NEW STRATOSPHERE-TROPOSPHERE RADAR WIND PROFILER FOR NATIONAL NETWORKS AND RESEARCH

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ABSTRACT

A radar wind profiler for Stratosphere-Troposphere (ST) operations has been developed and fully tested. The system has been selected and is in production for use by the U.S. National Weather Service (NWS) to replace 35 older ST systems in operation since 1989. The system is all new using a fully digital transceiver, a solid-state scalable transmitter, a scalable full beam steering phased array antenna, full health/status monitoring, and advanced signal processing algorithms to screen out interfering signals and to perform quality control on the data. Wind profile data are produced in real-time at each remote site from 170 m to 16 km, at both 6- and 60-minute intervals. A system description and data will be presented.

1 INTRODUCTION

In the central USA in the early 1990s, a “demonstration” Radar Wind Profiler (RWP) network of 35 systems was established by the National Oceanic and Atmospheric Administration (NOAA) to determine whether real-time wind profile data would improve nowcasting, forecasting, and atmospheric modeling (see www.profiler.noaa.gov/npn). Proven successful, the network was eventually transferred from the NOAA Office of Oceanic and Atmospheric Research (OAR) to the NWS and renamed the NOAA Profiler Network (NPN). The NPN is still operating today, and is composed of 30 404-MHz systems and five 449-MHz systems.

In late 2005, the NWS began procurement activities to upgrade or replace the aging NPN with new technology. A primary motivation for the refresh was to convert from using a transmit frequency of 404 MHz to 449 MHz (the officially designated frequency for ST wind profilers in the USA). The reason for the frequency change was to eliminate RWP transmit-off times, which were mandated to reduce interference to the Search And Rescue Satellite-Aided Tracking (SARSAT) system. The new NWS profiler network was called the Next Generation NPN (NGNPN).

In 2010, after a three year procurement effort, that included an operational performance “fly-off” between the two competitors’ radar systems, the DeTect ***Raptor FBS-ST 256e-12kW*** was selected by the NWS to replace the older systems. DeTect is now in production and will deliver more than 30 systems in the next three years. Honeywell Technology Solutions, Inc. is the prime contractor for this procurement and Wireless EDGE is responsible for installation.

2 SYSTEM DESCRIPTION

The Raptor FBS-ST is an innovative and unique RWP, with many design features not previously used for a commercial system. The design is all new, with attributes specifically designed for network-class systems such as redundancy, simplified maintenance, and a design for low, long-term ownership costs. The system is also specifically designed for scalability so that smaller, lower-powered systems or larger, higher-powered systems can easily be produced, yet with the same parts base. This allows production costs to be low, as well as allowing a customer or country to have more than one size—however, the training, repair logistics, parts depot, and virtually all of the radar is the same (e.g., whether boundary layer or full stratosphere-troposphere). A picture of the radar is shown in Figure 1. Table 1 shows the RAPTOR FBS-ST specifications.

Figure 1: DeTect, Inc. RAPTOR FBS-ST radar wind profiler. This picture shows the NOAA NWS demonstration unit produced and installed in Longmont, Colorado, USA.

Table 1: DeTect, Inc. RAPTOR FBS-ST Specification Summary

Specification	Value	Notes
Transmit Frequency	449 MHz	Can be produced for other frequencies.
Antenna Type	256 each Yagi-Uda elements in a circular thinned array	Thinning allows simplified amplitude tapering. Antenna is scalable in 64-element sizes.
Antenna Pointing	Full Beam Steering (FBS), ± 20° directly above the radar	Real-time control at 10 Hz.
Antenna Gain	31 dBi	Higher antenna gain is achievable with larger antenna. Current mechanical size is approximately 12 x 12 m.
Transmitter	12 kW peak, solid-state	Scalable from 2 to 12 kW and higher.
Maximum Range	16 km AGL, for 80% data availability	Will produce data higher, if backscatter supports.
Transceiver	Fully digital intermediate frequency, 16-bit ADC and DAC	High dynamic range.
Data System	Single Personal Computer type, using either Windows or Linux	All data are processed at the radar site, in real-time.
Digital Signal Processing	Adjustable from 128 to 16 k FFT	Several digital filter types are available as well as other signal processing parameters.
Quality Control	Included and runs in real-time at the radar site	Includes multi-peak picking algorithms, time-height continuity algorithms, and “Weber-Wuertz” QC processing.
Wind Accuracy	< 1 ms speed, < 10° direction	
Modes	Up to 8	Several modes can be run in sequence to optimize collection strategy for different height

Specification	Value	Notes
		regimes. RASS mode is also supported.
Data Averaging/Reporting	2 to 60 minutes each, user selectable	For example, both 6- and 60-minute report and averaging can occur simultaneously.
Health and Status	Full monitoring of system	A full health and status monitoring system is built into the radar.
Virtual Temperature	Optional subsystem	A Radio Acoustic Sounding System can be added.

