An interface to connect a 16-channel transmit array to an 8-channel parallel transmit system

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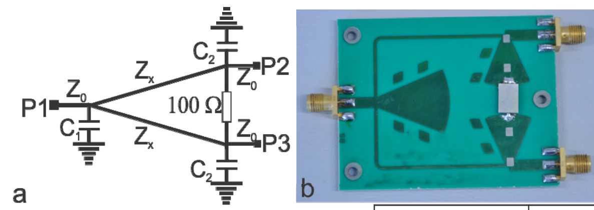
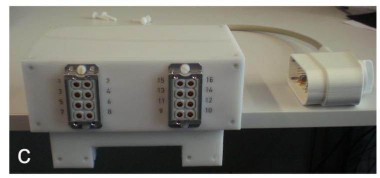
Target audience: RF engineers, researchers interested in ultra-high field (UHF) MRI and parallel transmit (pTx) systems.

Purpose: Dual-row transmit arrays offer additional degrees of flexibility to apply RF shimming and dynamic pTx methods especially to influence the B_1^+ field in the longitudinal direction [1, 2]. Furthermore, at 9.4 T, a 2x8 configuration of loops is preferable because the size of the loops can be quite long for head sized volume arrays in a 2x4 configuration thereby making the coil less effective. This project aims to develop a low loss interface to connect a 16-channel dual-row coil to an 8-channel parallel transmit system.

Methods: The interface module consists of eight miniaturized Wilkinson power dividers (Fig. 1a) realized using planar microstrip transmission lines on low loss Rogers 4003C substrate (ε_r=3.55). The λ/4 transmission line of a Wilkinson power divider was reduced to λ/8 using capacitive loading [3]. The capacitors were realized using microstrip radial stubs (Fig. 1b) instead of lumped components. Experiments were performed on a Siemens Magnetom 9.4 T Tim Tx Array Step 2 whole body MR scanner equipped with eight transmit channels, each delivering up to 1 kW of RF power. Each transmit channel of the pTx system feeds two adjacent coil elements in the same row. The RF phase to the second coil element was delayed by 45° using a coaxial cable (Fig. 2). Two high power connector modules are provided to plug in the 16-channel transmit array.
The coil [1] was tuned and matched to a head and shoulder phantom filled with tissue equivalent solution (ε_r=58.6 and σ = 0.64 S/m). Transmit (B_1^+) field maps in CP and CP2+ modes were acquired by driving the 16-channel coil through the interface module. Transmit field maps were acquired using the AFI technique [4] with the following sequence parameters: TR1/TR2/TE = 20/100/4 ms, resolution = 3.6x1.8x5 mm³, BW = 390 Hz, acquisition time = 5 min. The measured field maps were compared with the numerical model [5] to qualify this setup for safe application on human subjects. Transmit path losses were measured and the field maps were normalized to the voltage at the coil input.





Parameter	Value
S11/S22/S33	< -28 dB
Insertion loss	-0.11 dB
Amplitude Balance	0.01 dB
Phase Balance	0.1°

Fig.1: a) Schematic of a capacitive loaded Wilkinson power divider. b) Photograph of the planar power divider with radial stubs for 399.72 MHz. c) Interface module to connect 16-channel transmit array to an 8-channel pTx system.

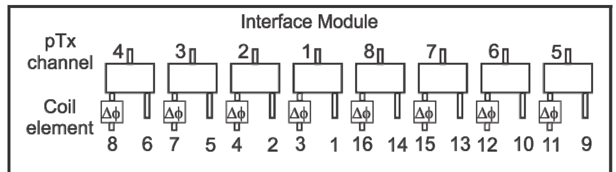


Fig.2) The block diagram shows the mapping of pTx channels to coil elements of the dual-row coil. A phase shift of 45° (Δϕ) is provided internally.
The picture on the left shows the corresponding numbering in the coil.

Results: The planar power divider provided excellent RF performance. The distributed nature of the circuit realization eliminates variation due to the component tolerance and hence the amplitude and phase of the two output ports were closely matched (Table in Fig. 1). As shown in Fig. 3, the spatial distribution of the B_1^+ field closely followed the predicted pattern in both the CP mode and the CP2+ mode. The transmit array was combined with a 31-channel receive array for enhanced receive sensitivity [1]. The mean transmit efficiency was within 20% of the predicted values, which includes the 5% loss introduced by the receive array.

Conclusion: We have presented a low loss interface module to connect a 16-channel dual row transmit array to an 8-channel pTx system. The measured excitation pattern and efficiency matches closely with the numerical results. Further miniaturization of the splitter module is possible using higher dielectric substrates.

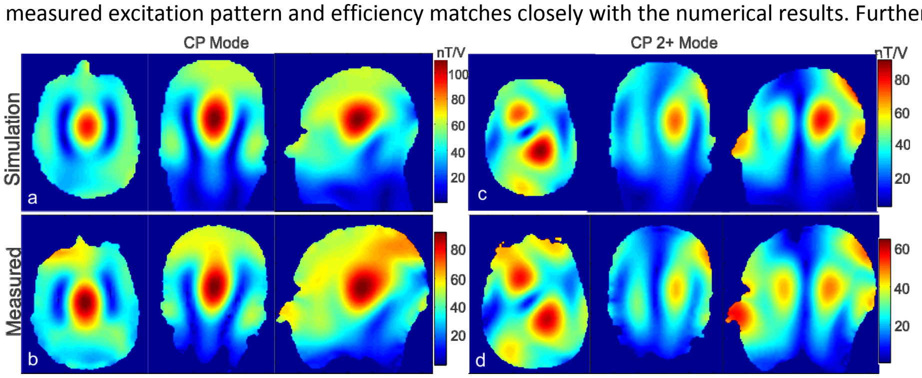


Fig. 3) a & c: Simulated field maps in CP and CP 2+ mode, respectively. b & d: Corresponding measured field maps. The B_1^+ distribution follows the predicted pattern. Maximum values (CP mode): Predicted 110 nT/V; Measured 92 nT/V.

References: [1] Shajan. G et. al. MRM 71: 870 – 879 (2014), [2] Wu et. al. Proc. ISMRM 2012 p638, [3] Scardelletti et al. IEEE Microwave and Wireless Components Letters, Vol. 12, No. 1, January 2002, [4] Yarnykh VL MRM 57: 192–200 (2007), [5] Hoffmann J et al. Magn Reson Mater Phy (2014) 27:373–386, Eichfelder G et. al. MRM 66(5):1468–1476 (2011).