Multi-channel External Reciever for Multi-Animal Imaging

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Synopsis A consequence of progress in genetic research is the need to evaluate the expression of a genetic modification in the developing or adult animal. MRI has been shown to be an excellent method for phenotyping the mouse, the mammalian genomic model of choice. The exponential increase in recent years of mouse genome experimentation requires a concomitant increase in the ability to rapidly image many samples. We have constructed a direct digital receiver system capable of simultaneous imaging 4 mice on a standard MRI scanner

Introduction It has been standard practice for researchers to reduce the time required for imaging multiple animals by placing them in a sufficiently large coil and imaging several animals at once. This time efficiency comes at a cost of signal-to-noise (SNR) per unit volume and optimal filling factor of the sample, the individual animal. Since SNR per unit volume varies inversely with the volume of the RF coil and signal strength can be substanstially increased by reducing the coil size to that of the sample of interest. For optimal throughput it is desireable to have a dedicated receiver channel for each coil, and for maximum flexibility in experimental design each transmit/receive channel should be individually accessable. To this end, we have developed a multi-channel external receiver system for whole body imaging of the mouse incorporating a standard single transmitter. We present the design and inital results.

Methods A modular MRI receiver was designed to perform as the entire acquisition signal path for the scanner. This included signal reception, digitization, signal filtration, and optionally, image reconstruction and display. The analog electronics (Fig.1) include coil arrays up to 4 volume coils developed on a Bruker Avance 4.7T/40 cm research imaging scanner (Bruker Instruments USA). The signal reception electronics include active diode switch for channel control, T/R switch, pre-amplifiers based on a modified commercial low noise GaAs FET amplifier (Advanced Receiver Research, Inc. Burlington CT USA). The multi-mouse imaging coil uses 2 or 4 coil volume array with element coils 30 mm inner diameter and 70 mm long. A block diagram of the coil array, switch/splitter , preamps, and switch/ combiner is shown in Figure 1. Imaging methods used a standard gradient echo sequence and standard multi-slice, multi-package features of the control software. A gating TTL pulse was added to the standard sequence to advance the diode switch for each slice when using the array in serial mode. If the array was used in combined parallel mode no such switch was needed since the switches are all pass. A digital receiver based on a PCI-bus card in a Linux computer is the basis for the direct digital IF reception of the receiver. The acquired data is transferred to the scanner data directory for reconstruction via scanner software or off-line reconstruction.(1,2) The digital electronics for the receiver were designed around PCI-based digital receiver boards (ECDR-GC214-PCI/TS, Echotek Corporation), in a rack-mount Linux based PCs. Each board allowed digitization of 2 independent analog input signals using 14-bit ADCs (AD6645AST-105, Analog Devices) which were operated at 80 MHz. Digital down-conversion and filtering were performed with on-board DSP chips (Graychip GC4016, Texas Instruments) resulting in 16 bit output dynamic range.

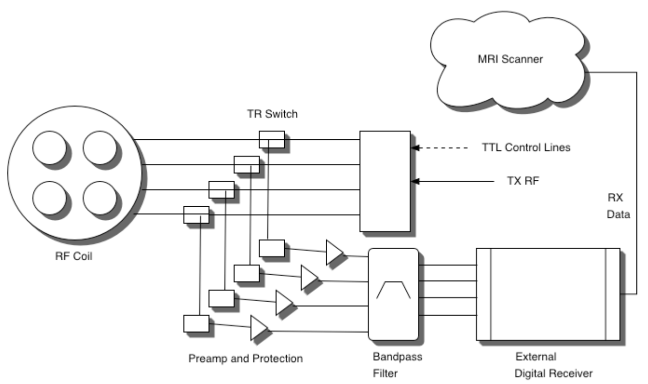

Figure 1. Block diagram of the Mouse coil and receiver system. All digital components are contained within the Linux system on the lower right of the diagram.

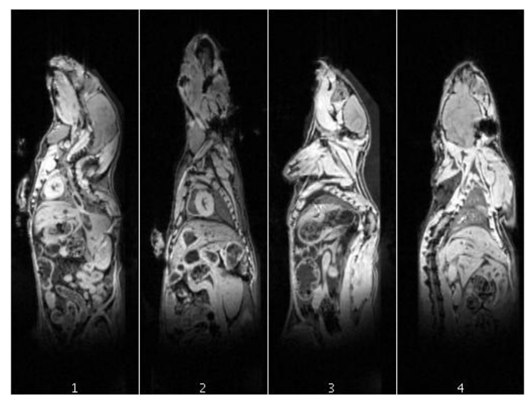

Figure 2. Four slice images taken from a 4 3D volume images of 4 fixed mice. The image is a 3D spoiled gradient echo with TR/TE=250/7 with a flip angle of 45 degrees , FOV = 9x3x3, data matrix of 384x128x128, NEX=1.

Results. We obtained comparable 2D and 3D images to single coil techniques but with 4 times increased specimen throughput. Figure 2 shows single planes of 3D volumes using a standard imaging sequence on the scanner. No operator modifications were required to pulse sequence.

Conclusions. We have developed an external receiver system suitable for use with a multi-mouse, multi-mode array RF coil capable of handling four mice simultaneous. The system may operate in parallel or serial mode and may be used with a multi-receiver scanner in parallel mode. The transmitted RF and received MR signal pathways allows variable gain in transmission and reception on each coil to allow for differences in coil performance due to sample variations. The flexibility of this design enables the experimenter to determine the optimal configuration for the protocol at hand. These modules operate in units of 4 and can be combined to be multiples thereof. Currently we are capable of using up to 8 channels on a single system.

References: 1) Morris H et. al Proc. ISMRM 10:906 (2002). 2) Chu R et al. Proc ISMRM 11:711 (2003).