Waveform Synthesis for Multifunction Airborne Radars

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Abstract:
Many different illumination waveform types are used in radar system, depending on radar's mission and whether or not pulse compression is present. Pulse compression waveform design is predicted on simultaneously achieving wide pulse for detection and wide bandwidth for resolution. The spectrum of the waveform is thus a critical parameter. Multifunction airborne radar provides a range of operational modes designed to assist the pilot in the execution of missions in Air-to-Air, Air-to-Ground and Air-to-Sea operations. These requirements place demands on various waveform characteristics like agility, bandwidth etc. This paper describes waveform generation through simulink model using system generator blocks. Simulation and detailed hardware implementation of an extremely compact on-field programmable waveform generator card is also described.

Keywords: DAC, DDS core, system generator, FPGA, PRF, NB waveform, WB waveform, RTSA.

I. INTRODUCTION

Waveforms are used to illuminate a target or an area with its electromagnetic energy and reflections from these targets are used for processing and further detection. Waveforms are modulated in most of the cases depending on radar requirements and compressed during processing to achieve better range resolution. The power spectrum of any waveform is the Fourier transform of its autocorrelation function. The waveform's autocorrelation function determines its ability to resolve in range. The spectrum of the waveform is thus a critical parameter. Narrow autocorrelations, correspond ing to wide bandwidths, are necessary for good range resolution. Bandwidth and autocorrelation functions are determined by the modulation present on the sinusoidal wave within the pulse and ambiguity functions are used for evaluation of these waveforms. Another crucial factor in waveform designing is the choice of PRF. All other conditions remaining the same, the PRF determines to what extent the observed ranges and Doppler frequencies will be ambiguous. That in turn, determines the ability of the radar not only to measure range and closing-rate directly,
but to reject ground clutter. For Airborne radars, medium-PRF is a compromise solution to overcome some of the limitations of both low and high-PRF waveforms as far as air detection is concerned. Bandwidth is another important factor for different modes of airborne radars. This paper describes the scheme for two different kinds of modes that have been implemented. Narrowband mode is used for air detection whereas wide band mode is used for ground imaging purpose. Narrow band mode has a provision of generating 256 different kinds of waveforms varying in pulse width and type of waveforms required. One of the waveform is selected and the same is used for transmission after up-conversion. For ground mapping purpose, wideband waveforms consist of wideband transmission waveforms and wideband de-chirp waveforms used for down-conversion. Bandwidth of these waveforms varies according to the requirement of image resolution.

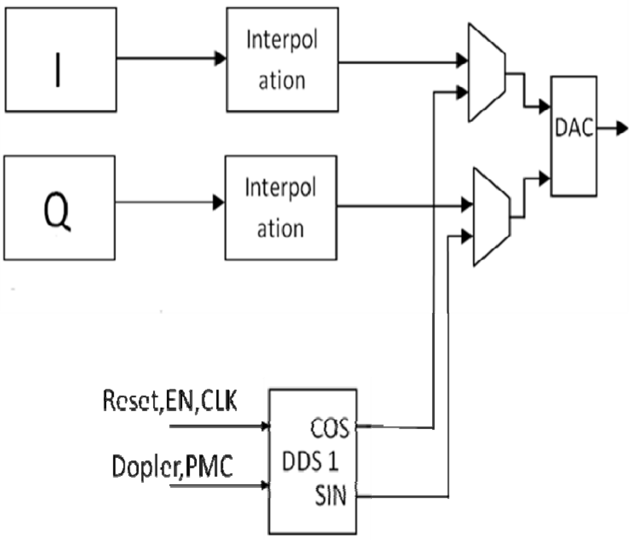
II. IMPLEMENTATION SCHEME

The implementation method is divided in two parts. First, software implementation is described and later hardware implementation process is explained.

The software implementation uses Matlab coding to generate I and Q coefficients of various waveforms. The scheme uses Xilinx system generator blocks integrated with Simulink in Matlab environment. Block RAMs are used to hold the coefficients (I and Q data) of waveform choices to be used in radar. The data level waveform is upsampled N times and presented to a multiplier. N depends on the input data rate to DAC and the DDS frequency where the DDS frequency is presented to the other port of the multiplier. Multipliers output for I and Q channels are added, quantized and converted to analog waveform and sent for transmission after up conversion. A core DDS block is used for the purpose of generating the carrier. The DDS core is provided with a particular data to generate the carrier frequency.
DDS core is provided with reset and enable signal used for synchronization and resetting the initial phase of DDS on pulse to pulse basis. The DDS is also presented with Target Doppler and Platform Motion Compensation data. These data are used either to introduce Doppler to the BITE targets or to compensate platform motion by shifting DDS core frequency. A timing generation module (not shown in above figure) is used to generate all timing and controls required for the scheme. The waveform generation

Figure 1: Simplified Implementation Scheme.

scheme is capable of handling 256 different waveforms. The selection of waveform comes from RC controller and depending on the selection, timing generation module generates the address counters for block RAM. The Doppler and PMC data can arrive through LAN or discrete lines depending on resource availability.



