4A.3 COMPACT AIRBORNE SOLID-STATE 95 GHZ FMCW RADAR SYSTEM

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1. INTRODUCTION

ProSensing Inc. has developed a low power solid state W-band radar, shown in Figure 1, for airborne measurements of clouds and precipitation. The system employs a simple homodyne receiver design in a palm sized package that minimized the number of components and system power consumption. An FPGA-based digital receiver /signal processor computes range profiles of reflectivity and pulse-pair derived velocity products at PRF's up to 14 kHz. Engineering test flights of the radar were carried out in September, 2002, on the CIRPAS Twin Otter, with the first airborne experiments planned for the summer of 2003.

2. SYSTEM DESCRIPTION

A block diagram of the pod mounted compact FMCW radar system is shown in Figure 2 with key system parameters summarized in Table 1. The transmitter IF waveform is multiplied from 15.8 GHz to 94.8 where it is amplified by a 300 mW IMPATT diode amplifier. To minimize the number of components, only a single down conversion stage is used to translate the received signal to an IF offset frequency of 24 MHz before digitization. A millimeter-wave I/Q detector is used instead of a simple mixer to reject noise from the unused upper sideband. The IF offset of 24 MHz is achieved by generating separate linear FM waveforms for the transmitter and receiver local oscillator which are offset by 4 MHz. The millimeter-wave receiver, including LNA, homodyne I/Q detector, x6 LO generation and IF amplification, is packaged in a microwave integrated circuit weighing 120 grams.

The radar's RF and IF sections are mounted in a fiberglass wing pod, manufactured by Zivko Aeronautics. The pod and RF unit weigh 36 kg.

A real-time FPGA-based processor has been developed that computes pulse-pair velocity products and reflectivity for 512 range gates at up to 14 kHz PRF (Figure 3). A graphical user interface, shown in Figure 4, was developed for system control and real time display of data products.

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Figure 1. 95 GHz cloud radar mounted on the wing of the CIRPAS Twin Otter.

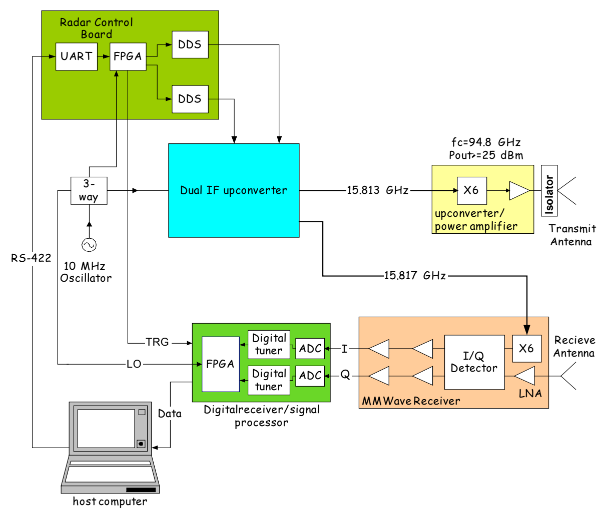

Figure 2. FMCW cloud radar system block diagram.

Table 1. Key system parameters for the compact FMCW cloud radar.

Parameter	Value
Center frequency	94.8 GHz
Transmit power	300 mW
Antenna type	30 cm diameter dual Cassegrain
Receiver type	In-phase and Quadrature homodyne detection
System Noise Figure	7.0 dB
Range Resolution	Any value 5-300 m
System power consumption	28V at 2.5 A

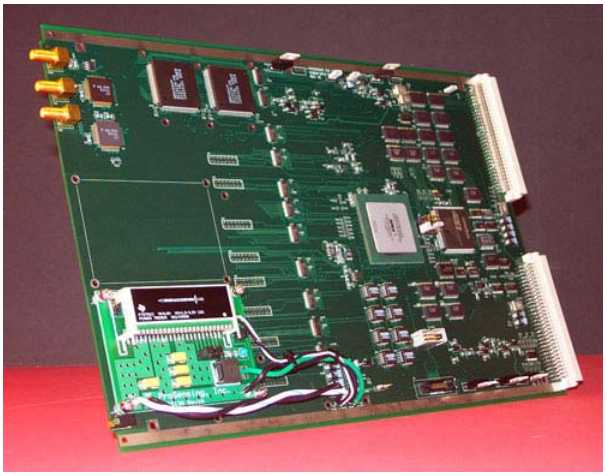

Figure 3. Two channel digital receiver/signal processor, accepting IF frequencies from 0 to 28 MHz. The FPGA processor performs up to 14,000 512 point FFTs per second to generate range profiles of the complex voltage. The voltage profiles are further processed by the FPGA into velocity and reflectivity profiles.

