

A Parallel Transceiver for Human Imaging at 9.4T

L. DelaBarre¹, C. J. Snyder¹, K. Ugurbil¹, J. T. Vaughan¹

¹Dept. of Radiology, University of Minnesota, Minneapolis, MN, United States

Objective: To develop and implement a parallel transceiver for automated B₁ shimming and other applications at 9.4T.

Introduction: In ultra-high field MRI, the incident RF transmit field becomes non-uniform in human anatomy due to short wavelength interference patterns in tissues. The consequential image inhomogeneities can be at least partly compensated by B₁ shimming. This is a process by which the RF field is actively controlled by adjusting the relative impedances (magnitude and phase) of independent elements in a coil structure.(1,2) The concept of controlling the phase angle and magnitude of an RF signal has been demonstrated for RF shimming by manual means such as trimming coaxial cable lengths and adding coax attenuators.(3) These mechanical approaches to coil field control are laborious, time intensive, and do not lend themselves to feedback driven algorithms for interactive and automatic image optimization. To solve these problems an electronic, computer controlled “parallel transceiver” was developed for the RF front end of a 9.4T system for human studies.(4)

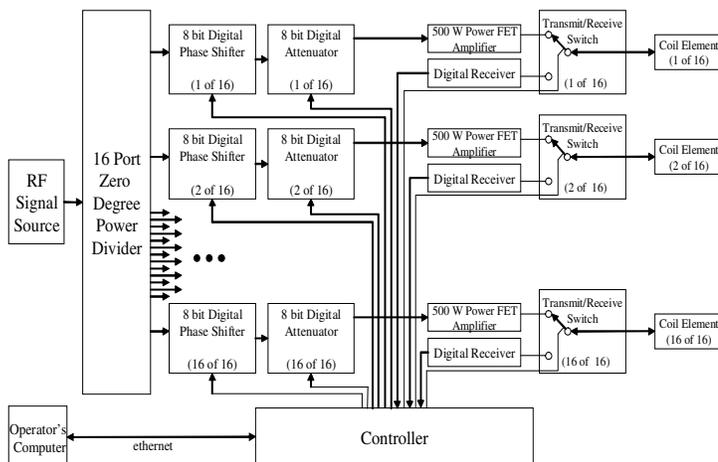
Design: The parallel transceiver schematized in Figure 1 combines a multi-channel, parallel transmitter together with a multi-channel digital receiver. A low level, transmit (carrier) signal from the console is split into multiple, equal phase and magnitude signals. Each of the split signal paths can then be independently modulated via console control by programmable digital phase shifters and attenuators (Figure 1). Each of the independently modulated signals is then amplified by multiple, channel dedicated broadband solid-state RF Power Amplifiers (Communications Power Corporation, Hauppauge, NY). The independently modulated transmit signals then pass through transmit-receive switches to their respective multi-channel coil elements. Receive signals from the same, or different, coil elements are then fed to a multi-channel digital receiver. The programmable transmitter phase and magnitude information is accessed from values stored in a lookup table. Upon reception of an optional trigger signal, the phase shifters and attenuators are updated to the next values. The user can prescribe and review phase and magnitude settings through either a web page interface or through a command language that can be scripted or incorporated into the spectrometer’s software.

Results and Discussion: The parallel transceiver described was built and tested. Test results characterizing the system are in Table 1. Human head 9.4T images acquired with this parallel transceiver are presented elsewhere.(5) With this innovation, four degrees of freedom in RF control are brought to the front end of the MRI system: phase, gain, frequency, and time. The 66 microsecond command cycle of this first generation transceiver is sufficient for controlling phase and gain settings for interactive RF shimming. The second generation system underway reduces this time delay to four microseconds to facilitate Transmit SENSE, automated shimming and other high speed applications requiring on-the-fly waveform modulation and feedback control. The broadband power amplifiers and other system components also allow for simultaneous or interleaved multi-nuclear applications, swept frequency methods, and other frequency dependent protocols.

Conclusion: The parallel transceiver reported both solves problems of, and derives new benefits from the shorter Larmor wavelengths of ultra-high field MRI. With four new degrees of freedom at the RF front end, new algorithm and feedback driven protocols will make many new high field imaging methods possible.

- References:** 1.) MRM 32:206-218 (1994) 4.) US Patent #10/957,870
 2.) MRM 52:851-859 (2004) 5.) Vaughan, ISMRM 14th Mtg. (Submitted)
 3.) MRM 53: 434-445 (2005)

Acknowledgements: NIH-EB000895, NIH-P41 RR008079, MIND Institute, Keck Foundation



RF Amp: Power	500 W / channel
Channels	16
Total Power	8 kW
Freq. Range	30-405 MHz
Phase: Range	0 – 358.6°
Resolution	1.4°
Magn: Range	0 - 63.75 dB
Resolution	0.25 dB
Max. Table size	~600 steps
Reconfiguration time	66µs
Digital Receiver speed	64 MHz
Intermediate Freq.	20 MHz
ADC depth	14 bits

Table 1. Parallel Transceiver Specifications