12R.6 A Dual-beam X-band Doppler Radar for Tropical Storm Research on High Altitude UAVs

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1. Introduction

Tropical storms get most of their energy transferred from the ocean surface and released as latent heat in moist convection in the eyewall. Tropical storms have been studied observationally and through numerical models for many years with the major goal of improving track and intensity forecasts. Current storm forecasting models greatly need environmental and within storm measurements (surface winds, temperature, profiled winds, and moisture, etc) over the open ocean where manned aircraft are unable to fly and satellite measurements are inadequate. With the transition of NASA's suborbital program from manned to Unmanned Aerial Vehicle (UAV), there is strong interest in utilizing long-duration, high-altitude UAV (HUAV) to provide this greatly needed information about storm structure during their mature stages and their genesis process as well. Thus, a UAV radar with similar capabilities to ER-2 Doppler Radar (EDOP) (Heymsfield et al. 1996) is desirable for studying the vertical structure of tropical cyclones as well as 3D reflectivity and wind field in clouds and precipitation below the aircraft. We describe in this paper the development of a new UAV radar (URAD) for studying winds for tropical storm research.

2. Radar Design

Two airborne radars have previously been developed by the NASA Goddard Space Flight Center (GSFC) for autonomous operation on a NASA ER-2 aircraft: the X-band EDOP and the W-band (94 GHz) Cloud Radar System (CRS) (Li et al. 2004). EDOP has two fixed pointing beams, nadir and 33° forward. It is capable to measure reflectivity and wind components in the along-track plane. CRS has a single nadir-pointing beam and it profiles the vertical reflectivity and vertical Doppler velocity structure of precipitation and clouds below the aircraft.

X-band frequency is the most desirable for airborne weather radars since high power transmitters and off-the-shelf components are readily available and thus costs are relatively low in comparison with other higher frequency radars. Furthermore, experience with EDOP has shown that the attenuation problem in heavy rain is tolerable with a nadir-viewing geometry, and its sensitivity is good (-20 dBZ at 10 km range for EDOP with 0.5 s integration time).

URAD, a dual-beam X-band Doppler radar, is under development for the study of tropical storm from high altitude UAV platforms, such as the Global Hawk. It combines a precipitation radar and a scatterometer (Carswell et al. 1994, Esteban et al. 2005) that measures both the 3D cloud/precipitation structure and surface winds with fixed nadir and conical/cross track scanning beams. Figure 1 shows the measurement concept of URAD on a Global Hawk. The nadir beam subsystem is a magnetron based, lower cost, smaller size and lighter weight version of EDOP that has flown in various NASA field campaigns and has provided important information on hurricanes and convective systems. The scanning subsystem uses a TWT transmitter and provides a new capability to measure surface and in-cloud/precipitation reflectivity and winds. With conical scanning of the radar beam at a 35° incidence angle with the ocean surface, information of surface wind speed and direction will be derived from the surface return over a single 360° sweep. Within cloud and precipitation regions, the conical scanning provides a 3D structure of reflectivity and winds.

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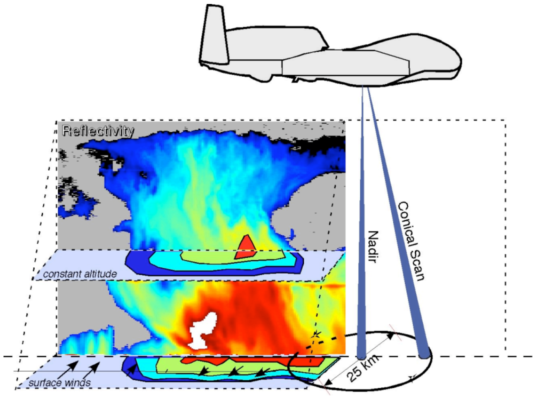

Figure 1 Measurement concept of URAD on a Global Hawk

One of the major design goals for URAD was to develop the radar as much possible using off-the-shelf components to reduce costs without compromising performance of the system. A number of the subsystems that were custom built for the aircraft systems a decade ago are now available commercially in production. Replacement or duplication of the new HUAV radar should be minimized once the first system is designed.

