# Simultaneous Dual-Nuclear $^{31}$P/$^{1}$H MRS at a clinical MRI system with time-sharing second RF channel

Eun-Kee Jeong[1,2], Nabraj Sapkota[3], Joshua Kaggie[3], and Xian-Feng Shi[4]

[1]*Radiology, University of Utah, Salt Lake City, UT, United States,* [2]*Utah Center for Advanced Imaging Research, University of Utah, Salt Lake City, UT, United States,* [3]*Dept. of Physics, University of Utah, Salt Lake City, UT, United States,* [4]*Dept. of Psychiatry, University of Utah, Salt Lake City, UT, United States*

**Target Audience**: Multi-nuclear MR spectroscopy and imaging community.

**PURPOSE**: $^{31}$P MRS provides the bioenergetics information in human body, while the $^{1}$H MRS is for relative concentration of a substantial number of cell specific metabolic products. Because of the time constraint to measure both nuclei within the same acquisition session, most of MRS studies report either$^{3}$ $^{1}$P and $^{1}$H MRS only. A novel acquisition method is developed to simultaneously measure $^{31}$P and $^{1}$H MR spectra at a clinical MRI system, equipped with the time-sharing second RF channel.

**METHODS**: This work requires developments of a hardware-chain that directs the $^{1}$H NMR signal toward one of the $^{31}$P Rx-channel and a pulse sequence that can simultaneously prepare both $^{31}$P and $^{1}$H transverse magnetizations within the same pulse sequence. The hardware modification, as indicated in Fig. 1, includes PIN-diode driven switches, preamplifier for 123.24 MHz $^{1}$H NMR signal, a RF mixer, a precision synthesizer, and a RF filter. Fig. 2 shows the $^{31}$P/$^{1}$H dnMRS pulse sequence that can simultaneously measure both MR signals at the exact same sampling window. The gradients pulses ($G_{dcr,y}$ $G_{dcr,z}$) and ($G_{rcr,y}$, $G_{rcr,z}$) indicate the dephasing and rephrasing crusher gradients before the center of the second 90$^{o}$ and after the center of the third 90$^{o}$ RF pulses, respectively. $G_{rcr,z}$ is the sum of the slice-selection and refocusing gradients for $^{31}$P excitation and half area of the $^{1}$H slice-selection gradient of the third 90$^{o}$. $^{31}$P/$^{1}$H dnMRS was measured on an MRS QA phantom using a custom-made $^{31}$P/$^{1}$H double-tuned RF RF coil and compared with conventional single-nuclear MRS. The residual water signal is used to identify individual FIDs with severe phase-error due to the subject's motion coupled with the poor shimming and to correct the phase-error on both $^{31}$P and $^{1}$H signals.

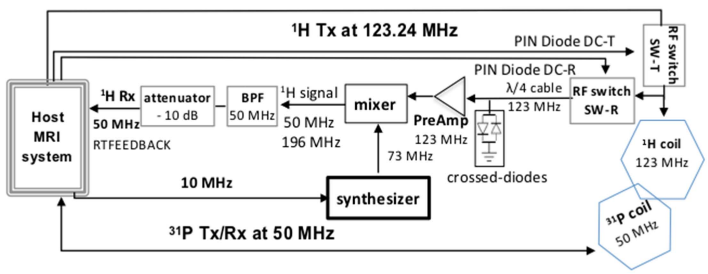


**Fig. 1.** *Schematic block diagram for simultaneous dnMRS. Arrows indicate the directions of the Tx RF pulses and MR signals. The 123.23 MHz $^{1}$H signal is directed to $^{31}$P Rx pathway using two PIN-diode driven RF switches (SW-T and SW-R) and converted to 49.9 MHz.*

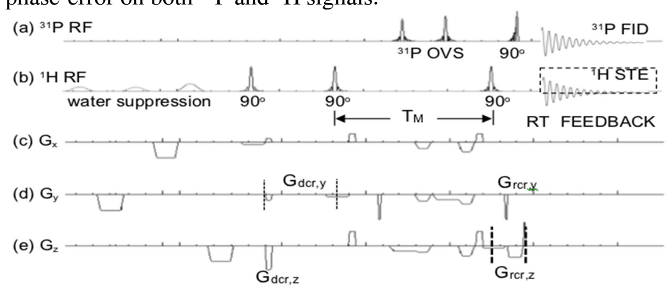


**Fig. 2.** *Pulse sequence diagram for a simultaneous water suppressed $^{1}$H and $^{31}$P MRS: (a) $^{31}$P FID MRS using 2D-OVS + slice-selective excitation, (b) STEAM for $^{1}$H MRS with, (c ~ e) gradient waveforms. The dotted box indicates the data acquisition of the $^{1}$H signal.*

