IMPLEMENTATION OF DDC AND DPC ON VIRTEX-7 USING SYSTEM GENERATOR

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Abstract— **The RADAR which has the ability to detect objects within a long range is called Range Detection and to distinguish between two closely spaced targets is called Range Resolution. By using short duration pulses the Range Resolution can be enhanced and results in less Range Detection. In order to overcome this Pulse Compression techniques have been used and Linear Frequency Modulated signal is used for this. The multichannel Pulse Compression system is realized by using all Digital method and the FIR filters are used to design this which can be re-used in different periods of Digital Pulse Compression.**

Index terms- **RADAR, LFM, DPC, DDC.**

I. INTRODUCTION

RADAR (Radio Detection and Ranging) is an electromagnetic system for the detection and location of objects. RADAR operates by transmitting a particular type of waveform and detecting the nature of the signals reflected back from objects. In RADAR systems, a signal is transmitted, it strikes and bounces off an object and are later received by the receiver. Once the RADAR receives the echo signal i.e returned signal, it calculates useful information as stated by Skolnik et al [10]. Any received signals from the receiver must be pre-processed before sending it to the Signal Processing stages. DDC helps in front end processing or pre-processing the received signal before transferring the data to Signal Processing units. In conventional RADAR system, baseband signal has been digitized and processed. Down conversion with Digital technology has advantage of reliability, programmability and stability with respect to environmental variations. Hence in modern RADARS Down Conversion has been done in Digital Technology. i.e DDC. The Signal Processing unit is the pulse compression. During World War II the Pulse compression technique was created and has been implemented at radio frequencies for over sixty years to enhance RADAR signals. Pulse Compression technique is continuously used in RADAR's, echography and Sonars to increase the range detection, range resolution and to increase the Signal to Noise Ratio (SNR). This can be achieved by modulating the transmitted pulse and then correlating the received pulse with the transmitted signal. Pulse Compression is an important signal processing technique used in RADAR Systems to reduce the peak power of a RADAR pulse by increasing the length of the pulse, without sacrificing the range resolution associated with a shorter pulse.

In order to obtain a very short pulse, it requires high peak power to get the adequate energy for large distance transmission. The RADAR equipment becomes heavier and sparking occurs in the antenna instruments, while handling a high peak power pulse. A pulse having a low peak power and a longer duration has to be used at the transmitter for good range detection as stated by H.A Said et al [1]. At the receiver end, the echo should have a high peak power and short width for a better range resolution as shown in Figure 1.
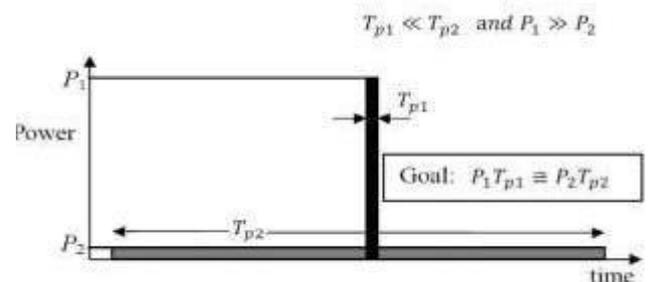

Figure 1: Transmitter and Receiver signals

Figure 1 shows the reason for using pulse compression. Several pulse compression methods have been used in the past. In 1945 R.H Dickie invented Linear Frequency Modulation (LFM) which is the most common and popular among them. The other popular Pulse Compression Techniques include Binary Phase Codes, Costas codes, Non-Linear Frequency Modulation and Poly Phase Codes.

