Comparison of Transceive Phased Array with TEM Volume Coil for Human Brain Imaging at 4 T.

N. I. Avdievich[1], A. S. Peshkovsky[2], and H. P. Hetherington[1]
[1]Radiology, Albert Einstein College of Medicine, Bronx, NY, United States, [2]RF Sensors, LLC, New York, NY, United States

Introduction: Systems with multiple transmitters or receivers have been shown to improve the quality of high-field MRI. Utilization of multiple transmit channels with adjustable phases and amplitudes enables the homogeneity of transmit B_1 field profile to be improved by "RF shimming" (1,2) and use of spatially selective RF pulses (3). However, this configuration is not yet common. Use of multiple receiver channels, is quite common and enables parallel imaging techniques and SNR enhancing phased arrays to be used (4). These experiments may be carried out using either a volume coil transmit/phased array receive setup or a transceive phased array arrangement, in which transmission is provided by a single channel (equipped with a network of power dividers, phase shifters and T/R switches) and reception is conducted separately by each RF coil of the array (1,5). While proper comparison between these two RF systems should ideally be performed separately for transmission and reception, it is expected that their reception profiles are similar under conditions of sufficiently homogeneous transmission produced by the transmit volume coil or the transceive array (see data below). Therefore, we limit the scope of this work to a comparison of the transmission properties of the transceive array (single channel transmission) and a transmit/receive (T/R) TEM volume coil.

Methods: An eight-channel 4 T (170MHz - ^{1}H frequency) surface coil phased array was built, as shown in Fig. 1. The coils were mounted on the outside of an acrylic holder (od - 25.4 cm, wall – 3 mm) with a spacing of 1.9 cm. Each coil measured 13 x 8 cm and was independently tuned and matched. To decrease radiation losses the array was shielded (od - 33.4 cm, length 25 cm). The surface coils in the array were decoupled inductively using a pair of 1.2 cm coupled loops connected in series with adjacent surface coils. Isolation between the surface coils loaded with a human head (or a phantom – 3.0 L, 50 mM NaCl) was greater than –15 dB. A home-built network (one-to-eight splitter and eight T/R switches with 0.15 dB insertion loss, -50 dB isolation) provided power to the array. The phase of each channel was adjusted so as to provide a 45° increment per channel to produce a total phase shift of 360°. A 16-element quadrature TEM head volume coil was constructed as previously described (6). The coil measured 23 cm in length with element id of 31.8 cm and shield diameter of 38 cm. Two-port drive was utilized for the TEM. Coils were compared in a few different ways. To evaluate the transmit efficiencies of the two coils, we measured the power required to produce a 90° flip angle in a transaxial slice near the center of a head and the phantom. The RF homogeneity was assessed by acquiring maps of the circularly polarized B_1^+ component of the transmit B_1 field (7). To evaluate circularity of the B_1, the B_1^- component produced during transmission, which does not contribute to the MR signal, was also mapped. B_1^- was measured using the same method (7); however, the phase at the driving ports was reversed to produce a circularly polarized field rotating in the opposite direction.

Results and Discussion: First, we compared transmit efficiency of the two coils. The phased array required ~2 dB higher power than the TEM, due primarily to the losses in the array driving network (also ~2 dB). Additionally, the TEM had a larger excitation volume and, thus, provided greater spatial coverage. The transceive phased array produced slightly better (±12% vs. ±15% max variation over the brain) homogeneity of the B_1^+ field than the TEM coil. The B_1^- component produced during transmission was also greater for the TEM. The ratio of B_1^-/B_1^+ averaged over the brain measured –10 dB and –12 dB for the TEM and transceive array, respectively. These values, however, correspond only to 5% (TEM) and 3% (array) loss in the average amplitude of the transmit field. Fig.2 shows maps of the B_1^-/B_1^+ ratio measured using the TEM and the transceive array on a head and the phantom. The pattern of the B_1^- component was very characteristic to each coil and was similar both for the head and the phantom, which implies that it is mostly determined by the driving configuration. The transmit B_1 field is nearly linear in the vicinity of the driving ports. SNR measured from the transaxial images near the center of the head (phantom) was very similar for both coils. It was ~ 4-5 times better in the periphery and ~ 10% better in the center of the head than that obtained using the TEM in the T/R mode.

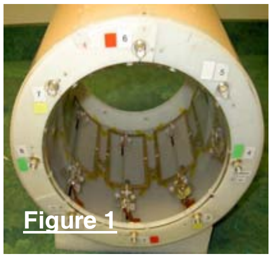

Figure 1

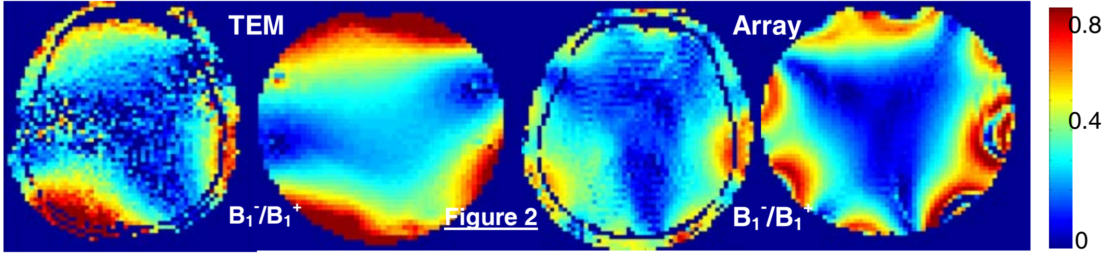

Figure 2

Conclusion: The transceive array provided substantially better SNR in the periphery and similar SNR in the center of the brain. Although the TEM was more efficient with regards to transmission, this was largely due to losses associated with power splitting. Alternatively, when multiple low power RF amplifiers of sufficient strength are available, the transceive array may provide an advantage over single output high power RF amplifiers, especially at high field strengths. Finally, the simpler engineering requirements for the construction of a transceive array can be a significant advantage..

References: 1) Adriany G. et al, MRM 2005;53:434-445. 2) Ibrahim TS et al, MRI 2001; 1339-1347. 3) Zhu Y, MRM 2004;51:775-784. 4) Roemer PB et al, MRM 1990;16:192-225. 5) Pinkerton RG et al, MRM 2005;54:499-503. 6) Vaughan JT et al, MRM 1994;32:206-218.7) Pan JW et al, MRM 1998;40:363-369.