# Software Defined Radio as a solution to testing RF Avionics

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*Abstract*— **Pulsed radar is an important technology used in both commercial and military aircraft. Learn how Software Defined Instrumentation utilizing Graphical Software Design and COTS PXI RF instrumentation can be configured to simulate and test different types of pulsed radar. This paper will cover fundamentals of pulse generation and analysis as well as advanced techniques such as the simulation of secondary radars that require real time interrogation handling and response generation. Illustrating this will be a case study on TACAN (Tactical Air Navigation) beacon emulation. The TACAN beacon is implemented on generic COTS PXI RF hardware. The functionality is defined in FPGA software. The hardware is reusable by loading and executing application specific FPGA software. TACAN has been around since the late 1950s. It is a military standard that combines distance measuring with direction finding, typically for aircraft to ground station navigation. The TACAN signal is defined in MIL-STD-291C and is ~1GHz.**

**The system is designed to utilize a PXI chassis with an RF downconverter, RF upconverter, and an IF transceiver with an onboard FPGA to receive/analyze a TACAN interrogation and generate a TACAN reply signal.**

**There are two major software tasks for the FPGA identified as follows: TACAN interrogation signal reception with parametric analysis and TACAN ground station composite signal transmission. The receiver will perform a minimal amount of parametric testing on the received pulse pair to create a trigger for the transmission of a response signal. The transmitter is responsible for the response pulse generation that adds a delay to simulate the selected distance in nautical miles and phase relationships to simulate the selected bearing in degrees. Components of the response pulse generation include 15Hz and 135Hz sine wave generation, Morse code identification, and randomly distributed pulses known as squitter to achieve relatively uniform average power.**

**The FPGA is programmed with visual programming language LabVIEW FPGA from National Instruments.**

***Keywords—COTS; FPGA; TACAN***

## I. Introduction

COTS RF equipment exists that can be reused/reprogrammed for testing avionics such as TACAN. The key component of this COTS equipment is an FPGA programmable IF transceiver. Fig. 1 is a block diagram of the software.

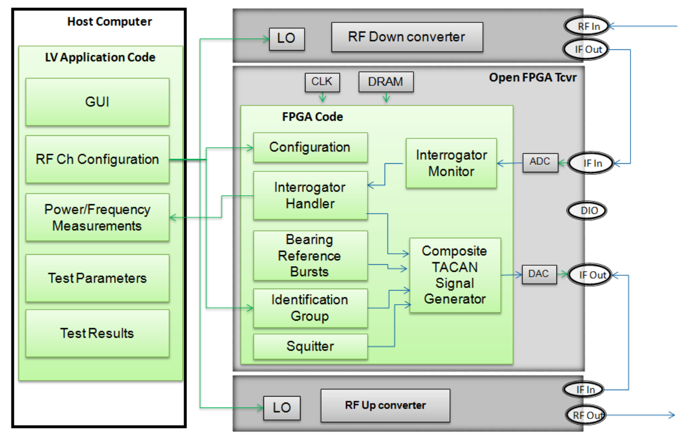


Fig. 1. Host and FPGA code block diagram

This paper will cover:

- COTS hardware
- What is TACAN (what is a pulse pair)
- Creating pulse shape array in Host code
- Reception & analysis of an interrogation pulse pair
- Transmission of response pulse pair

## II. COTS Hardware

- PXIe-8130 Embedded Controller running Windows
- PXI-5600 Downconverter
- PXI-5610 Upconverter
- PXIe-5641R IF Transceiver with FPGA Xilinx Virtex 5
- Replaceable with PXIe-5644R Vector Signal Transceiver

## III. TACAN Background

- Tactical Air Navigation System
- Navigation system used by military aircraft

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- Provides bearing & distance to ground or ship-borne station
- In use since late 1950s
- Frequency band 960-1215 MHz
- Radio transponder (secondary radar)

## IV. Pulse Pair (MIL-STD-291C)

Fig. 2 is a depiction of a pulse pair.

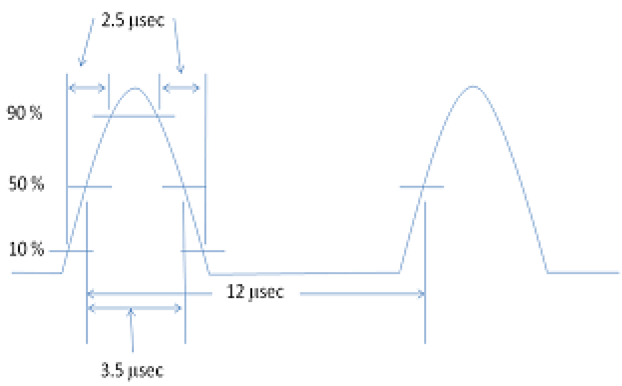


Fig. 2. Pulse Pair as defined by MIL-STD-291C

## V. Create Pulse Shape Array

### *A. Host Code creation of pulse array*

In Fig. 3 the block (white) waveform is an array of integers created from pulse parameters width & rise/fall time. This block data is then input into a Gaussian Peak Fit function shown in Fig.4 to produce the rounded (red) pulse.

