A Novel Broadband Coil for Multinuclear Spectroscopy

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Introduction: RF coils for multinuclear spectroscopy are resonant structures simultaneously tuned at discrete Larmor frequencies[1,2]. Although popular, the resonant nature has the following disadvantages for multinuclear applications. 1) Coil needs to be designed careful to avoid the interference of the different modes for different nuclei species. 2) Coil needs to be tuned to a drastically different frequency if the nuclei species changes. 3) RF power handling needs special attention, especially for capacitors used for coil tuning. A novel broadband RF transmitter is developed that utilizes the frequency-independent transverse electromagnetic (TEM) mode of a parallel-plate waveguide for both proton imaging and X-nuclei spectroscopy. Without using any reactive tuning components, the simple coil structure can function from 100 to 300 MHz. It was applied to ^{31}P spectroscopy of human forearm at 7 Tesla.

Methods: The coil consists of two continuous parallel conductors (Fig.1). According to microwave engineering theories, the electromagnetic field between the two conductors is the combination of TEM, transverse electric (TE) and transverse magnetic (TM) modes. The TEM mode does not have a cutoff frequency. Its wave impedance is frequency independent and its magnetic field distribution is uniform in a plane transverse to the main axis of the waveguide. These features make the TEM mode suitable for broadband MRI spectroscopy studies. Note that in Fig. 1, the entire coil does not have any reactive components for tuning.

Figure 1. The parallel-plate waveguide for multinuclear spectroscopy.

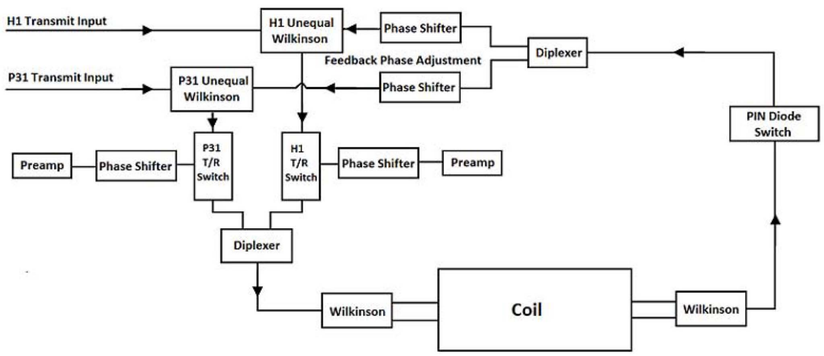
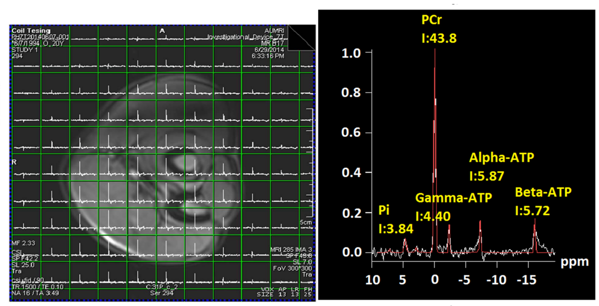


Figure 2. The schematic of the RF front-end.



(a) (b)

Figure 3. (a) The 31P CSI results overlapped on localizer image and (b) the result in a single voxel.

The RF front-end that can support multi-nuclear function is depicted in Fig. 2. The TEM wave impedance was matched to 50-Ohm cable impedance at first by using broadband Chebyshev matching network. The input power for both 1H and 31P are split into two branches to feed the coil by using a broadband Wilkinson power divider. Another broadband Wilkinson power combiner is applied to combine the RF power traveling through the coil into one branch and feed them in-phase with system power input through a third Wilkinson power combiner. The phase was adjusted for 1H and 31P individually after the RF power at different frequencies are split by using a diplexer. T/R switches are further applied to switch the parallel-plate waveguide from transmit to receive modes for signal reception.

Results and Discussion: The Chebyshev matching network, the broadband Wilkinson's power divider and combiner were designed from 100 to 300 MHz. When loaded with the human forearm, the reflection coefficient of the entire coil was -17.4 dB and -16.9 dB at 120 MHz and 297 MHz, respectively. The transmit efficiency of the proposed coil was compared with an eight-run birdcage coil of the same size at 7 Tesla. The measurement was performed by measuring the signal intensity with different voltage levels of a free-induction-decay (FID) sequence on a 7T Siemens Magnetom scanner. It was found that the transmit efficiency of the proposed coil is as good as a birdcage coil. Finally, Figure 3 shows the 31P CSI result acquired at 7 Tesla, where the localizer image was acquired by using the same coil. The scan parameters are: TR=1500 ms; TE=0.1 ms; bandwidth=5 kHz; cubic volume size= 25 mm; and 16 averages. These results clearly validate the use of proposed coil for both RF transmit and receive in multinuclear spectroscopy studies.

Conclusions: A novel broadband RF coil was proposed for multinuclear spectroscopy studies. Compared with conventional resonant coils, it is easier to construct and can provide signal excitation for different nuclear species with specific tuning. In addition, the RF power handling is easier to take care of due to the lack of reactive components.

References: 1) J. Ackerman *et.al.,* "Mapping of metabolites in whole animals by 31P NMR using surface coils," Nature, 283, 5743, January, 1980, pp. 167-170. 2) J. Murphy-Boesch *et.al.,* "Proton-decoupled 31P chemical shift imaging of the human brain in normal volunteers," NMR in biomedicine, 6, 3, May-June, 1993, pp. 173-180