Digital Magnetic Resonance Spectrometer (DMRS) from CIERMag: calibration and measurements methodology

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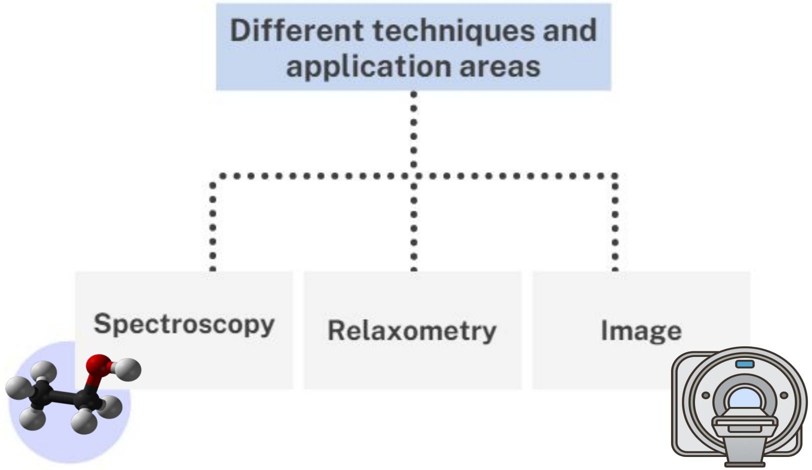
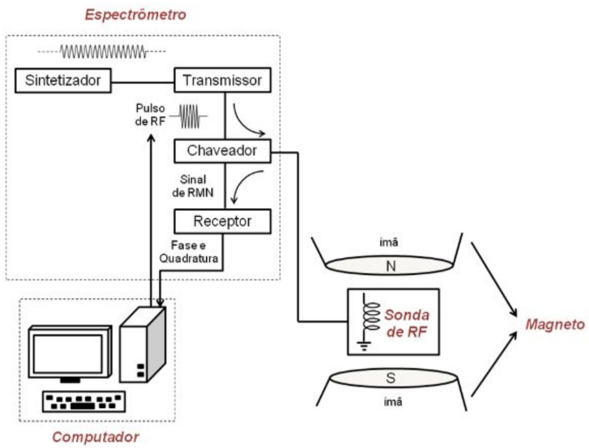
Abstract: Nuclear Magnetic Resonance (NMR) techniques have been evolving, and are present in various sectors of society such as medicine, industry, and agriculture. However, according to a review by Centro de Imagens e Espectroscopia por Ressonância Magnética (CIERMag), although they are practical to use in most applications, current NMR commercial equipment is restricted for modifications and does not allow new pulse sequences, or pulse shapes - i.e adiabatic pulses - to be introduced in an easy way. In an attempt to solve these problems, the project ToRM-15 (Magnetic Resonance Tomography 1.5T) began to be developed. It allows the creation of a Digital Magnetic Resonance Spectrometer (DMRS) based on reconfigurable hardware powered by a Field-Programmable Gate Array (FPGA). CIERMag has also developed software that allows the experiment planning and control, based on the Python Magnetic Resonance Framework (PyMR), and that uses the proprietary F - Language to develop pulse sequences. In this study NMR Methods for DMRS calibration such as spectrometer resonance frequency adjustment, receiver gain adjustment, and *flip* angle calibration were developed. Besides that, the pure water T2 value was measured using CPMG T2 = 2,045 ± 0,006 s.

Nuclear Magnetic Resonance (NMR)



Commercial Equipment



According to a survey conducted by the Center for Images and Magnetic Resonance Spectroscopy (CIERMag) the existing NMR commercial equipment, although are practical for use in various applications, they are restricted to drastic modifications.

- Not allow new pulse sequences or new waveforms - i.e. adiabatic pulses - to be introduced in a simple way.
- Equipment dedicated to only one application.
- Updates are expensive and challenging.

