Wireless Transponders for Parallel MRI: 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 from 1 to 3 GHz.

METHODS:

Our approach is to consider analog modulation of the MRI signal to between 1 and 3 GHz. For these frequencies we are constructing a system capable of both AM and SSB modulation. 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 suppressed sideband 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. 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 modulation has been prototyped. Figure 1 shows a spectrum analyzer screenshot of the sideband amplitudes of a 64 MHz signal up converted to 1.5 GHz. The carrier and upper sideband are 25 and 40dB down from the 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.

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. 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 errors, will always be received. If phase locking circuits in the receiver can lock to this carrier, 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. Since the simplicity of AM demodulation also depends on the use of a simple envelope detector – which is dubious above 1 GHz, we will likely also require synchronous demodulation for AM, in which case it loses any advantage to signal sideband demodulation.

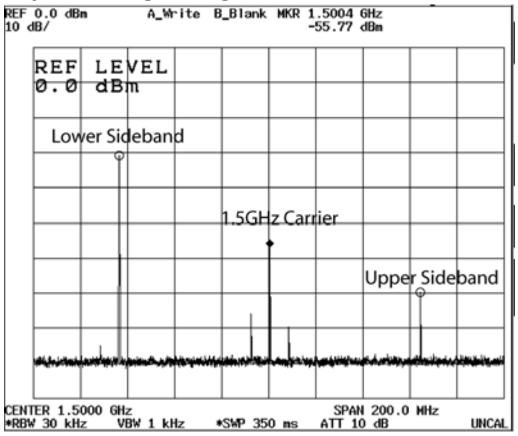

Figure 1: A 64 MHz signal upconverted with a 1.5GHz carrier has the upper sideband 40dB below the lower sideband. Span: 200MHz, amplitude: 10dBm/div.

CONCLUSIONS:

RF transponders for phased array coils offer the possibility of wireless reception and the elimination of cables and baluns for true balanced coils, but at the expense of local battery powered transmitter modules. Frequency division multiplexing naturally allows parallel transmission of channels. The key challenge is synchronization of the transponder local oscillators with the MRI scanner.

REFERENCES:

[1] W.E. Sabin, E.O Schoenike Eds, HF Radio Systems and Circuits 2nd Ed, Noble Publishing, 1998.