Development of a 64 Channel Parallel Transmit System

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Introduction: Many groups are investigating transmit arrays, mainly for transmit SENSE[1,2] and B1 shimming. Another potential application is a transmit/receive version of single echo acquisition imaging, where the spatial encoding in one direction is performed by the RF coil array [3]. Using these coils in a Transmit/Receive configuration has the potential to reduce the complication of phase produced by the RF coils and potentially eliminate the need for a "phase compensation gradient pulse", which is slice position dependent [4].

In order to investigate Transmit arrays on a large scale, our group has developed a 64 channel transmit system capable of producing 100 watts per channel was successfully developed. Phase and amplitude control is provided on a per channel basis to allow for B1 shimming. A separate mode of operation allows for independent channel modulation with the addition of high speed D/A cards controlled by a host computer. Our system presently supports eight channels for fast modulation, but can be expanded with the addition of more or higher channel count D/A cards.

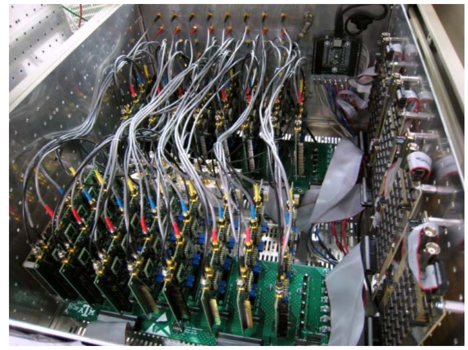

Figure 1: 16 vector modulator boards (64 channels). Digital rheostats on right, USB interface providing simple control for “static modulation” on back panel.

Methods: One approach to developing a multiple channel transmit array is to simply purchase off the shelf components and integrate them into a system. This can be both complex and costly. The approach discussed here is the in house fabrication of all system components, including modulators, RF power amplifiers, receive preamps and T/R switches.

The transmit system is a modular design consisting of vector modulators (HP HPMX-2005), 0.8W 34dB gain stage (Freescale MHW-1345N), 100W 24dB gain MOSFET amplifier (Freescale MRF6V3150NR1), PIN diode (MicroSemi UM9104F) based T/R switches, and monolithic (Minicircuits GALI-74+) receiver preamplifiers. The transmitter has a dynamic range of 60dB, with gain controllable from +5dB to +65dB for individual channels. Further, noise blanking is performed at the input to first amplifier stage and output of second amplifier stage to limit noise during receive. The vector modulators allow for simple phase and amplitude levels to be set using the digital rheostat array [5], which has a USB interface provided by an NI digital I/O unit (NI USB-6501). Control of this system is handled by a computer running a GUI based software we developed in house . The Varian scanner provides RF input to the system, and up to three digital control lines for modulator output trigger (in fast modulation mode), noise blanking and MOSFET gate bias control.

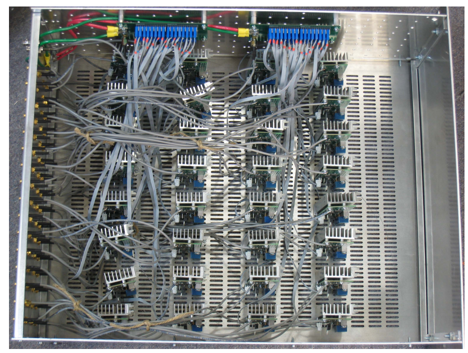

Figure 2: 32 0.8W first stage amplifiers, single channel per board. Power and blanking distribution at top, RF input/output at left.

A modular architecture allows for the parallelization of construction and testing of individual subsystems and channels. Construction, troubleshooting, and maintenance is further eased by separating channels onto discrete boards which are easily removed.

The ability to remove the gate bias from the power amplifier MOSFET is provided to limit temperature rise. This is especially effective due to the low duty cycle at which the system is normally operated. The high power supplies used for the 100W amplifiers are commercial 48V, 3kW front end supplies (Cherokee elec. CAR3010L1NH). Solid core RG-58 (Belden 8240) cable was used to connect the power amplifier output to the T/R switches. Lower loss cable was prohibitively large, so the 2.4dB of cable loss must be compensated for with higher output power from the amplifiers.

The receive preamplifiers and T/R switches are contained in individual enclosures. The preamplifiers provide 24dB of gain and the T/R switch provides 20dB of isolation. Cable runs from the coil to preamplifiers we kept minimal (i.e. preamplifiers and T/R switches are located next to the magnet) in order to improve the SNR of the system. The preamplifiers are based around a linear gain stage, so to limit temperature rise it was necessary to space out the units.

Conclusion: A modular design allows for parallelized construction and testing as well as easier debugging and servicing. The system we have designed will allow for both simple phase and amplitude adjustments on a per channel basis or modulation on a per channel basis.

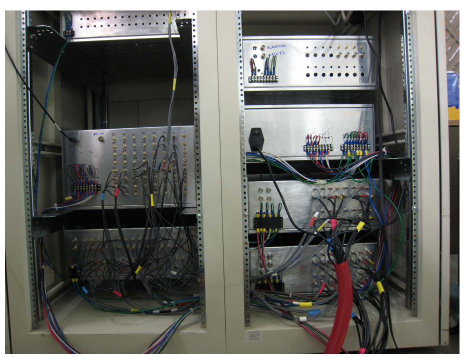

Figure 3: Partially assembled system. 32 of 64 channels in 19 in. rack enclosures with connections made.

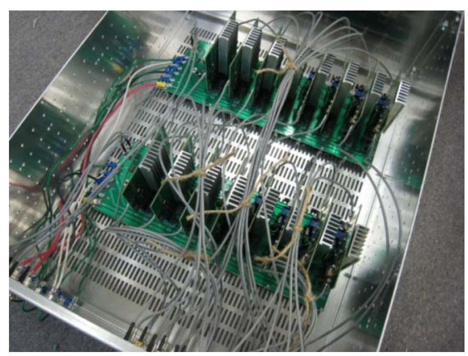

Figure 4: 16 100W output amplifiers. Power entry on left, RF input and output pigtails on right. High density is possibly by controlling the MOSFET gate bias.

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