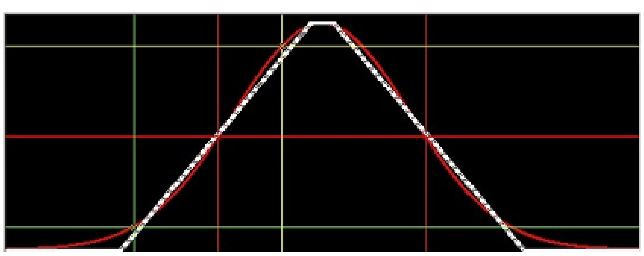

Fig. 3. Before and after look at pulse shape

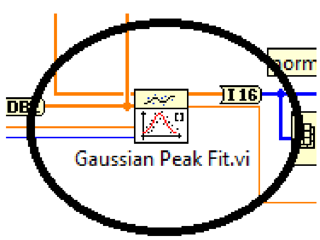


Fig. 4. Host code Guassian Peak Fit function

### *B. Download pulse shape array to FPGA*

In Fig. 5 the pulse shape array created by the Host code is downloaded to the FPGA via a fifo.

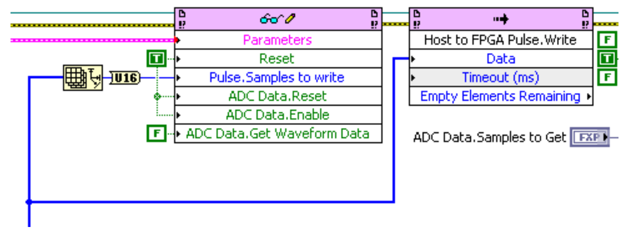


Fig. 5. Host code to download pulse shape array to FPGA

### *C. FPGA code reads pulse shape array into memory.*

In Fig. 6 the FPGA code reads the pulse shape info out of the fifo into memory for use whenever a pulse needs to be transmitted.

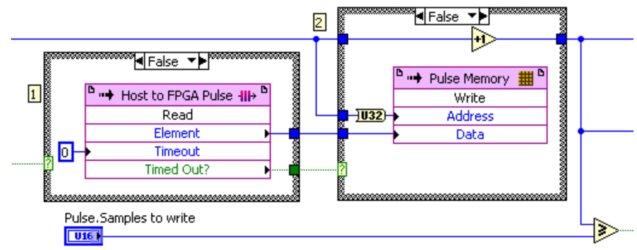


Fig. 6. FPGA code to read pulse shape array into memory

In Fig. 7, the FPGA code reads the pulse shape info out of memory whenever a pulse needs to be transmitted.

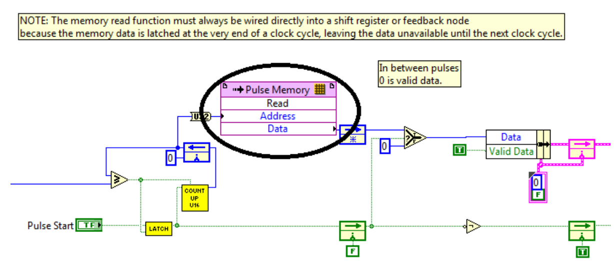


Fig. 7. Output pulse from FPGA memory

### *D. FPGA pulse memory transmission*

Fig. 8 shows the IF output of a pulse pair in RF envelope.

