11B.5 AN X-BAND PHASED ARRAY DOPPLER WEATHER RADAR

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1. INTRODUCTION

The Navy Center for Interdisciplinary Remotely Piloted Aircraft Studies (CIRPAS) is collaborating with ProSensing Inc. to add a weather mode to a rapid scanning X-band phased array military radar system. The radar is jointly operated by CIRPAS and the Naval Post Graduate School in Monterey, CA for the purpose of education and research. ProSensing is developing a state-of-the-art FPGA-based weather radar processor (WRP) system compatible with the radar at CIRPAS. This system will provide radar control, data acquisition and signal processing for 3-D weather radar measurements. The upgraded radar system is planned to be tested on severe storms during the 2004 spring tornado season in the US Central Plains.

2. SYSTEM DESCRIPTION

The rapid scanning radar system, as shown in Figure 1, is designed to operate as an air surveillance and target acquisition and tracking sensor system with key system parameters summarized in Table 1.

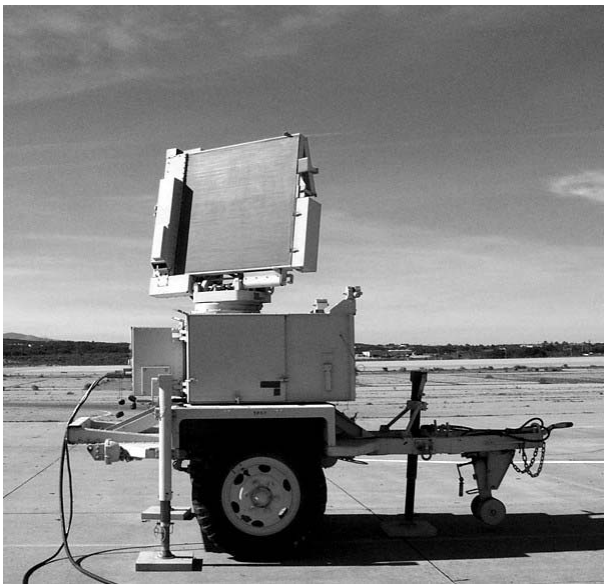

Figure 1. Tracking radar system antenna-transceiver section. The 1.2 m phased array antenna provides electronic elevation beam scanning and mechanical scanning in azimuth.

The radar operated by CIRPAS is a mobile system consisting of (1) a truck-mounted operator shelter with Radar Processor Group (RPG), which includes the signal processor, operator display and power generator and (2) a trailer-mounted Antenna Transceiver Group (ATG) including the RF transmitter, receiver and scanning antenna array. A simple block diagram of the system, modified for weather radar processing, is shown in Figure 2.

Table 1. Key system parameters for the rapid scan radar system.

Parameter	Value
Transmitted frequency	X-Band
Transmit power	23 kW
PRF	6.25 – 15 kHz
Antenna type	Mechanically rotated electronically scanned phased array
Azimuth BW	1.8 degrees azimuth 2.0 degrees elevation
Azimuth Scan	360 degrees, 30 RPM
Elevation BW	2.0 degrees
Elevation Scan	20 degrees sector
Range Resolution	150 m
Receiver IF frequency	72 MHz

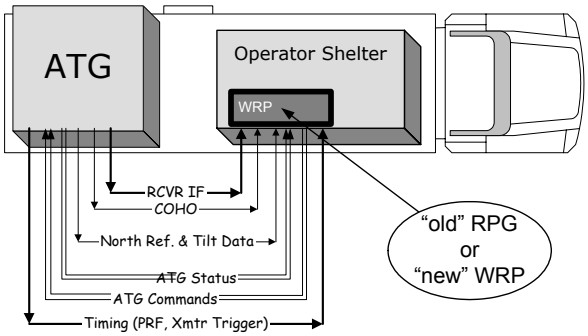

Figure 2. System block diagram showing the configuration of the upgraded radar system.

