A DDS-based Phasing and Pulse Unit for SuperDARN

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Abstract

We have developed a direct-digital synthesis (DDS) and micro controller-based phasing and pulse unit. This unit generates the pulsed transmit signals and the constant wave receive signals with the correct phases necessary to operate the steerable beam of a SuperDARN radar. It replaces timing computer, interface box and the core of the phasing matrix. The first of these systems has been in operation at Inuvik since December 2010; the other three Canadian radars will be upgraded during 2011.

Introduction

The phasing and pulse unit for the SuperDARN radars must provide 16 signals all at the same frequency and with progressive phases, and these are pulsed on and off according to the pulse sequence. As long as only one digital receiver is used, it also has to provide 16 CW signals, again at the same frequency and with progressive phases, to enable beam forming an the receive side. In addition, some supplementary digital signals must be generated.

Traditionally this has been done by the combination of a timing computer, an interface box and two frequency synthesizers separated by the transmit frequency. The timing computer [via the interface box] sets the frequency of the variable synthesizer and sends out the timing sequence, which turns the transmitters on and off. It also sets the switches on the phasing matrix to steer the antenna beam in the right direction.

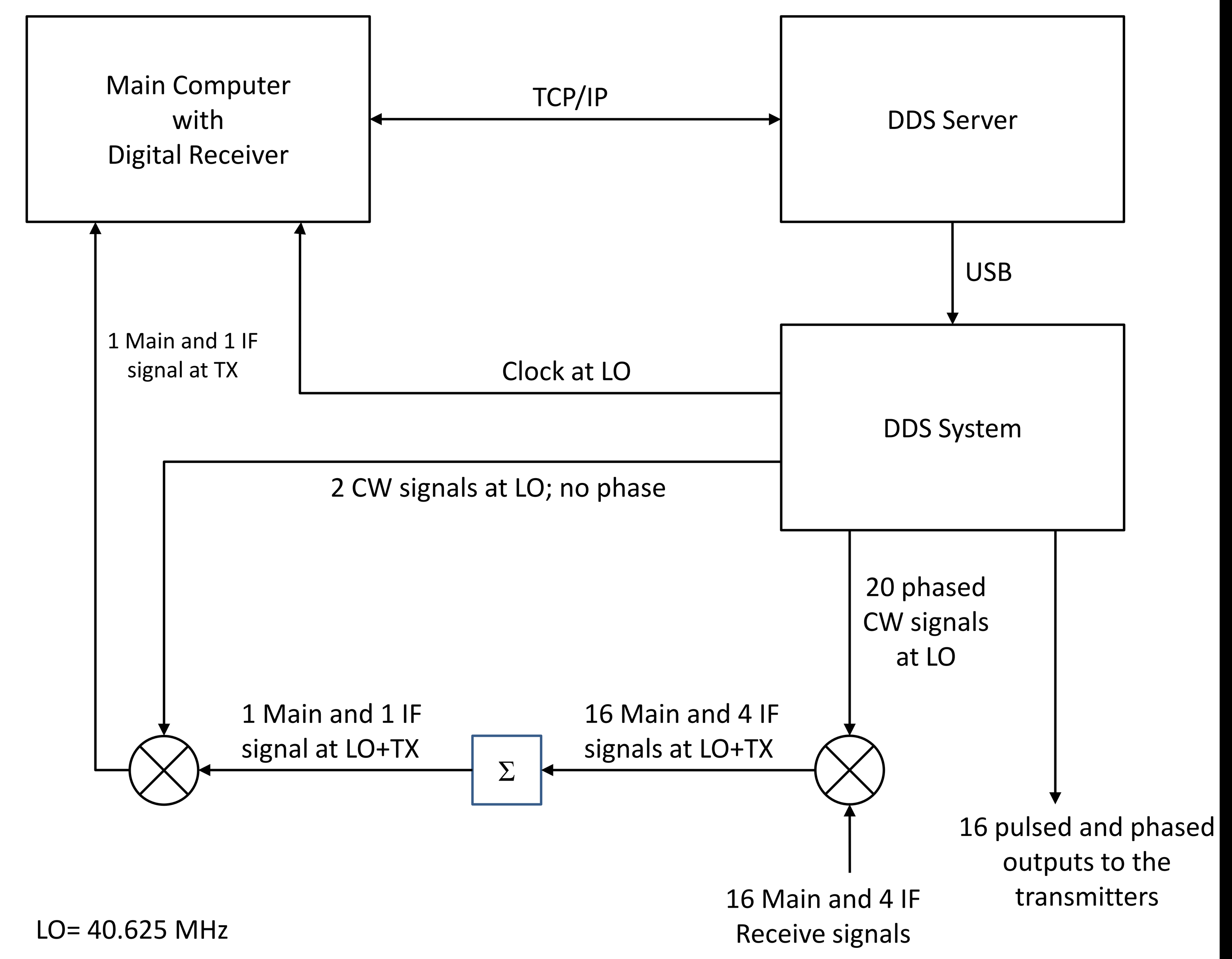
Two different designs exist to implement the phasing matrix.