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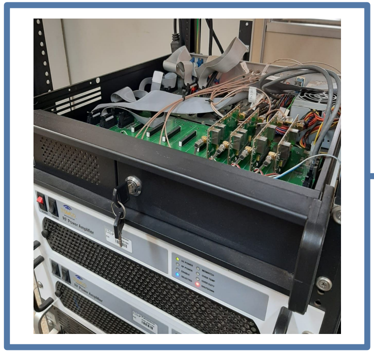
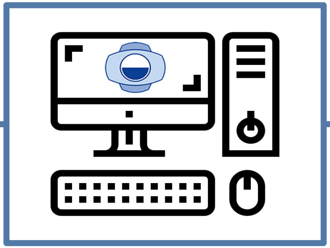
Digital Magnetic Resonance Spectrometer (DMRS) from CIERMag

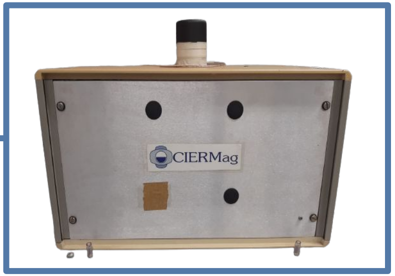


The Digital Magnetic Resonance Spectrometer (DMRS) is based on reconfigurable hardware powered by a Field-Programmable Gate Array (FPGA). The Digital Magnetic Resonance Spectrometer (DMRS) comprises an FPGA capable of NMR signal generation and acquisition. The Field-Programmable Gate Array was programmed to contain a temporal controller, an RF pulse generator, a module for RF modulations, and synchronous receivers.



Software background to perform and control the NMR experiments using the DMRS based in the Python Magnetic Resonance Framework (PyMR)

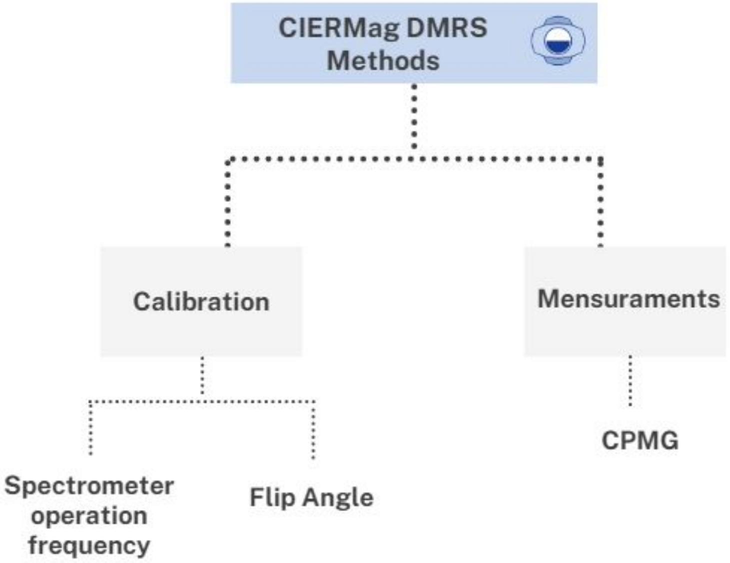
- ACQ Server
- PyMR IDE
- Console
- Linguagem F
- Plugins para Spyder and Eclipse



