Wireless Transponders for RF Coils: Systems Issues

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Introduction: In parallel imaging, the potential now exists for dozens of independent receiver coil channels. Cabling now becomes more complex as baluns are required for each channel and cables must be routed to minimize coil interactions. If it were possible to connect coil arrays using some form of wireless transponder for each coil, many of these issues could be alleviated. Here we report our progress towards a wireless transponder prototype and the systems issues that arise in up-converting and down converting between the MRI Larmor frequency and wireless transmission between 800 MHz and 2.5 GHz.

Methods: Our approach is to consider analog modulation of the MRI signal to between 800MHz and 2.5 GHz. For these frequencies we are constructing a system capable of both AM and SSB modulation[1]. Our modulator incorporates a polyphase filter designed for 64 MHz that takes the MRI signal as input and outputs in-phase and quadrature-phase signals. These signals are then fed to an AD8346 quadrature modulator to create a single sideband output. This IC accepts baseband modulation frequencies up to 70MHz. By disconnecting either the I or Q inputs, we can output double sideband suppressed carrier (DSSC), and by allowing a DC offset at the modulator input, full AM can be created. The local oscillator can be anywhere from 800MHz to 2.5 GHz. We employ a AD4153 fractional N phase locked loop frequency synthesizer and Vari-L VCO190-938T voltage controlled oscillator. For reception, an AD8347 quadrature demodulator has been chosen. During MRI transmit pulses, a global Q spoil signal must be broadcast to all receive coils. For this task we have chosen 418MHz Linx Technologies keyed AM ICs (TXM-418-LC, RXM-418-LC).

Results: At present, the polyphase quadrature modulator and 938 MHz fractional N synthesizer have been prototyped (Fig. 2). Figure 3 shows a spectrum analyzer screenshot of a modulator test for a 1.5GHz carrier. The carrier and upper sideband are 25 and 40dB down from the 64 MHz lower sideband signal. If we could frequency division multiplex channels, one can see that if a channel bandwidth of 1 MHz is chosen, we could interleave 64 channels before the carrier leakage from the lowest frequency channel interferes with the lower sideband of the highest frequency channel.

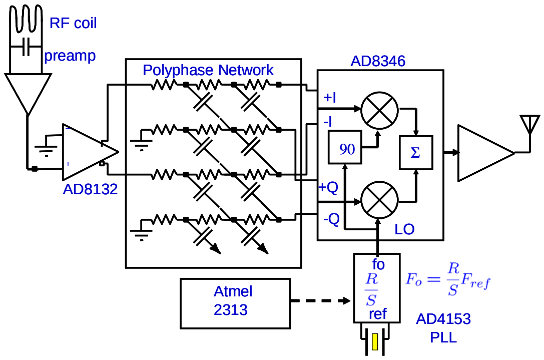

Figure 1: Transponder test system can generate single sideband output using the phasing method.

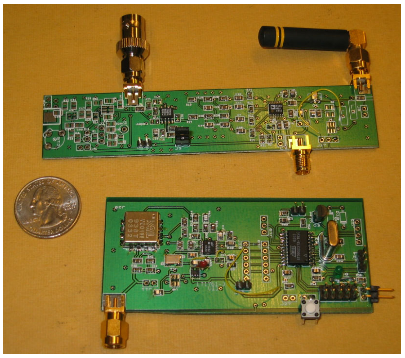

Figure 2: Transponder PCB prototype shows SSB modulator section with antenna (top) and fractional N frequency synthesizer for 930 MHz (bottom).

Discussion: The technical issues to overcome to make a high SNR wireless transponder for MRI are quite severe. The key problem is how to ensure that the transponded signal remains phase synchronous with the scanner. Several approaches have been suggested [2-4]. In simple SSB modulation, every local oscillator in the chain will add a phase and frequency error. In practice, a leaked copy of the carrier oscillator with the same error will always be received. Using synchronous detection, we can use a copy of this signal to downconvert, and in the process, subtract off all phase and frequency errors that were added. A very naïve view is that AM modulation will do the above automatically, since the undistorted phase of the FID is encoded in the carrier amplitude. Though this works extremely well in narrow-band voice, if the electronics ever causes the carrier phase to shift 90 degrees relative to the sidebands, destructive interference will occur and AM demodulation will fail. With sidebands separated by 128MHz, group delays within the system (eg filters) must be tightly controlled. Transmitting an auxiliary reference signal has been proposed in which the transponder local oscillator locks to the reference [3] but body coil transmission will likely cause phase slips for this method. Digital transmission [4] is now quite feasible given Wi-Lan 802.11a/g can achieve 54 Mbit/s in theory (30Mbps typically). However, the entire digital receiver must now be local to the coil, adding considerable complexity and the sampling clock synchronization must also be broadcast.

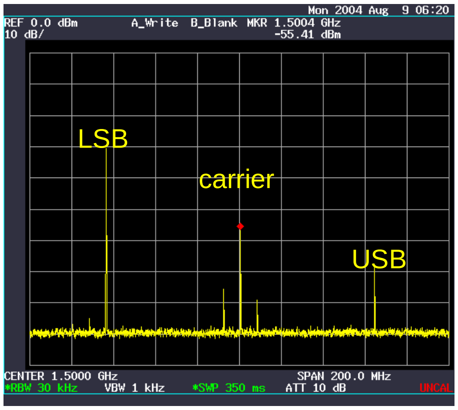

Figure 3: A 64 MHz signal upconverted by a 1.5 GHz carrier has 40dB attenuation of the upper sideband. Span:200MHz, 10dBm/div.

Conclusions: RF transponders for receiver coil arrays offer the possibility of wireless reception and the elimination of cables and baluns for true balanced coils, but at the expense of locally powered transponder modules. Frequency division multiplexing naturally allows parallel transmission of channels. The key challenge is synchronization of the transponder local oscillators with the MRI scanner and the achievable dynamic range. We are now designing the synchronous receiver and B1 coupled power supply.

References:

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