

The CSU-CHILL Radar is an advanced, transportable dual-polarized S-band weather radar system. The CSU-CHILL radar facility is operated by Colorado State University under the sponsorship of the National Science Foundation and the University. The radar serves as an advanced research instrument for radar meteorology, radar engineering, and remote sensing. The CSU-CHILL features a high-power dual-Klystron power amplifier, sophisticated transmitter controller, low side lobe antenna, and digital receiver system. Radar operations are performed through an interactive radar control system which communicates with the radar system through a TCP/IP connection. Local and remote users can observe radar data in real-time, while the archival system can store both the processed radar measurements such as reflectivity and Doppler velocity as well as the digitized base band signal data.

The radar system can be broadly classified into the transmitter, receiver, antenna control, and signal processing subsystems. Interconnections between the subsystems is handled through Gigabit Ethernet, which allows rapid changes to the system to fit the needs of advanced data collection experiments. Additional computational power may be added by simply plugging in another compute server.

## Key Features

- Dual-polarized, fully coherent dual transmitter radar system.
- Nine-meter parabolic reflector antenna, with 1 degree beamwidth.
- Inflatable low-loss radome.
- Communications between major subsystems through Ethernet.
- GPS-referenced timebase and local oscillators providing exceptional system stability and allowing for bistatic radar operation.
- Digital transmitter control, with independent programmable waveforms on each channel, programmable PRF and pulsing modes such as single, alternating, or simultaneous polarization.
- Comprehensive calibration subsystem to measure and compensate for transmitter power and receiver gain drift.
- Dual-channel digital receiver system, with programmable filters and the option to simultaneously receive signals at two different receiver bandwidths.



CSU-CHILL's 9-meter dual-polarized S-band Antenna

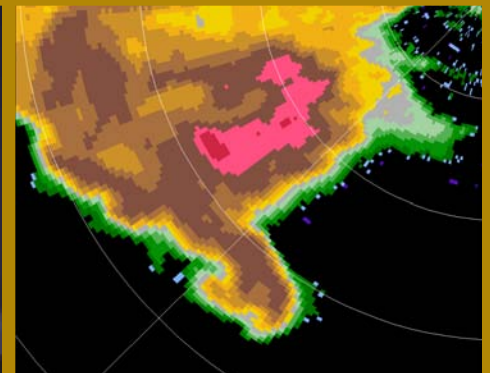
- Expandable, open architecture, based on the Linux operating system.
- Full-featured software suite for system control, data processing, archiving, monitoring, and remote access, with capability for remote operation and monitoring of the radar subsystems.
- Real-time control of the radar and distribution of radar data, including time-series, through TCP/IP networks to remote sites enabled by the VCHILL system.



CSU-CHILL Radome and Airlock Entry



Storm Observed on 11 May, 2005



CSU-CHILL Observation on 11 May, 2005

# Radar Hardware

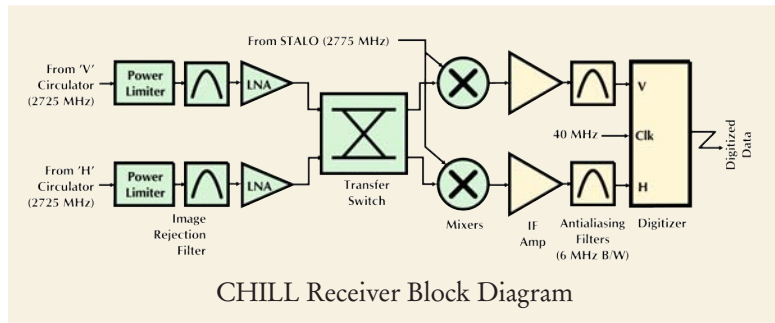
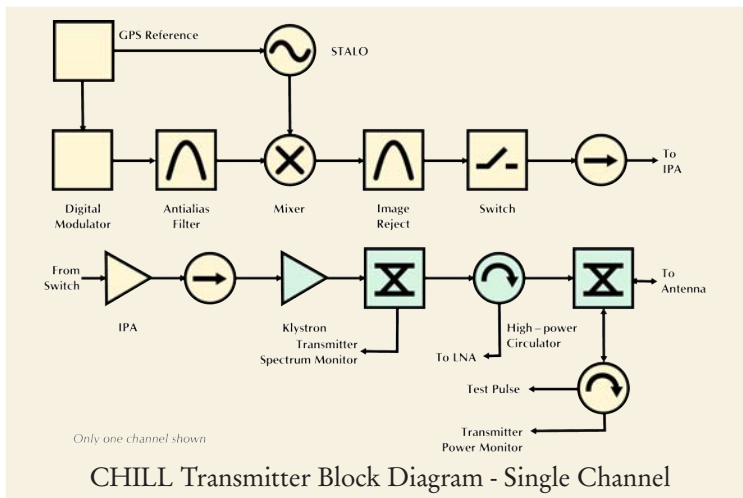
## Transmitter

