A geometrically adjustable 16 Channel Transceive Transmission Line Array for 7 Tesla.

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Introduction

At high fields, multi-element transmit arrays with a large number of independent channels are of considerable interest for RF transmission. With independent phase and amplitude control of its elements, such coils can be used to support RF shimming methods that can mitigate the sample-induced RF non-uniformities [1-3]. Furthermore, such an array can immediately be used for transmit [4, 5] and receive parallel imaging applications, and can be combined with additional receive-only arrays by using preamplifier decoupling [6] on all coils during reception. Feasibility of building up to 32-element transmit/receive array coils based on transmission line elements operating at ultra high frequencies has previously been demonstrated [7, 8]. However, given the strong coupling between the sample and the coil at high RF frequencies, it was difficult to achieve similar performance over the entire brain for different subjects and/or for varying head positions in a given subject in the RF coil. One potential solution to this problem is to design a coil that allows for adjustments of the coil geometry depending on the head size and shape, so a more balanced spacing between the subject and the individual resonance elements can be rapidly attained. The biggest hurdle for such an adjustable coil geometry is the need for equally 'flexible' decoupling strategies [9]. This hurdle can be surmounted by designing a capacitive patch between coils that allows for flexible geometries and adjusts the decoupling capacitance nonlinearly depending on the resonance element distance and geometry. We present a 16 element array that accomplishes this and provides excellent parallel imaging (SENSE [10]) and RF shimming capability at 7 Tesla.

Methods

A sixteen-channel geometrically adjustable transmission line array coil and holder was designed (Fig.1). The resonance elements were built from Cu-tape and a 12 mm thick Teflon substrate was used. The ground conductor for each such array element was 4 cm wide and electrically separated from neighboring elements. The length of the resonance element conductor strip was 15 cm. The mechanics of the coil allow for rapid spatial readjustment of the individual transmission line elements by 2.5 cm radially. Besides individual adjustment all elements can also be moved together. This way we can change the 'global' coil geometry between a minimal setting of 22 cm in the long axis (Top-Bottom) and 16 cm in the short axis (left- right) to a maximal geometry of 26 cm x 21cm. The elements were evenly spaced within the holder for the smallest possible coil geometry (16x22cm^2). Foam cushion around the inside of the coil ensure patient comfort and a minimal distance of 1.5 cm from the resonance elements. One element was shortened to 7 cm length and the neighboring elements were altered to create an opening in front of the face that allowed visual presentation. High voltage ceramic chip capacitors (ATC 100E) were embedded into the Teflon substrate and shielded to minimize patient E-field exposure. We designed a capacitive patch network between coils that allows for flexible geometries and adjusts the decoupling capacitance depending on the resonance element distance and geometry. As the dielectric for these patches we used 1mm Teflon. All experiments were performed using a 16 channel digital receiver system that was developed in-house. All data presented here were acquired with equal RF transmit power per channel. The transmit phase increments for each channel were adjusted for optimal image homogeneity. T/R switches in each of the 16 transmit paths blocked transmitter noise during reception and enabled the use of low noise preamplifiers in close proximity of the coil.

Results and Discussion

Minimal coil decoupling in the order of ~10-15dB between neighboring elements was achieved for various geometries. A typical noise correlation matrix is shown in Fig. 2A. The required decoupling capacitor values ranged from 0.5pF to 2.2pF depending on geometry, load and resonance element position. The resonance elements could be tuned and matched independently for each subject and no resonance peak split was observed. The biggest gain with such an adjustable coil seems the overall better transmit homogeneity due to the equidistant elements and more gains in SNR circumferentially over the brain, resulting in similar SNR over the cortex whether the frontal or occipital lobes are considered (Fig 2B). As expected for a multi-channel receive array coil the transceiver array also achieves highest SNR in the periphery. Depending on the head size, SNR compared to a 16 element fixed geometry array (20x25cm^2) of same substrate thickness and coil length was at least equal or improved by up to 15% in the center and up to 60% in the periphery. Fig. 3 shows a 7T low contrast image obtained with the adjustable coil. The coil also significantly improved 1-D and 2-D SENSE performance (Tab. 1), attaining average and maximum g-factors of 2.04 and 3.58, respectively, with 16 fold (4x4) reduction and maximal aliasing in the human brain at 7T which is a significant improvement compared to g-factors of 3.30 and 7.37 for the fixed geometry array.

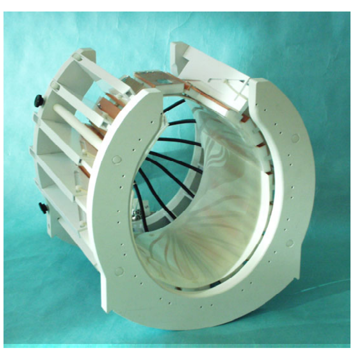

Fig. 1: Shows the adjustable coil holder.

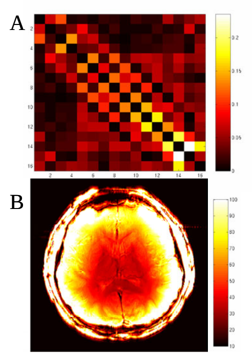

Fig.2: **A**: Noise correlation matrix **B:** SNR image, 336x256, 5mm TR/TE =18ms/6ms, 10deg

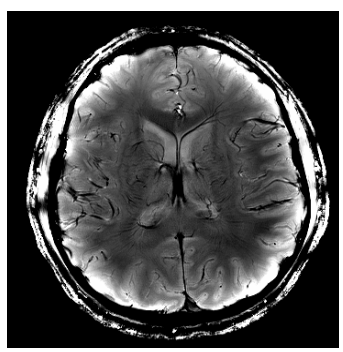

Fig. 3: T2*/Proton density image, 512x512 thk: 4mm, TR/TE= 20ms/5ms, 10deg Intensity corrected

Readout Direction (columns); **Phase encoding Direction** (rows)

Average Max	R=1	R=2	R=3	R=4
R=1	1 1	1.00 1.02	1.02 1.08	1.1 1.27
R=2	1.00 1.02	1.01 1.03	1.03 1.09	1.12 1.30
R=3	1.04 1.14	1.05 1.15	1.09 1.24	1.31 1.73
R=4	1.18 1.44	1.19 1.45	1.35 1.75	2.04 3.58

Tab. 1: 1- and 2-D average and maximal g-factors for the coil. Max. degree of aliasing equals R value given.

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