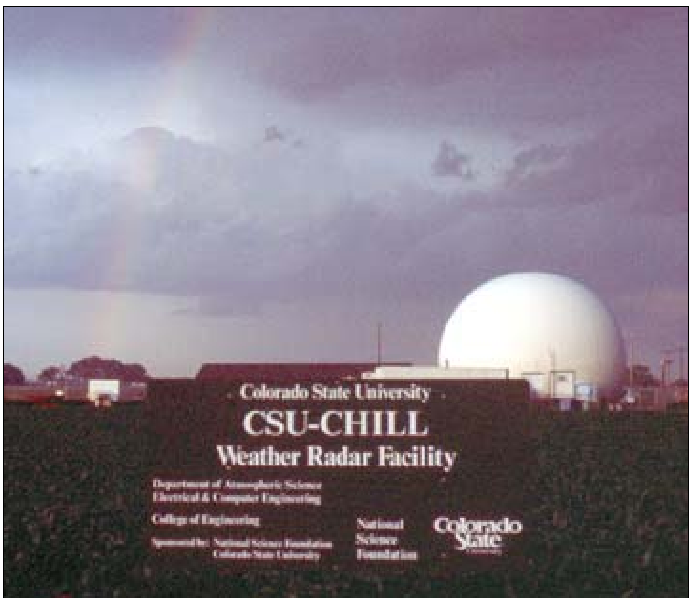
CHILL RADAR NEWS

May 2006 **Fourteenth Edition**

Overview (by Prof. Steven A. Rutledge, Scientific Director)

This is the fourteenth edition of the CSU-CHILL newsletter. This past year has been an interesting and busy year for the Facility. Our new, offset fed antenna has been built by Vertex/RSI and will be delivered to the Facility in late May. Preliminary testing of the antenna at the manufacturer, with involvement of Profs. Bringi (PI on the antenna grant from the NSF) and Chandra, along with David Brunkow, Chief Engineer, went very well. A new, larger radome is required to house the antenna, and we are converging on a final design of that dome, after many months of back and forth with that manufacturer. A new dome was needed in any case, to replace the current dome, which is well beyond its design lifetime. We are hoping that the new antenna and dome will be installed by mid-fall, allowing us to start collecting data with the new antenna. The new antenna is just one of several new editions and improvements for CHILL. Dave Brunkow has led the development of a new dual-receiver and signal processor and that will become CHILL and PAWNEE's primary signal processor. Further details on this new design and operation are provided in a later section. One unique feature of this new system is that basic I, Q time series can be sent over the Internet for post processing of radar moments off site. The V-CHILL system continues to be refined and has found its way into many classrooms across the country for educational activities. V-CHILL allows real-time and archived data to be displayed remotely over the Internet, using a windows-based Java application. Data displayed on V-CHILL is quality controlled and unfolded now. We also continue to make available case study data via V-CHILL. Currently five years of CHILL data are maintained on line to be viewed by V-CHILL. Please read this Newsletter and learn more about our 2005 data collection activities as well as more detail on the new antenna and other technical improvements.



The CSU-CHILL Radar Facility after a summer rain storm

2005 Operations Summary (by Pat Kennedy, Facility Manager)

Inside this issue:

Several of the data collection efforts undertaken at the CSU-CHILL radar in 2005 were in support of various engineering test programs. The first of these involved side by side operations with the truck-mounted prototype of the CASA (Collaborative Adaptive Sensing of the Atmosphere) radar. The CASA radars are modestly sized X-Band, dual polarization systems that are designed for installation on the antenna towers that are typically used in cellular telephone networks. The individual CASA radars each cover a range of approximately 30 km. Over these short ranges, good sampling of the near-surface region can be maintained. Coverage of larger areas will be done by combining the data collected by networks of CASA systems. A necessary first step in the CASA initiative is the verification of the performance

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2005 Operations Summary (continued)

obtained by the by the prototype CASA radar. To this end, the prototype CASA system that had been built at the University of Massachusetts was trucked to the CSU-CHILL site in late March. During April, efforts were made to collect synchronized scan data with the two radar systems (Fig.1).