The radar's minimum detectable sensitivity, predicted from the radar range equation [1], is plotted in Figure 5, for 30 m range resolution. The range resolution is continuously variable from 5-300 m, which is governed by the bandwidth of the digitally synthesized chirp waveform. The radar has a minimum range of approximately 20 m, where it achieves better than –45 dBZ sensitivity at 5 m range resolution.

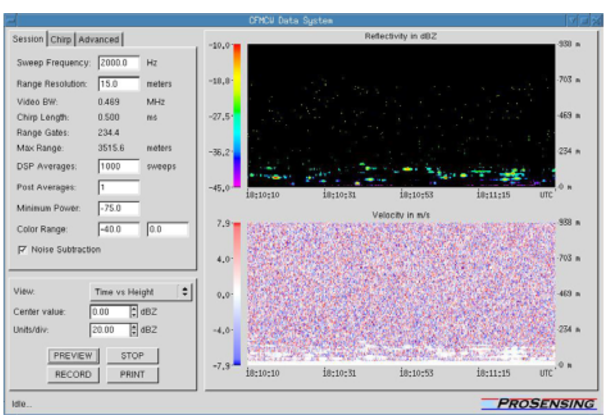

Figure 4. Graphical user interface for radar control and display of data products. Time/height plots of reflectivity and velocity for insects gathered April, 2002 in Amherst, MA are shown with the system configured for 5 m height resolution, 10 kHz PRF, and 0.1 s averages.

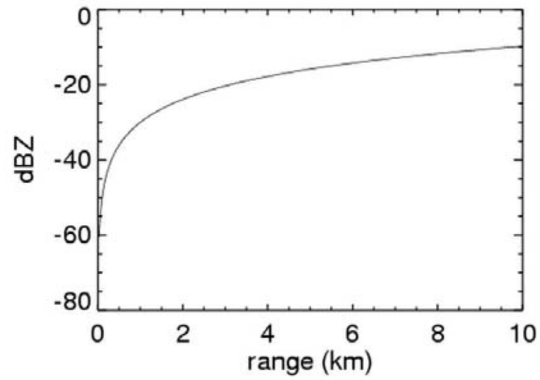

Figure 4. Minimum detectable reflectivity assuming 30 m range resolution, .25 second averaging, 2 kHz PRF, and 2 percent false detection rate.

An example reflectivity image for an ice cloud measured during December 2002 from the roof of ProSensing's facility in Amherst, MA is shown in Figure 5. More data gathered during the winter of 2002/2003 can be downloaded from the ProSensing web site, www.prosensing.com.

The radar is currently operated by the Rosenstiel School of Marine and Atmospheric Science, University of Miami, with airborne experiments planned for the summer of 2003, based out of the CIRPAS facility in Marina, CA.

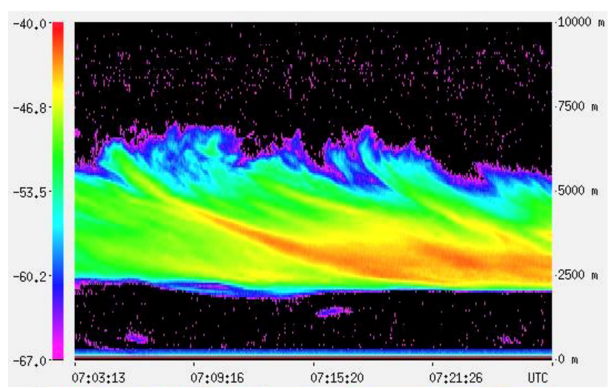

Figure 5. Time/height plot of backscattered power (uncalibrated reflectivity) for an ice cloud passing over Amherst, MA, December 25, 2002.

[1] Lhermitte, R. *Centimeter and Millimeter Wavelength Radars in Meteorology,* L'hermitte Publications, 2002, ISBN-0-9719372-0-6, pg. 248.