A High Field Transceiver/Receive-Only Surface Coil Array

R. G. Pinkerton[1,2], E. A. Barberi[3], R. S. Menon[1,2]

[1]Department of Medical Biophysics, University of Western Ontario, London, ON, Canada, [2]Imaging Research Labs, Robarts Research Institute, London, ON, Canada, [3]XLR Imaging, London, ON, Canada

Introduction

As the static magnetic field strength increases, the wavelength of the operational radio frequency (rf) approaches the dimensions of the coil and volume of interest. There arise several imaging problems in this full wavelength regime such as; increased radiation losses, increased power deposition, and dielectric resonance effects that create inhomogeneous images and signal loss. To reduce total power deposition and dielctric resonance effects, an appropriately sized array of surface coils may be used instead of whole body volume coils to transmit rf to specific regions of imaging interest (VOI). Presented herein is a novel high field surface coil array that can both transmit and/or receive with the added benefit of allowing arbitrary surface coil placement to optimize for fast parallel imaging techniques while maintaining the high signal to noise ratio (SNR) inherent to surface coil designs. The ability to independently transmit and receive through each surface coil within this array enables either transmit and/or receive-only fast parallel imaging techniques to be employed.

Methods

The transceive array coil (as shown in Fig. 1) consists of 8 identical rectangular surface coils (21.0 cm length, 8.1 cm width) constructed out of 50 □m thick 1.27 cm wide copper. Each surface coil element coil element was conformed to the outside of an acrylic 24.1 cm i.d. 25.4 cm o.d. cylindrical shell. A simple and effective purely capacitive decoupling network [1] was employed between the surface coil elements to eliminate the effects of nearest neighbour mutual inductance on resonance splitting and signal and noise correlation. A second rf coil is required to transmit rf power into the VOI when the transceive array is in receive-only mode. To fulfill this purpose, an oversized head (OH) coil with transmit-only/receive-only capability (TORO) is used along with the transmit/receive driver to dc bias the active decoupling networks on both coils. The OH coil is a hybrid resonator (44.4 cm i.d. 45.7 cm o.d) with 3 distributed capacitors along each of its 32 rungs. The third rf coil used in this experiment is the hybrid birdcage used on our system (26.7 cm i.d, 27.9 cm o.d.) with 2 capacitors along each of its 16 rungs. The purpose of the hybrid birdcage is to serve as a system standard SNR reference to compare with the performance of the transceive array. All imaging data was obtained using a 4 T Varian Unity INOVA whole-body MRI/MRS system (Palo Alto, CA, USA) interfaced to Siemens Sonata Gradients and Amplifiers (Erlangen, Germany). A FLASH sequence was used to acquire all images. The imaging parameters used for all head images are: $FOV_x = FOV_y$= 24 cm, TR = 20 ms, TE = 5 ms, a slice thickness of 1 cm, tip angle of 11˚, $N_{RO} = N_{PE} = 256$, $N_{ave} = 2$, $\square_{RO}$ = 2.6ms. SNR maps were calculated for all coils using a magnitude NMR phased array method [2] to account for additional magnitude noise accumulating from combination of multiple receiver channels.

Results

The SNR images of each coil configurations are shown in Fig. 2. The mean SNR values within the brain volume and at the center of the brain (50 x 50 pixel region of interest (ROI) as outlined by the white box in Fig 6d) are shown in Table 1. A SNR decrease of 10.7% and 22.3% is measured in the center brain region and a SNR increase of 37.7% and 15.6% over the brain volume for the transceive array in transceive mode and receive only mode respectively compared to the standard head birdcage. A maximum of a 9-fold increase in SNR is measured in the brain region nearest to transceive array compared to the reference birdcage. Both the hybrid birdcage values demonstrate a pronounced dielectric resonance in the centre of the coil, with the centre SNR considerably enhanced relative to the mean.

Discussion

Through the use of capacitive decoupling networks and coil placement, a transceive array is able to transmit and receive through each surface coil element independently while maintaining the use of conventional 50Ω amplifiers and pre-amplifiers. The variability of subject loading on each surface coil element within the array varies the transmit power required for a 90˚ tip. A solution to this problem would be to use multiple low power rf amplifiers to transmit to each surface coil element independently, or to implement the design on an elliptically conformal coil former to provide equal loading of all elements. This first solution would provide i) the ability to individually tailor the B_1 field (both magnitude and phase) of each coil (allowing for means to achieve transmit SENSE [3], ii) a means to accurately calibrate the transmit power delivered to each coil, and iii) would be less costly than a single high power rf amplifier.

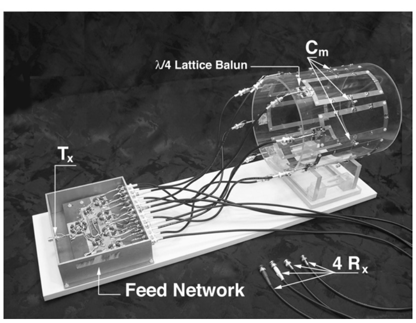

Figure 1: Transceiver array with capacitive decoupling networks (C_m) re placed between each surface coil element within the transceive array.

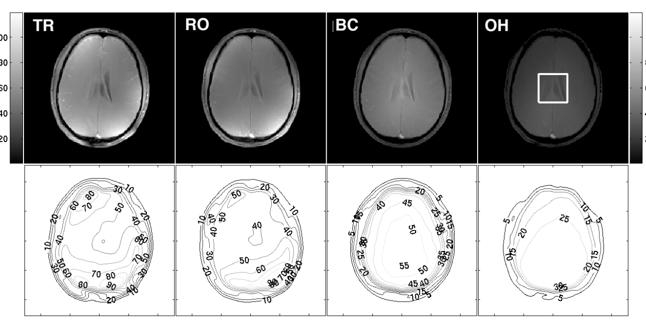

Figure 2: SNR image (above) and smoothed contour plot (below, Gaussian filtered data σ = 5 voxels) of a human head for the Transceive Array (24.1cm i.d.) in a) Transceive mode, b) Receive-Only mode (transmit with Oversized Head coil in TORO mode), c) Hybrid Birdcage (26.7cm i.d.), and d) Oversized Head Coil (44.4cm i.d.). The white box in image d) corresponds to the ROI for mean snr calculations shown in Table 1.

Coil Type	TR	RO	BC	OH
Mean SNR	57.3	48.1	41.6	23.8
Center SNR	48.1	41.9	53.9	28.6

Table 1. SNR comparison for total mean snr within head volume, and mean snr within a 50x50 pixel centered brain ROI (as outline by the white box in the OH snr image in Fig 2 (left)) for the transceive array in transceive mode (TR), receive only mode (RO), hybrid birdcage (BC), and oversized head coil (OH).

References

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