A Simple Vector Modulator Approach to Phase and Amplitude Control for B1 Shimming

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Introduction: B_1 shimming is an alternative approach to Transmit SENSE as a method of compensating for full-wave effects at high fields. In order to perform B_1 shimming, independent amplitude and phase control of the overall RF pulse is required for each element or input port of a multi-port coil. Digital attenuators and phase shifters with sufficient resolution are quite expensive. This paper presents an inexpensive alternative which combines a vector modulator (Agilent, HPMX-2005) with digital potentiometers (Analog Devices, AD7376AR10) to realize a simple and scalable system to control an array for B_1 shimming. In addition, we demonstrated that by replacing the digital potentiometers with more expensive fast digital-to-analog boards, the system is capable of full modulation for transmit SENSE.

Method: We have designed a modular control system for B_1 shimming. Currently, four channels have been constructed and fully tested, but the system will support up to 64 channels. The system schematic is shown in Fig 1. A PC running software developed in-house (Fig 2 at bottom of the page, right picture) is used to control phase and amplitude of each channel. This software communicates with one National Instrument USB-based DAQ card to control up to 64 digital attenuators and a 128-channel digital tuning board [1] which provides 128 independent DC voltage sources simultaneously. The digital tuning board features 128 digital rheostats, each of which provides 128 positions from two given input voltages. Each vector modulator requires two analog inputs, for the real and imaginary vector components. Each channel also has a 4-bit digital controlled attenuator, which is too coarse for the general amplitude control but suitable for providing extended dynamic range. Input RF to the system is provided by our Varian Inova console followed by power splitters that feed each channel. To do B_1 shimming for a four-channel TEM array [2,3,4], for example, we can use the console to generate the desired wave form. Then we can use this transmitter system to control the phase and amplitude of each channel. Both amplitude and phase can be easily tweaked for optimal B_1 homogeneity. Using vector modulators, which cost less than $4 each, instead of phase shifters and variable gain amplifiers can significantly reduce the cost of large transmit arrays. This is especially important for our 64 channel transmitter, which is currently under construction.

Discussions: Although designed for B_1 shimming, this transmitter can be reconfigured to perform Transmit SENSE by simply changing connections in a manner similar to the vector modulator array constructed by Stang et al [5]. This is achieved by replacing the digital tuning board with a high-speed analog output card (Fig 3). Transmit SENSE requires full modulation, and we have tested our system's full modulation capability with a multi-slice (in the axial direction) experiment. In this experiment, a sinc waveform was produced with an NI high-speed analog output card. A high-speed phase ramp was used to produce frequency offsets for different slices. The results were compared with those generated directly by our GE Omega system. Figure 4 shows that our system is capable of full modulation, such as used in Transmit SENSE[6].

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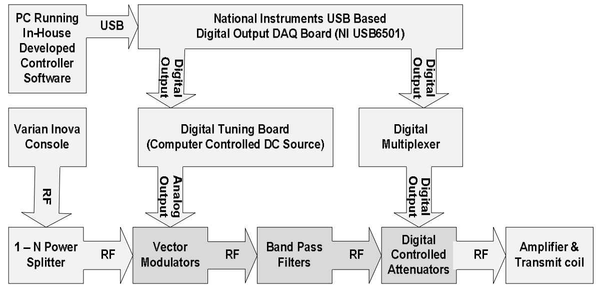

Fig.1 Amplitude and Phase Control for B_1 Shimming

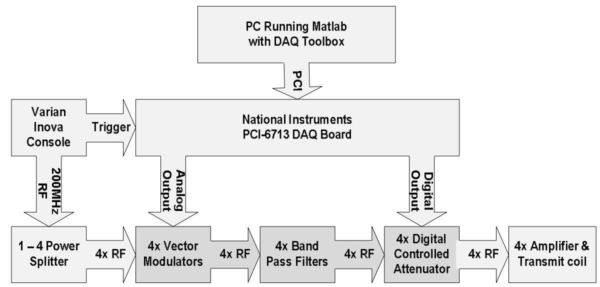

Fig.3 Transmit SENSE configuration

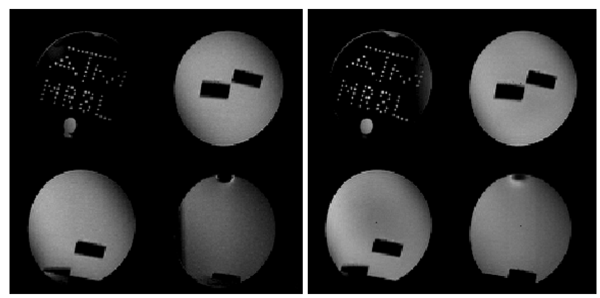

Fig.4 Multi-slice images from our system (left) vs. GE Omega (right)

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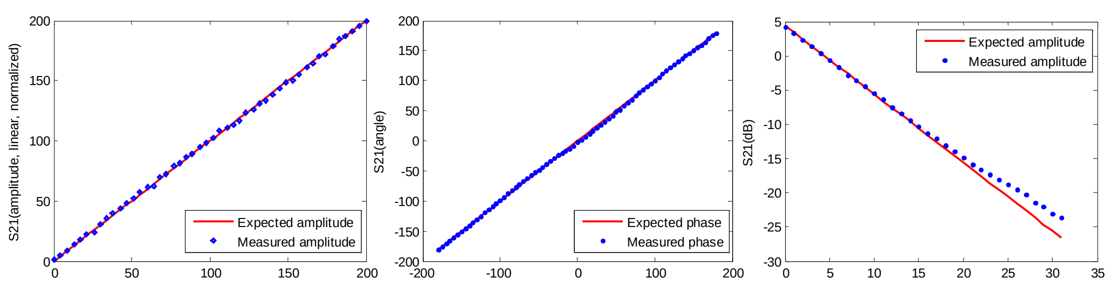

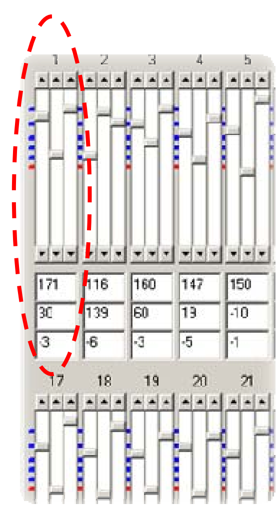

Fig.2 Using the GUI (right), one can control amplitude, phase and digital attenuation (amplitude 171 out of 0~200, phase 30 degrees, and -3dB attenuation for channel 1 in this example) of each channel by dragging the vertical scroll bars or by typing into the text boxes. Responses of a channel to inputs are shown in the left three plots.