An Easily Integrated Eight Channel Parallel Transmit System for Transmit SENSE Applications

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Introduction

There is increasing interest in the development of complex RF pulses, largely driven by full-wave effects at high-field MRI. The use of a single channel transmit system has imposed limitations on work in this area due to both the length of the RF pulses and a lack of B1 field uniformity at higher field strengths. The use of array transmit coils allows for the acceleration of complex RF pulses analogous to receive arrays as well as the synthesis of uniform B1 fields(e.g. Transmit SENSE), even at increased main magnetic field strengths[1,2]. Research in this area has driven a need for multichannel transmit systems, as well as a way to effectively decouple transmit array coils. We have constructed an eight channel transmit chain with a decoupling amplifier output stage using current source amplifiers [3] and an eight element array coil made with series tuned loop elements.

Materials and Methods

The parallel transmitter (Fig. 1) we have constructed is based on hardware previously designed for use in B1 shimming applications [4]. Modulation is accomplished with a commercially available vector modulator IC (HPMX-2005) which allows for independent modulation of both amplitude and phase of each channel [4,5]. This requires two baseband signals for each channel, in-phase (I) and quadrature (Q), which are produced by an FPGA based cards manufactured by National Instruments. The control software and user interface have been written in the LabView programming environment. The final amplification stage is a set of eight RF current source amplifiers that are built around the MicroSemi ARF475FL MOSFET [5]. These amplifiers provide approximately 25dB of decoupling, which is independent of the array coil configuration. This has allowed for the use of an eight channel array coil that utilizes loop elements. The array is construed on a cylindrical former with and internal diameter of 10 inches shown in Figure 2. No additional steps have been taken to mitigate inter-element coupling.

The transmit system is designed for easy integration with an existing MR system. Only two connections with the scanner are needed, a single main RF line and a digital unblaking signal. The RF signal is a simple hard pulse with the frequency and any bulk phase shift handled by the MR system. The unblanking signal is a digital signal that goes low during the RF transmit window. This triggers the playback of the waveform envelope as well as unblanking the amplifiers.

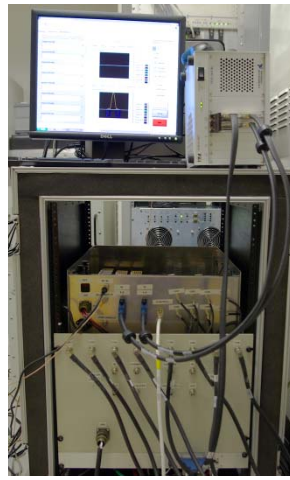

Figure 1: Eight channel transmit system modulators, driver amplifiers and DC power supplies installed in a 19 inch rack case. Host computer and NI control hardware on top.

Figure 2: Eight channel series resonante loop transmit array with balanced fed to minimize coupling when used with current source amplifiers. Coil array has a 10 inch internal diameter. No decoupling efforts beyond the use of current source amplifiers were used.

Preliminary Results

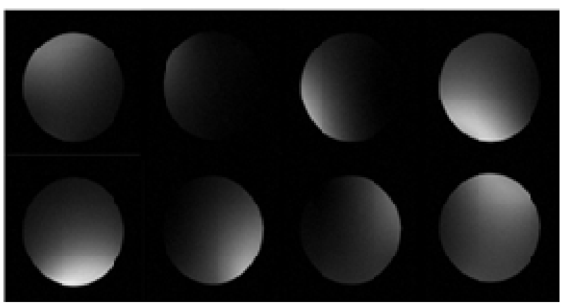

Figure 3: Eight gradient echo images acquired on a GE 3T clinical scanner with series resonant loop array transmit coil. Only one channel was used to transmit for each image. Inter-element coupling is well suppressed.

Gradient echo images showing single channel excitation have been obtained. A commercial, homogenous ball phantom was imaged using our parallel transmit system in conjunction with a GE Signa 3T whole body scanner. A single channel of the parallel system was used to produce the transmit pulse, with the GE systems body coil being used to receive. All other transmit channels were active, but had an waveform envelope that was set to zeros. In Figure 3 we see the resulting images, which show a distinct lack of coupling for a multichannel loop array. Additionally, the parallel transmit system was used to produce a uniform excitation. Figure 4 shows the calculated excitation pattern, and the actual results obtained.

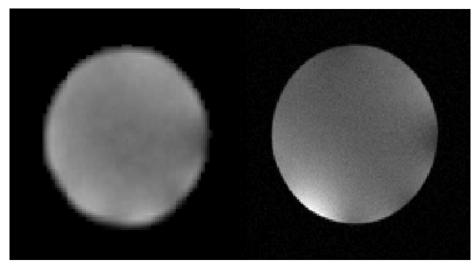

Figure 4: Left) Bloch simulation of uniform excitation. (Right) The image resulting from the uniform transmit pulse. A good level of agreement between the simulated excitation and imaging results was obtained.

Discussion

We have construed a low cost, eight channel parallel transmit system which can be easily integrated with an existing MRI system The use of RF current source amplifiers allows for arbitrary transmit arrays to be easily decoupled, as shown by our use of an array of loop elements. This results in the ability to obtain relatively independent field patterns for each channel, aiding in the design of multi-channel RF excitations.

References

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