DETECTION OF MR SIGNAL DURING RF EXCITATION USING A TRANSMIT ARRAY SYSTEM

Ali Caglar Ozen[1,2], Koray Ertan[1], and Ergin Atalar[1,2]

[1]*Electrical and Electronics Engineering, Bilkent University, ANKARA, Turkey,* [2]*UMRAM, Bilkent University, ANKARA, Turkey*

Introduction: Most of conventional MRI applications are based on a time interleaved approach for RF excitation and signal detection. The idea of concurrent RF excitation and reception was implemented in a few recent studies using sideband excitation [1, 2] and swift [3] techniques. In sideband excitation technique, the necessary decoupling between MR signal and RF pulse is achieved by filtering out the excitation frequency band. In the continuous swift technique, partial decoupling is achieved using mechanical adjustment of receiver and transmitter coils. The remainder of signal was separated using a series of signal processing technique.
According to our simulations (MATLAB: Mathworks, Natick, MA), voltage induced on a receiver coil due to RF excitation pulse from the transmit coils must be reduced by at least 80dB to make this voltage comparable to the voltage induced from the spins. Note that more decoupling is needed to bring coupling to the noise level depending on the required SNR. In this study, magnetic field decoupling of 75dB is achieved between transmitter and receiver. This method of transmit/receive isolation enables detection of MR signal during RF excitation which is significant for imaging species with ultra short T2 values, and measurement of spin properties during excitation.

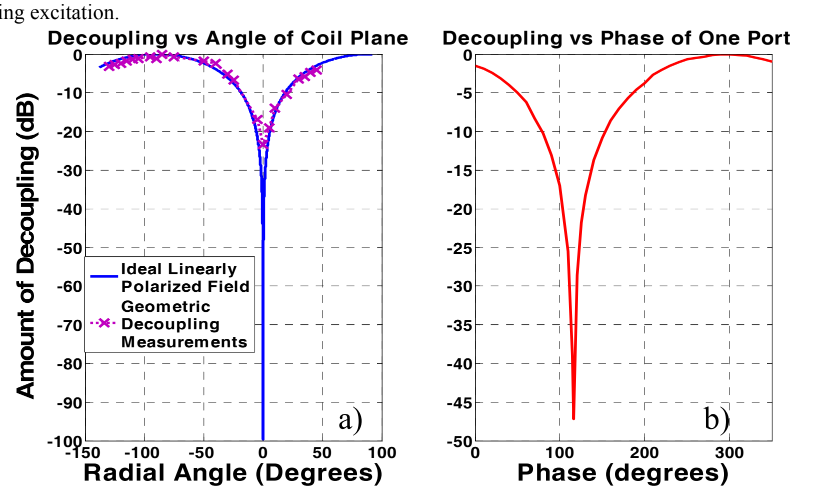

Figure1: (a) Linearly polarized magnetic field calculations and measurements with respect to angle of the receiver coil plane and (b) decoupling amount measurements with respect to the phase of the second port of the birdcage coil

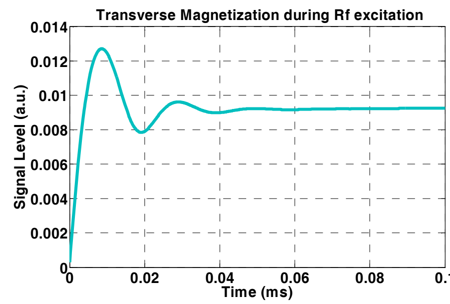

Figure2: Transverse magnetization during rectangular B1 excitation calculated from Bloch equations

