A Dual-Mode Radar Signal Controller for a Drone Detection System

Yun-Taek Im [a*], and Young-San Choi [a]
[a] *Korea Atomic Energy Research Institute, 989-111 Daedeok-daero, Yuseong-gu, Daejeon 34057, Korea.*
HANARO Management Division.
[*] *Corresponding author: ytim@kaeri.re.kr*

1. Introduction

With the rapid growth of unmanned drone technology, it poses a threat to several important national facilities, including nuclear facilities [1]. As a countermeasure to this, it is necessary to develop techniques for detecting unmanned drones, and radar is one of several countermeasures for detecting drones [2, 3]. In this paper, we describe a radar signal controller that can use the FMCW radar method at short-range and the pulse Doppler method at medium or long-range to enhance capability for detecting drones.

2. System Implementation

In general, radars are distinguished as continuous wave radar and pulse wave radar. In most radar systems, transmitters and receivers are close, so the transmission signal may be leaked to the receiver. Therefore, the continuous wave radars are suitable for short-range detection, and pulse wave radars are suitable for over medium-range detection when the system handles higher power.

Most drones can take off without runways, it can approach critical security facilities from anywhere. Therefore, short-range, medium-range, or long-range drone detection capabilities are necessary. Fig. 1 shows the detection scenario using a dual-mode radar system.

2.1 Dual Mode Radar

A linear frequency modulation technique is commonly applied in both a continuous wave radar and a pulse wave radar. DDS is used to generate these linear frequency modulation signals, allowing control of magnitude, phase, and frequency. And the received signals are essentially processed by using FFT or IFFT [4].

In this paper, the system uses three DDSs, one for transmitters and the others for receivers. For accurate time control, FPGA is used, and transmission and reception of signals are synchronized using the 50 MHz oscillator provided externally. Fig. 2 shows the functional block diagram of the radar signal controller.

In FMCW radar mode, it has a bandwidth of 25 MHz and a resolution of 6 meters. The maximum near-field drone detection range is approximately 3 kilometers.

In pulse-Doppler radar mode, it has a bandwidth of 12.5 MHz and a resolution of 12 meters. The detection range in this mode is approximately 3~12 kilometers. The single-delay line canceller is used, and the number of pulses for Doppler signal processing is 16. Detailed specifications are described in Table I. However, depending on the timing control of the FPGA, the detection distance, frequency, and algorithms are to be variable in both modes.

Radar signals in both modes are processed at TMS320F28335 to detect signals from targets using FFT (or IFFT). Fig. 3 shows the implemented system.

2.2 Test Results

In FMCW radar mode, the frequency of the transmission signal was generated from 62.59765625 to 87.59765625 MHz to check the status of the received signal, while the LO Frequency is from 62.5 to 87.5 MHz. Fig. 4(a) & (b) show I & Q received signals in FMCW radar mode and the test results of the FFT of the signal.

In pulse-Doppler radar mode, the sampling time is adjusted to test the TX and RX signals. Fig. 5(a) & (b) show I & Q signals received in pulse-Doppler radar mode and results using FFT and IFFT.

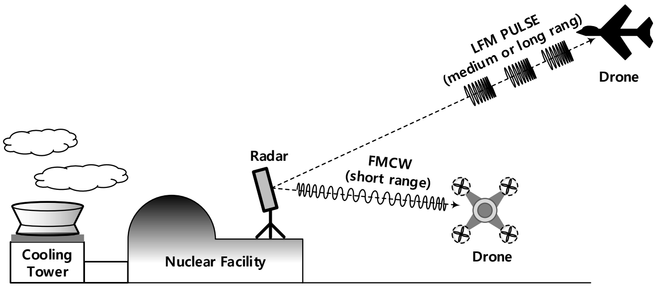


Fig. 1. Detection scenario using a dual-mode radar system.

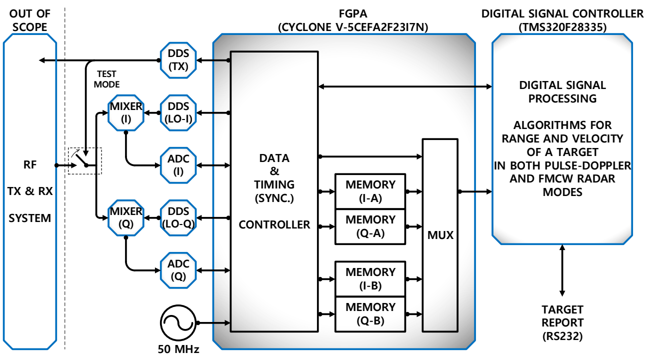


Fig. 2. Functional block diagram of the radar.

