals in multipulse sequences arise. Consequently, there is a need for investigating the possibility of two-frequency NQR in order to increase the degree of reliability of NQR signals detection.

2 Experimental

The two-frequency NQR experiments were carried out with two home-made NQR pulse spectrometers for the range 0.5–6 MHz (Fig. 1). The probe head consists of two coils connected with the corresponding spectrometer. For remote NQR two crossed semitoroidal radio-frequency coils [1] create a two-frequency radio field. The common pulse generator was used as well. The block scheme of this spectrometer is distinguished from the one used in [3] by one master frequency 1 MHz for pulse generator and two radio-frequency generators. This distinguishing feature reveals the frequency offset dependence of the two-frequency signal more clearly. For detection of the signal on the third frequency a receiver with a planar coil may be added.

The experiment was carried out at room temperature with 50 g plastic explosive PVV-4, containing 80% of RDX. The quantity of HMX (5 g) was not enough for two-frequency experiments. Instead of HMX, 50 g of sodium nitrite (NaNO$_2$) were used, as the closest to it in relaxation parameters (Table 1). The temperature of NaNO$_2$ was 77 K.

Fig. 1. Block scheme of the two-frequency NQR spectrometer.