**P1R.9 NRC DUAL-FREQUENCY AIRBORNE RADAR FOR ATMOSPHERIC RESEARCH**

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## 1. INTRODUCTION

The National Research Council Institute for Aerospace Research (NRC Aerospace), in cooperation with ProSensing Inc., is currently developing a state-of-the-art dual frequency airborne radar system for atmospheric and flight safety research for its Convair-580 research aircraft. The choice of W and X-bands for the NRC Airborne radar system is based on suitability for airborne installation (less power and smaller antennas) while providing high resolution and high sensitivity for detection of weak clouds, and the expected research applications of the radar. The ***N***RC ***A***irborne ***W*** and ***X***–bands radar system (NAWX) will be integrated onto the NRC Convair-580 in December 2005. This poster highlights the NAWX system specifications and capabilities.

## 2. NAWX RADAR SPECIFICATIONS

The NAWX antenna subsystem includes three W-band and three X-band antennas and a two-axis motorized reflector plate for one of the W-band antennas (Fig. 1). The NAWX radar electronics and data system will be rack mounted inside the aircraft cabin while the antenna subsystem will be housed inside an un-pressurized blister radome (137”x28”x25”). Three of the regular aircraft windows are replaced with metallic window plates fitted with customized bulkhead feedthrough adaptors, for connecting the antenna ports from the W and X-bands RF units to the externally mounted antennas. Figure 2 shows one of the window plates with one of the bulkhead feedthrough adaptors that connect the W and X band waveguide ports from the RF units to the externally mounted antennas.

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### 2.1 *Radome and Antenna Subsystem*

The main radome is being constructed as a sandwich structure using materials that have low loss at X-band and satisfy the mechanical airworthiness requirements. For the W-band, the radar beams will be transmitted through a different window material to minimize the radome insertion loss. Tests of different window materials are being done to identify materials with low loss at W-band that are also suitable for aircraft operations in severe weather and altitudes up to the service ceiling of the aircraft. Figure 3 shows the test set-up at ProSensing facility as one of the NRC Aerospace manufactured W-band radome samples is tested and Figure 4 presents the corresponding theoretical modeling output using Ansoft Designer® software and measured insertion loss. The one-way insertion loss of the window materials tested so far is on the order of 0.5-1 dB.

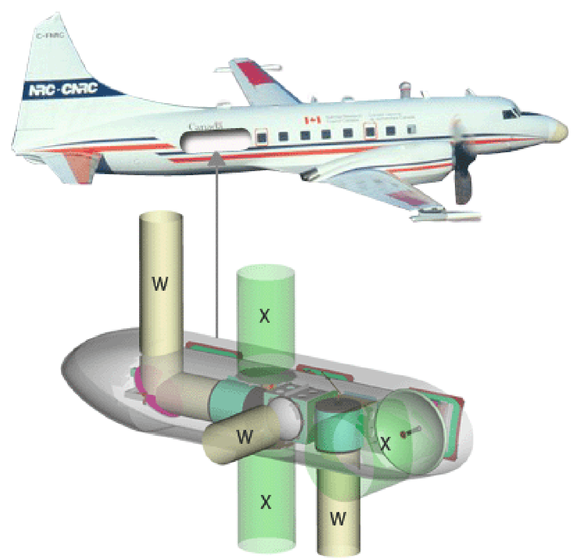


**Figure 1. The NAWX radar antenna configuration on the NRC Convair-580 aircraft. The W-band (X-band) beams are shown in pale yellow (green).**

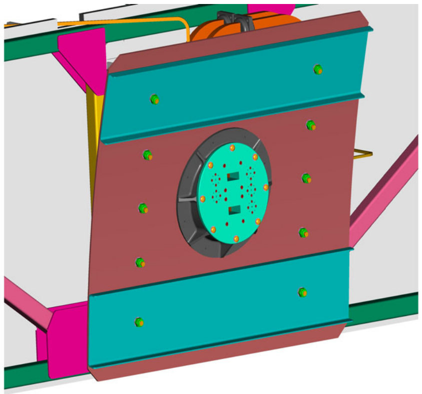

**Figure 2. One of the three window plates of the NAWX installation on the NRC Aerospace Convair-580 showing a bulkhead feedthrough adaptor with 5 W-band and 2 X-band waveguide ports.**