Figure 1: MA-1 prototype CASA radar positioned next to the CSU-CHILL ra-

Plots showing example system test data collected when the two radars were pointing at common azimuth and elevation angles are presented in Fig. 2. In general, the data collected by the prototype CASA radar were

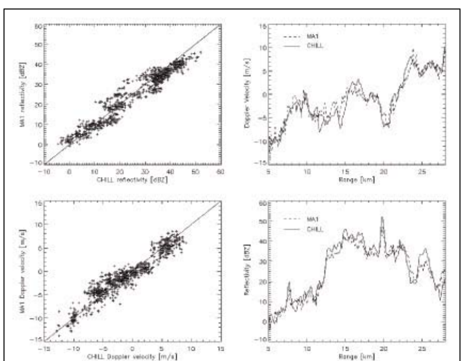

Figure 2: Examples of comparative reflectivity and radial velocity data collected by the CASA and CSU-CHILL radars. Both radars have parked their antennas at common azimuth and elevation angles. (Plots taken from Junyent et al., 2005)

found to be quite satisfactory.

The second major engineering test program was centered on the parallel receiver and signal processing system that was designed and built in-house at the CSU-CHILL facility. In essence, the parallel system taps into the radar's existing analogue IF signal path. These input signals are digitally processed to provide a real time stream of time series data (individual I, Q voltage representations) from each transmitter pulse at ~1000 range gates. The parallel data system also has the capability to synchronize its timing to the highly accurate time pulses that are available from GPS satellites. (Details on the parallel receiver are contained in the Engineering section of this Newsletter). In July and August the parallel receiver system was brought on line at the CSU-CHILL radar. During this same period, a single polarization version of the parallel receiver data system was installed at the CSU-Pawnee radar. This arrangement allowed the overall system timing in the two CSU research radars to be synchronized to a common GPS time base. In this configuration, the two CSU research radars could operate in bi-static mode (i.e., one radar (typically the Pawnee) serving as the transmitter while the other radar remained in receive-only mode). These bi-static data collection experiments were done under the general direction of Prof. Steve Frasier (University of Massachusetts, UMASS), and Prof. V. Chandra of CSU. They were interested in evaluating the nature of forward scattered signals produced by Bragg scattering from turbulent eddy structures in the boundary layer. To characterize the general boundary layer depth and clear air scattering environment, the University of Massachusetts also provided a truck-mounted, vertically pointed S-Band radar (Fig. 3). During the bi-static project operations, the CHILL and Pawnee antenna were aimed to position their common sampling volume over the UMASS profiling radar. The data collected during the bi-static experiment is currently being examined.

An additional application of the CSU-CHILL radar parallel receiver system took place during a 20-hour project conducted during July and August for Rita Roberts of NCAR. Rita's project, **R**efractivity **E**xperiment **F**or H_2O **R**esearch **A**nd **C**ollaborative operational **T**echnology **T**ransfer (REFRACTT), involved the adaptation of Fabry's conducted during July and August for Rita Roberts of NCAR. Rita's project, **R**efractivity **E**xperiment **F**or H_2O **R**esearch **A**nd **C**ollaborative operational **T**echnology **A**nd **C**ollaborative operational **T**echnology **T**ransfer (REFRACTT), involved the adap-

Figure 3: Vertically-pointed, bi-static, S-band FMCW radar from the University of Massachusetts (UMASS). This radar profiled the backscattering characteristics of the clear air boundary layer. During the bi-static experiment involving the CSU radars, the antennas of the CHILL and Pawnee systems were positioned so that their beams intersected above the UMASS

tation of Fabry's technique for mapping atmospheric water vapor fields to the CSU-CHILL and NWS Denver (KFTG) radars. (Specialized time series recording equipment was temporarily installed at KFTG). Data were also collected for this project by the NCAR's S-POL radar. Fabry's water vapor sensing technique is based on measurements of the absolute phase of the radar signal that is backscattered from solidly stationary ground targets. Since these targets are immobile, the return signal absolute phase is only influenced by changes in the refractivity along the beam path to the target. During the warm season, these refractivity variations are primarily due to changes in the atmospheric water vapor content. To support the REFRACTT 20-hr project, the CSU-CHILL parallel receiver was used to calculate and archive the I and Q signal components averaged over an integration cycle of approximately 50 pulses at each range gate location. Rita has been able to generate regional scale low-level moisture field maps from selected REFRACTT cases by compositing the data collected by the radars. Rita has also obtained NSF support for a formal refractivity measurement field project scheduled for the summer of 2006. Both the CSU-CHILL and Pawnee radars will be participating in this project.

