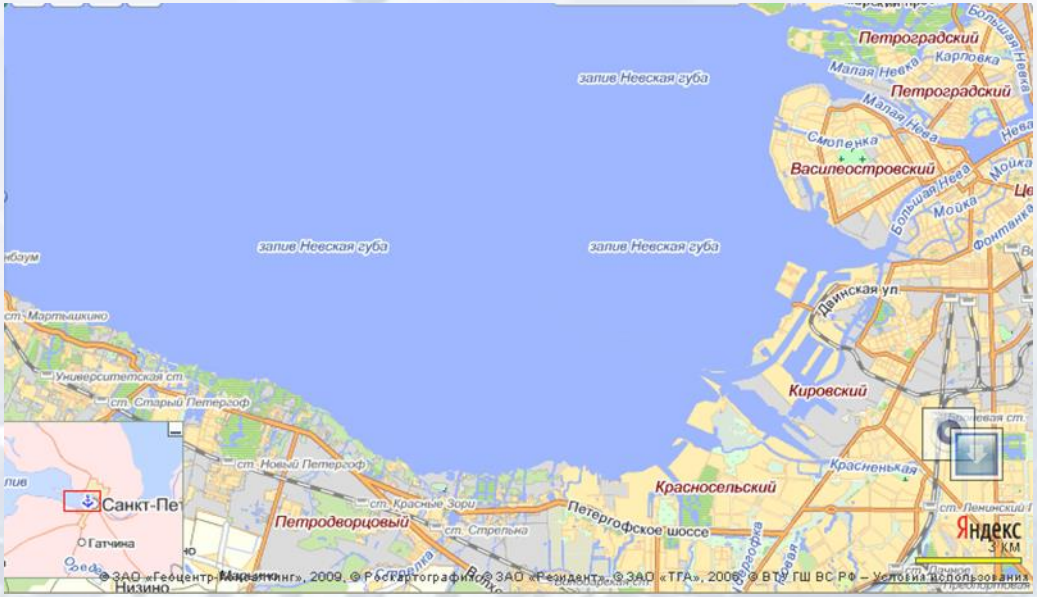
# RuMex in Saint Petersburg 2013

# Welcome! Bienvenida!

# Saint Petersburg - 1703

Peterhof – 1705

- Saint-Petersburg University - 1724
- Institute of Physics - 1901
- Laboratory of Radiospectroscopy - 1949
- Department of Quantum Magnetic Phenomena - 1993
- **NMRCM --- 2004**
- **Spinus --- 2004**
- **RuMex --- 2011**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ст. Старый Петергоф
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# Fedor I. Skripov (1921-1961)

Bulletin of the Academy of Sciences of the USSR
Physical Series, Vol. 22, p. 1127 (1958)

# Applications of the weak-field free nuclear induction technique in high-resolution radio spectroscopy

A.A. Morozov, A.V. Mel'nikov, F.I. Skripov

APPLICATIONS OF THE WEAK-FIELD FREE NUCLEAR INDUCTION TECHNIQUE IN HIGH-RESOLUTION RADIO SPECTROSCOPY

- A.A.Morozov, A.V.Mel'nikov & F.I.Skripov

Some years ago Packard & Varian[1] proposed a new technique for observing free nuclear precession, a technique which made it possible to extend investigations of this effect into the range of very weak magnetic fields (of the order of the Earth's field). What is observed is essentially a decaying chain of oscillations induced in the receiver coil owing to precession of the nuclear magnetization vector, arising after nonadiabatic removal of an auxiliary strong field (the equipment has been described in Ref.2). Until now, the new technique has been used almost exclusively for precision measurements of weak fields. Yet it undoubtedly presents a considerable interest from the viewpoint of radio spectroscopic studies; in particular, in view of the great homogeneity of the Earth's field, the technique allows of realizing a very high absolute resolving power (to fractions of a cycle) with relatively simple equipment.