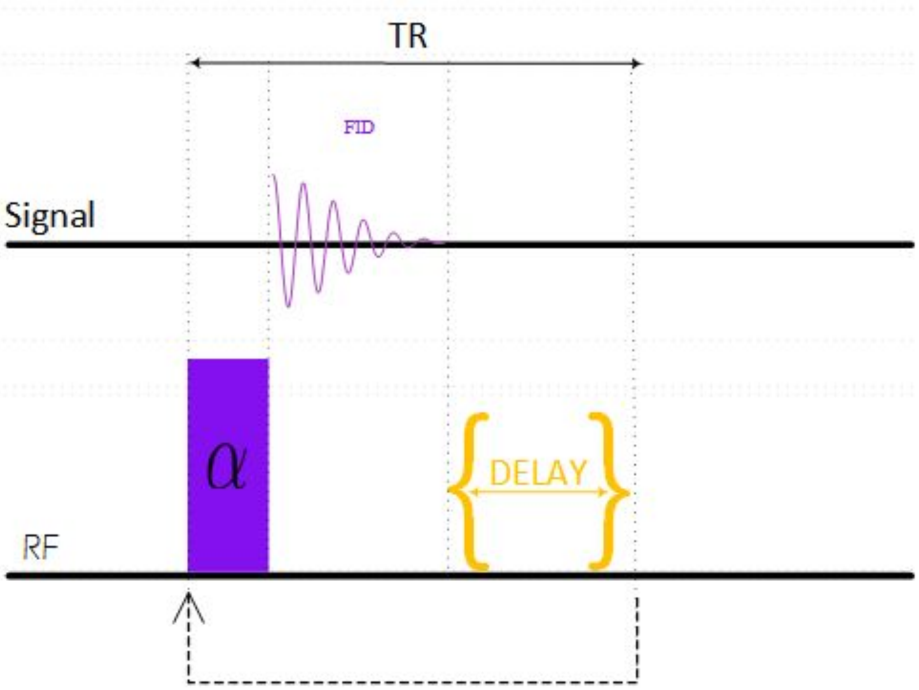
The experiments were done in H permanent magnet with 35 mm gap. The RF coil has an optimal operating region of 15 mm in diameter by 15 mm of thickness with greater than 96% homogeneity for a region of 12 mm in diameter by 14 mm in length. The magnet field intensity is 0.5463 T and operating at 23.256 MHz for (H^1) nuclei.

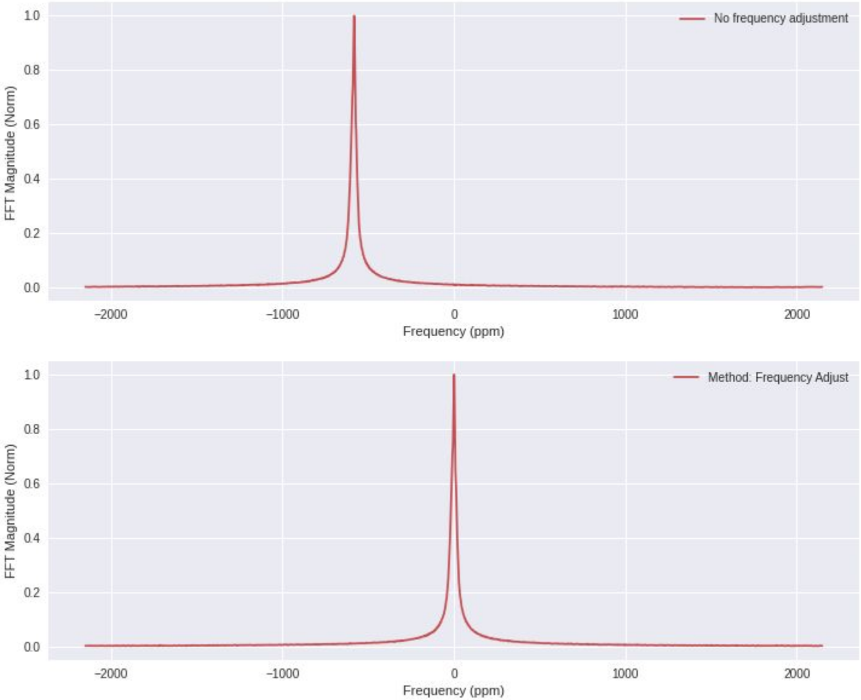
Objectives and Methodology

In the CIERMag context, a Method represents an experiment project that contains all the information about the experiment from pre-processing to post-processing. The experiment project includes the pulse sequence, the validation scripts, and the acquisition, execution, and processing protocols.



Spectrometer operation frequency adjustment





Spectrometer operating frequency adjustment: The upper part of the graph shows the spectral peak shifted about 600 ppm with respect to the center, before the spectrometer operating frequency correction. The bottom one shows the peak after correction.