Prof. V. Chandra was the P.I. of an

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2005 Operations Summary (continued)

NSF-funded Research Experience for Undergraduates (REU) project during the summer semester of 2005. A group of six students from five different institutions participated in the program. Each student worked on a radar-related research topic and made a final presentation of their results at the end of the summer. As a part of their activities, the REU students were given a tour of the CSU-CHILL radar as well as several introductory lectures presented by radar staff members.

Finally, target of opportunity CSU radar operations were conducted outside of more formal, NSF and 20-hr project activities. One goal of these operations was to further test the real-time multiple Doppler radar data processing software that has been developed by Brenda Dolan, a CSU graduate student studying under the joint direction of Profs. Steve Rutledge and V. Chandra. In Brenda's processing scheme, real time data from a network of radars is interpolated to a regional-scale three-dimensional Cartesian grid. In areas where suitable inter-radar beam geometries exist, the wind field components are synthesized using standard multiple Doppler processing techniques. At grid points where dual polarization data are available, hydrometeor identification and polarimetrically refined rain rate products are generated. Examples of the real time plots produced by Brenda's program were presented in the 2004 edition of this Newsletter.

During May and June of 2005, it became possible to test Brenda's software with the inclusion of data from the CSU Pawnee radar. (The Pawnee radar was out of service during 2004 due to a Klystron failure that permitted pressurized coolant to mix with the insulating oil bath in the modulation transformer on which the tube is mounted.) A regional composite made from data collected by the CSU-CHILL and Pawnee radars and from the NWS WSR-88D radars at Denver, CO (KFTG), and Cheyenne, WY (KCYS) on 9 June 2005 are shown in Figure 4. The plot depicts the echo patterns at 2.5 km MSL (approximately 1 km AGL) at 2227 UTC when a group of strong thunderstorms was located ~50 km northwest of CHILL. The horizontal wind vectors are color coded to indicate the Doppler radar pair from which they were computed. A noteworthy feature within the Fig. 4 example plot is the anti-cyclonic circulation in the vicinity of the echo core near X= -40, Y= 20 km. Severe weather spotters confirmed the existence of anticyclonic rotation in the storm's cloud base. A more detailed analysis of this case is underway. In summary, Brenda's automatically generated, multiple radar analysis products will be useful in both real time and post analysis settings.

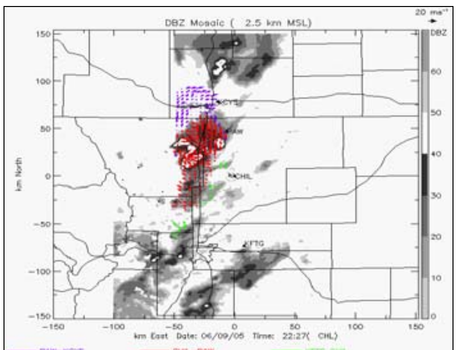

Figure 4: Mosaic reflectivity plot (gray shades) assembled from data collected by two research radars (CSU-CHILL and Pawnee) and two NWS WSR-88D radars (KFTG / Denver and KCYS / Cheyenne) at 2227 UTC on 9 June 2005. Analysis height is 2.5 km MSL. Horizontal wind vectors are synthesized from various Doppler radar pairs; the particular radar pairs used are identified by color coding

Reference: Junyent, F., V. Chandrasekar, D. Brunkow, P. C. Kennedy, and D. McLaughlin, 2005: Validation of first generation CASA radars with CSU-CHILL. Preprints, *32nd Conference on Radar Meteorology*, Amer. Metor. Soc., Albuquerque, NM CD, paper P10R.4

CHILL Facility Developments (by David Brunkow, Senior Engineer)

Calendar year 2005 has been a busy one in terms of facility upgrades and new developments. During August, the new 8.5 meter dual-offset Gregorian geometry antenna was tested on Vertex/RSI's range.
Dual offset antennas of this size have not been generally available, so there were a number of design issues to be resolved through a cooperative effort between CSU and the manufacturer, Vertex/RSI. The goal of the project was to produce an antenna with significantly improved sidelobe performance, while not giving up the high cross-polar performance of the current CSU-CHILL antenna.