The CSU-CHILL radar uses two independent klystron transmitters in order to achieve maximum polarization flexibility and channel isolation. The klystrons are driven by a digital modulator/waveform generator, that can, under software control, generate a variety of modulated RF pulses from a baseband pulse definition. Each klystron develops approximately 1 MW/Ch output power. The transmitter output is sampled to monitor the spectral purity and the transmitted power.

Each transmitter's waveform may be independently adjusted, allowing each polarization to have different inter-pulse or intra-pulse coding. This feature can also be used for correcting differences between the transmitters.

The primary frequency reference used by the radar is a GPS-stabilized Oven Controlled Crystal Oscillator. The GPS stabilization allows for long-term drifts to be corrected, while preserving the high phase noise performance of the crystal oscillator. The STALO is phase-locked to the reference, which helps maintain the radar's long-term stability.

The digital modulator may be programmed with several sophisticated waveforms and transmitter triggering sequences, such as alternating or simultaneous polarization and staggered PRT/PRF. Mode changes are under software control, and new modes can be quickly added to the system.

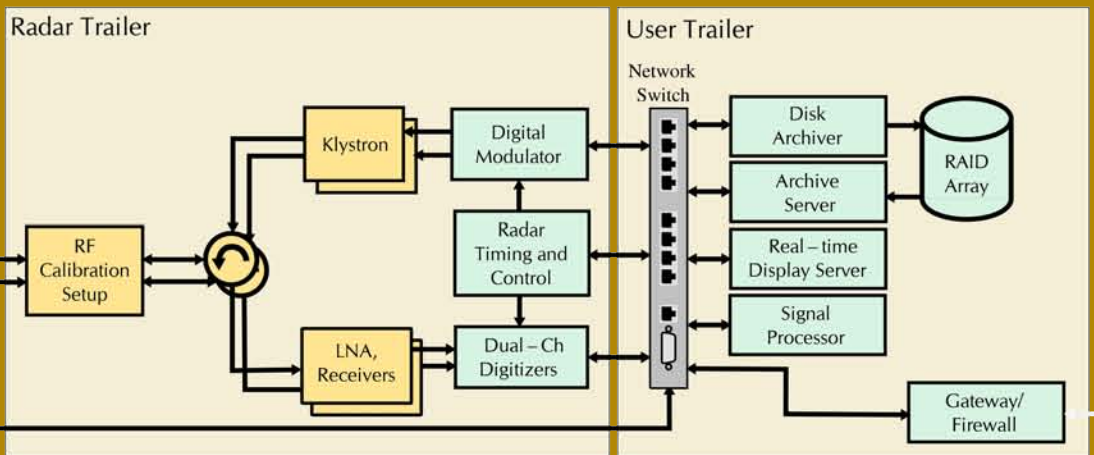
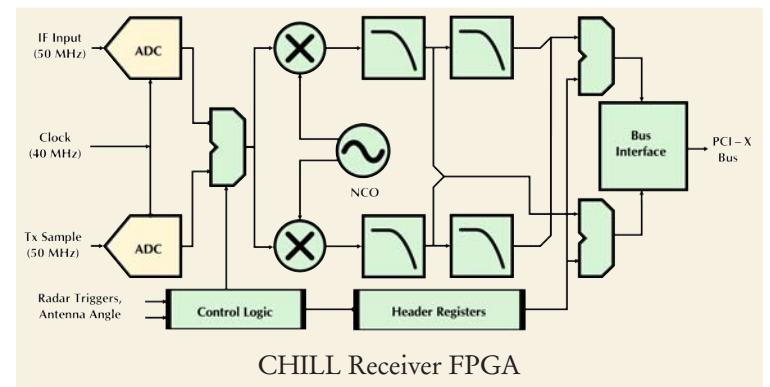


