PAUL C. LAUTERBUR

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Research Notebook - Table of Contents

Spatially Resolved Nuclear Magnetic Resonance Experiments.

The distribution of magnetic nuclei, such as protons, and their relaxation times and diffusion coefficients, may be obtained by imposing magnetic field gradients (ideally, a complete set of orthogonal spherical harmonics) on a sample, such as an organism or a manufactured object, and measuring the intensities and relaxation behavior of the resonances as functions of the applied magnetic field. Additional spatial discrimination may be achieved by the application of time-dependent gradient patterns so as to distinguish,

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[illegible signature] — Sept 3, 1971

for example, protons that lie at the intersection of the zero-field (relative to the main static field) lines of three linear gradients.

The experiments proposed above can be done most conveniently and accurately by measurements of the Fourier transforms of the pulse response of the system. They should be capable of providing a detailed three-dimensional map of the distributions of particular classes of nuclei (classified by nuclear species and relaxation times) within a living organism. For example, the distribution of mobile protons in

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tissues, and the differences in relaxation times that appear to be characteristic of malignant tumors [R. Damadian, Science, 171, 1151 (1971)], should be measurable ~~in~~ an intact organism.

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Classification of Spatially Resolved Nuclear Magnetic Resonance Experiments

1. Time-independent methods: based upon the combination of independently measured spectra in a distinct set of field gradients.

   a) orthogonal gradients; in two dimensions, a pair of orthogonal first-order gradients acting on a set of <u>n</u> elements can produce as many as $\underline{n}^2$ images. The ~~def~~ degree to which an image of the whole array free from significant false elements can be generated by a particular truncated set of gradients is not yet known.

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b) non-orthogonal gradients: examination of simple test cases suggests that additional linear gradients quickly eliminate many false aspects of the two-dimensional image generated by a pair of orthogonal gradients. No rigorous evaluation of the efficiency or limits of such a process has yet been carried out.

2. Pulsed gradient methods: the rapid application of a sequence of gradients provides a unique history and modulation pattern for each point in the sample volume. Cross-correlation of the resonance response with a function derived

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from the modulation sequence could generate an image.