The offset design allows a more massive feedhorn/OMT than the conventional center-fed design. The new antenna has an electro-formed symmetric OMT coupled to a profiled corrugated horn (Fig. 1). The feedhorn/OMT structure can be rotated 45 degrees to allow ±45◦ linear polarization operation as well as the normal vertical/horizontal polarization. The port to port isolation of the OMT was measured at 60 dB. The feedhorn/OMT pattern was measured in an anechoic chamber at Vertex/

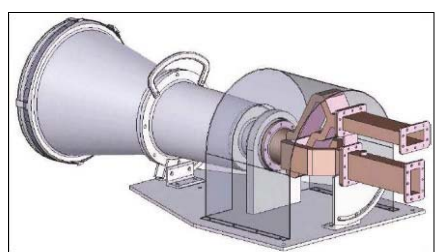
Figure 1: Cutaway view of the OMT/feedhorn assembly.

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CHILL Facility Developments (contiuned)

RSI in the 0, 45, and 90 degree planes. The peak off-axis crosspol level was measured at -34 dB. These measured feedhorn patterns were then input into a far-field simulation software package to predict the final co and cross polar patterns which were used to satisfy the requirements of the critical design review.

To achieve the desired beam pattern characteristics, the relative positions and shapes of the antenna components must be very precisely controlled. Measurements of the main reflector surface confirmed that its shape has an RMS error magnitude of less than 0.010 inches.

The offset feed antenna's radiation patterns were measured at Vertex/RSI's test

Figure 2: The offset feed antenna mounted on the positional at the Vertex/RSI test range.

range facilities (Fig. 2). The excellent matching of the main beam horizontally and vertically polarized patterns down to the -25 dB level is evident in Fig. 3. This pattern

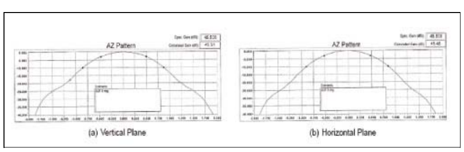

Figure 3. Horizontal and Vertical Polarization: Main Beam Patterns

matching was improved by partially blending the first sidle lobe patterns with the main beam pattern ("shouldering"). Examples of more complete co-polar pattern plots in the azimuth and elevation planes are shown in Fig. 4. The very low sidelobe levels are due to freedom from main beam ob-

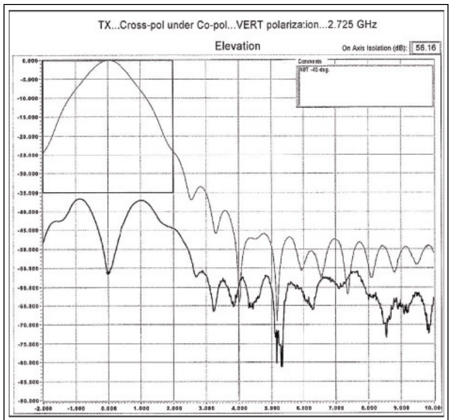

Figure 4. Azimuth and Elevation Patterns – Vertical Polarization

structions that the offset feed design provides.

The pattern measurements shown in Figs 3 and 4 were obtained on a far-field test range. This range was not suitable for measuring low cross-pol levels because of the limitations of the polarization purity of the source antenna and also due to ground reflections. To solve this problem, Vertex/RSI built a new source horn identical to the feedhorn used on the dual offset antenna. This source horn was mounted on a shorter (228 meter) range which put the source horn at a 12º elevation angle. The short range defocuses the main lobe, but the cross-polar pattern is already 'de-focused' and is considered representative of what would be measured in the far-field.

