Non-resonant microstrip (NORM) RF coils: an unconventional RF solution to MR imaging and spectroscopy

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INTRODUCTION: Conventionally MR RF coil is a resonant device which resonates at the Larmor frequency so that the NMR signal in question can be excited and received. Obviously NMR experiments with different nuclei or at different static field strengths require different RF coils which resonate at desired frequency or frequencies. The resonance requirement of RF coils creates many experimental complexities and technical challenges particularly in designing high frequency coils, double or multiple tuned coils and parallel imaging arrays. In this work, we present an unconventional RF coil solution using non-resonant microstrip transmission line for MR applications. This non-resonance coil technique significantly simplifies the RF coil design and also overcomes numerous RF technical difficulties in designing high frequency coils, multiple tuned coils and parallel imaging coil arrays. ^{1}H MR images and ^{13}C spectra acquired using the non-resonant coil and the coil array were presented to demonstrate the feasibility of the technique. NMR sensitivity comparison was also performed between the non-resonant coils and conventional resonant coils.

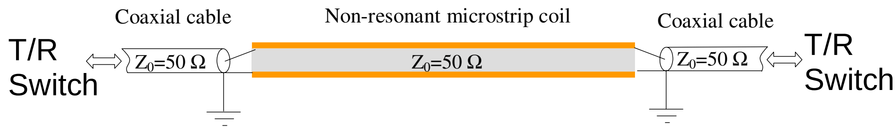

Fig. 1 Diagram of the **no**n-**r**esonant **m**icrostrip (NORM) coil and its connection to the MR system. The characteristic impedance of the microstrip is designed to be 50Ω which ensures impedance match to the system. Therefore, unlike the conventional resonant RF coils, there is no need to have matching and tuning elements (e.g., capacitors and/or inductance). Because of the non-resonance feature, a NORM coil can operate with any frequency for MR experiments with any nucleus at any static field strength. In other words, a NORM coil is able to serve as a 1H imaging coil and also multiple tuned coils for multi-nuclear MR applications. This is a truly "one-fit-all" RF coil.

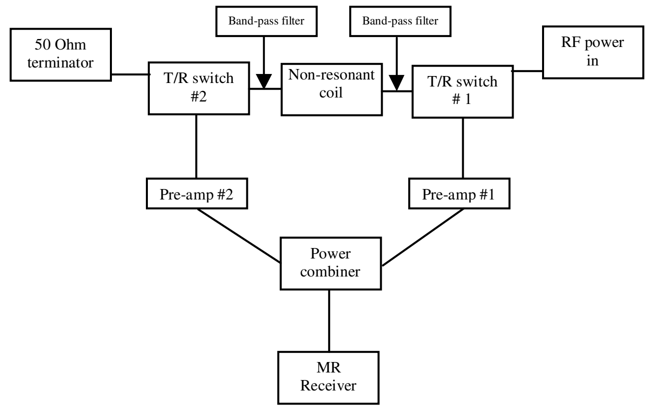

Fig. 2 Block sketch for the circuit of the proposed **no**n-**r**esonant **m**icrostrip (**NORM**) coil or one non-resonant element in a coil array. During the excitation phase, RF power from the RF amplifier is delivered from the RF amplifier, via T/R switch #1 and a band-pass filter (optional) to the non-resonant microstrip coil (with a characteristic impedance of 50 Ohm), and then the residual RF power goes to the 50 Ohm terminator via a band-pass filter (optional) and T/R switch #2. 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 received by the NORM coil and transmitted to the pre-amps #1 and #2 through the two T/R switches #1 and #2, and then is combined at a power combiner and further transmitted to the Receiver of the MR system; MR image or spectroscopy is obtained.