## Receiver

CSU-CHILL uses a 14-bit digital IF dual-channel receiver, with the provision for switching between receive channels in the alternating mode. The 0.8 dB Noise Figure LNAs lower the system noise considerably. The entire receiver assembly is mounted on a temperature controlled plate in order to prevent thermal drift between the channels.

A single conversion brings the S-band (2.725 GHz) signal to a 50 MHz IF. Analog SAW filters are used for image rejection and anti-aliasing. The 50 MHz IF signal down-converted to 10 MHz by sampling at a 40 MHz. The 10 MHz digitized signal is digitally down-converted to baseband and filtered.

The digitization and down-conversion are performed using a high-performance digitizer board with an integrated FPGA. This FPGA is used to implement computationally demanding applications such as pulse compression. The filtered data is then read into a Linux host, that broadcasts the digitized data on the local network.



# Radar Software

## Signal Processor

CSU-CHILL's signal processor is implemented on general purpose Linux computers. The digitized base band signals are obtained from the digitizer through a Gigabit Ethernet link. The same link also carries various control and status information packets that help synchronize the radar state. Ground clutter filtering is implemented using a selectable filter. The polarimetric moments estimated from the covariances are made available to a variety of client programs. Typical clients include the disk archive subsystem, display servers, and status monitoring programs.

## Display, Control, and Monitoring

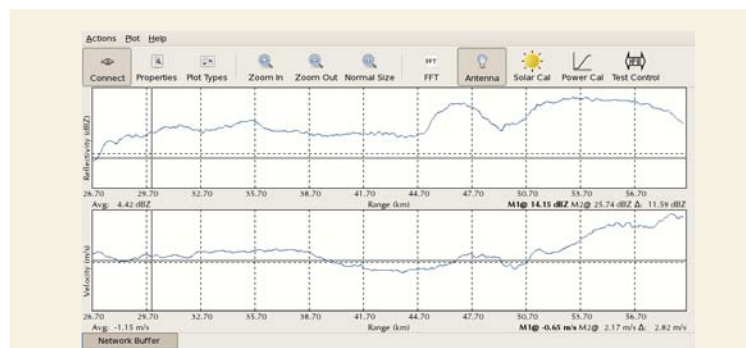
The display programs available at CHILL allow visualization of the real-time data from the radar, as well as archived data. The A-scope is a low-level troubleshooting program that plots moments calculated directly from the digitized base band signals. It can also display spectra, perform solar calibrations, perform power calibrations, and many other useful functions.

Real-time data may be viewed using the CHILL radar display program, which allows for the user to specify zoom levels, colormaps, geographic basemaps, and overlays. It can also display range profiles of selected moments.

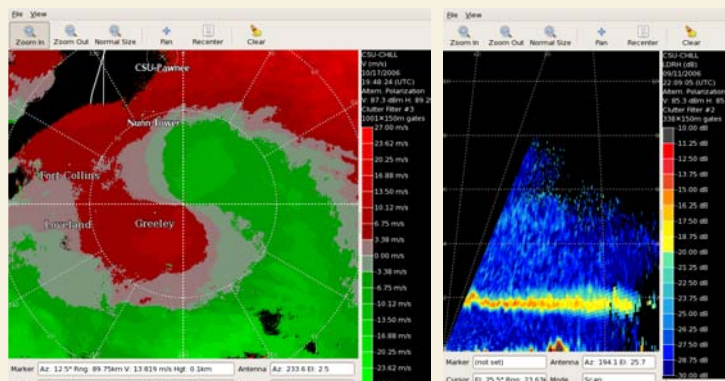
The Java VCHILL display is a platform independent radar data browser and viewer, that can show both real time as well as archived scans. VCHILL allows radar data to be exported to Google Earth and other programs.

