Onboard RF Combination for Receiver Channel Reduction

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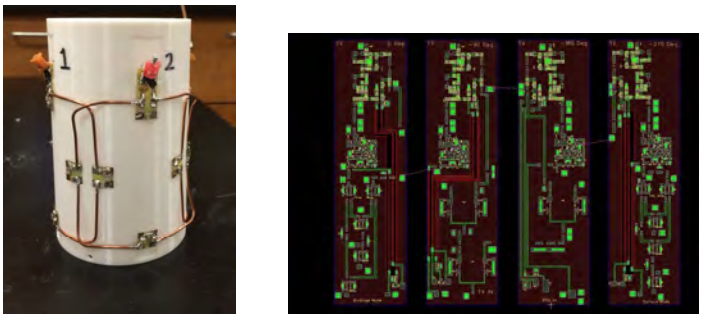
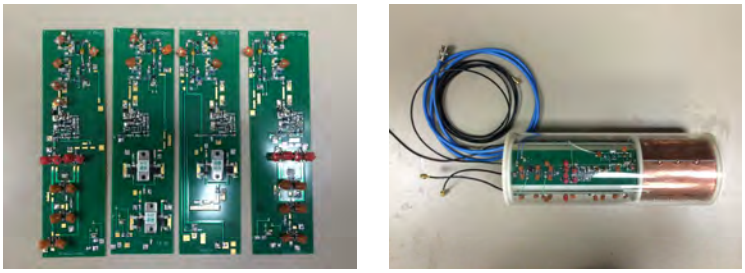
Introduction: Multi-channel surface receiver arrays are a popular approach for improving the signal-to-noise ratio (SNR) in MRI when sample noise is dominant[1]. It has been demonstrated that even at the center of the human head where conventional circularly polarized birdcage coils perform very well, the SNR can still be significantly increased by using a receiver array[2]. In order to support their functionality, multi-channel receiver systems are normally required on a MRI scanner. However, the number of channels a system can support may be less than desired and sometimes, a system simply does not support multi-channel receive. The aim of this study is to develop an onboard RF combination circuit that can support multi-channel signal reception with fewer or just one RF receiver channel.

Methods: A four-channel receiver array was developed for rat brain imaging at 9.4 Tesla (400 MHz). It consists of four rectangular loops that are 66-mm wide and 70-mm long (Fig. 1a). The four coils were mounted on a 72-mm diameter plastic housing with a shield 12-mm away. Each element was tuned by using ten 8-pF and two 4.7-pF capacitors distributed at four locations and matched to 50-Ohm by using a balanced Pi-network. A T/R switch is connected to each coil to switch between transmit and receive modes. During RF transmit, corporate-fed Wilkinson's power dividers and phase shifters were used to split single RF power input to four different branches and form a circularly polarized field (Figs. 1b and 1c). During RF reception, signals from each channel are amplified by a low-impedance low-noise amplifier at first. The electrical length between the input of the LNA and the input of the Pi matching network was adjusted to multiples of 180^{o} to facilitate the decoupling. The amplified signals are then combined via a two-stage network of quadrature hybrids (Figs. 1b, 1c and 2). Appropriate phase shifting was applied so that maximum signal is achieved at the center of the coil array. The combined signals were sent to a single-channel receiver system on a Bruker's scanner.



(a) (b)



(c) (d)

Figure 1. (a) The 4-channel array. (b) The schematic and (c) the implementation of the RF front-end. (d) The finished coil set.

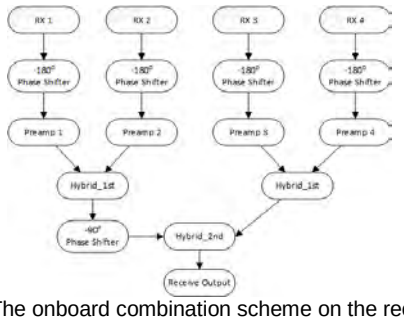
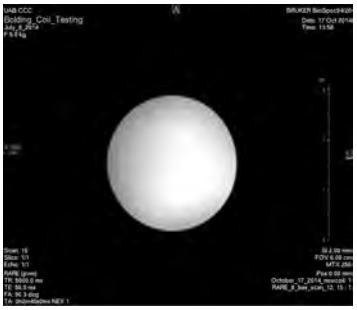


Figure 2. The onboard combination scheme on the receive end.



(a)

Figure 3. Spin-echo images acquired on a 9.4 Tesla scanner.

Results and Discussion: Figure 2(c) shows the finished front-end circuit boards which consist of four T/R switches, four LNAs, three high-power Wilkinson's power dividers, and multiple quadrature hybrids. The four circuit boards were mounted behind the shielded four-element array (Fig. 1d) inside an acrylic tube of 4-in in diameter. Experiment was performed by using a 1-in diameter saline water phantom filled with 55-ml NaCl solution. Spin-echo images were acquired by using 5000-ms TR; 56-ms TE; 60-mm by 60-mm FOV; 2-mm slice thickness; 256-by-256 matrix size; and one average (Fig. 3). The SNR, which was measured as the ratio of the signal intensity at the center of the phantom to that in the background, was 202.

Conclusions: An onboard circuit was prototyped to combine signals from multiple receiver elements into a single output by using quadrature hybrids and phase shifters. Experiment results demonstrated its validity. This design can be used to support more receiver elements than a scanner can physically support.

References: 1) Roemer, P. B., et al. "The NMR phased array." Magnetic resonance in medicine 16.2 (1990): 192-225. 2) Wiggins, G. C., et al. "32-channel 3 Tesla receive only phased array head coil with soccer ball element geometry." MRM 56.1 (2006): 216-223.