2.1 ANTENNA

The antenna element type most typically used for ST systems (i.e., systems designed for near ground to 16+ km) has been a Coaxial-Collinear (COCO). A COCO element is usually a center-fed array of half-dipoles inside of a radome material (fiberglass or plastic) and is about 5+ m long and about 8 cm in diameter. Many COCOs are set up in an array, and by using a Beam Steering Unit (BSU), the array can be pointed off axis and vertical. Always two COCO arrays are used, perpendicular to each other, so the antenna can point in three or five directions (e.g., N, E, V, or N, S, E, W, V). COCO arrays have performed reasonably well, but there are several limitations including: 1) the large element size is difficult to ship and replace in the array, 2) antenna pointing directions are limited to the 3 or 5 directions, 3) they are difficult to amplitude taper and therefore sidelobes are difficult to manage, 4) they are very narrow bandwidth and therefore "ring" after transmit (which prevents low height data capture), 5) they are a specialized part and not necessarily easy to manufacture, 6) an individual COCO element failure can have a significant impact on the overall antenna beam, and 7) the BSU uses high-power mechanical relays which can wear out in as little as 18 months.

The RAPTOR FBS-ST uses individual Yagi elements instead of the COCO sticks. For steering, the RAPTOR uses solid-state phase shifters located near the base of each individual Yagi element. This arrangement allows: 1) simplified maintenance, 2) Full Beam Steering (FBS) in any direction above the radar (± 20 degrees), 3) very good control of amplitude taper and therefore good sidelobe control, 4) the array and the Yagi elements are wide bandwidth with reduced "ringing" (so for example, the first range gate for the above system is 165 m), 5) the Yagi elements are essentially a commodity item making them a low- or no-risk item for long term (20+ year) use, 6) the antenna is very fault tolerant (as even large percentage failures have a small impact on the pattern, and 7) by using solid-state phase shifters, there are no moving parts to replace. Two other significant benefits of using a Yagi element are the ability to easily scale the antenna array size and the ability to use new antenna beam pointing strategies. The antenna is shown in Figure 2.

Figure 2: Top side of antenna array (left) and underside of array (right). Underside picture shows the solid-state phase shifters.

2.2 TRANSMITTER

The transmitter for the RAPTOR FBS-ST is a solid-state unit composed of 2-kW units. The 2-kW units are individually fully functional High Power Amplifiers (HPAs), so that the transmitter is easily scaled from 2 kW to 12 kW or more. The 2-kW units use four 500-W modules internally. Taken as a whole, this means that the transmitter can “gracefully degrade” from the transistor level, through the 500 W module and even at the 2 kW level and still produce power. The power supplies are external Commercial-Off-The-Shelf (COTS) units supplied in an “N+1” redundant configuration.

The transmitter feeds through a high-power Transmit/Receive (T/R) subsystem. The T/R uses a two-circulator design to allow one to be used as an isolator for the transmitter. While very slightly increasing insertion loss, this design fully protects the transmitter from RF feed cable, connector, or other antenna problems which might create a high VSWR condition.

2.3 DATA ACQUITIION SYSTEM

The data acquisition system designed by DeTect for the RAPTOR radar product line is a modern implementation utilizing COTS Software Defined Radio (SDR) card technology. This has allowed DeTect to use only a single internal PC card for all signal generation, reception, and initial processing. This simplified design reduces parts count and increases reliability and allows a fully digital Intermediate Frequency (IF) transceiver. The data system and the transmitter are shown in Figure 3.

Figure 3: The RAPTOR transmitter is shown on the far left. The 2-kW modules can be seen along with the redundant DC power supplies. The antenna and electronics power supplies are shown in the top middle. Below these systems are the health monitor, the transceiver subsystem, and the wind profiler computer.

Like the transmitter power supplies, the power supplies for both the antenna phase shifters and the internal electronics are fully redundant. Redundant fans are used to improve reliability. The transceiver also uses redundant externally accessible cooling fans.

