PC controlled 8-transmit channel circuit with independent phase and amplitude control for 7T

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Introduction: *B*1 shimming and parallel transmission [1, 2] requires independent phase and amplitude control of the RF pulse in each transmit channel. In this work, a PC controlled 8-transmit channel circuit with independent phase and amplitude for 7T MR scanner is designed. The phase and the amplitude can be adjusted independently by PC via a 16-channel Digital Analog Converter (DAC). Then the output RF pulses of each channel are connected to RF power transistor and MOSFET [3, 4] to be amplified large enough for driving transmit array.

Material and method: Figure 1 shows the block diagram of this design. The PC is utilized to send out digital voltages which determine how many degree and dB the phase and the amplitude of each channel are to be adjusted respectively. We developed a Graphic User Interface (GUI) with 8 pairs of spin buttons (Figure 2) for PC using Visual C++ (Microsoft Corporation) to control the output voltages. These digital voltages are converted to analog voltages using the 12-bit DAC with 16 voltage output channels (AOB16/12, Kontron Company). The outputs of the DAC are connected to the control pins of the voltage variable phase shifters (JSPHS42, Mini-circuits Inc.) and attenuators (MVA2000, Mini-circuits Inc) respectively. The work frequencies of these two components both cover 298MHz, so they are able to perform well at 7T scanner for adjusting the phase and the amplitude of the pulse. The phase shifter and attenuator of each transmit channel are connected to the outputs of the DAC independently. Therefore, the 16 outputs of the DAC can exactly control the phase and amplitude of the 8-transmit channels. Thus the output RF pulse of each transmit channel can be controlled to be with independent phase and amplitude. The output of each channel is connected to an RF power transistor (MRF321, M/A Company) and then a MOSFET (MRF177, M/A Company). The output power can be amplified up to 100W which can be used for transmission. The circuit board of this 8-transmit channel is shown in figure 3. We have finished two channels of this circuit and will complete the whole 8 channels soon. But this does not affect the test results because the circuits for each channel are identical.

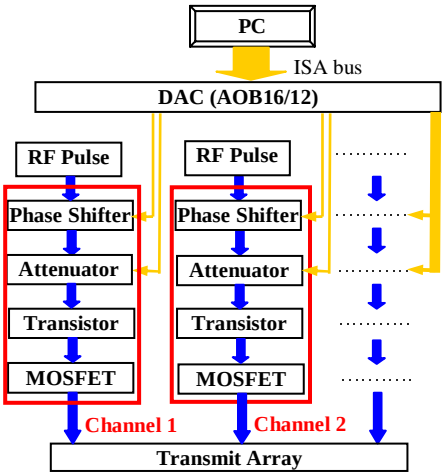

Figure 1 Block Diagram. Yellow lines denote control signal while blue lines denote the pulse.

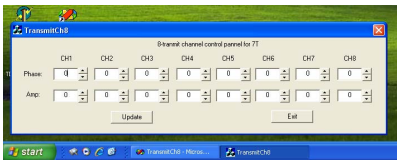

Figure 2 GUI on PC for output control

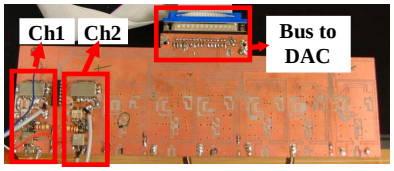

Figure 3 Circuit board of 8 transmit channels

Results: We utilized the benchmark signal to test the performance of the control circuit of this design (figure 4). A 298MHz sine waveform was outputted to the 8-transmit channel circuit and an oscilloscope was used to display the output waveforms from the circuit. By adjusting the spin buttons on the GUI, we could change the phase and the amplitude of the sine waveform. The phases varying with the phase control voltage at 4 different power attenuation values are plotted in figure 5. When the phase control voltage varies from 0V to 12V, the pulse phase can be shifted from -30° to 380°. It is noticed that at different power attenuation value there is a small difference in the relationship between the shifted phase and the phase control voltage. This is due to the phase shift caused by the attenuator at different control voltage and can be compensated by adjusting the phase control voltage in application. In figure 6, the amplitudes of the pulse varying with the amplitude control voltage at 4 different phases are shown. The output power can be attenuated from 31dB to 5dB when the voltage varies from 0V to 10V. The phase control voltage also has a little effect on this varying curve due to the power attenuation caused by the phase shifter at different phase control voltage. This effect can be ignored because it is very small. Several samples of the pulse waveforms with different phases and amplitudes are shown in figure 7.

Conclusion: The voltage variable phase shifters and attenuators have been utilized to control the phase and amplitude of RF pulse of 8-transmit channels independently. The control voltages of these shifters and attenuators are from a DAC which is connected to a PC. Thus the phase and the amplitude of the pulse of each channel can be controlled by using GUI software on the PC. The phase adjustment range is from -30° to 380° while the range of power attenuation is 26dB. All the components perform well at 298MHz so that this circuit can be used at 7T. This is just a preliminary work. The whole 8-channel circuit will be completed soon and then connected to transmit array on 7T MR scanner. Thus *B*1 shimming and parallel transmission can be performed using this PC controlled multi-transmit channel.

References: [1] Katscher U, et al., Magn Reson Med, 49: 144-150, 2003. [2] Zhu Y, Magn Reson Med, 51: 775-784, 2004. [3] Heilman JA, et al., 15th ISMRM Proc.: 171, 2007. [4] Hoult DI, et al., 16th ISMRM Proc.: 1139, 2008.

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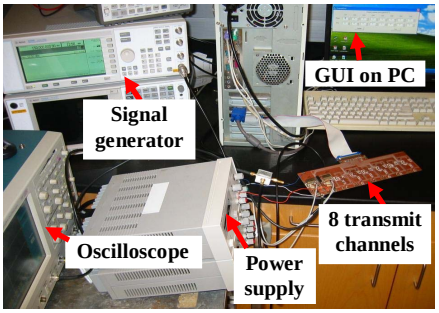

Figure 4 Testing setup for phase and amplitude control circuit.

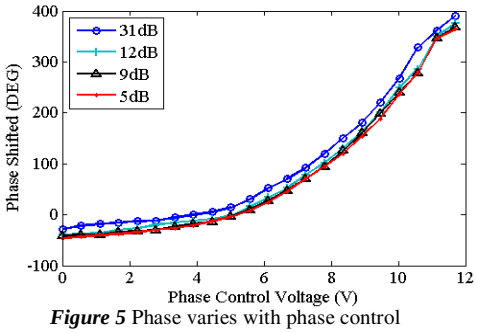

Figure 5 Phase varies with phase control voltage at 4 different power attenuations

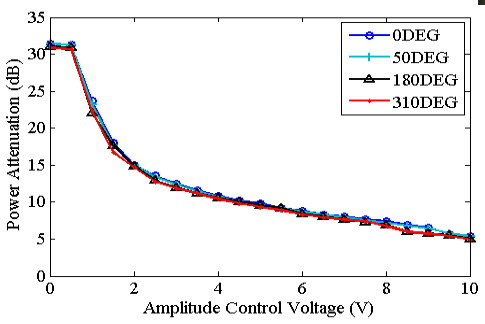

Figure 6 Amplitude varies with amplitude control voltage at 4 different phases.

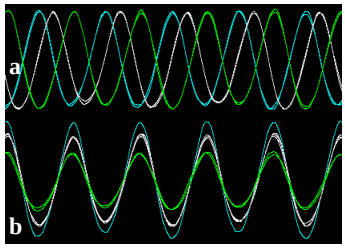

Figure 7 Samples of waveform with different phases (a) or amplitudes (b).