The antenna control program allows for a variety of scans to be scripted and scheduled for sequential execution. All radar operating parameters are controlled from the scan definitions.

The Radar Status Monitor provides an up-to-date snapshot of the status of various radar subsystems. For example, the transmitter power levels and spectra may be viewed in real-time to ensure that the transmitter is operating according to specifications.



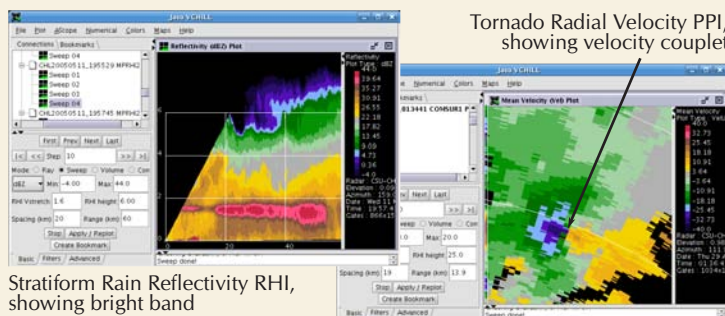
A-scope Range Profiles of Reflectivity and Velocity



Winter Storm Radial Velocity PPI, showing velocity shear

Stratiform Rain LDR RHI, showing the bright band at 2 km

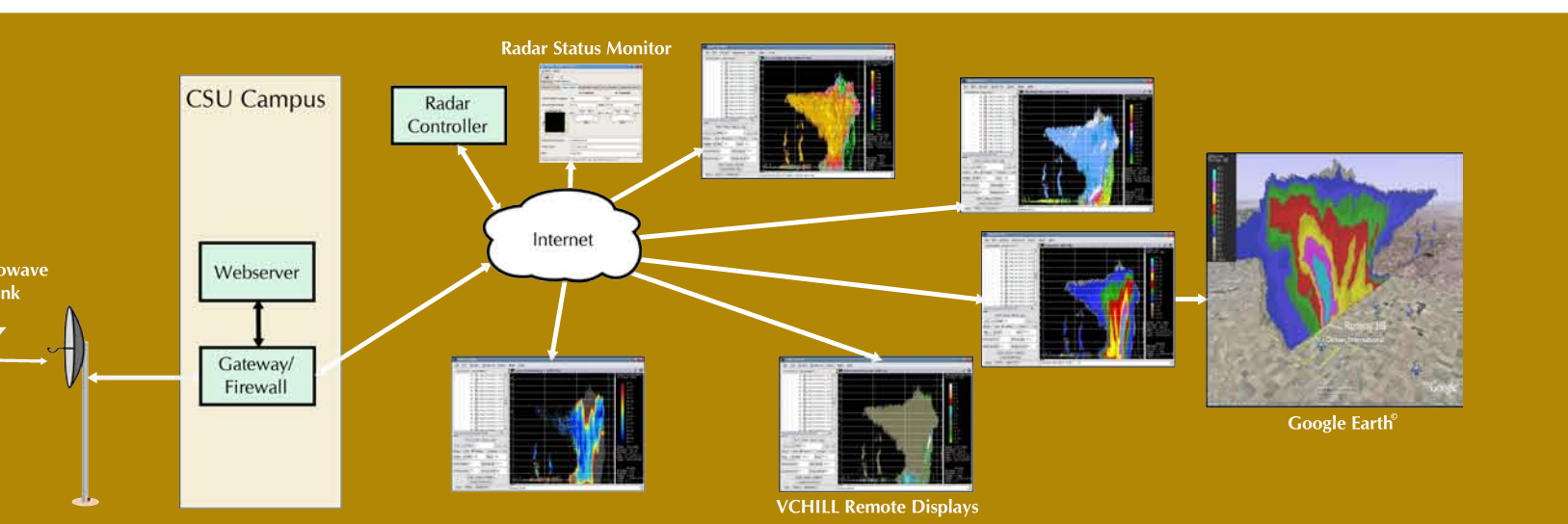
Real-time PPI and RHI Displays



Stratiform Rain Reflectivity RHI, showing bright band

Tornado Radial Velocity PPI, showing velocity couplet

VCHILL Archive Browser RHI and PPI



# Technical Specifications

## Antenna

Shape	Parabolic
Diameter	8.5 m
Feed Type	Scalar
Gain	43 dBi (including feed loss)
Beamwidth	1.1 degrees
Maximum Sidelobe	-27 dB (along any $\Phi$ -plane)
Inter-channel Isolation	-45 dB
ICPR	-38 dB (two-way)
Scan Types	PPI, sector scan, RHI, fixed pointing, vertically pointing
Max. Slew Rate	18 degrees/sec

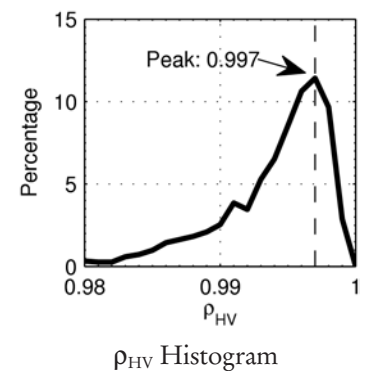
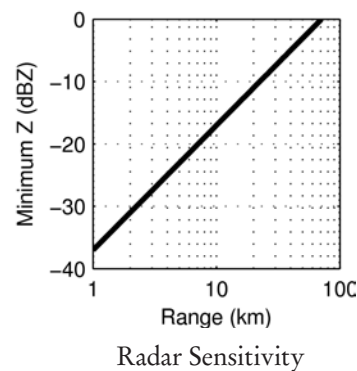
## Transmitters

Architecture	Coherent MOPA, STALO and COHO are GPS stabilized
