RF Coil Element Mounted Power Amplifiers

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Objective: To design and test the efficacy of a local (in the magnet) RF power amplifier.

Background: With the advent of multi-channel transmit MRI (1), the need for high performance and cost efficient, RF power amplifiers is immediate. Locating eight, sixteen or more power amplifiers remote to the multi-channel transmit coil requires as many large diameter coaxial cables which consume both valuable space and power. Power attenuation can be 3dB (half) of the amplifiers' output. A rack of 16, 2kW amplifiers can cost a half million dollars or more. The solution to these problems will be to incorporate the RF power amplifier directly into the body coil elements, thereby eliminating expensive cables and losses.

Methods:

Power amplifier: To test the feasibility of a magnet bore compatible RF power amplifier, a 500W, class AB linear power amplifier measuring 2" x 4" x 10" was designed and built according to our specifications by Communication Power Corporation (CPC) in Hauppauge, NY 11788 (www.cpcamps.com). The amplifier circuit consisted of 4x Motorola ,150 W power FETs, combined to produce the nominal 500Woutput with heat generating inefficiencies cooled by the 4x10"aluminum heat sink is shown in Figure 1, together with a filtered power supply which is located remote to the magnet.

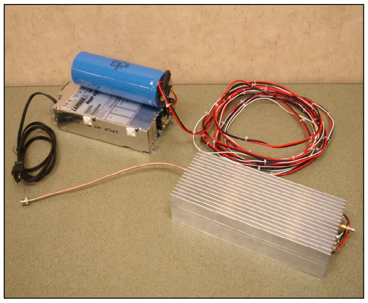


Figure 1. Power supply (with blue capacitor), and local RF power amplifier module

Test Set: The imaging test set-up consisted of the RF power amplifier interfaced to a single-element transmission line or TEM coil element as shown in Figure 2. The coil in turn was tuned to 300 MHz, and matched to a 2 liter, spherical silicone oil phantom. The amplifier was powered by the red and black power leads shown, filtered through the EMI room shield's patch panel. Similarly, the RF signal feed was also filtered from a source outside of the room. The power amplifier was connected directly to the RF coil element and placed with the phantom into the center of our 7T Magnex, 90cm bore sized magnet.

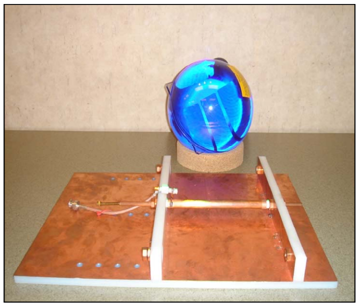
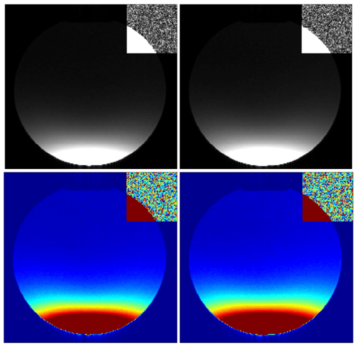


Figure 2. TEM element with phantom

Imaging Test: To test the efficacy of an RF Power amplifier interfaced to the coil element in the magnet bore, two tests were performed. In the first test, one channel of our remote, 16 x 1kW transmit channel power amplifier was used to drive the RF coil element via a TR switch, in transmit and receive mode. In the second test, our local amplifier drove the coil element, both located together in the magnet center. A Giga-tronics power meter was used to assure that equal power was used to drive the coil in each test. The local and the remote amps were both of the same Class AB linear design. Using our prototypical Siemens/home-built 7T system, the phantom was imaged by 2D FLASH sequence, TR/TE = 483/3.88ms covering a 192 x 192mm FOV with 1.0x1.0mm resolution and 5.0mm slice thickness. 125V drove a 90 degree flip angle. SAR = 6.8 W/kg

Results and Discussion:

Figure 3 shows the image results acquired with the RF coil connected to a.) the local power amplifier and b.) the remote power amplifier. The images and the windowed noise were clean and essentially identical. The local power amplifier supplied 3dB less power compared to the remote amplifier, the difference being lost in the 40 foot cable between the remote amplifier in the equipment room and the coil in the magnet. Placing a power amplifier local to the coil is compatible with the MR measurement and twice as efficient as the remote alternative.



Local amp image Remote amp image

Figure 3.

The amplifiers tested above might be mounted on the body coil as in Figure 4. In this initial experiment, we have replaced the bulk of the lossy cable with the bulk of a lossy heat sink. The size of the heat-sink can be reduced if the efficiency of the amplifier is increased. Using Digital Signal Processing (DSP) based error correction the dynamic range efficiency of the RF power amplifier module can be sustained over a range of 10 -15 db. By this method, a second, 1 kW, 300 MHz, class AB amplifier design power amp MOSFETs will be built. The approximate gain of the amp will be +18db with a gain linearity of +/1 db and phase linearity of +/-7.5 degrees over a 30 db dynamic range. The error correction affords a 20% improvement in efficiency and accommodates an equivalent reduction in required heat sink size. To further reduce the sink size and mass to that of the RF coil element itself, a class E nonlinear amp is being developed using more sophisticated DSP techniques to restore linearity while loss is limited to less than 20%.

Conclusion:

The efficacy of a local RF power amplifier interfaced to a coil in the magnet bore has been demonstrated. Work continues to make this approach more compact and efficient.

Figure 4. Future, multi-channel body coil fo

References: 1.) MRM2006;56:1274-1282

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