# Engineering description of a scanning, L-band, pulse-compression radar for clear-air atmospheric research

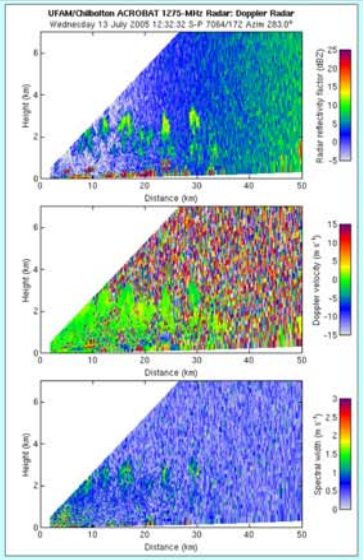
**J. D. Eastment** (RAL), O. T. Davies (Chilbolton Observatory), J. C. Nicol (U. Reading) and E. G. Pavelin (Met Office)

## Radar hardware

ACROBAT is installed on the fully-steerable 25 m dish of the Chilbolton Observatory in southern England.

Racks containing the radar's exciter, receive IF, DAQ and timing / control sub-systems are housed in the control-room.

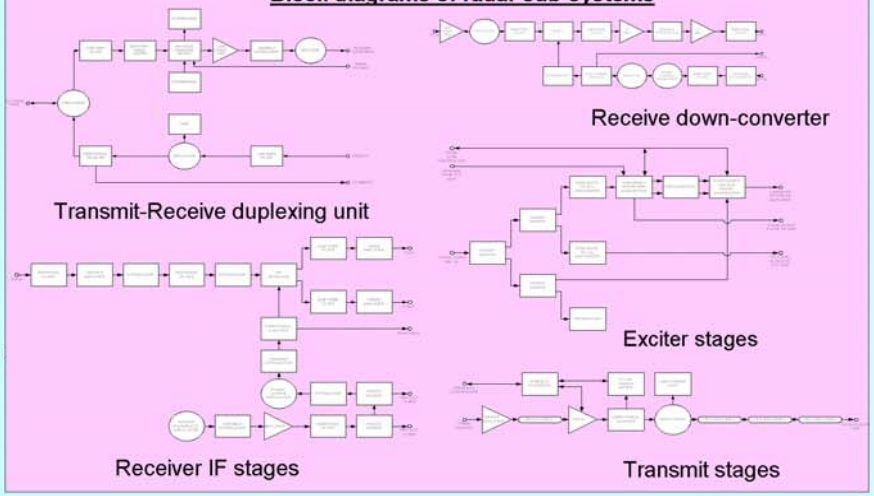
## RHI of developing convective plumes




## What is ACROBAT?

The Advanced Clear-air Radar for Observing the Boundary layer And Troposphere (ACROBAT), located at Chilbolton Observatory near Andover in southern England, is a fully-coherent, scanning, L-band, single-polarisation, pulse-compression Doppler radar. The radar was designed and constructed by members of the Radio Communications Research Unit, with assistance from the University of Reading and funding from UFAM, the Universities' Facility for Atmospheric Measurement.

## Block diagrams of radar sub-systems




## Detecting convection in the boundary layer

At L-band wavelengths, radar backscatter from the clear atmosphere arises due to Bragg scattering from turbulent refractive index inhomogeneities. These Bragg returns make the 'clear-air' radar technique possible, whereby a sensitive radar can detect echoes from the air itself and thereby measure its motion. Since convection is associated with pronounced temperature and humidity gradients, ACROBAT has proved to be an excellent tool for studying convective structures in the boundary layer.

