Studies on MR Reception Efficiency and SNR of Non-resonance RF Method (NORM)

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INTRODUCTION: Non-resonance method (NORM) for MR signal excitation and reception has been advocated due to its unmatched advantages in multinuclear and parallel imaging applications (1). In this work, we established a simulation model and systematically investigated the reception efficiency and SNR of the NORM technology using numerical analysis and in vivo MR imaging. The results were validated with the conventional resonant coil method. For comparison, human leg images at 7T were acquired and presented.

METHOD: Although the non-resonance circuitry can be realized in different ways, in this study, we used microstrip to implement the non-resonance method. The connection setup for non-resonance method in MR experiment is shown in Fig 1. To evaluate the reception efficiency using numerical method, a model for non-resonant and resonant coils was established as shown in Fig 2. The radiation source was used to mimic excited bulk spin.

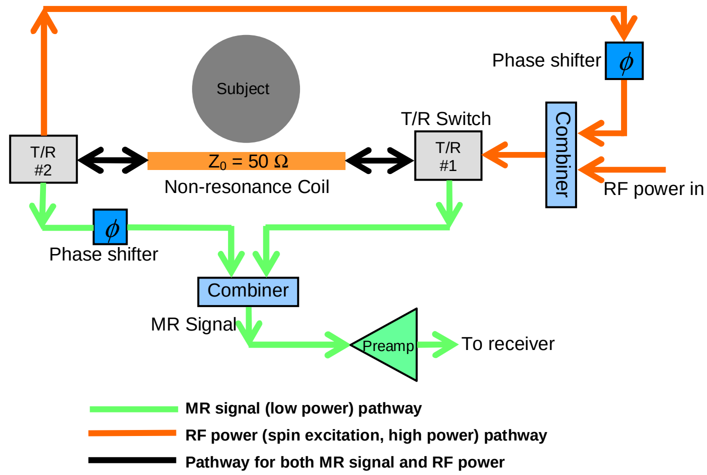

Fig. 1 Block sketch for the connection circuit of the proposed **no**n-**r**esonance **m**ethod (**NORM**) coil or one non-resonant element in a coil array. During the excitation phase, RF power from the RF amplifier is delivered to the power combiner from the RF amplifier, via a power combiner and T/R switch #1 to the non-resonant coil (with a characteristic impedance of 50 Ohm), and then the residual RF power coming out from another end of the non-resonant coil goes to the input port of the power combiner via T/R switch #2 and a phase shifter which ensures the currents/voltages are in phase at the input port of the power combiner. When the RF power goes through the NORM coil, the RF magnetic field (B1) is generated and the MR sample is excited. During the reception phase, MR signal radiated from the excited sample is detected by the NORM coil and transmitted to the two T/R switches #1 and #2, and then the MR signal from one end of the non-resonant coil goes though a phase shifter in order for it to be in phase with the MR signal coming out from another end of the non-resonant coil. After the phase adjustment, the two signals are combined at a power combiner. The combined MR signal goes to the preamplifier to get amplified before the signals are sent to the Receiver of the MR system. MR image or spectroscopy is then obtained. Compared with the previous connection shown in ref 1, the RF excitation power should be much reduced due to the re-use of the residual RF power although the reception part kept almost the same.

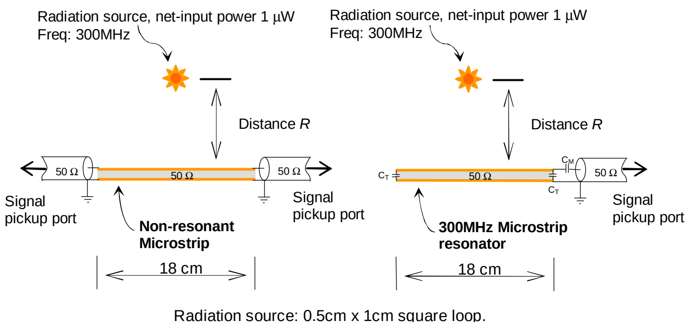

Fig. 2 A simulation model for investigating the reception efficiency of NORM technology and the conventional resonance technology. Both coils were made from microstrips with the same characteristic impedance, dimensions, and substrates. The resonant coil was terminated with termination capacitors on each side to form a resonator. FDTD algorithm was used to calculate the electromotive force (EMF) generated on the coils due to the radiation source.

With normalized 1 μw net input power on the radiation source, the electromotive force induced in non-resonant and resonant coils were numerically computed by using FDTD algorithm. To validate the MR SNR in in vivo system, non-resonant and resonant coils with identical dimensions and substrates were built and used to acquire the leg images from healthy volunteers at 7T. Most importantly, both coils were matched to system 50 Ohm. The distance between the coil and subject was kept same in the comparison study.

RESULTS: Based on the model established, FDTD simulation results show the induced EMFs in the non-resonant and resonant coils with different distance of radiation source were nearly the same (Table 1), which means the non-resonant coil has the same reception efficiency over the conventional resonant coil. This can also be seen in Fig 3. In the human leg MR SNR comparison at 7T, it illustrated the same result – Highest achievable SNR of the non-resonant coil was 2599:1 while highest achievable SNR of the conventional resonant coil was 2429:1. No statistical difference was observed.

Table 1. Simulated electromotive force on the non-resonant and resonant coil based on the model shown in Fig 2

Distance *R* (cm)	1	2	3	4	5
EMF (mV) NORM / Resonator	3.29/3.18	2.22/2.19	1.38/1.37	0.86/0.856	0.566/0.562
Distance *R* (cm)	6	7	8	9	10
EMF (mV) NORM / Resonator	0.394/0.391	0.286/0.283	0.217/0.214	0.168/0.166	0.135/0.133
Distance *R* (cm)	12	14	16	18	20
EMF (mV) NORM / Resonator	0.0924/0.0912	0.0694/0.0691	0.0557/0.0558	0.0476/0.0476	0.0421/0.0427

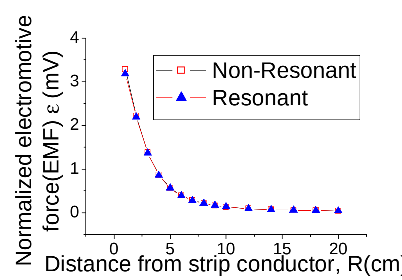

Fig 3 Plot of EMF induced in the non-resonant coil and resonant coil from a 1uW radiation source at different distance from the coils.

CONCLUSIONS: Non-resonance method is advantages in MR signal excitation and reception. Due to its frequency independent property, a non-resonant coil can be used for MR examinations for any nucleus at any field strength. With the use of microstrip, the non-resonance method would provide superior decoupling performance in parallel imaging arrays. These advantages of the non-resonance method are not a trade-off of MR sensitivity.

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REFERENCES: (1) Zhang X, et al, ISMRM 16, p435 (2008).

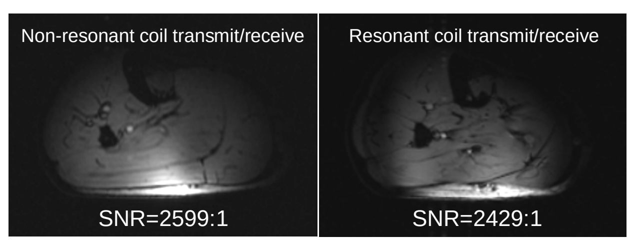

Fig. 4 SNR comparison between the conventional resonant microstrip coil and non-resonant microstrip (NORM) coil at 7T. The gradient echo images were acquired with the same corn oil phantom. The experiment setup and acquisition parameters are exactly the same. The distance between the coil and subject was the same.