The original design employs four delay lines that can be switched on and off. The ratio of the delays is 1, 2, 4, 8, so that 16 equally spaced delays can be generated. The advantage of this design is that it is frequency independent. The disadvantage is that only 16 fixed beam positions are possible. An improved design exists, with 13 different time delays and up to 8192 beam positions.

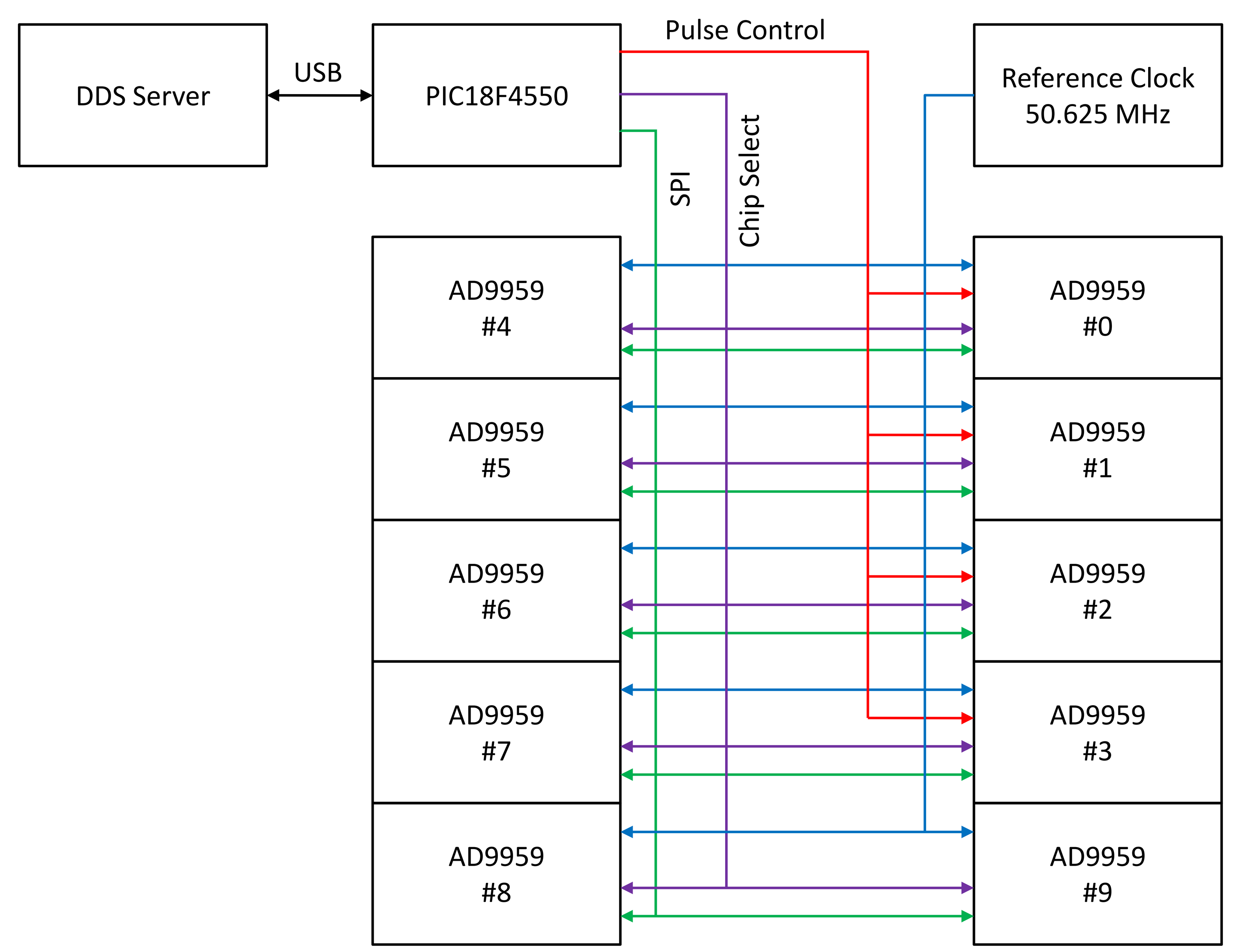
The other design starts out with two signals at the same frequency and the desired phase shift between two adjacent antennas. It achieves the 15 necessary phases through repeated mixing of the last signal [with the greatest phase] with the original phase. This is a very complex process and prone to spurious signals, but since the initial phase can be set at intervals of 1.4 degrees the beams can be steered to a great number of positions.