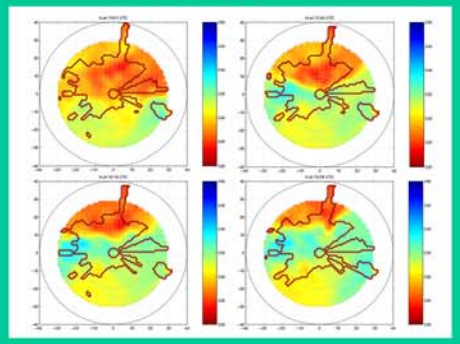
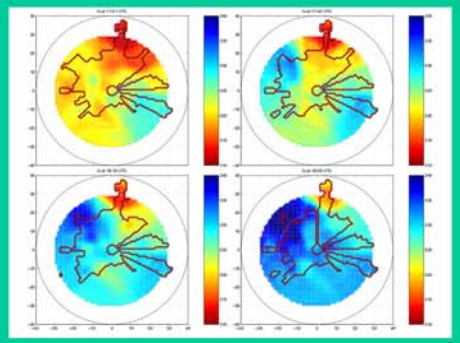
## Specification of the ACROBAT radar

| PARAMETER | VALUE AND COMMENTS |
|---|---|
| **Radar type** | Fully-coherent, single-polarisation, pulse-compression Doppler radar. Flexible waveform generation and signal processing. |
| Operating frequency | 1275 MHz |
| Transmit polarisation | Horizontal |
| Receive polarisation | Horizontal |
| System noise figure | 3.5 dB including duplexer / miscellaneous losses |
| Transmit power | 1 kW peak pulse at feed |
| Range resolution | 150 m, typical |
| Maximum number of range gates per ray | 800 |
| Number of pulses averaged per ray | (8 coherent averages) × (256-point FFT) × (8 incoherent averages) = 16384, typical |
| Maximum unambiguous range | 90 km, typical |
| Maximum unambiguous velocity | ±8.4 m / s, typical |
| **Antenna type** | Prime-focus fed parabolic dish |
| Diameter | 25 m |
| Gain | 47.5 dBi |
| Beamwidth | 0.6° (FWHM; -3 dB, 1-way) |
| First sidelobe level | -20 dB (1-way, estimated) |
| Scan rate | Typically 0.1° / second in azimuth and elevation |
| Far-field distance | 5.3 km |
| **Receiver type** | Single-conversion super-heterodyne, 60 MHz IF |
| Noise figure | 1.7 dB excluding duplexing / miscellaneous losses |
| IF type | Linear amplifier with I/Q detector |
| IF bandwidth | 4 MHz |
| Video bandwidth | 2 MHz |
| Dynamic range | 72 dB |
| **Transmitter type** | Travelling wave tube amplifier (TWTA) |
| Peak power | 2 kW at TWTA output |
| Pulse-width | 0.4 µs, typical |
| Pulse repetition frequency | 2500 Hz, typical |
| Pulse-coding | 8-bit BPSK complementary codes with 800 ns chips, typical |
| **Data acquisition / processing system** | Pentium PC plus custom ADC / timing cards |
| Number of channels | 4 (of which 2 are in use) |
| Number of bits per channel | 12 |
| Sampling rate | 2.5 MHz |
| System timing / clock frequency generation | Derived from crystal-controlled reference |
| Algorithms used | FFT-based processing: full Doppler spectrum and 0 th, 1 st and 2 nd moments |
| Real-time control / display system | Local colour monitor and web-page |
| Archive data format | NetCDF |
| **Measurables** | Doppler spectrum; SNR, $Z_e$, $v_r$ and I / Q time-series data |
| Observation mode | Non-continuous, event-based operation |
| Typical studies performed | Clear-air studies; boundary-layer investigation; refractive index measurements; wind mapping and vertical profiling |

## Detecting changes in atmospheric refractivity

ACROBAT is a fully-coherent system, enabling it to accurately measure the phase of radar returns. By isolating the signals from stable ground-clutter targets, and by tracking their phase variation over time, changes in refractive index along the atmospheric paths to the targets can be monitored. This enables fields of refractivity variations to be derived. Since the radio refractive index of the atmosphere is highly dependent on humidity, refractivity measurements are extremely useful in tracking humidity anomalies associated with the onset of convection and precipitation.

Sea-breeze front



Outflow from a storm