Improved Homogeneity of the Transmit Field due to Simultaneous Transmission with Phased Arrays and Volume Coils.

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Introduction: Due to RF field/ tissue interactions at high-field, 4-8T, (1,2), the transmit field from head-sized volume coils shows a distinctive pattern of inhomogeneity, with enhanced sensitivity in the center of the brain. Conversely, surface coil phased arrays provide increased peripheral sensitivity. In theory, simultaneous transmission from these two devices could provide a very homogeneous transmission field. Previously Hyde used a volume coil and a single surface coil for simultaneous reception demonstrating improved SNR (3). To avoid interactions between the two coils, a counter rotating current (CRC) surface coil consisting of two parallel rings carrying opposite currents (4) was used. Recently simultaneous reception for improved sensitivity in the center of the human brain has been reported using a volume coil and a CRC array (5). This work describes the use of a CRC phased array in conjunction with a TEM volume coil for simultaneous transmission for improved homogeneity of transmit magnetic field at 4T.

Methods: A 16-element quadrature TEM head volume coil (element id - 31.8cm, shield diameter – 38cm, length 23.9cm) was constructed for 4T (6). The CRC phased array consisted of four 9x10cm CRC surface coils (Fig. 1). Each CRC coil contained two coplanar loops separated by 9mm and connected in series. The intrinsic decoupling between surface coils loaded with a head or a phantom was better than -20dB. Low input impedance preamplifiers (input impedance ~4Ω) were still used to optimize the system performance (5). The intrinsic isolation between the volume and CRC coils was better than -17dB. During transmission, the RF power was split in between the TEM and the phased array. The phases of RF were adjusted so as to provide 0º, 90º, 180º, and 270º phase shifts at the corresponding coils in the array. The phase shift between the TEM and the array was adjusted using a cylindrical phantom and a pickup coil. The transmission network consisted of a four-way splitter and four T/R switches, enabling delivery of RF power to the array during transmission and connection of the surface coils to the preamplifiers during reception. This enables both simultaneous transmission and reception with the CRC array and the TEM volume coil.

Fig 1.

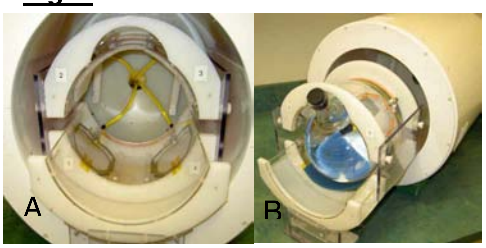


Fig 2.

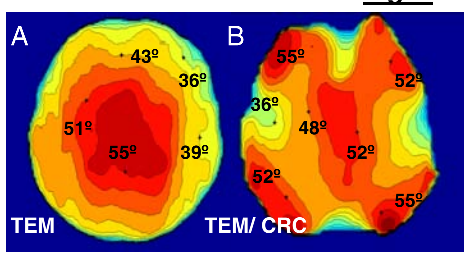
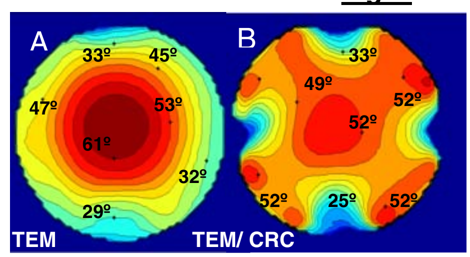


Fig 3.



Results and Discussion: Fig.2 shows the transmit B_1 field obtained by the TEM volume coil alone (2A) and with simultaneous transmission from the volume coil and the array (2B) using a transmit power ratio of 2:1. The transmit B_1 field is substantially more homogeneous than that obtained by the volume coil alone in the regions covered by the array. Increasing the number of CRC coils to 8, or increasing the diameter of the existing 4 coils would eliminate the residual low B_1 regions seen between the coils. To mimic conditions seen at 7T in the human head, where the B_1 varies by more than a factor of two (8), we used a large 3L spherical phantom (o.d. 21.5cm) filled with 50 mM NaCl. RF power was split in 1:1 ratio between the TEM and the phased array. Again, the transmit B_1 field obtained using the TEM and the CRC array simultaneously (Fig.3B) was more homogeneous than that obtained by the TEM coil alone. Additionally, the power required to achieve an average rotation of 90° across the head was the same for both configurations. Previously, high field inhomogeneity corrections have been demonstrated by using phased arrays (2) or multi-port driven volume coils (1). These methods improve field homogeneity due to combining a homogeneous mode with higher order modes, but result in substantial phase distortion. Conversely, in our method, the TEM and phased array have similar phase distributions but different spatial profiles.

Conclusion: We have developed a four-channel CRC phased array and TEM volume head coil capable of simultaneous transmission and reception. Using this system enables substantial improvements in the homogeneity of the transmit B_1 profile as compared to the volume coil alone, which becomes more pronounced with increasing field strength. Further improvements in B_1 field homogeneity can be obtained with larger numbers of surface coils in the phased array.

References: 1) Ibrahim TS et al, MRI 2001;19:1339-1347. 2) Adriany G et al, MRM 2005;53:434-445. 3) Hyde JS et al, MRM 1988:6:235-239. 4) Froncisz W et al, MRM 1986;3:590-603. 5) Avdievich NI et al, Proc ISMRM 13, 2005, p 327. 6) Vaughan JT et.al., MRM 1994;32:206-218. 7) Pan JW et al, MRM 1998;40:363-369. 8) Vaughan JT et.al., MRM 2001;46:24-30.