II. IMPLEMENTATION OF DIGITAL DOWN CONVERTOR

The Digital Down-Converter is the first Signal-Processing element in the FPGA processing chain. It contains a Numerically Controlled Oscillator (NCO), a pair of Mixers and a Decimation filter. In RADAR's input signal Bandwidth varies as per operational requirements and hence FIR filter & DDC output data rate changes. To consider this Bandwidth variation needs, Input signal is sampled with ADC at higher

sampling clock. Decimation is done at the end of DDC to reduce data rate to processor for reducing the processing difficulty while extracting information of interest. DDC allows signal to be shifted from its (IF) Intermediate frequency down to baseband and reduce greatly the amount of effort required for subsequent processing of the signal without any loss of information carried. In order to overcome the drawbacks of Conventional DDC having Single stage FIR filter (over FPGA resource consumption and poor RADAR performance), Multistage FIR filter approach is followed, which is more efficient. The NCO is a Programmable Local Oscillator for the digital receiver The LO signal, generated in quadrature (cos and -sin), is multiplied with the incoming signal to shift the frequency down to base band. The anti-aliasing (decimation) filter eliminates unwanted alias frequencies from the down-converted signal. Unlike a traditional digital receiver, which uses CIC filters, this design makes use of FIR filters for removing alias frequencies. A DDC allows the frequency band to be moved down the spectrum so that the sample rate can be reduced, filter requirements and further processing on the signal of interest become more easily realizable as stated by T. Hollis et al [4]. After each important signal-processing block, programmable scalars are provided to adjust the gain at various points along the chain. This helps mitigate overflow errors. The Block diagram of Digital Down-Converter is as shown in the Figure 2.

Figure 2: Digital Down Convertor
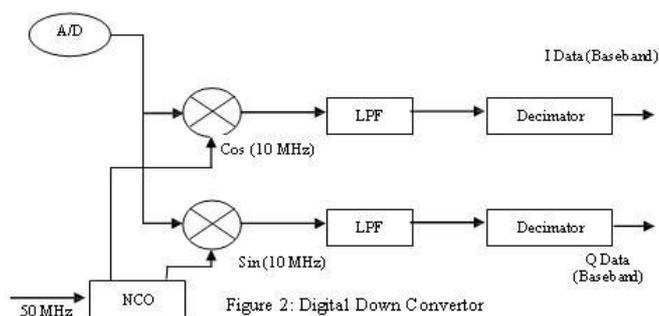
III. DIGITAL PULSE COMPRESSION

The Pulse Compression Filter is an example of a Matched Filter because the filter is designed to identify the characteristics of the transmitted pulse as they are returned to the receiver in the form of reflected pulses. Received pulses with same characteristics as of the transmitted pulse are identified by the Matched Filter where other received signals pass relatively unnoticed by the receiver. Digital Pulse Compression compresses transmitted chirp pulses of various pulse widths to pulse. It performs a complex convolution of the input signal (at 5 MSPS rate) against a pre-stored waveform as stated by M. Vamsi Krishna et al [5]. This complex convolution is done using real FIR filter blocks, with the data re-arranged to ensure that the result is correct. The Digital Pulse Compressor performs a complex convolution of the input signal (at 5 MSPS rate) against a pre-stored waveform. This complex convolution is done using real FIR filter blocks, with the data re-arranged to ensure that the result is correct. Note that this requires four real convolutions, two

of which share a common set of coefficients. Thus, we generate four filter blocks, two FIR block process I data and remaining two FIR block process Q uncompressed baseband data. The filters accept data for each channel on same clock cycles, so the data from the I and Q streams must be fed simultaneously to each filter. The resulting data stream must be added or subtracted, depending on whether the real or imaginary part is being computed as shown in Figure 3. DPC implementation is based on real time convolution for that we are using four FIR blocks. DPC Coefficients are generated using hamming window which results in suppression of range side lobe and widening of main lode.

Equation to be solved for real and imaginary (I, Q) compressed data are shown in (1) and (2)