Our system uses multiple DDS-based digital-to-analog converters to directly generate all signals for transmission and reception with the correct frequency and phase, as well as a micro controller for programming them and for generating the pulse sequence. The direct frequency generation results in a very low system noise; the use of a micro controller for the pulse sequence removes any jitter from it. The frequency can be set in steps of 0.1 Hz, the phase in steps of 0.02 degrees.

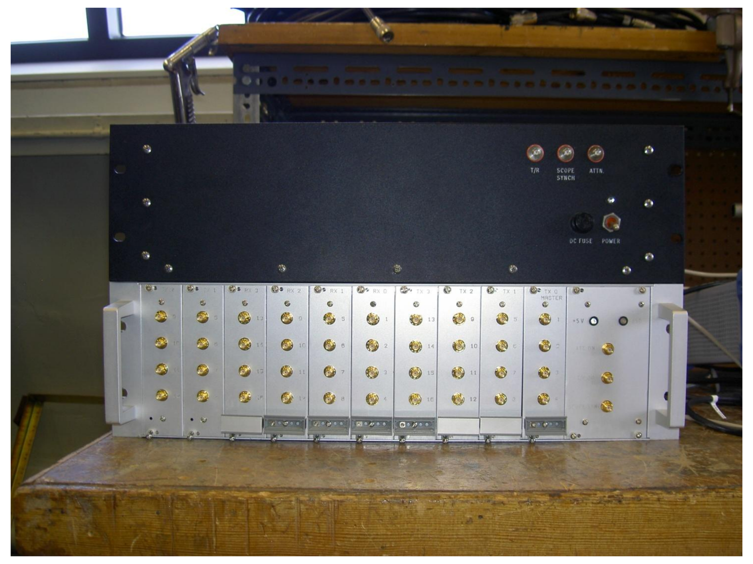
Block Diagram of Radar Components connected to the DDS System