Table I: Design Specification

	FMCW Radar	Pulse-Doppler Radar
TX Bandwidth [MHz]	25.0	12.5
TX Frequency [MHz] (Test Mode)	62.5 ~ 87.5 (62.59765625 ~ 87.59765625)	62.5 ~ 75.0
LO Frequency [MHz]	62.5 ~ 87.5	68.75
Pulse Width [μ s]	819.2	20.48
Resolution [meter]	6	12
Number of Pulse	1	16
FFT Size	512 x 2 (Up & Down Sweep)	1024 x 16 (Range x Doppler)
Detection Range [meter] (Test Mode)	0~3072	3,072~12,288 (0 ~ 9,216)
PRT [μ s]	Variable	100 (Variable)
DDS	14 bit (400 MSPS)	
FPGA	Intel Cyclone 5 Device Family (5CEFA2F23I7N)	
Digital Signal Controller	TMS320 Series (F28335)	

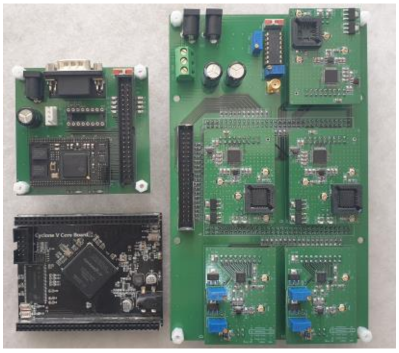


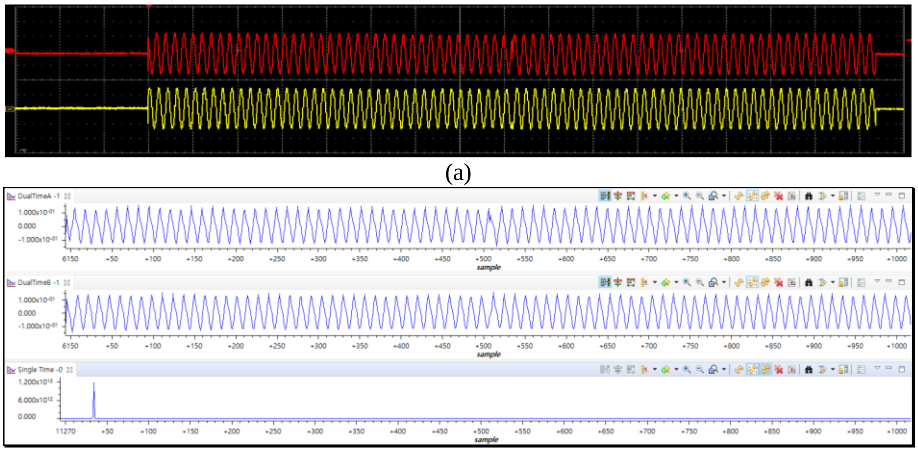
Fig. 3. Implemented dual-mode radar signal controller

3. Conclusions

This paper shows a dual-mode radar signal controller for drone detection in critical national facilities such as nuclear facilities. DDSs are used to control transmission and reception signals, and FPGA is used for an accurate time synchronization. The controller is designed to detect drones in FMCW radar mode at short range, and it is to do drones in pulse-Doppler radar mode at medium or long range.

REFERENCES

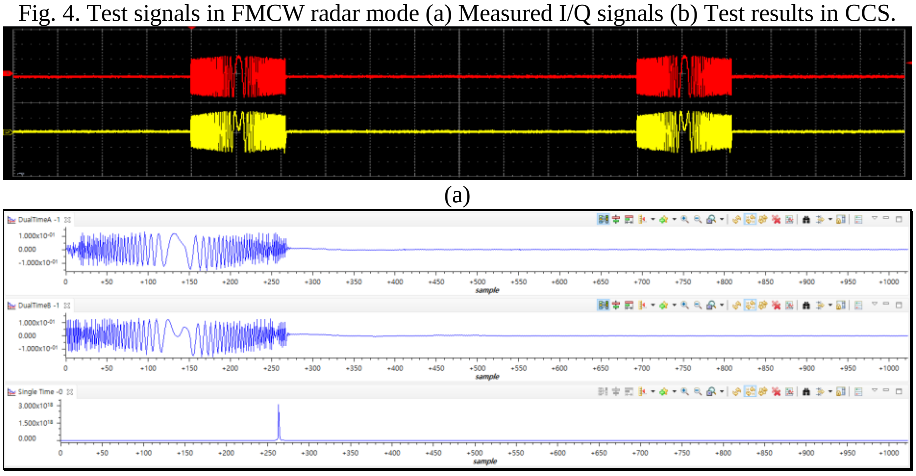
[1] Jae San Kim, A Study on the Possibility of Unmanned Aerial Vehicles (UAV)' Threat in Nuclear Facilities, Transactions of the Korean Nuclear Society Autumn Meeting, Goyang, Korea, October 24-25, 2019.
[2] Soon-phil Hwang, and Doo-hwan Kim, A Study on the Establishment of Anti-Drone system for the Protection of National Important Facilities, Journal of Digital Convergence, Vol. 18, No. 11, pp 247-257, 2020.
[3] Seunghyeok Lee, Yongchul Jung, and Yunho Jung, Design of Multi-Mode Radar Signal Processor for UAV Detection, J. Adv. Navig. Technol. 23(2): 134-141, Apr. 2019.
[4] Mahafza, Radar Systems Analysis and Design using MATLAB, Chapman & Hall/CRC.



(a)

(b)

Fig. 4. Test signals in FMCW radar mode (a) Measured I/Q signals (b) Test results in CCS.



(a)

(b)

Fig. 5. Test signals in pulse-Doppler radar mode (a) Measured I/Q signals (b) Test results in CCS.