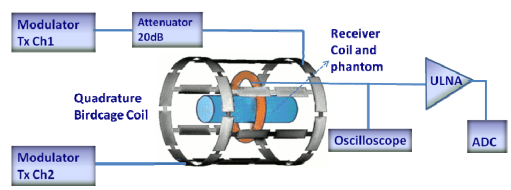

Figure3: Schematic of the implemented setup

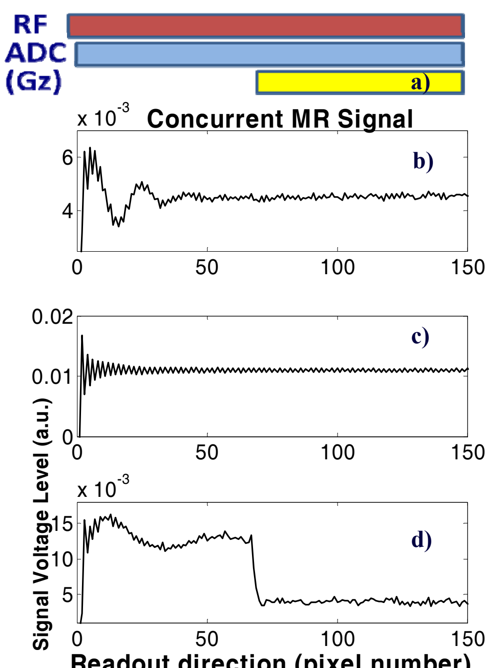

Figure4: (a) Pulse sequence timing diagram; (b) Concurrent MR signal acquired using 3T transmit array system with TR=1000ms, Resolution=512, Acquisition BW: 50Hz/Px; (c) input RF pulse amplitude is increased; (d) Lower input RF amplitude and Slice selection gradient is turned on.
All of the concurrent MR signal data is taken from scanner's raw-data storage and plotted here without any processing.

Theory: In order to accomplish magnetic field decoupling between transmit coils and the receiver coil, linearly polarized magnetic fields can be utilized. Linearly polarized fields have a plane where the electric field is zero, thus the perpendicular component of the magnetic field is zero [4]. This plane can be steered into the angular direction where the receiver loop coil lies (Fig.1). Components of the magnetization vector are calculated [5] for rectangular RF excitation (MATLAB) and the transverse magnetization is shown in Fig.2. The expected MR signal for a rectangular RF excitation should yield a decaying oscillation.

Method: Schematic of experiment setup is given in Fig.3. Note that the RF power amplifiers following the modulators are discarded in the setup since they introduce a significant noise/voltage fluctuation during excitation. Two methods of field decoupling is used in the experiments that result in a decoupling of 75dB. First, geometric decoupling of 25dB is achieved by simply rotating the receiver coil against one of the transmit coils. This method is limited to 30dB decoupling since the transmit coil is not completely linearly polarized and it is a slightly elliptically polarized. Therefore a second transmit coil is driven with another phase/amplitude-controlled source which provides 50 dB decoupling. Once the RF signal is reduced to noise level (1mVp-p) of the oscilloscope (Tektronix, TDS 5052), the receiver loop is connected to MRI system's digitizer via ultra low noise preamplifier circuit. Pulse sequence diagram of modified FLASH sequence that is used to detect the MRI signal is shown in Fig.4a.

Results: Fig.4b presents the MR signal acquired using Siemens 3T Tim Trio Transmit Array System. The raw data is acquired with all the gradients are turned off, meaning that signal is acquired from the whole sample. When the B1 field is increased, the frequency of the oscillation in the MR signal is observed to increase Fig.4c. Turning on the slice selective gradients in the data acquisition chain, the MR signal decreases in magnitude (Fig.4d) which can be interpreted as the first step for a possible gradient encoding scheme to be implemented in the ongoing studies.

Conclusions: Observation of transverse magnetization during excitation is a promising approach for investigation of additional spin properties. The proposed method enables simultaneous transmission of RF excitation pulse and reception of MR signal by steering the zero-magnetic field plane formed by linear polarization of transmit coil fields using a transmit array system. Unlike the other isolation approaches, our technique requires neither high power demands for off-resonant excitation; nor post processing algorithms for frequency modulated B1 field based reconstruction. In current implementation, the SNR of acquired concurrent MR signals is lower than the SNR of FID signals obtained from a standard excitation/acquisition scheme, alternative of additional methods are necessary to increase the SNR of the concurrent MR signal. Very low power requirement is the one of the important features of the proposed method. Another advantage of the proposed method is that it can easily be combined with other methods to increase performance. The method does not have a concrete spatial encoding scheme, yet it is compatible with both gradient encoding and RF-encoding approaches.

References: [1] Brunner D, ISMRM 2011; [1] Brunner D, ESMRMB 2011; [3] Idiyatullin D, ISMRM 2011; [4] Eryaman Y, MRM 2010; [5] Roberts J, Concepts in Magnetic Resonance, 1991