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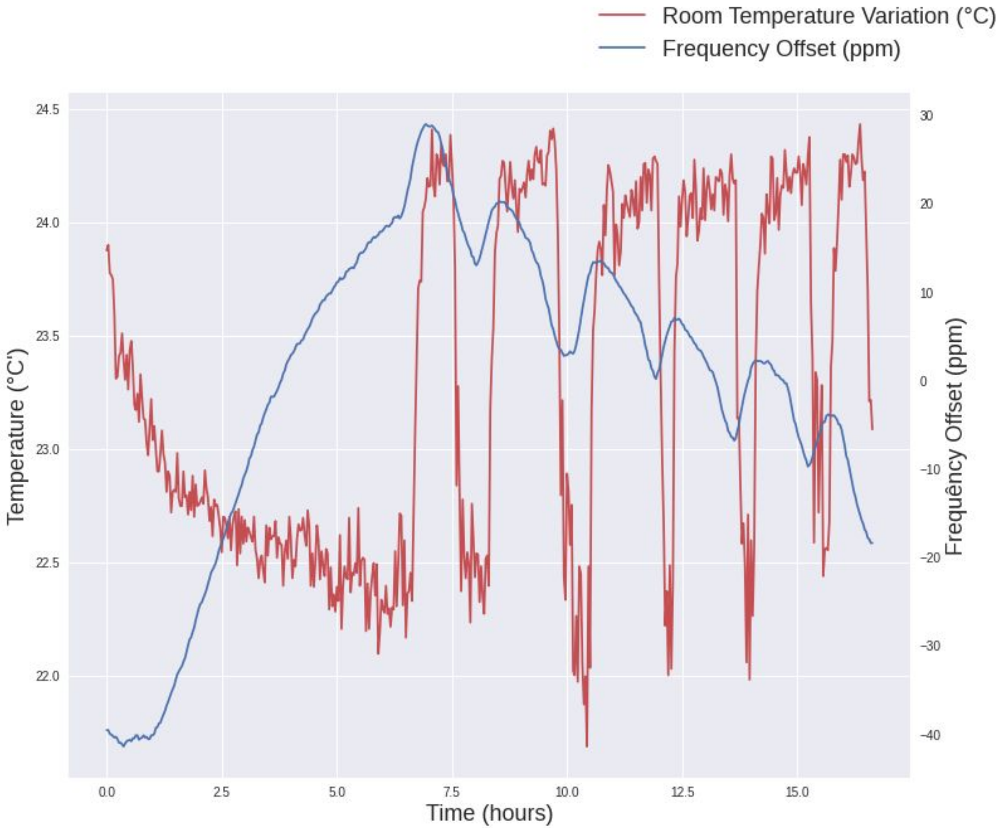
Relationship between the spectrometer operating frequency variation and the room temperature variation



Relationship between the spectrometer operating frequency variation and the room temperature variation: The data acquisition run over 16 hours. A 2.5°C variation in temperature generated a 70 ppm change in operating frequency, which represents an average rate of change of 4.3 ppm/h. This relationship is in agreement with what was expected, since permanent magnets are sensitive to temperature variations.