2.4 SIGNAL PROCESSING

The signal processing used for the RAPTOR RWP takes advantage of the high computation power of a modern PC and many of the techniques developed since the NPN was placed in service. The techniques include time-series processing improvements, long FFTs, special DC and other filtering, spectral-level multi-peak picking algorithms, and time-height continuity quality control. All processing takes place on the same computer which is controlling the radar, and data are processed in real-time. Data products include the traditional moment data (0^{th} - power, 1^{st}- radial velocity, and 2^{nd} - spectra width), wind barbs, and estimated turbulence. Time-series and spectral displays are also available in graphical form to monitor low-level signal processing. Representative wind barb data is shown in Figure 4.

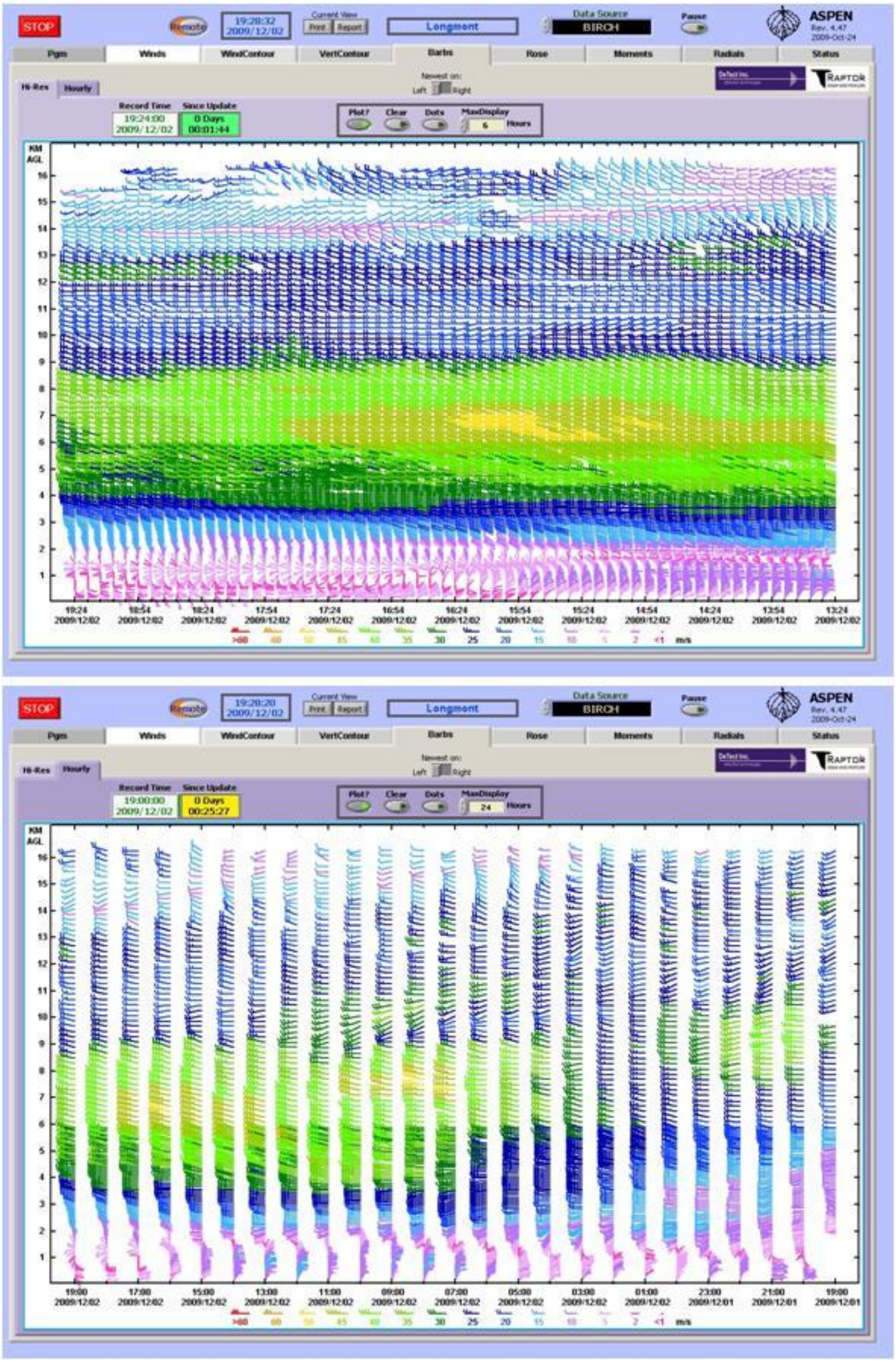

Figure 4: Wind barb data from the RAPTOR FBS-ST 256e-12kW. Top image is 6-minute data. The bottom image is hourly data. All data are processed in real-time on the wind profiler computer.

