The Application of the Clinical MR Scanner for Multinuclear Research

N. V. Anisimov[1], A. G. Agafonnikova[2]

[1] Faculty of Fundamental Medicine, Lomonosov Moscow State University, Moscow 119991, Russian Federation, anisimovnv@mail.ru
[2] Faculty of Physics, Lomonosov Moscow State University, Moscow 119991, Russian Federation

It is reported the use of 0.5 T clinical MR scanner Bruker Tomikon S50 not only in biomedical research, but also for technological applications. For this purpose, NMR signals were registered from nuclei other than protons. Typical MRI equipment only works on protons. We carried out technical work that allowed us to register nuclei different from protons.

The ^{19}F NMR signal was recorded during the perfluorocarbon compounds (PFC) research. Particular attention was paid to the preparation Perftoran®, well-known as blood substitute. We experimented with animals (rats), which were intravenously injected with this drug. In addition, by the ^{19}F MRI method, the human gastrointestinal tract was studied, for which the volunteer swallowed capsules, filled with PFCs – perfluorodecalin and perfluorotributylamine. In all cases, at a specified time interval, the localization of the drug was monitored by MRI, and by NMR its transformation and the dynamics of excretion from the organism were monitored.

Studies were also carried out using test samples (phantoms) to optimize the parameters of the ^{19}F MRI scanning of specific PFCs – perfluorodecalin and octafluorocyclobutane in the gas phase. The latter drug is a potential contrast agent for lung research.

In the process of multinuclear research, NMR spectra and MR images from ^{31}P, ^{11}B, ^{23}Na nuclei were obtained at natural abundance, and for ^{13}C, ^{2}H – for isotope enrichment. For isotopically unenriched samples of ^{17}O, ^{29}Si and ^{14}N, only NMR spectra, (but not MRI) have so far been reliably recorded. In addition, outside the magnetic field, the nuclear quadrupole resonance spectra of ^{35}Cl (28.1 MHz) were successfully detected from powdered potassium chlorate. For ^{23}Na, NMR spectra and MR images of various parts of the human body, including the brain, were obtained.

We successfully recorded ^{13}C signals using the polarization transfer methods – the Overhauser effect and the DEPT and INEPT techniques. We obtained NMR spectra using these methods not only by rf excitation of protons, but also fluorine nuclei. We used these techniques when recording the ^{13}C signal from perfluorodecalin. It is hydrocarbon compound in which the hydrogen atoms are replaced by fluorine.

We conducted experiments on the simultaneous recording of NMR signals from two types of nuclei with close gyromagnetic ratios. The pairs $^{1}H/^{19}F$ (isoflurane – C_3F_5HClO) and $^{13}C/^{23}Na$ (sodium bicarbonate – $NaHCO_3$ were chosen. The excitation of signals for both nuclei of pair was carried out simultaneously – by

a short single pulse or by a sequential selective RF excitation of each nucleus from the selected pair. The reference frequency of the phase detector was set equal to the half-sum of their Larmor frequencies. The speed of digitization of the signal was less than their difference, and the filtering of the signal (digital and analog) was disabled. A useful result – the spectrum on which NMR lines from both nuclei from the selected pair are represented, was achieved due to a multiple spectral "aliasing" of both signals relative to the reference frequency of the phase detector – the undersampling effect [1].

Multinuclear resources of the scanner were also used for technological applications – non-invasive identification of alcohol-containing products. It was assumed on the basis of measuring the amplitudes of ^{1}H, ^{2}H, ^{13}C, ^{17}O NMR spectra and relaxation times for each of the branded samples with a volume of 0.5 liters and a 40% strength, to reveal their possible differences. The reason for the differences was that the products were made from different raw materials and brought from different geographical regions [2]. The spectra of all the above mentioned nuclei were obtained. Due to the large volume of the sample, they are obtained with a high signal-to-noise ratio at an acceptable time (~10 min).

It was noted that the difference in the T_2 values is most clearly seen on the ^{17}O NMR spectra. This difference is well revealed by the linewidth. On the spectra of ^{2}H, this difference is less pronounced, and for protons – it is not detected at all. It is due to the fact that the ^{17}O NMR lines are very wide, and the contribution of the inhomogeneous broadening is very small, in contrast to the ^{1}H NMR lines.

The clinical scanner can be successfully used for multinuclear applications – both medical-biological and technological. The ability to examine large samples in it creates favorable opportunities for recording nuclei with a low natural abundance and a small gyromagnetic ratio. To increase the sensitivity to signals from such nuclei, it is also useful to implement the double resonance methods.

1. Anisimov N.V., Pavlova O.S.: Appl. Magn. Reson. **49**(5), 523 (2018)
2. Martin M.L., Martin G.J.: NMR Basic Principles and Progress **23** (1990)