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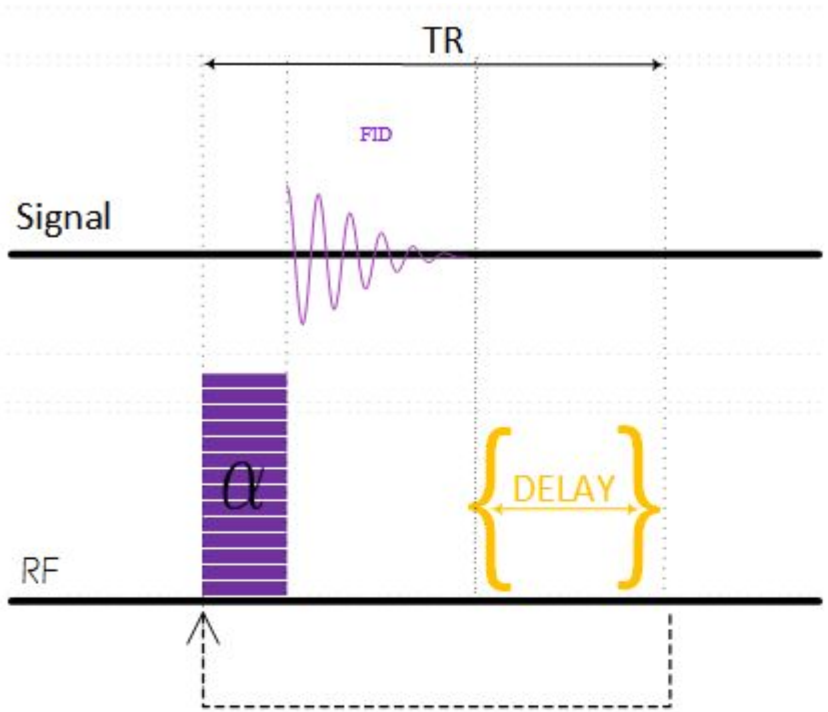
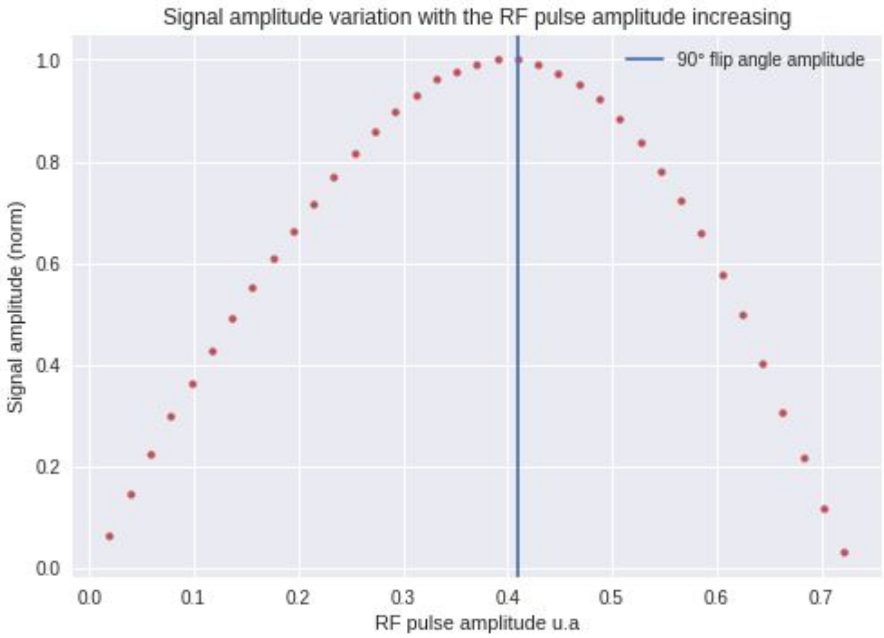
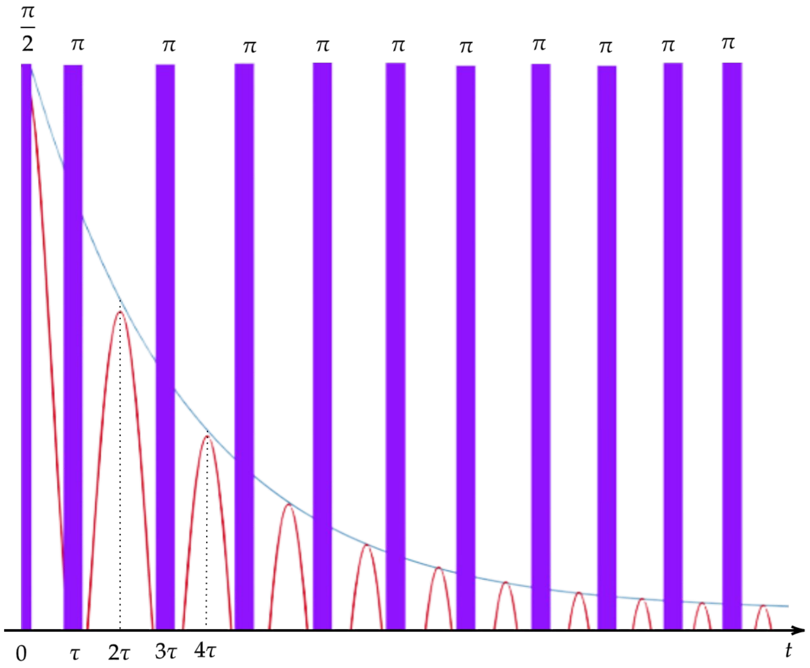
Flip Angle Adjustment