Detailed Block Diagram of the DDS System

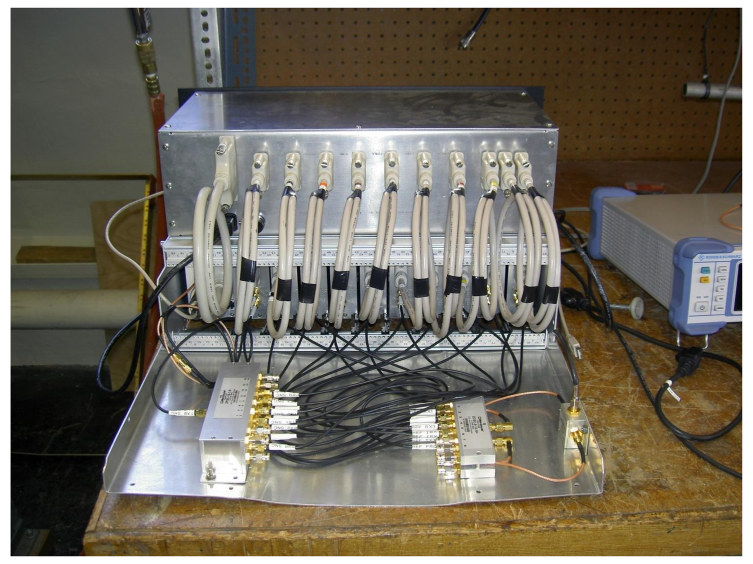


Front View



The black box on top contains the power supply and the signal distribution. The bigger module to the right of the lower rack contains the PIC18F4550 microcontroller, then following from right to left the smaller AD9959 modules 0 to 9. Main and interferometer hardware is not shown.

Rear View



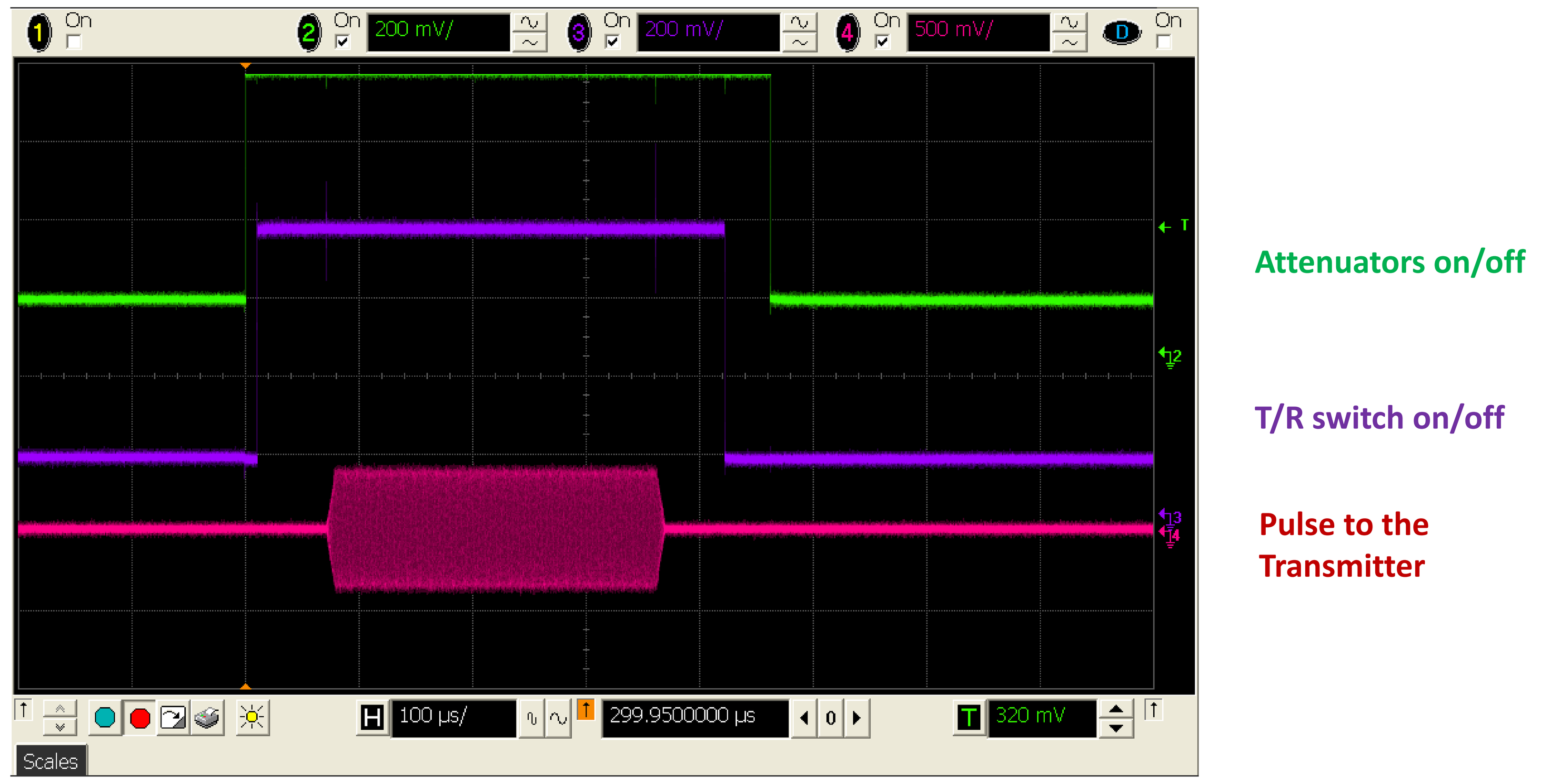
The thick grey cables lead from the signal distribution to the separate AD9959 modules. The splitters on the right side of the bottom shelf distribute the reference clock signal to the AD9959 modules. The splitters on the left side distribute the synchronization signal generated by AD9959 module #0 to the other modules. The cables from each splitter to the modules all have equal length to avoid synchronization problems