Wavelength	11.01 cm (2.725 GHz)
Peak Power	1 MW (per channel)
Final PA Type	Klystron (Varian VA-87B/C)
PRT Range	800 - 12000 $\mu$ s
Polarization	Horizontal, Vertical, Alternating, Slant 45/135, Left/Right Circular
Waveform	Programmable, intra- and inter-pulse modulation supported. Gaussian pulse weighting is standard
Pulse Width	Programmable (0.2 - 1.6 $\mu$ s)
Max. Duty Cycle	0.16%

## Receivers and Signal Processing

IF Sampling	Two channels, 14 bits at 40 MHz
Sensitivity	-38 dBZ @ 1 km (0 dB SNR)
Noise Figure	3.4 dB

Noise Power	-113 dBm @ 1 MHz bandwidth
Dynamic Range	80 dB
Bandwidth	Programmable. Simultaneous 1 MHz and 5 MHz channels are available
Range Resolution	Min: 30m, Typ: 150m programmable
Max. Range Gates	6000
Clutter Suppression	Selectable Chebyshev/Elliptic notch filter, Spectral filters
Processing Modes	Pulse Pair, Spectral, range oversampling and averaging, beam-indexed mode
Available Data	Time-series (I/Q samples), polarimetric variables including $K_{dp}$ , available in real-time and archived data
Polarimetric Fields	$Z_h$ , V, W, NCP, $Z_{dr}$ , LDR, $\Phi_{DP}$ , $\rho_{HV}$ , $K_{dp}$ , Average I/Q (for refractivity), SNR, Received Power
Data Formats	Binary time-series files (with associated calibration info), Internal archive format, UF (Universal Format), netCDF



NSF Science Camp Visits CSU-CHILL

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