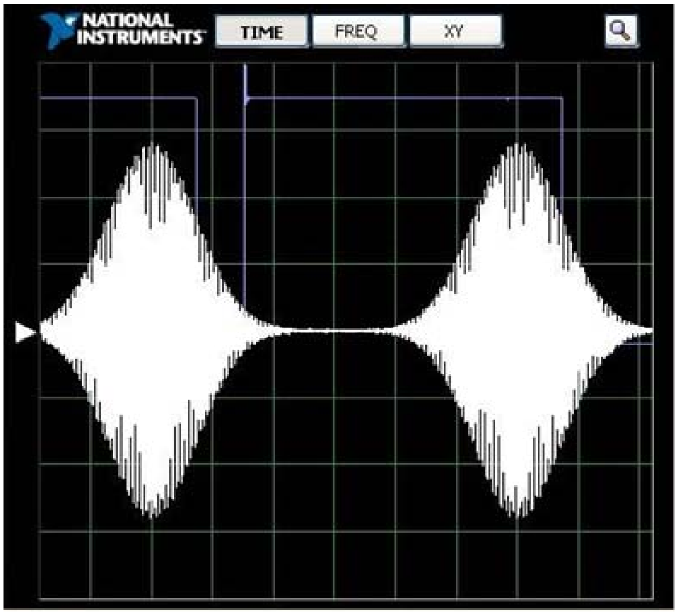


Fig. 8. IF output of Gaussian shaped pulses in RF envelope.

## VI. Reception & Analysis of Pulse Pair

To detect a valid pulse pair, a pulse needs to be detected. This is accomplished by finding a peak in the received pulse data. Fig. 9 shows FPGA code that uses feedback nodes to detect a peak.

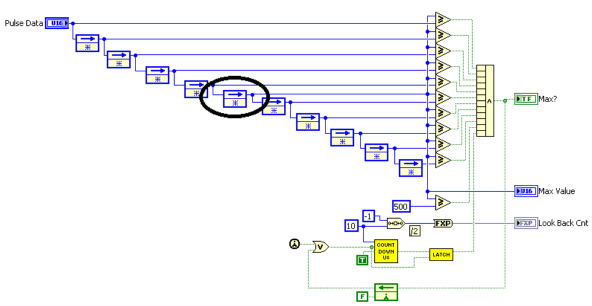


Fig. 9. Use of feedback nodes to detect a peak

Once a peak has been detected, look back memory is used to determine if a pulse has preceded the pulse just detected and that the preceding pulse is at the specified spacing to create a valid pulse pair. Fig. 10 shows code implementing the look back memory.

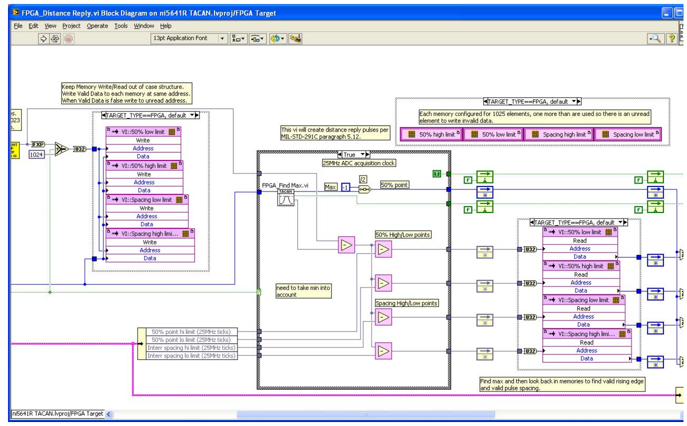

Fig. 10. Lookback data memory in FPGA code

## VII. Transmission of Response Pulse Pair

Now that a valid interrogation pulse pair has been detected, the response pulse pair is transmitted with the appropriate delay to simulate distance from the beacon. Fig. 11 shows an interrogation pulse pair followed by a response pulse pair at a simulated distance of 0nmi. At 0nmi the pulse pairs are separated by 50µsec per MIL-STD-291C.

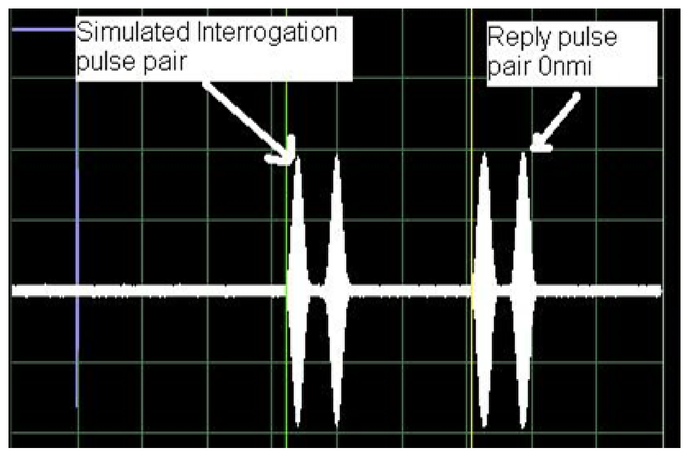


Fig. 11. Interrogation and Response pulse pairs

## Summary

- Software defined instrumentation provides environment for multiple applications
- FPGA programming is ideal for implementing pulsed based RF test equipment.
- Hardware reuse is cost effective.