An Elliptical Open-Faced Transceive Array for Ultra High Field Parallel Imaging and fMRI Applications

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Introduction

A number of challenges are being encountered when designing parallel imaging coil arrays for ultra high frequencies. Several effects arise when the dimensions of the coil approach the RF wavelength. In addition geometrical constrains make it difficult to use separate volume transmit coil/receive-only-arrays within a confined head gradient setup. Furthermore, strong coupling to the sample at ultra high frequencies mediates interaction between the separate array elements and makes it more challenging to decouple them. However the strong sample-coil coupling aids the use of transmission line elements with RF ground planes in close proximity. Transmission line arrays with the ability to transmit and receive with the same coil resonance structure address all these issues [1,2]. The ability to present fMRI tasks as well as the patient comfort is greatly helped by open-faced coil designs [3]. It has been demonstrated by Vaughan [4,5] that open-faced transmission line TEM coils can be built, that compensate for the missing resonance elements by adjusting RF current and phase. Here, a close fitting elliptical transceive TEM array coil design is presented. The resonant elements are realized in microstrip technology and decoupled for individual phase and amplitude control.

Methods

A fifteen-channel elliptical transceive transmission line array was built. The dimensions are 24 cm in the long and 19 cm in the short axis. The opening in front of the face is 12 cm wide. Fifteen of the array elements were embedded in the coil holder (Fig. 1). A ¼-inch thick Teflon substrate was used and the coils were built from copper tape according to microstrip design formulas [6]. The ground conductor for each array element was 2cm wide and electrically separated from neighboring elements to avoid eddy currents. The array elements were evenly spaced within the holder, with a distance of 3.5cm between them. Imaging experiments were performed on a 7 Tesla Magnet (Magnex Scientific, UK) equipped with a Varian console (Palo Alto, CA) and Siemens gradient amplifier (Erlangen, Germany). All experiments were performed using a 16 channel digital receiver system that was developed in-house; this receiver used an Echotek (Huntsville, AL) ECDR-814 board to over-sample the 20 MHz IF at 64 MHz and 14 bits, allowing for quadrature detection, band pass filtering and down conversion to be done digitally. A single 8 kW RF amplifier (CPC, Brentwood, NY) was utilized and the RF power was split 16-ways (Werlatone, Brewster, NY) leaving the addition of a sixteenth, removable coil as an option. The transmit phase increments for each channel were adjusted for optimal image homogeneity. T/R switches with low insertion loss of 0.2dB in each transmit path blocked transmitter noise during reception and enabled the use of low noise preamplifiers.

Results and Discussion

Sufficient coil decoupling was achieved without preamplifier decoupling by using a decoupling capacitor [7] between neighboring elements. With this, no resonance peak split was observed and the coils could be tuned and matched for each subject independently. The average Q_0/ Q_L ratio of the individual coil elements was measured to be 265/60, indicating a 75-80% transmit efficiency. Decoupling capacitor values of 0.5pF to 1.8pF were needed to achieve decoupling values of at least–15dB between neighboring elements for the unloaded coil when measured in a S12 network analyzer measurement. Loaded with a human head load the coil decoupling between neighboring elements increased and could be adjusted to be better than -20dB. After the initial decoupling capacitor adjustments there was no need to readjust decoupling for individual subjects, which simplified the experimental setup time significantly. By adjusting the transmit phase and amplitude for each array coil we achieved good imaging performance while obtaining RF shimming capabilities in addition (Fig.2). Future work will focus on improving the initial results by systematically studying the relationship between phase and amplitude adjustments on RF efficiency and homogeneity.

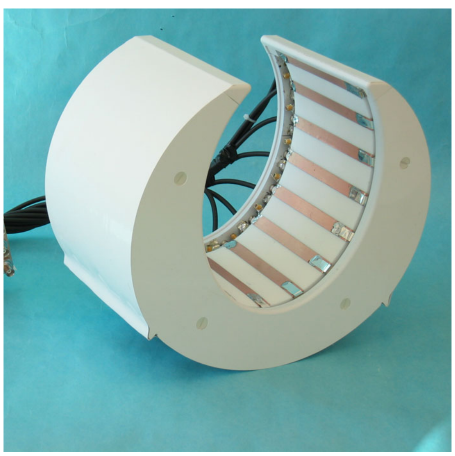

Fig. 1: Shows the open-faced elliptical array coil. The width of the coil opening was 12 cm.

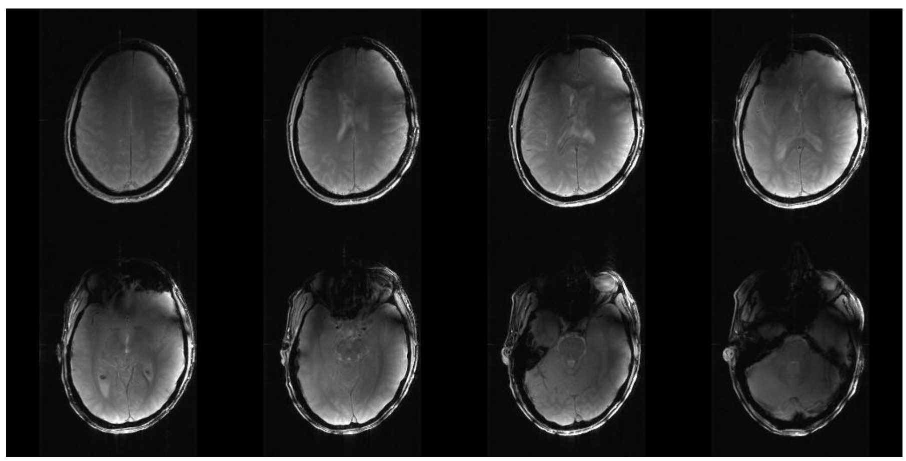

Fig. 2: Scout FLASH image acquired with the fifteen channel open-faced array: TR/TE=20ms/5ms, 256x256, FOV 25cmx 25cm, Slice thickness: 5mm.

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