18th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Amsterdam 1996
3.3.1: MR Imaging Systems and Reconstruction Techniques

# A MINI NMR IMAGING SYSTEM FOR TEACHING AND TRAINING

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*Abstract* — **This work presents a mini NMR (Nuclear Magnetic Resonance) imaging system that has been developed for cost-effective bioengineering pre-graduate students teaching and training. It consists of a compact permanent magnet, an RF electronic modular system, a signal acquisition subsystem and a computer; all these parts can operate independently, allowing easy and intuitive manipulations. Manual interaction with each module is possible, although a computerised automatism can also be programmed. Being a completely open system, students can manipulate almost every parameter of an NMR signal acquisition, visualising in real time the different effects. The system has proved to be reliable enough to allow the implementation of several research experiments. To the authors best knowledge, there is no commercial system with these characteristics available on the market.**

## I. INTRODUCTION

NMR imaging systems usually require a high investment both in installation and maintenance. This fact makes prohibitive to have one of these installations on a university technological department just for pre-graduate teaching and training. Although there is abundant educational material available to the NMR teacher, mainly based on multimedia systems, the complexity of the NMR experiment makes almost impossible to implement efficiently every process step in a software simulator or in a virtual NMR system [1, 2].

Other restrictions imposed to the design included weight limitations of the system itself as well as a strict confination of the fringe magnetic field. Only under those conditions a system can be placed in a teaching bioengineering laboratory nearby other equipment, including computers with colour monitors [3]. The magnet compactness is also an advantage for RF shielding; in fact, the prototype does not need any external shield.

## II. MATERIALS

Apart from the NMR equipment itself, the laboratory has a GPIB controller system hosted on a PC computer, which is connected to the department network. Thus signals can be displayed and processed in any other workstation. The PC computer can also control the NMR unit by means of an appropriate user interface and the GPIB bus. The acquisition system consists of a Tektronix TDS-524A oscilloscope connected to the computer through the same GPIB bus.

The entire equipment can be divided into two different functional parts: the magnet and the electronic system.

### *A. THE MAGNET.*

The static field is created by a compact permanent magnet built with ferrite blocks, which provides a field of 0.1211 T. The Larmor frequency for $^1H$ is 5.017 MHz. Being so compact, the NMR system was placed in a rectangular room (4x5 $m^2$) with no shielding. Ferrite magnetic field depends however on the temperature, and for this reason a compensation system has been integrated in the magnet. Additionally, the temperature of the room is continuously monitored in order to assure that it is within the range that provides the best field homogeneity (22° C ± 3° ).

### *B. THE ELECTRONIC MODULAR SYSTEM.*

This electronic system consists of five different modules.

*Module A: Power supplies.*

This block consists of the three power supplies needed for the full system.

*Module B: Temperature compensation circuit.*

This circuit provides the static field homogeneity required for NMR imaging when temperature changes. The temperature dependent shimming procedure introduces an accurate DC current in two coils located on the poles of the permanent magnet [4, 5]. A manual control is also possible in order to experiment with an inhomogeneous static magnetic field to visualise T2* variations [6].

*Module C: The transmitter.*

This unit produces the RF pulses. It may generate gaussian pulses to induce flip angles of 90° and 180°. The user can modify three parameters: main lobe width of the gaussian 90° pulse, main lobe width of the gaussian 180° pulse and the amplitude of both pulses.

The baseband pulse is generated by the pulse wave generator (PWG). This pulse is mixed with a Larmor frequency carrier signal, provided by a quartz crystal oscillator. The output of the mixer is driven to an RF amplifier. All these parts can be manipulated independently.

*Module D: The signal acquisition subsystem.*

The RF pulse is transmitted to the sample by means of a transmitter/receiver circuit (T/R) connected to a single coil. This coil also receives the Free Induction Decay (FID) from the sample at the Larmor frequency, driving it to the receiver module. The coil itself is shielded to reduce the RF interferences during reception [7, 8, 9].

*Module E: The Receiver.*

The first stage of this module is a Low Noise Amplifier (LNA), followed by a quadrature detector whose inputs are the FID and the carrier signal used for excitation. Finally, the real and imaginary channels are applied to active low pass filters, whose gain can be modified by the user.

## III. RESULTS

The system has proved to be a useful tool for a pregraduate laboratory, providing flexibility of use. It is robust enough to support daily manipulation of its components, and after a first course students have been able to deal with basic NMR concepts without major difficulties. Failure rate is very low: in six months of intensive use there has only been one problem.

The system flexibility is also high, allowing the design of several experiments related with research projects.

## IV. CONCLUSIONS

We have designed and built a mini NMR imaging system for teaching and training whose main characteristics are: very low implementation and maintenance costs, compactness, reliability, flexibility and compatibility with the rest of the laboratory equipment. The system has been implemented with off–the–self technology, redesigning those modules that couldn't be scaled down. The results have been very satisfactory both as NMR imaging system and as a teaching device.

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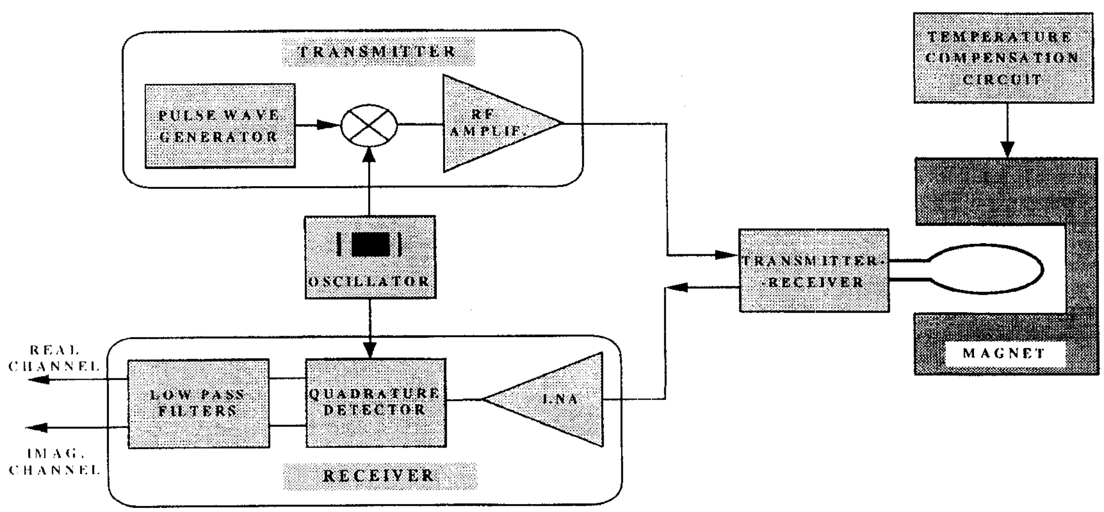


**Fig. 1.** Block diagram of the mini NMR imaging system.