Frequency Translation for ^{1}H Decoupled Multichannel ^{13}C Spectroscopy

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Target Audience: MR Engineers

Purpose:

In vivo NMR spectroscopy has the potential to provide clinically useful data, but it has seen limited use due to poor Signal-to-Noise Ratio (SNR) [1]. The use of array coils to improve SNR is well established in MRI [2, 3]. Array coils and the multi-channel receivers to support them have become widely available, but are typically limited to use with Hydrogen (^{1}H). We propose a simple mixer-based method to adapt widely available multichannel 1H receivers for use with other nuclei, allowing the improvement of SNR through the use of parallel receive techniques.

Materials and Methods:

In the early days of multichannel MRI, others made system modifications to add multichannel capabilities to clinical MRI systems with approaches based on time division multiplexing [4]. Once multichannel receivers became more common, others used frequency translation to adapt these receivers for nuclei other than Hydrogen [5]. This is accomplished by using active radiofrequency (RF) mixers to translate the received signal to the ^{1}H frequency. Mixing is performed after the low noise amplifier (LNA) to preserve the noise performance of the system.

Advances in semiconductor technology have led to the development of non-magnetic active mixers, which allow us to move the frequency translation process into the scan room or even the magnet bore. Additionally, the increased interest in *in vivo* ^{13}C spectroscopy has introduced the complication of ^{1}H decoupling, which is very desirable to simplify ^{13}C spectra. Because we are using the ^{1}H receiver while simultaneously transmitting on ^{1}H, there is a very real possibility that some of the high-power decoupling signal will bleed through the mixer or couple from the transmit cable to the receive cables. In order to avoid this problem, we mix to a frequency slightly different from the ^{1}H. This is possible because the bandwidth of the decoupling signal is relatively narrow (at most a few tens of kHz) and the receiver bandwidths are typically at least 1 MHz.

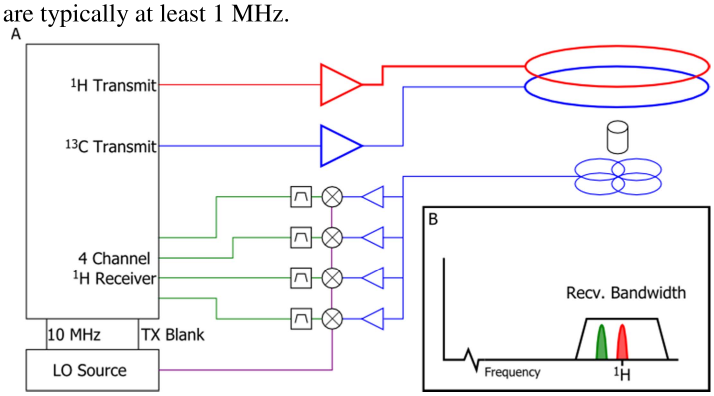

Figure 2: A - Block Diagram of multichannel frequency translation system. Signals in red are at the ^{1}H frequency, signals in blue are at the ^{13}C frequency, signals in green are at the translate frequency, and signals in purple are at the LO frequency. **B** – Illustration of spectrum at receiver. Colors again correspond to frequency.

Since many clinical systems have one or two channels of multinuclear transmit and receive capability, we are able to use the existing transmit system and only perform frequency translation on the receive side of the system. Because we are mixing only on the receive side, the local oscillator (LO) must be at a consistent phase between signal averages to ensure phase stability. This is accomplished by generating the LO with direct digital synthesis (DDS) and resetting the phase of the LO before each acquisition.

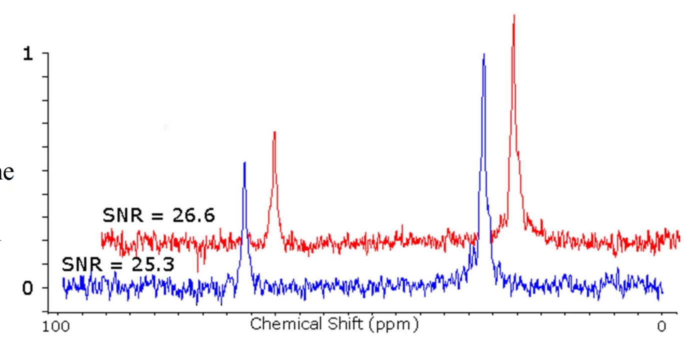

Figure 1: Comparison of spectra acquired with stock Varian system (blue) and frequency translation receiver (red).

Results and Discussion:

Proton decoupled ^{13}C spectra were acquired of isopropyl alcohol on a 4.7T Varian Unity Inova small animal system. Figure 2 shows the reference and frequency translated spectra, which clearly have comparable SNR. Additionally, the frequency translated spectrum has comparable linewidth and no visible coherent interference.

Conclusion:

Frequency translation allows us to adapt widely available multichannel ^{1}H receivers for use with other nuclei. By translating to a frequency slightly different than the ^{1}H frequency, we can perform ^{1}H decoupled ^{13}C spectroscopy with no spectral degradation. Testing of a 4-channel system is imminent, and construction of a 16-channel system is underway.

References:

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