An Easily Integrated Multichannel Modulator for all Field Strengths

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Introduction: The trend to increased main magnetic field strengths in MRI has yielded improved SNR, but introduces non-uniformities in B1 [1]. One solution for this is to use multidimensional RF transmit pulses to correct for variation in the B1 pattern. In addition, multi-dimensional RF pulses have applications in recovering signal loss due to B_0 non-uniformities that is seen in sequences like those used in fMRI [2,3]. Parallel transmit (PTx) can be used to accelerate the spatially selective RF pulses in the same way that parallel receive accelerates image acquisition [4]. Because of the broad applications of parallel transmit it is desirable to have multichannel modulators that can work across a range of frequencies and be integrated easily with existing MR systems. We have previously shown vector modulators for use in B1 shimming and fast modulation techniques [5]. We have developed an improved vector modulator that can scale to high channel counts, and can be used with MRI systems at virtually all field strengths.

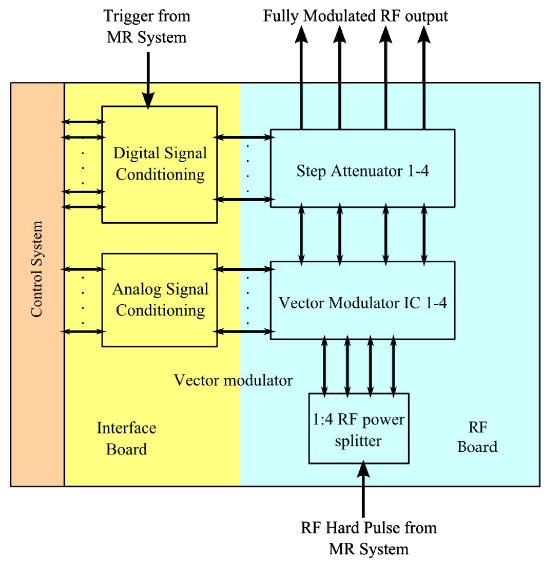

Figure 1: The modulator's interface and RF sub-circuits are located on different PCBs. Making it straightforward to change the modulators for use with different control systems. The low pass filters are on a daughter board that can be easily replaced when operating at higher frequencies. Only an RF hard pulse and trigger line are needed from the MR system.

Materials and Methods: The vector modulation system is based around broadband, commercially available components that can function from 20 MHz to 1500 MHz. Each module incorporates four independent modulator channels. The interface and RF sub-circuits have been separated on different circuit boards, making possible to use different control and analog wave form generation systems with the modulators. For example, we have used an off-board control system based around PXI-7853R (National Instruments, Austin, TX) mixed signal cards and custom software. Alternate, a low frequency system for B1 shimming, similar to what we have previously implemented, can be used [6]. The low pass filters, located on daughter boards, are used to remove higher order mixing products. Changing the filter daughter boards is all that is required to use the modulators at a range of frequencies.

The modulators only require unmodulated RF at the center frequency and a digital signal to trigger waveform generation. This makes it simple to integrate with existing MRI systems with only two connections – the input cable to the RF amp (with a hard-pulse selected) and a trigger. This approach avoids difficulties in maintaining phase locking and exact frequency matching between the transmitter and receiver chain by using the RF generated by the existing MR system.

Dynamic range of the modulators was measured as the difference of the maximum and minimum output amplitudes. The new modulators have a dynamic range in excess of 57dB, improving on the old design by better than 19dB. This was achieved through a combination of improved signal conditioning and new RFICs. The modulators were used to perform a 2D EPI excitation of a checkerboard pattern. We also used a commercial modulator to provide a comparison point.

Channel	Dynamic Range (dB)	
	New	Old
1	58	44
2	59	38
3	57	44
4	59	38

Table 1: Dynamic range was measured for each channel of four channels with our old and new vector modulators. The new modulators show an increase in dynamic range of more than 22dB. This is largely due to reduced LO leakage.

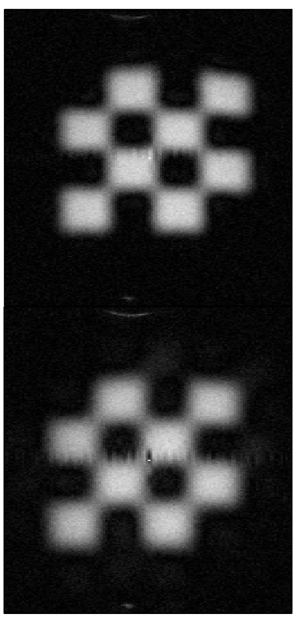

Figure 2: A checkerboard excitation obtained using a commercial modulator (Top) and our vector modulator (Bottom). We are able to obtain similar results in both cases. The FOV of both images is 4cmX4cm

Results and Discussion: We have constructed a low cost, expandable, modulation system that is easy to integrate with existing MR systems. They have successfully been used at both 128MHz (3T) and 200 MHz (4.7T), with only simple modifications needed for 300MHz (7T) operation. Spatially selective transmit pulses were tested using a 4.7T system and a checkerboard excitation pattern with good results. We compared the results using a single channel of our modulator system and a commercial scanner, as shown in Fig.2. The new modulators show a significant improvement in dynamic range as compared to the previous design.

References:
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