METHOD: To attain an efficient signal excitation and reception, the characteristic impedance of the non-resonant microstrip coils was designed to 50Ω, matching to the MR system. Based on the calculation and bench test, the width of the strip conductor of the non-resonant coil was 17-mm and substrate thickness was 6-mm. The dielectric material was Teflon. Length of the coil was 30 cm. The two ends of the non-resonant microstrip were connected directly to the system T/R switches via the 50Ω coaxial cable, without the use of any tuning/matching capacitors as shown in Fig 1. This non-resonant microstrip structure can take any frequency for MR imaging and spectroscopy. Fig 2 depicts system connection method for the non-resonant coils. The two T/R switches and two preamps ensure the signal reception efficiency. In Fig 2, if no T/R switch #2 and pre-amp #2, and the one end of the non-resonant coil directly connects to the 50Ω terminator, then at least 50% of the NMR signal will be lost in the 50Ω terminator and NMR SNR will degraded by half as reported in (1). To demonstrate the parallel imaging array capability, a 4-element NORM coil array was designed and constructed. The gap between adjacent elements was 20 mm which meets the broadband decoupling condition of the microstrip (2). To validate the sensitivity of the NORM coil, a resonant coil with the same dimension was build for the SNR comparison. All MR experiments were performed on a GE 7T whole body MR system.

RESULTS: Reflection coefficient S11 measured at the input port of the NORM coil was better than -25 dB, indicating a good impedance match. In the 4-element NORM array, the decoupling between the two adjacent non-resonant element was better than -35dB and between the next closest elements was better than -50dB, illustrating the excellent decoupling among the elements. Fig 3 shows the result of the SNR comparison between the same-sized NORM coil and the conventional resonant microstrip coil at 7T. The highest achievable SNR of the two coils are comparable (NORM coil is slightly better). With the same NORM coil, the ^{13}C spectrum was obtained from a corn oil phantom without any coil adjustment, as shown in Fig 4. Obviously, if the NORM coil is fed by different frequency, the spectra of ^{31}P, ^{23}Na, ^{19}F, ^{17}O, etc, from appropriate samples can also be detected. The NORM coil is truly a one-fit-all coil. Finally, the 4-element NORM coil array was used to acquire ^{1}H images from the same corn oil phantom at 7T. Well-defined image profiles from each individual NORM element imply the great performance of parallel imaging with the NORM array at 7T.

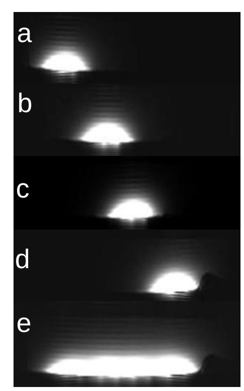

Fig. 5 Gradient echo images acquired from a corn oil phantom using the 4-element non-resonance microstrip array at 7T. a-d are the individual image acquired from each non-resonant element, and e is the combined image. FOV = 30cm x 30cm.

CONCLUSIONS: Non-resonant coil is feasible and efficient for MR application. The reception efficiency of non-resonant coil is comparable to the conventional resonant coils. The proposed NORM coil design can significant simply the conventional coil designs and provides a promising solution to almost all kinds of RF coil designs.

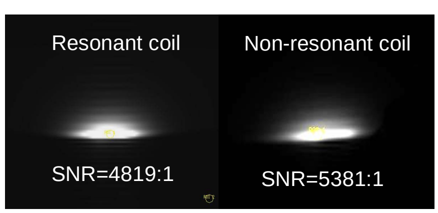

Fig. 3 SNR comparison between the conventional resonant microstrip coil and non-resonant microstrip (NORM) coil at 7T. The gradient echo images were acquired with the same corn oil phantom. The experiment setup and acquisition parameters are exactly the same. The distance between the coil and subject was the same.

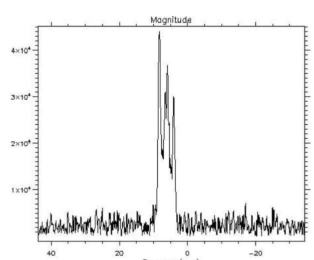

Fig. 4 7T ^{13}C spectrum acquired from an corn oil phantom (natural abundance) using the same non-resonant coil that was used for 1H imaging at 7T.

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REFERENCES: (1) Lee R, et al, MRM 45: 673-683 (2001); (2) Helszajn J, Microwave planar passive circuits and filters.