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Nuclear Magnetic Resonance in Condensed Matter

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Book of Abstracts

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1. Introduction

The magnetic resonance basic idea consists in reorientation of spin magnetization caused by a weak-amplitude radiofrequency field when its frequency is in resonance with the frequency with which the magnetization precesses in a strong static field. The special case of a weak field rotating around the strong field is usually used in the magnetic resonance applications while it is easily treated. F. Bloch and A. Siegert [1] studied more general case of the magnetic resonance with elliptic polarization of the radiofrequency field in particular the commonly used case of simple linear oscillation.

2. Magnetic-resonance sounding of aquifers

The magnetic resonance sounding (MRS) is a particular case of the magnetic resonance in the Earth's magnetic field as a static field that is quite weak (of the order of 510^{-5} T). Whereas the radiofrequency-field produced by the surface antenna (fig. 1) is linearly polarized and can be compatible with the geomagnetic field amplitude, therefore the significant Bloch-Siegert effect can be in the MRS.

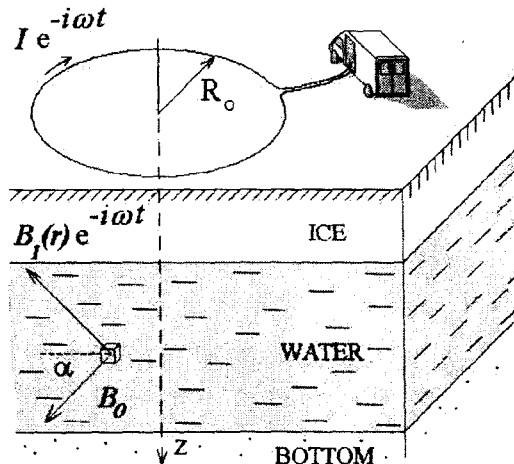


Figure 1: Scheme of MRS experiment on the ice of Ob reservoir.

3. Bloch-Siegert shift in MRS

Using Magnus expansion for average Hamiltonian in rotating frame, one arrives at the equation

$$\tilde{H}_1^{(1)}(t) = (\omega_1^2/4\omega_0)\tilde{I}_z$$

that implies the resonance offset (Bloch-Siegert shift)

$$\Delta\omega = -\omega_1^2/4\omega_0$$

where ω_0, ω_1 are resonant, and spin-precession frequencies.

The MRS amplitude is [2-5]

$$e_0(q) = (\omega/I_0) \int_V f(\vec{r}) \{M_{\perp}(\vec{r})B_{1\perp}^2(\vec{r})/|B_{1\perp}(\vec{r})|\} dV(\vec{r})$$

where I_0 – current amplitude, $q = I_0\tau_p$ is the rf-pulse moment, τ_p – pulse duration. f – free-water content. $M_{\perp}, B_{1\perp}$ – components of the magnetization and rf field.

4. Experimental proof of the Bloch-Siegert effect

Frozen in winter Ob reservoir (fig. 1) had been chosen as a model to prove experimentally the Bloch-Siegert effect (resonance frequency - 2514 Hz, Earth's field inclination - 74° , antenna radius R_0 - 50 m).

Fig. 2 exemplifies a good agreement between measured and calculated data (100% water content, depth 1-11 m).

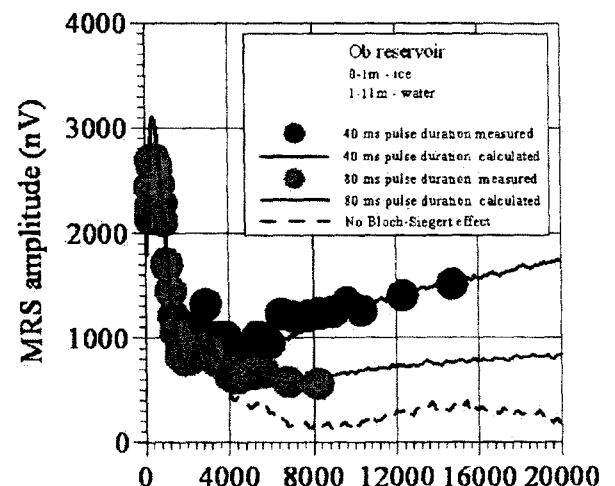


Figure 2: The MRS amplitude vs pulse moment at 40ms and 80ms pulse durations calculated (circles) and measured (lines). Dashed line – calculated without the Bloch-Siegert effect.

The inversion without the Bloch-Siegert effect gives additional nonexistent 80-95 m, 100 % water-content layer.

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