2.5 PROFILER HEALTH MONITOR

Critical to any operational weather system is good knowledge of the health and status of the system. Especially on derived weather products, such as what originate from a wind profiler, often the final data can appear as good quality, even if, for example, the antenna or transmitter are failing. The RAPTOR wind profiler uses an external Profiler Health Monitor (PHM) designed by DeTect to monitor all critical voltages, currents, temperatures, cooling fan condition, RF power levels, and other digital status bits. Over 120 values are continuously monitored and reported. The PHM utilizes a high-reliability, commercial-grade data acquisition system, so that it can independently monitor values and halt radar operations, even if the wind profiler computer is frozen or stopped. The PHM can also be used to monitor various facility values such as door alarms, shelter temperature, and air conditioning. All values are reported to the wind profiler computer and displayed numerically and graphically. Other status information not measured directly via the PHM, but rather through the computer (such as phase shifter condition) is also displayed. In Figure 5 the PHM hardware is shown as well as 1 of many screens on the computer showing health and status data.

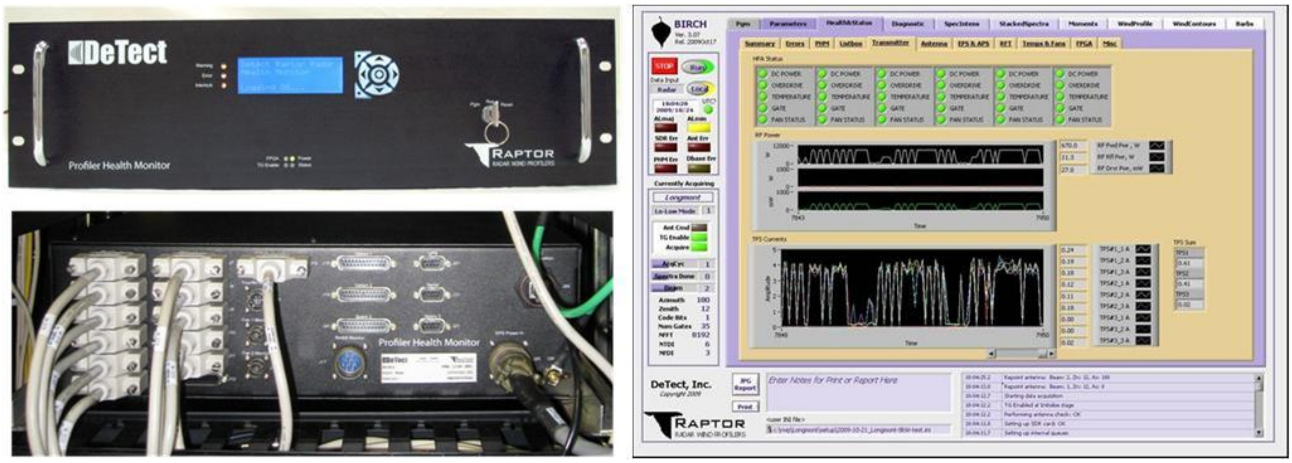

Figure 5: The RAPTOR Profiler Health Monitor is shown on the left (front and back of the unit), with one of the many health and status screens shown on the right.

3 SUMMARY

A recent procurement activity conducted by the NWS resulted in the DeTect, Inc. RAPTOR model FBS-ST 256e-12kW RWP being selected to replace 35 older systems located in the central USA. DeTect (www.detect-inc.com) will produce these systems over the next three years. The systems are designed for long-term (20+ years) national-network use and have features designed in for high reliability, simplified maintenance, redundancy, and scalability. The antenna is a new operational implementation for stratosphere-troposphere RWPs, and with full beam steering allows high flexibility in beam pointing strategies (used to improve data quality) and very good control of sidelobes (reducing interference from/to other radio devices). The antenna does not use any wearing parts, allowing high reliability and straight-forward maintenance. The transmitter is solid-state and designed for scalability as well. With both a scalable antenna and transmitter, the system can be produced larger or smaller to fit physical size constraints, monetary budgets, or desired height collection regime. The data processing system is state-of-the-art and utilizes modern technology for the acquisition hardware as well as the signal processing algorithms.