$$R = conv(R\_ch, R\_ch\_flip) + conv(I\_ch, I\_ch\_flip) \quad (1)$$

$$I = conv(I\_ch, R\_ch\_flip) - conv(R\_ch, I\_ch\_flip) \quad (2)$$

where

R = Real part of compressed signal
I = Imaginary part of compressed signal
R_ch = Real part of chirp signal
I_ch = Imaginary part of chirp signal
R_ch_flip = filter coefficient processing real part of chirp
I_ch_flip = filter coefficient processing imaginary part of chirp
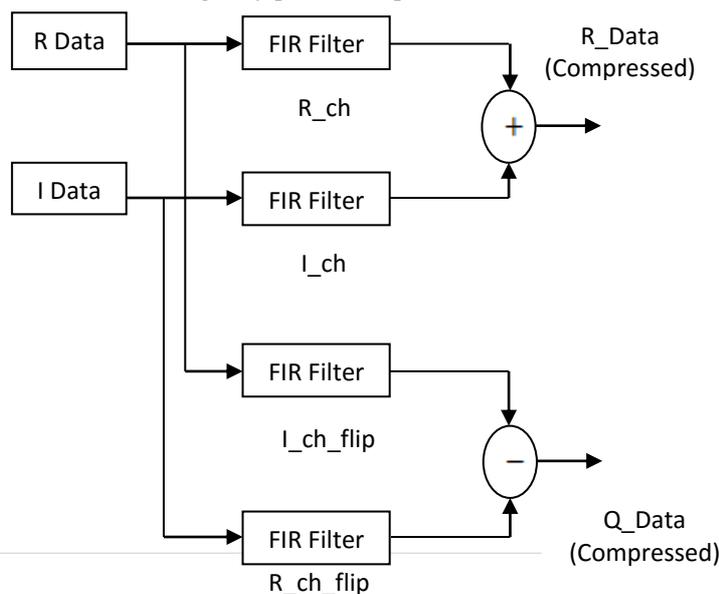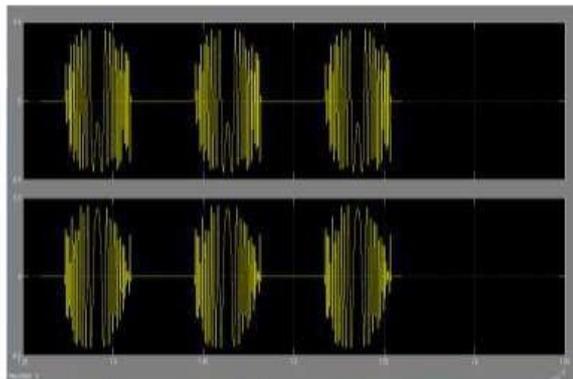

Figure 3: Digital Pulse Compression

IV. RESULTS AND DISCUSSIONS

First we use MATLAB to write a code for LFM waveform and plot its real and imaginary parts. The coefficient's of the real and imaginary parts of LFM Waveform are saved in .mat format so that it can be used by FIR filters for complex convolution. System Generator has been used to design the DDC and DPC blocks. Digital Down Convertor (DDC) was used to convert the incoming IF signal to baseband (I and Q) and its output is shown in Figure 4.

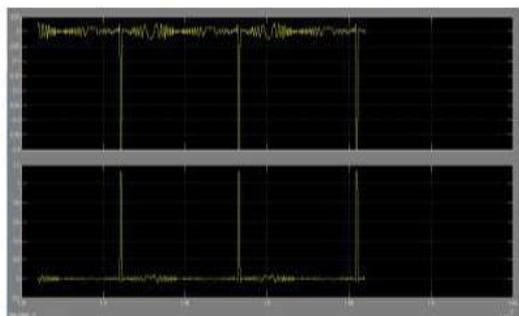Amp

Figure 4: Output of DDC (Inphase and Quadrature)

Amp

Figure 5: Output of DPC

This output is then fed to the Digital Pulse Compression (DPC) block using FIR Filters where complex convolution calculations has been done and its output is as shown in Figure 5.

V. CONCLUSION

In this paper we have introduced the software design of the signal processing FPGA in the multichannel pulse compression system. Digital Down Convertor (DDC) was used to convert the incoming IF signal to baseband (I and Q). DDC is implemented efficiently using Multistage FIR filters. Digital Pulse Compression (DPC) was used to compress the pulse and this process is done by Matched Filter which performs a correlation between the received signal and the replica of the transmitted signal. Pulse Compression has been achieved through Linear Frequency Modulation. We develop the FPGA program by System Generator. We have used System Generator tool in the development of FPGA Digital Signal Process since it can greatly increase the efficiency of software development without losing its accuracy.

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