Functional Description of the DDS System

- Most of the high-level programming is done on the DDS server, allowing for easy modifications to the operations
- The PIC18F4550 programs the AD9959 via the chip select lines and the Serial Peripheral Interface [SPI]. It also generates the pulse sequence with two of its timers. In addition to this, it can reset the AD9959 and perform an I/O update. This activates the previously programmed values and is issued to all AD9959 simultaneously.

- AD9959 #0 is programmed as master, and all other ones as slaves. This causes AD9959 #0 to generate a synchronization signal, which is used by the other 9 modules.
- AD 9959 #0 to #3 output the 16 pulsed and phased signals to the transmitters. They have been programmed for amplitude modulation with amplitude 0 at low pulse control and full amplitude at high pulse control with a 10 µs ramp up/ ramp down to decrease sidebands.
- AD9959 #4 to #7 output the 16 phased CW signals for mixing with the received signals from the main array.
- AD9959 #8 outputs the 4 phased CW signals for mixing with the received signals from the interferometer array.
- AD9959 #9 outputs 3 CW signals with phase 0, two for the final mixing of the combined main and interferometer signals, and one as clock signal for the digital receiver.
- The DDS system installed in Inuvik does not have AD9959 #8 and #9. The signals are obtained by splitting the main array CW signals for antennas 5 to 8 [interferometer] and 0 [clock].

Signal Levels during Transmission of one Pulse



Conclusion

The first system of this kind has been in operation in Inuvik since December 2010, which demonstrates its reliability.

The noise level in the backscatter is much lower than with our other radars.

Since most of the functionality of the system is implemented in software, it is very easy to reprogram it for different operation modes.

Selected References

AD9959: 4 Channel 500 MSPS DDS with 10-Bit DACs Data Sheet (Rev B, 07/2008)

Microchip PIC18F2455/2550/4455/4550 Data Sheet

Microchip PICDEM FS USB Demonstration Board User's Guide

Microchip MPLAB IDE User's Guide

Microchip MPLAB ICD 3 In-Circuit Debugger User's Guide

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