Developing a Generic Software-Defined Radar Transmitter using GNU Radio

A thesis submitted in partial fulfilment of the requirements for the degree of
Master of Sciences (Defence Signal Information Processing)

by

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Abstract

Research into the development of software defined radars (SDRs) often combines the GNU Radio software toolkit, with the Universal Software Radio Peripheral (USRP) hardware platform.

Studies have already demonstrated that these tools can be combined to develop and implement versatile, low-cost, SDR systems. These studies focus on the question as to whether or not a GNU Radio and USRP based SDR can address a specific set of requirements for a particular radar application; but do not explore the characteristic behaviour of the technology.

Understanding the characteristic behaviour of this technology, more specifically its limitations and accuracy, is critical to radar designers considering using these tools to achieve SDR design requirements.

This thesis examines how effectively GNU Radio and the USRP can be combined to create a software-defined radar transmitter. A SDR transmitter has been developed using these tools as a subject for experimentation and implemented to produce a set of generic radar waveforms at a frequency of 5.8GHz. This set consists of continuous wave, 1 μs pulsed waveforms and frequency modulated continuous waveforms with sweep ranges from 0.5 to 25MHz.

Characterisation tests thoroughly investigated and verified limitations of the USRP performance, and identified many others that were unknown at the time or did not match expected values. Waveform verification tests demonstrated that these tools can be used to accurately transmit CW, pulsed and frequency modulated waveforms with characteristics similar to those in this study.

GNU Radio and the USRP can be combined to effectively produce a generic radar transmitter, however some imperfections such as intermodulation products and poor local oscillator suppression may be unacceptable for some radar transmission applications.

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Acronym	Term
ADC	Analogue-to-Digital Converter
API	Application Programming Interface
BB	Baseband
COTS	Commercial-Off-The-Shelf
CW	Continuous Wave
DAC	Digital-to-Analogue Converter
DDC	Digital Down Converter
DSP	Digital Signal Processor
DSTO	Defence Science and Technology Organisation
DUC	Digital Up Converter
EWRD	Electronic Warfare and Radar Division
FAQ	Frequency Asked Question
FFT	Fast Fourier Transform
FIFO	First-In, First Out
FMCW	Frequency Modulated Continuous Waveform
FPGA	Field Programmable Gate Array
GPL	General Public License
GPS	Global Positioning System
GPSDO	GPS Disciplined Oscillator
GRC	GNU Radio Companion
GUI	Graphical User Interface
IC	Integrated Circuit
IF	Intermediate Frequency
IM	Inter-modulation
LO	Local Oscillator
MBW	Modulation Bandwidth
MIMO	Multiple-Input Multiple-Output
MMIC	Monolithic Microwave Integrated Circuit
NCO	Numerically Controlled Oscillator
OIP3	Third Order Output Intercept Point
OS	Operating System
PC	Personal Computer
PLL	Phase Locked Loop
PPM	Parts per million
PRF	Pulse Repetition Frequency
PRI	Pulse Repetition Interval
RBW	Resolution Bandwidth
RF	Radio Frequency
SDR	Software-Defined Radar
SFDR	Spurious Free Dynamic Range
SNR	Signal to Noise Ratio
UHD	‘Universal Software Radio Peripheral’ Hardware Driver
USRP	Universal Software Radio Peripheral
VBW	Video Bandwidth
VCO	Voltage Controlled Oscillator
VGA	Voltage Gain Amplifier