An example of the results obtained on the short length test range with the antenna rotated 45º about the bore sight axis is shown in fig. 5. The performance specifications in this plane called for on-axis isolation of better the 43 dB and peak off-axis cross-pol levels of -35 dB or less; these specifications were met. (Note: the copolar pattern in Fig. 5 should not be interpreted as the far-field pattern.) shown in fig. 5. The performance specifications in this plane called for on-axis isolation of better the 43 dB and peak off-axis cross-pol levels of -35 dB or less; these specifications were met. (Note: the copolar pattern in Fig. 5 should not be interpreted as the far-field pattern.)

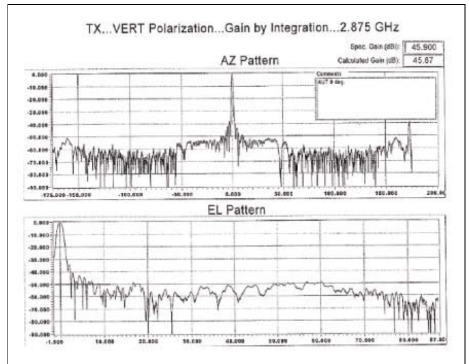

Figure 5: Co-polar (upper curve) and cross-polar (lower curve) measurements in the plane oriented at a 45º angle across the face of the antenna.

The second major CSU-CHILL engineering effort during 2005 has been the development and initial testing of a parallel receiver / signal processing system in the radar. This system is parallel in the sense that it operates independently of the radar's existing Lassen Research DRX digitial receiver / signal processing hardware. The basic goal of the parallel receiver is to develop and archive the complex voltages (i. e., the I and Q values associated with each transmitted pulse) at all range gate locations in the radar's two (horizontal and vertical polarization) receiver channels. The archival of this raw received data stream permits the maximum flexibility in the application various signal processing techniques in post-processing. The time series data, in addition to archiving, can also be passed over the network to computation servers which can calculate the routine meteorological moments. The moment data can also be archived, or displayed with the Java VCHILL software. Figure 6 shows a block diagram of the parallel receiver hardware and software.

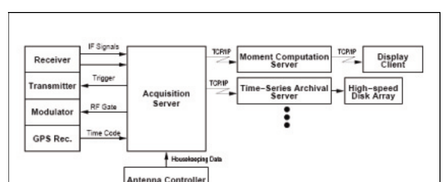

Figure 6. Parallel Receiver Block Diagram

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CHILL Facility Developments (continued)

The CHILL digital receiver is based on the ICS-554 digitizer board (Fig. 7) from ICS incorporated. This board is capable of sampling four channels at up to 105 MSs^{-1} with a resolution of 14 bits. The board also includes a Xilinx Virtex II Field Programmable Gate Array (FPGA), containing either 1 or 3 million gates. The FPGA is used in post processing the digitized data. Both the generation of the local oscillator signal and the quadrature mixing is done digitally, eliminating the I/Q gain errors that plague analog designs.

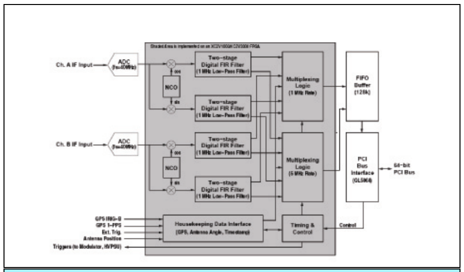

Figure 7. ICS554 Block Diagram

The FPGA on the digitizer card also generates the timing reference pulses for the overall radar system (transmitter triggering, received signal sampling, etc.) The FPGA timing has been phase locked to an externally received GPS signal. This GPS locking capability was also incorporated into a second version of the parallel receiver hardware was installed in the CSU-Pawnee radar in July 2005. Through the use of the common GPS time base, bi-static data (Pawnee transmitting and CHILL receiving) was successfully by the CSU-CHILL and Pawnee radars for a 20 hour project directed by Prof Steven Frasier of the University of Massachusetts. It is anticipated by June 2006, signal processing at both of the CSU radars will primarily be done using the ICS / FPGA based hardware.

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CHILL Radar Dome at sunrise

Acknowledgements:

The CSU-CHILL Radar Facility is supported by NSF Cooperative Agreement ATM-0118021, and supplemented by cost sharing funds from Colorado State University