An Inexpensive, Scalable Vector Modulator and Application to 2D RF Pulses

K. Feng[1], N. A. Hollingsworth[1], J. C. Bosshard[1], D. C. Noll[2], and S. M. Wright[1]

[1]Electrical and Computer Engineering, Texas A&M University, College Station, TX, United States, [2]Biomedical Engineering, University of Michigan, Ann Arbor, MI, United States

Introduction:

It has previously been reported the use of vector modulators for B_1 shimming [1]. In that application, all vector modulators were fed with the same RF pulse, and vector modulators were used to vary the overall phases and amplitudes of the RF pulses for each channel. Other groups have also reported the use of vector modulators for MRI parallel transmission [2]. Besides the reported application in "static modulation", the vector modulator system is also fully capable of high speed modulation for more complex transmit pulses. 2D pulses have interesting applications such as curved slice selective excitation [3] and spin labeling [4]. By providing the vector modulators with a hard pulse from a Varian Inova system, and generating complex analog modulation control signals from an eight channel D/A card, we were able to output four totally independent RF waveforms. Results shows that the system generates 2D pulses or phase modulated slice selective pulses that perform comparably to the modulator in the host Inova console.

Methods and Results:

In this experiment, the vector modulator was provided with an RF hard pulse from the scanner. A PC running MATLAB with the DAQ toolbox was used for control, and an NI PCI-6713 card was used to generate analog waveforms for the vector modulator. The NI card also provides 8 digital I/O lines for a digitally controlled attenuator on each channel. As this particular experiment involved only one channel on the four channel board, the other three channels went connected directly to dummy loads. The system diagram is shown in Figure 1.

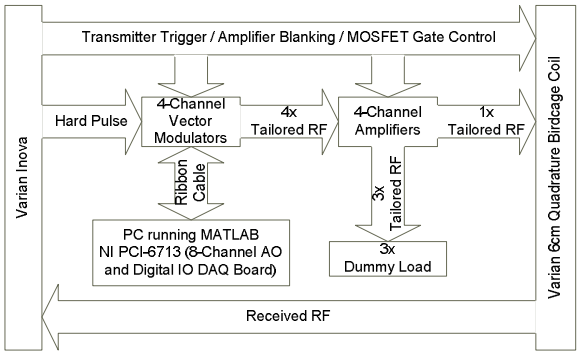

Figure 1. Experiment setup. The Varian Inova system provides RF input and 2 digital lines to the system. One digital line functions as both NI analog output trigger and amplifier noise blanking, the other turns on/off MOSFET gate bias.

Figure 2 shows a picture of the 4 channel vector modulator board used in this experiment. It receives the RF input (hard pulse), trigger input, analog and digital input from NI card, and plays out four independent RF waveforms as output. A plastic bottle filled with distilled water was placed inside a 6cm quadrature birdcage coil as a phantom.

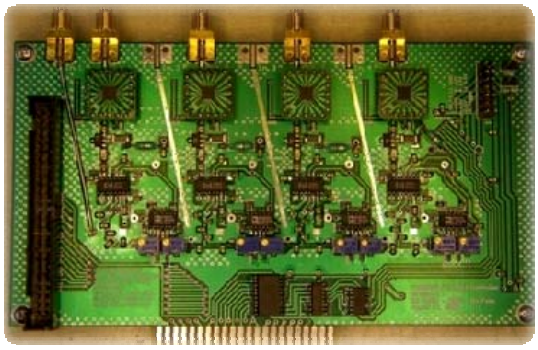

Figure 2. Four-channel vector modulator board. Connector to NI DAQ on left, power and static modulation connections via card edge connector, RF input on left most SMA, RF outputs for channels 1-4 on other SMAs. Top right header pins are used for power supply and NI analog output trigger. Bottom card edge connector is not used for this application.

An EPI 2D pulse sequence was used to excite a checkerboard pattern onto the phantom. The vector modulator was also used to generate the refocusing 180 degree pulse. Initially, the 2D RF pulse was generated from the same waveform files using the Varian system modulator and Varian system amplifier. This image was saved as the control image. The system was then configured to use the vector modulator to generate the RF waveform, which was then fed into a prototype 100 watt amplifier. The same waveform files used to control the Varian modulator were used. The vector modulator was also used to generate the refocusing 180 degree pulse. . Figure 4 shows the results. While the checkerboard is distorted in this initial test, the images are essentially indistinguishable. The results clearly show that the vector modulator system can produce the same result as the commercial modulator, an advantage when scaling up to multi-channel systems

Discussion:

For initial comparisons against the Varian system, we actually "downgraded" the system to 100kS/sec sample rate, so that the RF pulse generated by the system can better compare to the Varian Inova system. However, the NI card can output at 740kS/sec simultaneously for all 4 channels, potentially supporting faster RF pulses or allowing higher resolution waveforms. Results using 740kS/sec show similar results as with 100 kS/sec, but with sharper edges in the direction it scans.

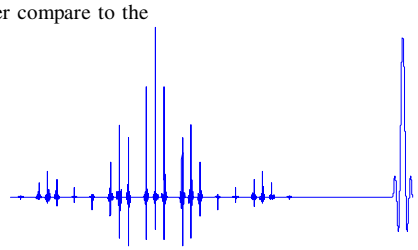

Figure 3 (left side). 2D pulse used in this experiment. As k-space is scanned line by line, the checker board pattern is transmitted. A slice selective 180 degree pulse is then used to flip the spins for a spin-echo image. Each peaks on the left is approximately a sinc pulse.

Although these experiments demonstrated the 2D pulse using only one channel, the system is easily scalable, and is being used in an eight channel system for full transmit SENSE and a 64 channel system for B1 shimming applications.

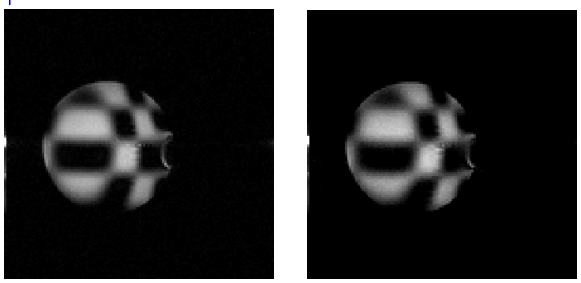

Figure 4. Left: 2D checkerboard excitation using only Varian system components. Right: Same excitation using the vector modulator and the in-house built RF amplifier.

Acknowledgment:

Support from NIH (1R01NS058576) is gratefully acknowledged.

References:

1. Stang P et al, Proc. Intl. Soc. Mag. Reson. Med. 15 (2007), p. 169.
2. Feng K et al, Proc. Intl. Soc. Mag. Reson. Med. 16 (2008), p. 1130.
3. Börnert P, MAGMA, 2003, 6(2): p. 86-92.
4. Wu, EX et al, MRM, 2002. 48(2): p. 389-93.