SELECTIVE MAGNETIZATION AT MAGNETIC RESONANCE IMAGING IN LOW FIELD (the earth's field)

J.Stepišnik, M.Kos, V. Eržen, University E. Kardelj, Physics Department and J.Stefan Institutut, 61000 Ljubljana, Jadranska 19, Yugoslavia

Abstract

The most important part of the magnetic resonance imaging setup, the magnet, is replaced by the teresterial magnetic field. The possibility to restrict the imaging by new method to selected portion of the sample is considered.

In order to avoid the expenses and the difficulties related to the instalation of large magnet an attempt is made to employ for NMR imaging the earth's magnetic field. Its stability and homogenity are inside the required range. At the low field the transverse magnetization is not created by the rf pulse, but by the spin prepolarization in the direction perpedicular to the earth's magnetic field[1]. In this way the initial magnetization is not determined by the magnitude of the earth's magnetic field but by the value and the duration of the prepolarizing magnetic field. Thus, the expected low sensitivity due mostly to low free precession frequency in the earth's magnetic field but the larger number of the coil turns increases the receivness in the low field. If one compare the signal to noise ratio of the spin response in the low and high magnetic field, when interrogating the body with cross section of about 3 dm^2 the result is[3]

$$(S/N)_L/(S/N)_H = 0.2(m_{oL}\sqrt{T_{2L}})/(m_{oH}\sqrt{T_{2H}}) \quad (1)$$

Thus inspite of the fact that the earth's magnetic field is about ten thousand times weaker than the field usually used for NMR imaging, the signal-to-noise ratio is only a few times lower than those in the high field if the prepolarization, m_{oL}, is about the same as the magnetization, m_{oH}, in the high field. T_2 is the spin-spin relaxation time.

At the Varian and Packard's technique[1] polarizing magnetic field which is initialy applied to the sample is switched-off when the magnetization reaches its equlibrium value. The time evolution operator at the end of the switching period can be expressed as[3,4]

$$U_s = T\exp\left(-i\sum_j \int_0^{t_s} (\dot{\varphi}_j(t) I_{yj} + \gamma B_{jeff}(t) I_{zj})\,dt\right) * R(t) \quad (2)$$

where the effective magnetic field $B_{jeff}(t)$ results from the teresterial field and the decaying prepolarizing magnetic field and where $\dot{\varphi}_j$ is the time derivative of the rotation angle.

$$\varphi_j(t) = tg^{-1}(B_p(t,r_j)/B_e) \ . \quad (3)$$

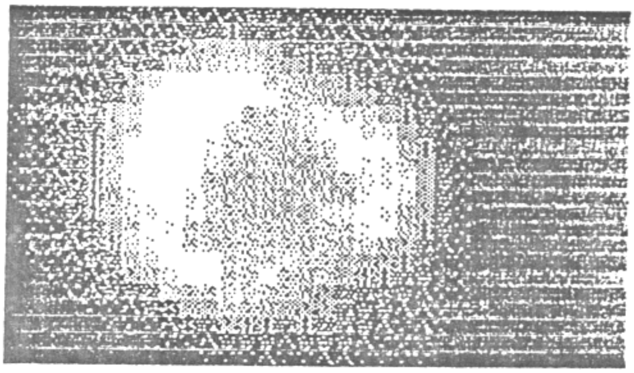
and R(t) is the rotation operator which turns the magnetization for 90 degree around y-axis. From this one can find easily that whenever the first term in the exponent of (2) is much larger than the second one

$$\dot{\varphi}_J >> \gamma B_{J,eff} \text{ or } \dot{B}_p >> B_{eff}^2 \gamma, \quad (4)$$

the time evolution operator (2) is close to unity operator and the magnetization retains its direction perpendicular to the earths magnetic field. It means that the polarizing field is removed in the time shorter than the Larmor period. In the case of an adiabatic field cutting $\dot{\varphi}_J << \gamma B_{J,eff}$ the magnetization is rotated in the direction of the earth' field.

The selective magnetization is achived by applying the magnetic field gradient in the moment of the field switching in such a way thet the condition (4) is accomplished only in the thin slice of the sample. Three different method has been studied and one of the also tested in the following experiment. It uses the reversed Helmholtz coils with the field paralel to the polarizing field. This additional field is switched off simultaneously with the main field but more slowly. Thus just the magnetization around the zero point of field gradient is preserved. Other two methods are described elsewhere[4].

Preliminary experimental demonstration of MRI in the earth's field (MRIE) has been performed on the home made setup[1,2,3,4], but without any radiofrequency shielding. The coils has been placed temn metters outside of the building to reduce magnetic disturbances caused by the electric instalations. The fantom images has been reconstructed from the signals obtained from the different orintations of the sample in the gradient field.



The cross sectional view of the pumpkin by MRIE. Its diameter is 17cm.

References
1.M.E.Packard, R.Varian, Phys.Rev. A94 (1954) 941.
2.G.J.Bene', Physics Reports 58 (1980) 213.
3.J.Stepišnik, V.Eržen, M.Kos, to be published.
4.J.Stepišnik, Progress in NMR Spectr. 17 (1985)187-209.