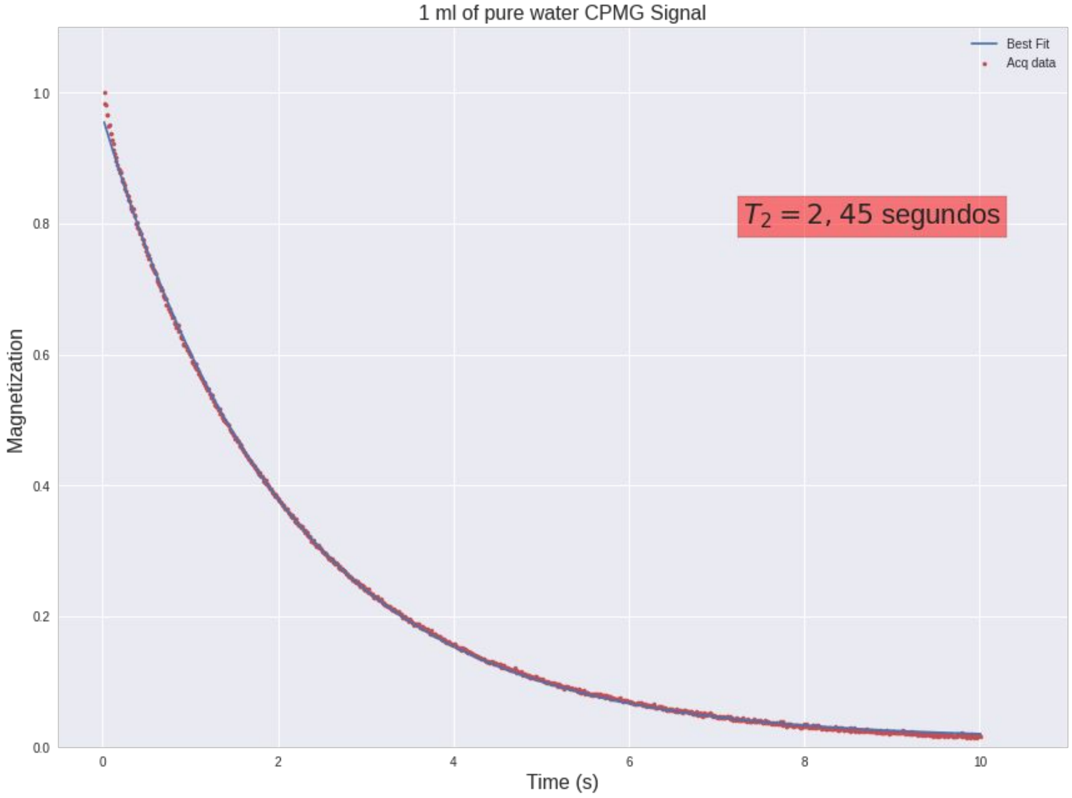




Flip Angle Adjustment: The figure shows a sweep by varying the amplitude of the RF pulse. When the flip angle reaches 90° then the signal strength is maximum, as represented in the graph.