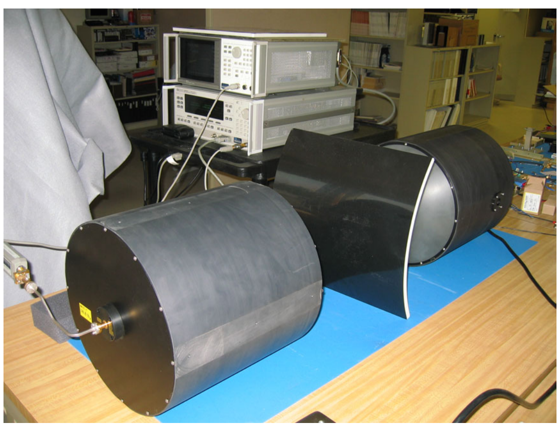

**Figure 3. Radome window test set-up using two W-band NAWX lens antennas.**

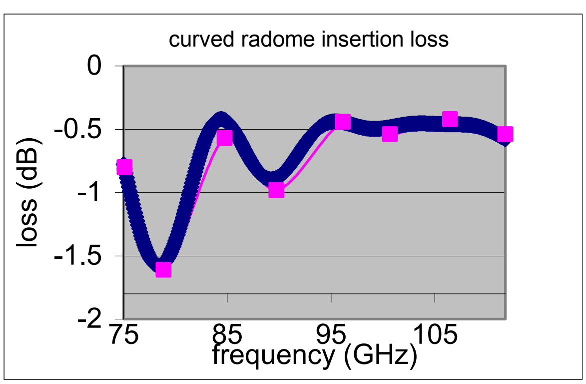


**Figure 4. Theoretical and measured radome insertion loss.**

**Table 1. NAWX radar specifications**

| NAWX specifications | X-band | W-band |
|---|---|---|
| RF output frequency | 9.41 GHz +- 30 MHz | 94.05 GHz |
| Peak transmit power | 25 kW magnetron split between two ports | 1.9 kW typical |
| Transmit polarization | H and V | H or V |
| Maximum Pulse Repetition Rate | 5 kHz | 15 kHz |
| Transmitter max. duty cycle | 0.1% | 3 % |
| Pulse width | 0.11-1 microseconds | 0.1-10 microseconds (standard or linear FM chirped) |
| Antenna ports (electronically selectable) | 4 (between two pairs) | 5 |
| Receiver cannels | 2 | 2 |
| Receiver polarization | Simultaneous H and V | Co and cross-polarization |
| Doppler | Pulse pair and FFT | Pulse pair and FFT |
| Transmitter Front-end Losses | 1.5 dB typical | 3.5 dB typical |
| Receiver front-end losses | 1.5 dB typical | 3.0 dB typical |
| LNA noise figure | 2.8 dB typical | 4.8 dB typical |
| IF output to digital receiver | 60 MHz | 54 MHz |
| Antennas | 1 x 25” dual-polarization 2 x 18” single-polarization | 2 x 12” dual-polarization 1 x 12” single-polarization |
| Minimum detectable @ 5 km | -5 dBZ (150 m resolution) | -30 dBZ (60 m resolution with 10x pulse compression) |

### 2.2 *Radar Electronics and Data Systems*

The NAWX system will have a fully polarimetric and Doppler measurement capability at both frequencies. Summaries of the NAWX system specifications are listed in Table 1. The two radars will have the following common features:

- Two channel 14-bit digital receivers,
- Electronic switching at both frequencies, allowing near-simultaneous sampling of the atmosphere in three planes along the flightline using six antennas,
- Innovative design incorporating NRC-developed INS-GPS integrated navigation system (Leach et al. 2002) for real-time Doppler correction,
- Synchronized operation and data collection for dual-wavelength analysis, and

- Pulse pair and FFT Doppler processing.

*W-band:*

The NAWX W-band component uses a space qualified W-band Extended Interaction Klystron (EIK) tube with a 1.9 kW peak power and 3% duty cycle, designed by CPI Canada for the CloudSat mission (Stephens et. al., 2002). The W-band in NAWX radar consists of five subsystems:

- RF unit containing the Millimeter-wave transmitter and two receivers, IF section, and power supplies,
- Antenna system, consisting of 2 dual-polarization and one single polarization 12" diameter lens antennas and motorized two-axis reflector plate,
- Host computer containing the digital receiver and a time stamp generator card,
- 2-channel digital oscilloscope for sampling the detected transmit pulse, and
- Chiller for stabilizing the temperature of the RF unit.

The three W-band antennas and the two-axis motorized 18" reflector allow 3-D cloud profiling as shown in the Figure 1. Using the motorized reflector plate, the W-band beam from the aft-looking dual-polarized 12" W-band antenna can be reflected up to 40° in forward direction in either the horizontal or vertical (nadir) planes for a dual-Doppler measurements (Fig. 5).

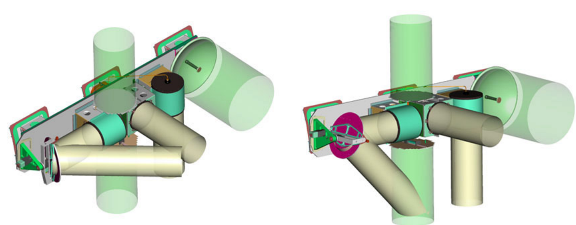

**Figure 5. NAWX antennas beam pattern in Dual-Doppler modes.**

A dual channel DDS board (developed by ProSensing) will be used to change the output frequency of each pulse for frequency hopping mode to de-correlate samples of the radar parameters and to generate standard pulses or linear FM chirp waveforms with selectable bandwidth and pulse length. Combined with a user programmable digital filter, the DDS will allow pulse compression ratios ranging up to 40:1. One DDS will be used to generate the pulse waveform (chirped or fixed frequency pulse) and a second to change the pulse center frequency for frequency hopping. The advantage of this, slightly more complicated design, is that the chirped waveform will be independent from frequency hopping and thus, for a given chirp bandwidth and compression ratio, only one matched compression filter will need to be designed. The frequency hopping DDS will be able to produce at least 24 different frequencies and a total frequency range of 120 MHz at W-band. This range allows 12 independent frequencies at 15 m (10 MHz TX pulse bandwidth), and 24 at 30 m or coarser, range resolution.

*X-band:*

The X-band radar transmit pulse is generated by a Raytheon MK-2 radar modulator and 25 kW EEV magnetron. One percent of the transmitted pulse power is sampled to measure the phase of the transmitted pulse for coherent-on-receive Doppler processing. An Electro Magnetic Sciences (EMS) Inc. high power switchable circulator directs the transmitted pulse towards a 26" dual-pol side looking antenna, or towards a pair of 18" flat plate slotted waveguide array antennas for measuring in the zenith and nadir directions. Four identical receiver channels are connected to the four antenna ports via fixed circulators.

## 3. ACKNOWLEDGMENTS

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## 4. REFERENCES

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