In the present report we shall give two examples of application of the weak field technique to the problems of radio spectroscopy.

The first problem consists of investigating the fine structure of nuclear resonance signals due to indirect (electron shell) interactions of nonequivalent nuclei in a molecule. It has been noted by Gutowsky et al[3] that the character of the splitting in this case does not depend on the field level, provided the inequality $|\nu_A - \nu_B| \gg a/h$ is fulfilled ( $a$ is a coupling constant characterizing the magnitude of the splitting; $\nu_A$ and $\nu_B$ are the resonance frequencies of the interacting nuclei). Hence in such investigations the absolute resolving power is important and the use of weak fields is justified.

For our investigation we chose tributyl phosphate (TBP): $O = P(-O-CH_2-CH_2-CH_2-CH_3)_3$. In strong fields this molecule would yield a nuclear resonance signal with a very complex structure owing to a) chemical shifts due to nonequivalently located proton groups, b) indirect magnetic interaction between these groups and c) indirect interaction of the protons with the $P^{31}$ nucleus. In the case of a weak (the Earth's) field, the chemical shifts virtually disappear, which in turn should lead to the absence of splitting produced by the indirect magnetic interactions between proton groups (nonfulfillment of the inequality $|\nu_A - \nu_B| \gg a/h$). Such simplification of the spectrum, which makes it possible to separate the mutual influences of nuclei of different types (in this case $H^1$ and $P^{31}$), is one of the advantageous features of the weak field technique.

One of the photographs of the free nuclear induction signal obtained from a TBP sample with a volume of 600 $cm^3$ is reproduced at the top in Fig.1,a. The recording was carried out by means of a loop oscillograph with a film advance rate of 30 mm/sec; so that the individual periods of the signal, which had a frequency of ~2160 cps, are not resolved in the photograph. In order to slow

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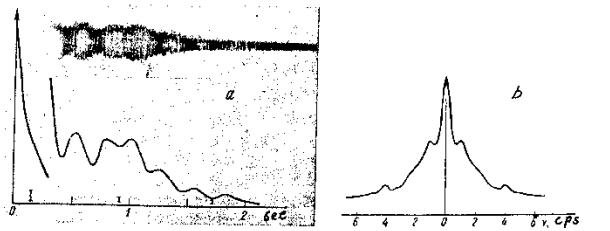


Fig.1. a - Photograph of free proton induction signal from tributyl phosphate (TBP) and its averaged envelope (in the t = 0 to 0.6 sec range the vertical scale is 5 time smaller than for t > 0.6 sec); b - spectral representation of the same signal (Fourier transform).

down the attenuation of the free precession, the sample was heated to 200°. As may be seen in the photograph the signal envelope exhibits a clearly pronounced beat pattern, indicative of the multiplet character of the spectrum.

The initial signal-to-noise ratio exceeds 40. Inasmuch, however, as the beats are evident primarily after the amplitude has decreased by an appreciable factor, further processing of the experimental results was based on careful averaging of the signal envelopes from the 9 best photographs (with preliminary subtraction of the average noise level). The final appearance of the envelope is shown in Fig.1,a (bottom) with evaluations of the probable error at different points. The multiplet structure of the spectrum obtained by numerical conversion (Fourier transforms) is shown in Fig.1,b.* It will be seen that there are clearly resolved components of the signal only ±1 cycles distant from the central peak (it should be noted that the actual resolution of the equipment is even higher, so that essentially the natural line width is observed in this case).

