Muti-Channel, In-bore Power Amplifiers for Multi-channel Coil at 7T

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Objective: To develop and demonstrate eight independent RF power amplifiers interfaced to an eight channel transceiver head coil inside a 7T magnet.

Introduction: The advent of parallel transmission in MRI has created a need for multiple, independently controlled power amplifier channels. Meeting this need with multiple, intermediate powered amplifiers as opposed to using single high power amplifier brings a number of additional advantages. Significant gain and phase linearity and power efficiency can be preserved by not having to combine intermediate stage amplifiers to a final stage. By moving these intermediate stage power modules from the equipment room to the magnet bore, significant cable losses can be avoided. By getting rid of multiple, large, high-power cables, more transmit channels can be added to the coil. These many improvements in efficiency and space will have significant economic benefits as well. As the size of the amplifiers decrease, there is potential to place the amplifier closer to the coil or on the coil itself. Previously, a single 500 W A/B linear RF amplifier has been operated in a strong magnetic field.[1] In this work, 8 1 kW in-bore RF amplifiers are combined with B_1^+ shimming.

Materials & Methods: Eight 1 kW A/B linear RF amplifiers were positioned inside the bore of a 7T magnet and powered a B_1^+ shimmed 8-channel transmit head coil. The 6 x 7.5 x 26 cm, 1 kW modules based on LDMOS transistors were manufactured by Communications Power Corporation (CPC, Hauppauge, NY) according to custom specifications. Each module was supplied DC power and ground, a control line, and an analog waveform input. The DC lines were twisted pairs to minimize magnetic field interaction. These solid state amplifiers are broadband with an operating range of 40-305 MHz. The fidelity of the RFPAs is ±1.0 dB gain linearity and ± 7.5° phase linearity. The efficiency is 40% at full power; the remaining energy is dissipated by the aluminum enclosure which acts as both a Faraday cage and heat sink. The RFPAs DC power supply and control circuitry resided in the magnet suite's equipment room. A phase and gain controller[2] (CPC), replicated a single RF waveform for the 8 channels and then independently modified the phase and magnitude of the waveform for each channel to facilitate B_1^+ shimming.[3,4] Two RF coils were used: an eight channel transcieve stripline array, and an 8 channel stripline TEM transmit structure with an internal 32-loop low-impedance preamplifier decoupled receiver. The decoupling of the coil's transmit structure was designed to be operated with a 50 ohm RF source, which the in-bore RF amplifiers provided. The experiments were conducted in a Siemens (Erlangen, DE) Magnetom 7T actively shielded magnet outfitted with an SC72 gradient set. The amplifiers were placed on the service-side of the head coil, inside the bore at a position where the magnetic field is estimated to be 5 tesla. B_1^+ shimmed gradient recalled echo images were collected on a head and the results investigated for spurious noise.

Results & Discussion: The gradient echo images did not present any RF artifacts, suggesting good amplifier fidelity. Since the RF amplifiers are A/B linear, no pre-emphasis or feedback was required to accurately reproduce the input waveform. The characteristic impedance of the RF amplifier is 50 ohms so pre-existing 50 ohm RF coils work without modification. High-power RF losses are reduced by having the RF amplifier next to the coil instead of suffering the losses of > 15 m of cable which can dissipate half the available RF power with standard coaxial cable.

Conclusion: Eight in-bore 1 kW linear RF amplifiers powered an 8 channel transceiver channel RF coil with minimal high power RF losses, and without introducing artifacts.

References: 1: Vaughan & Myer, ISMRM 2011, p1851. 2: Vaughan, MRM 2006; 56(6):1274-82. 3: Van de Moortele, ISMRM 2009, p 367. 4: Van de Moortele PF MRM. 2005;54(6):1503-18.

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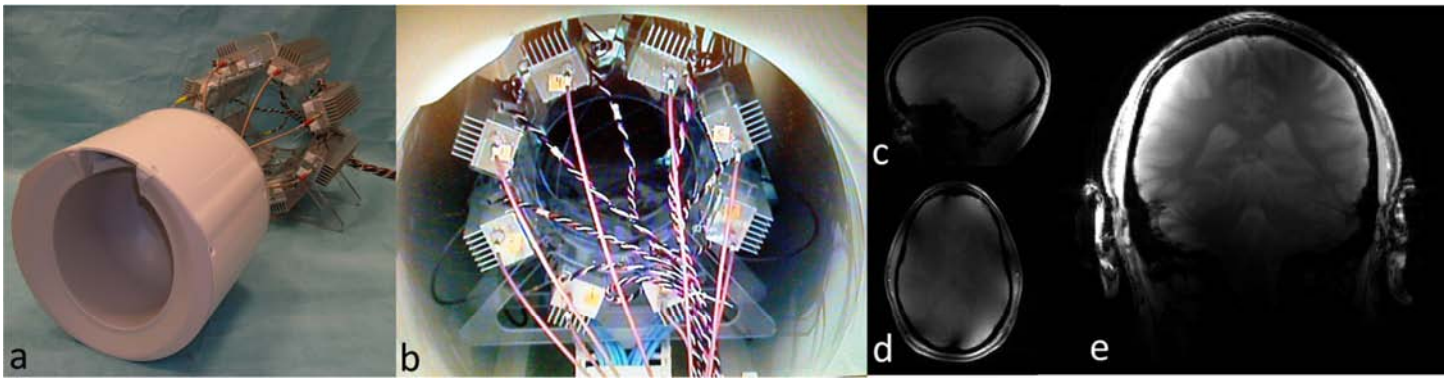

Figure 1. The 8 in-bore RF amplifiers are arranged on a circular former behind an 8 channel transmit / 32 channel receive coil. **(a)** The in-bore amplifiers are shown in operating position inside the bore of a 7T magnet. **(b)** FLASH images (1x1x5mm, TR/TE=150/4 ms) acquired with the in-bore amplifiers do not present any artifacts. **(c-e)**