The pulse-to-pulse beam scanning of the radar is ideal for gathering 3D-weather data. The radar beam is mechanically scanned in azimuth over 360 degrees at a constant rate of 30 rpm. In elevation, the antenna beam is scanned electronically over a 24-degree sector. The beam can also be frequency scanned in azimuth by +/-

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3.5 degrees, allowing the beam to momentarily dwell on a fixed azimuth angle, even while the antenna is rotating. This 360x24 degree volume can be uniformly sampled in a few seconds at a volumetric resolution of 2 deg (elevation) x 1.8 deg (azimuth) x 150 m.

As part of the development, ProSensing will migrate the radar system shown in Figure 1, onto a flat bed truck, allowing rapid deployment in the field and mobile operation.

3. WEATHER RADAR PROCESSOR

ProSensing is currently developing an FPGA-based real-time signal processor to add a weather surveillance mode to existing rapid scanning military radar systems. This effort involves:

1. Development of processing and data compression algorithms suitable for FPGA implementation. Algorithms will include notch filters for clutter rejection and staggered PRT for de-aliasing velocity data.
2. Development of a radar control module allowing instantaneous radar beam pointing angle control suitable for weather surveillance.
3. Development of an interface between the radar and the data system to merge raw radar data with auxiliary information including antenna pointing angle, absolute time, and GPS.
4. Development of system control, post processing and display software.

A block diagram of the weather radar processor (WRP) card is shown in Figure 3. The WRP includes a two-channel digital receiver/signal processor, accepting a 72 MHz IF frequency from the transceiver. The WRP's digital tuner performs I/Q detection and digital filtering to convert the radar echo to base-band. The FPGA then computes several algorithms simultaneously, including reflectivity, pulse-pair derived velocity products and full-spectra at each range gate.

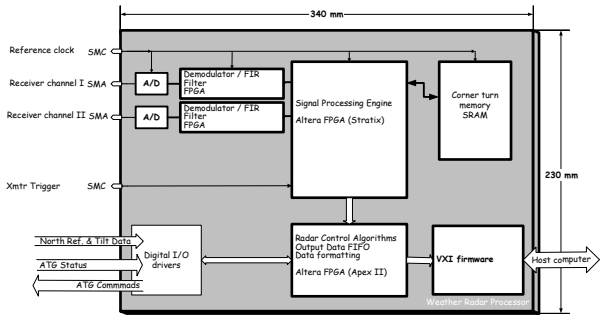

Figure 3 Block diagram of the weather radar processor card.

The radar can detect a 0 dBZ target at a range of 30 km with a single pulse at unity SNR. The radar's minimum detectable sensitivity, predicted from the radar range equation, is plotted in Figure 4, for 150 m range resolution

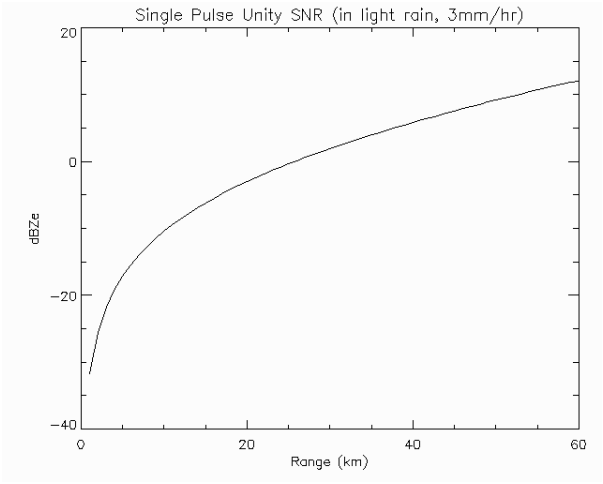

Figure 4. Minimum detectable reflectivity assuming 30 m range resolution, .25 second averaging, 2 kHz PRF, and 2 percent false detection rate.

Currently, ProSensing is working on the development of the Weather Radar Processor with a support from Thales-Raytheon System, manufacturer of the radar system. After system integration, ProSensing will work with CIRPAS to test the upgraded radar system on severe storms during the 2004 spring tornado season in the US Central Plains.