Inasmuch as the spin of the $P^{31}$ nucleus is 1/2, any group of equivalently located protons in the TBP molecule should give a doublet signal. The centers of all the doublets should coincide, while the magnitude of the splitting should be the greater, the stronger the interaction with the $P^{31}$ nucleus. Hence the end components ($\Delta\nu$ = ±4 cps) are obviously due to protons of the three $CH_2$ groups closest to the P core, etc. The central and most intense line in the spectrum is formed by superposition of the unresolved components from the more remote parts of the molecule. It must be noted, however, that upon more detailed examination of the spectrum there become evident certain anomalies that cannot be explained in the framework of the above simple scheme. Among these anomalies are the presence of the broad peaks at $\Delta\nu$ = ±2.5 cps, the very slow falling off of the spectral curve at large values of $\Delta\nu$, and the very poor agreement between the integral intensities of the observed components and the number of H atoms in

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*The data at this stage of the work must be regarded as preliminary inasmuch as the method of conversion to the spectrum requires more rigorous justification. In particular, the symmetric character of the spectrum was postulated in carrying out the Fourier transform (in this case symmetry should be expected on the basis of the current concept regarding the mechanism of the effect).

# Vladislav A. Ivanov (1936 - 2007)

- № 659411/26 (21.03.1960)

"Способ исследования внутреннего строения материальных тел“.

СОЮЗ СОВЕТСКИХ СОЦИАЛИСТИЧЕСКИХ РЕСПУБЛИК

ГОСУДАРСТВЕННЫЙ КОМИТЕТ СССР
ПО ДЕЛАМ ИЗОБРЕТЕНИЙ И ОТКРЫТИЙ

# АВТОРСКОЕ СВИДЕТЕЛЬСТВО

№ 1112266

На основании полномочий, предоставленных Правительством СССР, Государственный комитет СССР по делам изобретений и открытий выдал настоящее авторское свидетельство на изобретение:

"Способ определения внутреннего строения материальных объектов"

Автор (авторы): Иванов Владислав Александрович

Заявитель: он же

Заявка № 0659411 Приоритет изобретения 21 марта 1960г.

Зарегистрировано в Государственном реестре изобретений СССР

8 мая 1984г.

Действие авторского свидетельства распространяется на всю территорию Союза ССР.

*Председатель Комитета*

*Начальник отдела*

МПФ Гознака. 1979. Зак. 79-3083.

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SOCIALIST REPUBLICS

(19) SU (11) 111 2266A

THE STATE COMMITTEE OF THE USSR ON BUSINESS
OF THE INVENTIONS AND DISCOVERIES

## EXPOSITION of the INVENTION

To the author's CERTIFICATE

(21) 659411/18-25
(22) 21.03.60
(46) 07.09.84. Bulletin № 33
(72) V.A.Ivanov
(53) 539.143.43(088.8)

(56) 1.Haranga F.N. The general course X-ray technics.. *Изд.* 2, M., Gosenergoizdat, 1956. p. 3-364.

2. Skripov F.I. The condition and perspectives of development nuclear-precessional magnetometers. The collection of the technological information on geophysical instrument making. *Num. 4,* 1958, p. 51-58.

The method of definition of an interior structure of material objects, mainly biological, is differing from others that for getting volumetric picture of interior structure of material objects with the elimination of a radiation injury and for showing of distribution on a volume of different kind of atoms up, the material objects put in an exterior inhomogeneous magnetic field which generated so, that the signal of a free precession of nucleuses of atoms, which the analyzable object consists from, is existed successively in restricted parts of object, adjoining to each other, and on an input of a receiving device there is a frequency filter selecting a band of frequency of a precession of nucleuses, contained in restricted part of object in an exterior magnetic field.

The invention dates from the introscopy that is observation of an interior structure of material objects without violation of their integrity.

The method of observation of an interior structure of material objects founding on use of property of the large penetrating ability of electromagnetic radiation of a short-wave part of a spectrum (x-rays, gamma rays, etc) is known and property of different objects differently to pass (to absorb) this radiation.

The defect of a known method is that an irradiation by x-rays and gamma rays exert a harmful biological influence upon alive organisms. Besides the known does not allow to reveal a picture of distribution of kinds of atoms in analyzable object, that is important for an estimation, for example, biological processes, flowing in the objects.