**RESULTS**: Raw and phase-corrected $^{1}$H and $^{31}$P FIDs are displayed in Fig. 3, and frequency-domain spectra are shown in Fig. 4. Several $^{1}$H FIDs were corrupted by motion-induced phase errors and corrected as shown in Fig. 3. The same motion introduced minor phase-error into $^{31}$P FIDs, because of $\Delta\theta_{31P}(t) = \frac{\gamma_{31P}}{\gamma_{1H}}\Delta\theta_{1H}(t) = 0.409\,\Delta\theta_{1H}(t)$. $^{31}$P spectra in Fig. 4 are almost identical from both techniques; however, reduced SNR was observed for $^{1}$H using dnMRS, probably because of increased reflection at the additional RF components along the $^{1}$H signal pathway.

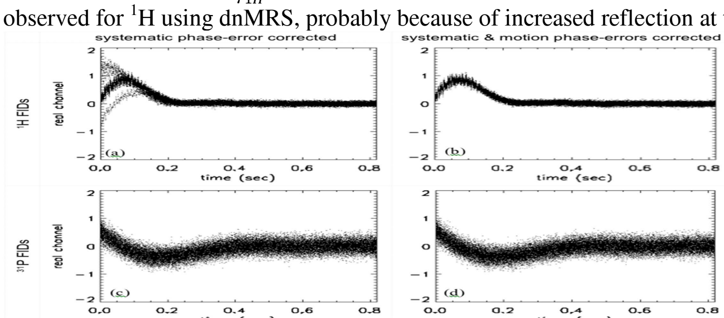


**Fig. 3**. *20 real-channel $^{1}$H FIDs are overlaid each other with (a) systematic phase-error correction and (b) systematic and motion-induced phase-error correction. Note negligible improvement in $^{31}$P FIDs, because the change in $^{31}$P phase is 40 % of that in $^{1}$H phase.*

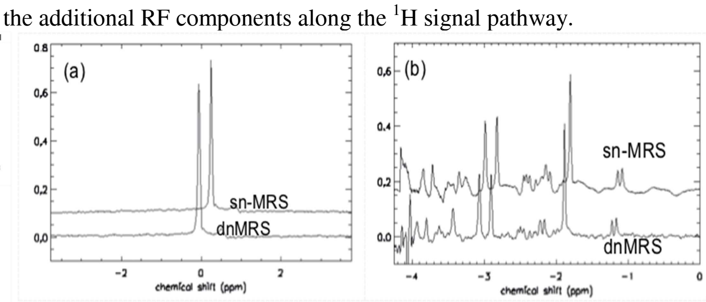


***Fig. 4.*** *(a) $^{31}$P and (b) $^{1}$H spectra measured using (top) the conventional single-nuclear acquisitions and (bottom) dnMRS, using identical acquisition parameters including the voxel locations and the shimming. sn MR spectra were measured using STEAM for $^{1}$H and slice-selective 1D FID with OVS in other two spatial dimensions for $^{31}$P MRS.*

**DISCUSSIONS:** Current method requires minor add-on hardware, unlike a similar dual-nuclear $^{19}$F/$^{1}$H imaging using a major hardware modification [1]. The method can be used for any multi-nuclear MR imaging and spectroscopy.

**CONCLUSIONS:** Simultaneous dual-nuclear single voxel $^{31}$P and $^{1}$H MRS were successfully measured using a novel acquisition method at a clinical MRI system that is equipped with a timesharing RF channel, with independent localizations and voxel dimensions for each nucleus.

**ACKNOWLEDGEMENTS**: Supported by NARSAD Independent Investigator Grants, NSF CBET 1133908, VA Merit Review Grant, Margolis Foundation, Siemens Medical Solution, VISN 19 MIRECC, DA031247, R21MH096858 and the Utah Science Technology and Research initiative.

**REFERENCES**: [1] ). Keupp J, et.al., Simultaneous Dual-Nuclei Imaging for Motion Corrected Detection and Quantification of $^{19}$F imaging Agents, MRM 2011, 66: 1116