The above process happens inside Xilinx virtex 5 FPGA used for narrowband (NB) waveform generation purpose. NB waveform is having a 5 MHz bandwidth and used for Air to Air tracking purpose. Digitally generated NB waveforms are sent to DAC for converting to analog and up conversion thereafter. Similarly wideband (WB) waveforms are also generated through the waveform generator card for higher resolution purpose. WB waveforms are generated using DDS (AD9858) and Multiplier approach. Based on the trigger arrival from Radar Controller and register values set through FPGA command, DDS o/p signals are swept from start to stop frequency set value with a pre determined update rate. The actual required bandwidth is generated after multiplication inside synthesizer module.

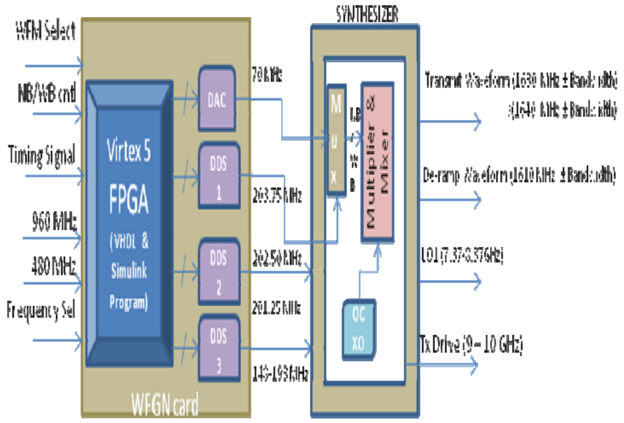


Figure 2: NB and WB waveform generation

III. HARDWARE REALIZATION SCHEME

The above described waveform generation scheme has been implemented through an extremely compact hardware board. Following functions are carried out in this module namely generation of wideband Up-chirp waveforms for transmission, Local Oscillator signal, generation of Narrow band waveforms at 70MHz as well as Control and timing functions. It also handles RF and digital Interfaces for control, status and RF signal between the modules.

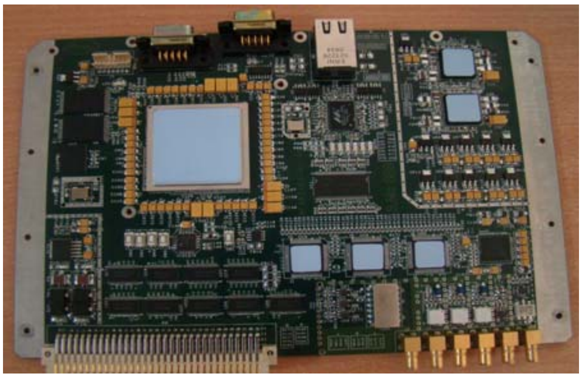


Figure 3: waveform generator card

AD9858 ASICs from Analog devices are used for the generation of Wideband Waveforms and CW LO frequencies. There will be totally three DDS chips on the board. Programmable Narrow band waveforms are generated by storing I/Q coefficients for different waveforms, reading and up converting to 70MHz using NCO/DDS carrier. Up-conversion process is digitally carried out in FPGA. These digitized waveforms are converted to Analog waveforms in DAC working at 480MHz clock. The NB and WB waveform generation are functioning with clock frequencies which are derived from System clock for coherency.

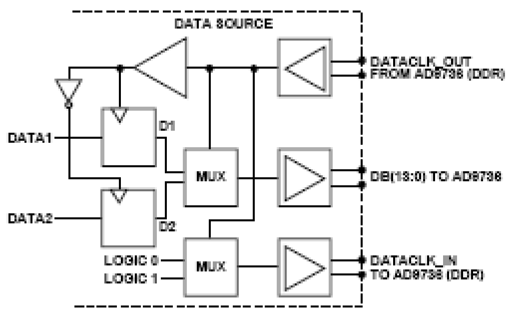


Figure 4. Data and Clock synchronization scheme

The clock scheme for the board has been implemented in a unique way. The DAC gets the 480 MHz clock generated through a Master OCXO. The internal circuitry within DAC generates 240 MHz (half of 480 MHz) which is used for data generation purpose inside FPGA. Digitally generated waveform data are sent to DAC along with a loop back clock from FPGA for data synchronization purpose within DAC.