The purpose of the invention - is receipt of volumetric picture of an interior structure of material objects with the exception of a radiation injury and for showing of distribution on a volume of different kind of atoms.

“The method of definition of interior structure of material objects, mainly biological, differing from others that for getting volumetric picture of interior structure … material objects put in an exterior inhomogeneous magnetic field which generated so that the signal of a free precession of nuclei of atoms, which analyzable object consists from, is existed successively in restricted parts of object, adjoining to each other, and on an input of receiving device there *is frequency filter selecting a band of frequency of a* precession of nuclei, contained in restricted part of object in an exterior magnetic field.”

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*Председатель Комитета*

*Начальник отдела*

МПФ Гознака. 1979. Зак. 79-3083.

Richard Ernst was awarded the Nobel Prize (in Chemistry) in 1991 for his contributions towards the development of Fourier Transform nuclear magnetic resonance spectroscopy and the subsequent development of multi-dimensional NMR techniques.

Peter Mansfield and Paul Christian Lauterbur were awarded the Nobel Prize (in Physiology or Medicine) in the fall of 2003 for the development of MRI.

# Our scientific interests are:

- nuclear magnetic relaxation of various nuclei in liquids and especially in ionic solutions;
- NMR in low magnetic fields and in the Earth magnetic field; ESR in low magnetic field;
- liquid crystals (NMR spectra and relaxation);
- NMR in solids; pulse NMR in magnetics;
- NMR in heterogeneous systems;
- NMR tomography in low magnetic fields;
- NMR and ESR in biological objects;
- practical applications of NMR and ESR.

# OUR INTERNATIONAL COLLABORATIONS

# Three educational programs

## for Master of Science are realized at the Department

- **Magnetic resonance and its applications.**
- **Tomography technologies in modern medical diagnostics.**
- **Quantum radiophysics.**

Annual International Symposium and Summer school
**Nuclear Magnetic Resonance in Condensed Matter**

Spinus 2013

Winter school-conference for young scientists «Spinus»
**Magnetic resonance and its applications**

**RuMex-2013**

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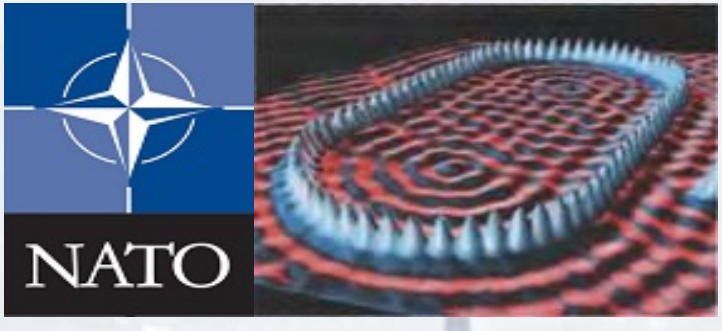
**On Nanoparticles, Nanomaterials and Nanoprocessing**



# NANOTECHNOLOGY IN THE SECURITY SYSTEMS (NSS-2013)

## (http://www.natonano.com)

**CO-DIRECTORS:** Bonca Janez (J.Stefan Institute, Ljublyana, Slovenia)

Kruchinin Sergei (Bogolyubov Institute for Theoretical Physics, Ukraine)

### List of Invited Speakers

A. Balatsky (Los Alamos Nat. Lab., USA)

V. Chizhik (Institute of Physics , Russia)

A. Geim (Univ. Manchester, UK,)

Y. Divin (Forschungszentrum Julich ,Germany)

L. Lattanzi (CIT , USA)

J. Wei (Univ.of Toronto , Canada)

K. Bennemann (Freie Univ., Germany)

N. Bogolyubov Jr.(Steklov Institute, Russia)

N. Guskos (Athens Univ., Greece)

D. Logan (Oxford Univ.,UK)

H. Kim (ETRI , Republic Korea)

A. Palevicius (KUT,Lithuania )

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# Thank you
# for your kind attention!

# Gracias por su atención!