Key subsystems for URAD include: 1) nadir RF transmitter/receiver, 2) scanning RF transmitter/receiver, 3) data system and processor, and 4) the antennas and scan positioner. The block diagrams for both sub-systems are shown in Fig. 2. The nadir subsystem utilizes a modified version of low-cost, magnetron based marine radar transceiver, which has been upgraded with an improved local oscillator and receiver front-end (shown in Fig. 3). The data system/processor is based on a compact PCI (cPCI) Linux-based PC system using a Pentium M host computer and an extremely compact commercial digital receiver (right side picture in Fig.3). This data system also captures high-speed navigation data from the aircraft that will be required for accurate antenna positions. Figure 4 shows the flat plate antenna, antenna drive design and TWT for the scanning subsystem. The same kind slotted waveguide antennas have been used in commercial airliner weather radars. The scanning subsystem utilizes a TWT-based transmitter and a two-axis antenna positioner. With the planned two-axis scanning antenna, a conical scan would take about 6 seconds, followed but a cross-track scan that takes about 2 seconds, covering about 1.5 km of distance along the flight track. Figure 5 shows the radar layout on a Global Hawk. The specifications for scanning and nadir-looking subsystems are provided in Table 1.

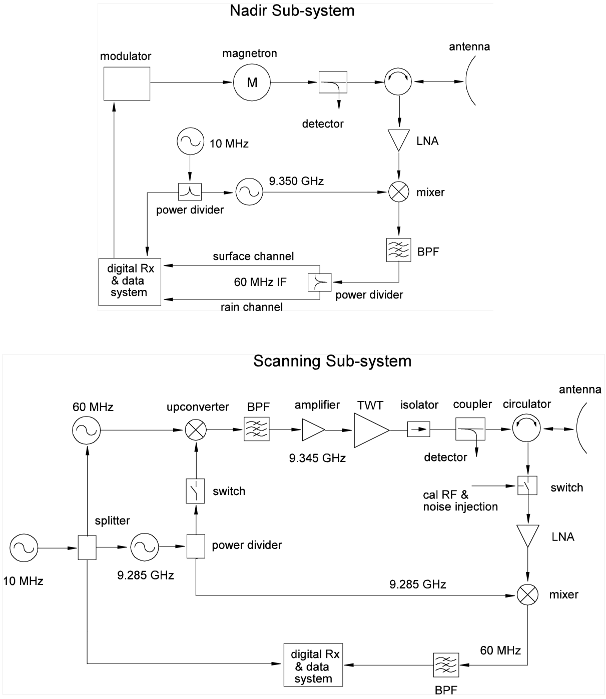

Figure 2. Block diagrams of nadir and scanning subsystems.

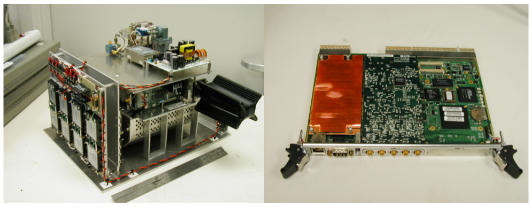

Figure 3. Nadir subsystem transceiver modified from a Furuno FR1510 marine radar transceiver and the compact PCI single board computer with the digital receiver daughter card attached.

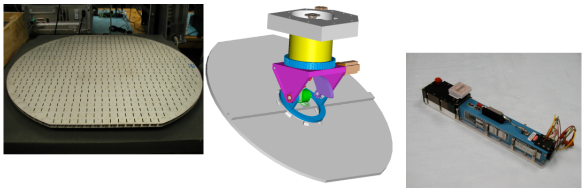

Figure 4. Flat plate antenna, antenna drive design and TWT for the scanning subsystem.

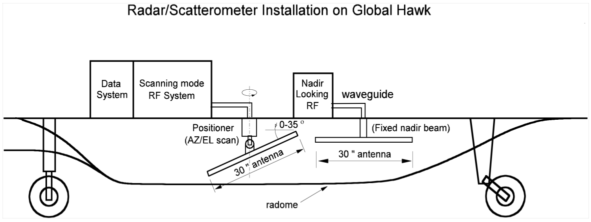

Figure 5. URAD layout on a Global Hawk.

Table 1: URAD System Characteristics

	Scanning Subsystem	Nadir Subsystem
Transmitter	TWT	Magnetron
Peak Power (kW)	8	12
RF Freq. (GHz)	9.345	9.410
PRF (kHz)	5/4	1.5/1.2
Pulse Width (ns)	250-2000	70-1500
Doppler Range (m/s)	+/- 160	+/- 48
Unambiguous Range (km)	30	100
Range Resolution (m)	150	37.5
Sensitivity (dBZ) @10 km	-10	-15
Scanning Mode	conical, cross track	N/A
Power Consumption (W)	400	150
Weight (lbs)	180	80

3. Summary

There is tremendous potential for UAVs to carry down-looking weather radars for measurements of reflectivity, horizontal and vertical winds from tropical storms. With the operation from HUAV platforms, this dual beam X-band radar under development is promising to provide greatly needed information for tropical storm research. The current goals are to develop a low cost high power, high-sensitivity and compact radar system. In the long term, it is expected that solid state transmitters will play a more important role for UAV-based weather radars.

Acknowledgments

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