This unit also acts as timing and control module for the Exciter receiver unit and Front end unit. It receives commands (calibration parameters etc.) through LAN Interface. Messages are decoded and appropriate controls are generated. This board comprises of Ethernet port (10/100), COM port for RS232 interface and Single ended I/O lines. It receives mode parameters from Host through Ethernet and based on these parameters, all waveform signals, timing and control signals are generated. The memory subsystem of waveform generator card comprises of Flash and DDR2. Flash is used to store the lookup tables for up-chirp generation whereas DDR2 is used as run time memory.

IV. TESTING AND RESULTS

Waveforms were verified for different properties through Real Time Spectrum Analyzer. Phase vs. Time, Frequency vs. Time measurement were verified for all the waveforms and compared with ideal characteristics so that clean waveforms are produced and transmitted. Following are few plots taken using Real Time Spectrum Analyzer (RTSA) during waveform quality measurements.

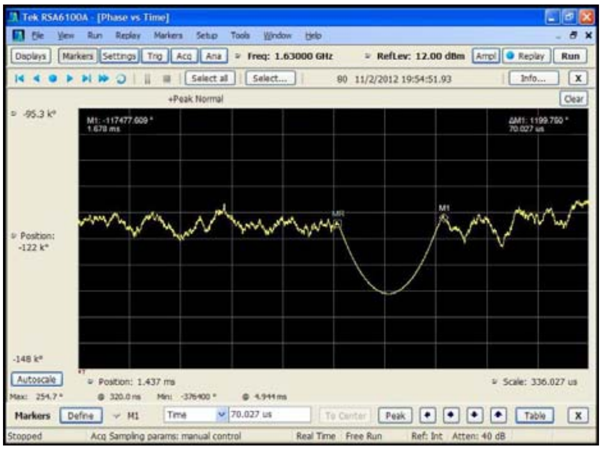


Figure 5. Phase vs. time for LFM

The above plots shows phase vs. time of LFM which is a parabola. The parabola is generated for width of the LFM pulse of 70 us as the case here. Similarly plot of frequency vs. time for LFM waveform is a measure of linearity of the waveform as shown below in figure 6.

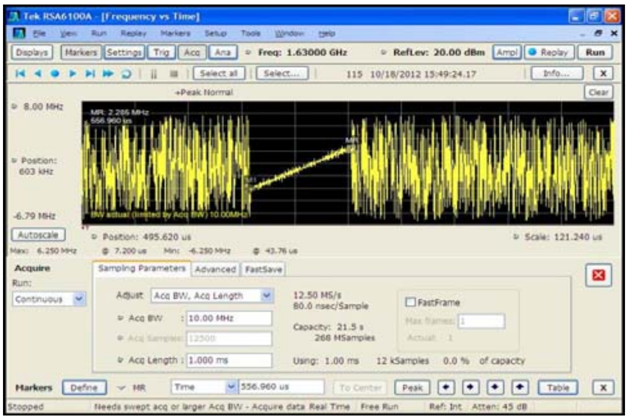


Figure 6. Freq vs Time plot of LFM

The frequency increses linearly during the presence of the pulse while rest of the plot shows noise in absence of pulse.

V. CONCLUSION

Current trends in modern radars are that all the electronics should have low power consumption and dissipation. It should have less packaged volume and weight as well. These are particularly true for airborne radars because radar as a pay load uses aircraft resources. The waveform generator board described here have the advantages of all the three mentioned above and it is very appropriate for airborne radars. Leaving those hardware advantages, it has added flexibility of on-field programmability. Choice of PRF is important in waveform designing. All other conditions remaining the same, the PRF determines to what extent the observed ranges and Doppler frequencies will be ambiguous. For Airborne radars, medium-PRF is a compromise solution to overcome some of the limitations of both low and high-PRF waveforms as far as air detection is concerned. The waveform card in the context here have the capability of storing a number of waveforms which can be useful in the selection of MPRF waveforms for various air to air modes and high resolution waveforms for air to sea and air to ground mode.

REFERENCES

[1] Merrill I Skolnik, "Introduction to Radar systems" , *Third Edition, Tata McGraw-Hill Publishing Company Limited*.
[2] www.xilinx.com\support and documentation help.
[3] ISE Project Navigator version 12.4 software manuals and tutorials from ISE help.
[4]George W Stimson, "Introduction to Airborne Radar", Second Edition.

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