Measurements using CPMG





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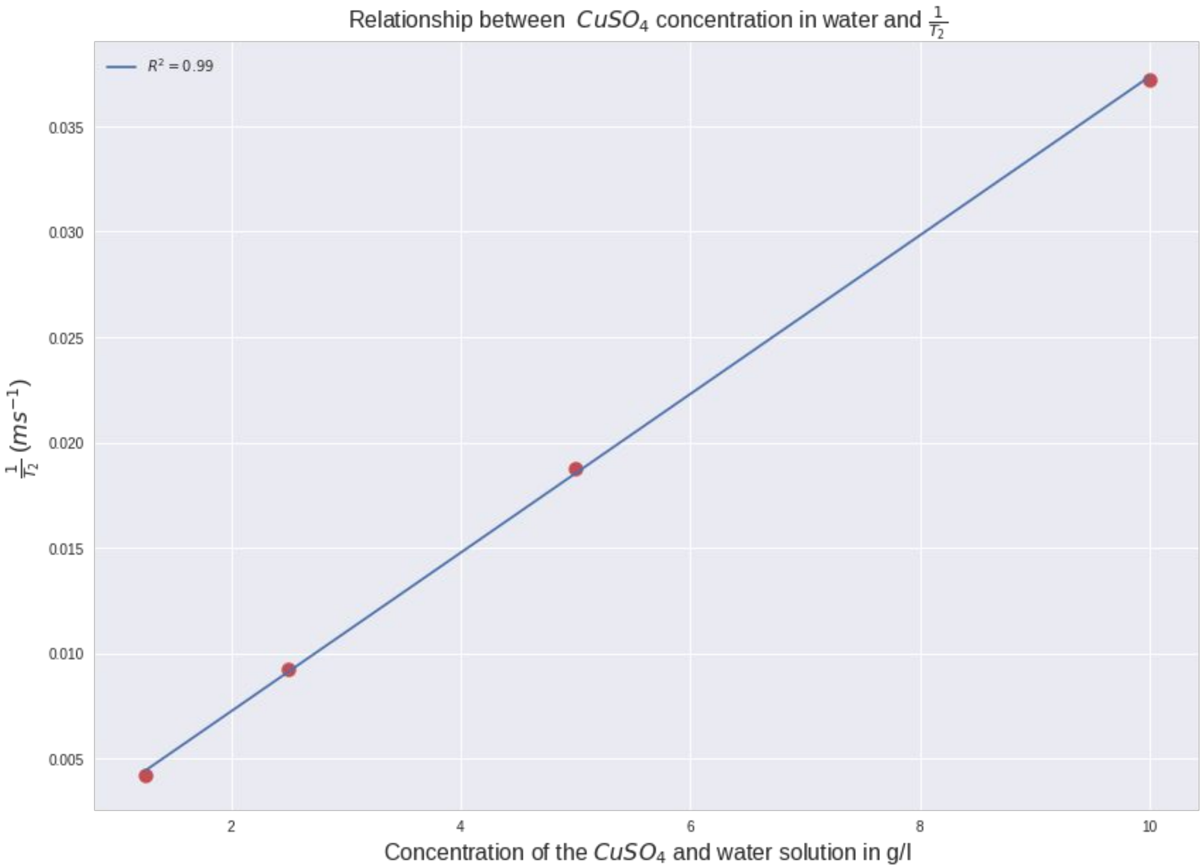
Measurements using CPMG



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Conclusion

DMRS is an alternative that avoids obsolescence and makes the development of new NMR techniques simpler. The results shown in this poster for the calibration methodologies comply with the pre-experiment adjustments necessary for the measurement reliability. Furthermore, measurements of relaxation times demonstrate that the equipment is functional and ready for use.

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O CIERMag


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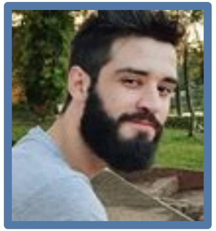
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Thank you!

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