Simultaneous Acquisition of Echo Planar Images on Proton and Phosphor Frequencies

A. Jesmanowicz, S.-J. Li and J. S. Hyde
Biophysics Research Institute, Medical College of Wisconsin, Milwaukee, WI USA

ABSTRACT

The purpose of this study was to establish feasibility for simultaneous MRI acquisitions at two different NMR frequencies (H^1, P^{31}) using the same gradient sequence. Two acquisition channels were used with a single broadband linear power rf transmitter. To the best of our knowledge, this has never been tried before. The results are encouraging, despite finding a damping effect of the H^1 excitation pulse on the P^{31} signal.

INTRODUCTION

The pixel size in the frequency encoding direction for an EPI sequence is given by the following formula:

$$Vx = 2\pi / (\gamma \cdot Tacq \cdot Gx).$$

Thus for a given gradient ***Gx*** and acquisition time ***Tacq,*** the pixel size for the P^{31} image is larger than for H^1 by the ratio of gammas. The FOV for phosphor imaging is effectively about 2.5 times larger, as seen in Fig. 1. This is a drawback of simultaneous acquisition. It does not apply to the slice selection because the slice thickness given by:

$$Sl\_thick = 2\pi \cdot Sinc\_cyc / (\gamma \cdot Pw \cdot Gz)$$

can be compensated by changing the number of rf pulse sinc cycles for the same pulse duration ***Pw***. Slice positions can be matched for both nuclei by frequency selection.

METHODS

All studies were carried out on a 3T 30/60 Bruker Biospec scanner equipped with a home made balanced torque three-axis local head gradient coil (1). A 16 element multifrequency endcapped bandpass birdcage head coil was constructed. It was matched and simultaneously tuned to H^1 and P^{31} frequencies, and connected to the broadband quad combiner by a single pair of coaxial cables for quadrature excitation and reception for both frequencies. Transmit pulses were created in two separate modulators, added in a hybrid combiner and fed to the broadband rf power amplifier Dressler LPPA 14020. The NMR signals were amplified first in a single broadband low noise pre-amplifier and then split to two separate second stage amplifiers. Signals were then sent to mirror image rejection mixers with output signals at an IF center frequency of 1.25 MHz. The signals were anti-alias bandpass filtered ±0.25 MHz and fed to an offline SGI Challenge 10000 workstation equipped with two Pentek 16 bit A/D converters and sub-sampled at 1 MHz. Further filtering and phase detection was done digitally. The two anti-alias filters were the only ones in the system when it was used for multi-nuclei acquisition. When amplification is linear, there is no need for additional filters. Linearity was checked experimentally at the proton frequency. The system can be tuned to any nucleus in the range of 10 to 140 MHz by a simple reference frequency change, two nuclei at a time.

RESULTS

Figure 1 shows simultaneous single-shot EPI images of a phantom filled with a 400 mM solution of $Na_2H_2P_2O_7$. Imaging parameters: FOV=12 cm (H^1), 30cm (P^{31}), slice 60 mm, 64x64, ½NEX, TE=10.8ms. As long as a single P^{31} peak dominates, there is an advantage in acquiring a series of 64 EPI images and averaging, rather than making a 64×64 multi-shot image. The total acquisition time is the same, but the S/N is better for EPI.

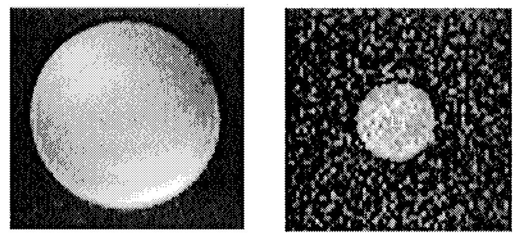

Fig. 1 (a) H^1 EPI image (b) P^{31} EPI image

Figure 2 shows a scaled phantom containing P^{31} samples in four forms (viols left to right): **PE, Pi, Pcr** and **ATP**. The top row has a five times smaller concentration. In the P^{31} image (Fig.3), the shift in the phase encoding direction due to the chemical shift is apparent. The three peaks of **ATP** produce no detectable signal. Imaging parameters: FOV=30cm (P^{31}), slice 150 mm, 64x64, ½NEX, TE=7.9 ms, TR=5 sec, 100 averages.

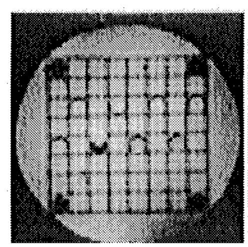

Fig. 2. H^1 ref. image - scaled.

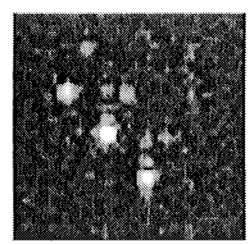

Fig. 3 . Mixed P^{31} EPI image

DISCUSSION

It has been shown here that simultaneous MRI acquisition of two or more nuclei is possible. An interaction between H^1 and P^{31} nuclei was found in $Na_2H_2P_2O_7$ (data not shown). For a 90° H^1 pulse, the P^{31} signal was too small to detect. It was restored when the H^1 resonance frequency was shifted by 50 kHz. To the best of our knowledge, this observation is novel. Irradiation of solvent protons may alter relaxation behavior of other nuclei. For this reason, all H^1 images were acquired with a flip angle below 10°. This is not a big problem because proton signals are stronger than phosphor by several orders of magnitude.

REFERENCES

1. Wong, E. C., Bandettini, P.A., Hyde, J.S. in *Proc., 11th SMRM,* p. 105, 1992.