X-Band Wake Vortex Radar

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Wake Vortex Detection

- Airport systems for real-time detection and monitoring of wake vortices at take-off and landing are in the research and development stage both in the U.S. and Europe
- There is a key need to increase airport safety and to increase air traffic throughput by reducing aircraft separation in crosswind conditions
- LIDAR (LIght Detection And Ranging) sensors have been tested, but their utilty appears to be limited to clear air conditions
- Low power X-band radar can potentially provide all-weather wake vortex detection, and provide high-resolution weather monitoring in the TMA

Figure 3 : Real Image of Wake Vortex Hazards

Figure 4 : Ground Effect on wake vortices.

Barbaresco et al., "Wake Vortex Detection & Monitoring by X-band Doppler Radar: Paris Orly Radar Campaign Results,"

Wake Vortex Radar Performance Goals

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Detection range: 2 km

Front-end characteristics:
Frequency range : X Band (9.6GHz nom)
RCS Detection: 0.01m2 (nom)
Dynamic Range: 90 dB per Vaisala RVP900
Pulse to Pulse phase stability : per Vaisala RVP900
Digital sampling rate (IQ): per Vaisala RVP900

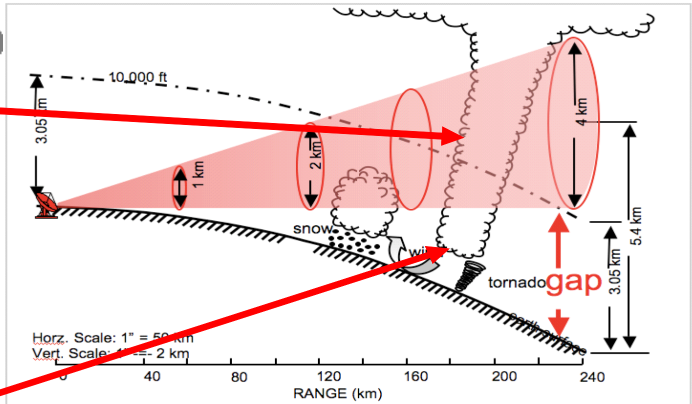
Beam characteristics:
Full 2D (azimuth and elevation) electronic scanning
Electronic beam scanning range: +/- 15 ° (in elevation plane), +/- 45° (in azimuth plane)
Mechanical tilt antenna face in elevation: -10 ° to 90° (zenithal)
Elevation beamwidth: 1° to 2°
Azimuth beamwidth: 1° to 2°
Dual polarization at reception : HH and VV
Volume exploration renewal period: 1s to 200s (depending on operating mode)

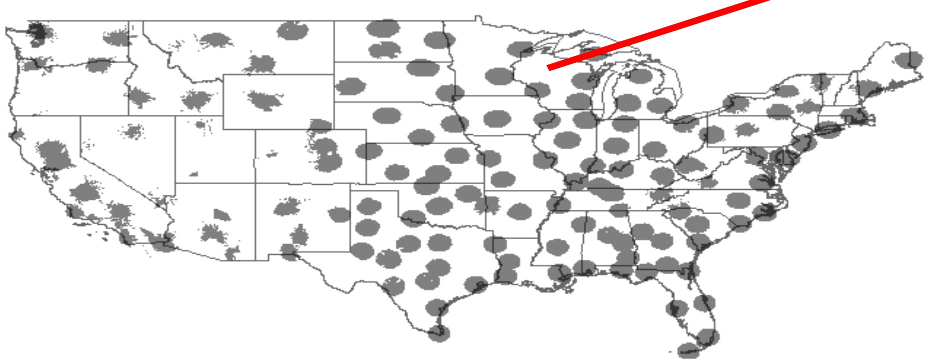
Waveform characteristics:
Duty cycle: > 20 %,
Pulse duration: 0.5 µs to 40 µs,
Pulse repetition interval : 400 µs to 1000µs,
Range resolution : 40 meters

Weather Detection – CASA

- Traditional ground-based weather surveillance has relied on a sparse population of large long range high power radars (e.g. NEXRAD WSR-88 S-band radars)
- However, there is a need to be able to provide coverage at lower altitudes as well where the current long-range radar networks have significant gaps

NEXRAD coverage at 3 km (~10k ft) AGL.





NEXRAD coverage at 1 km (~3200 ft) AGL.

Wide spacing and earth curvature prevents the radars from seeing down low, where weather hazards that impact human activity are occurring

CASA Test Network

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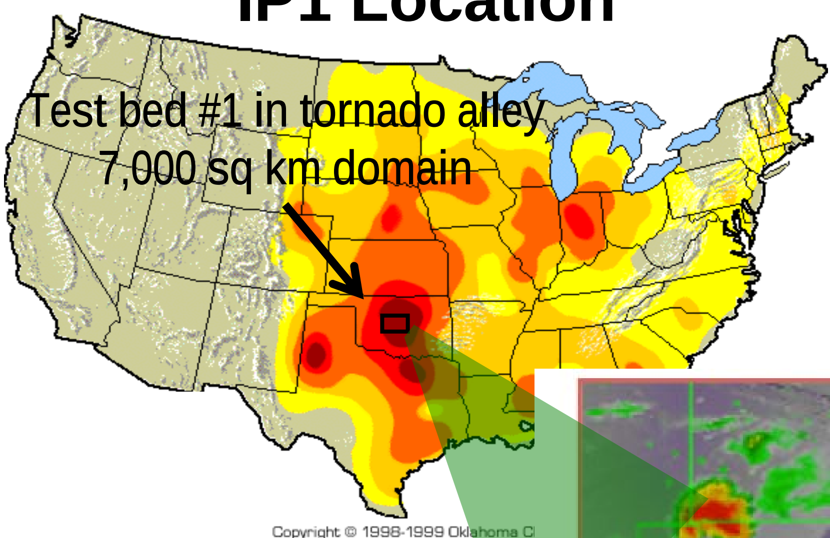
IP1 Location

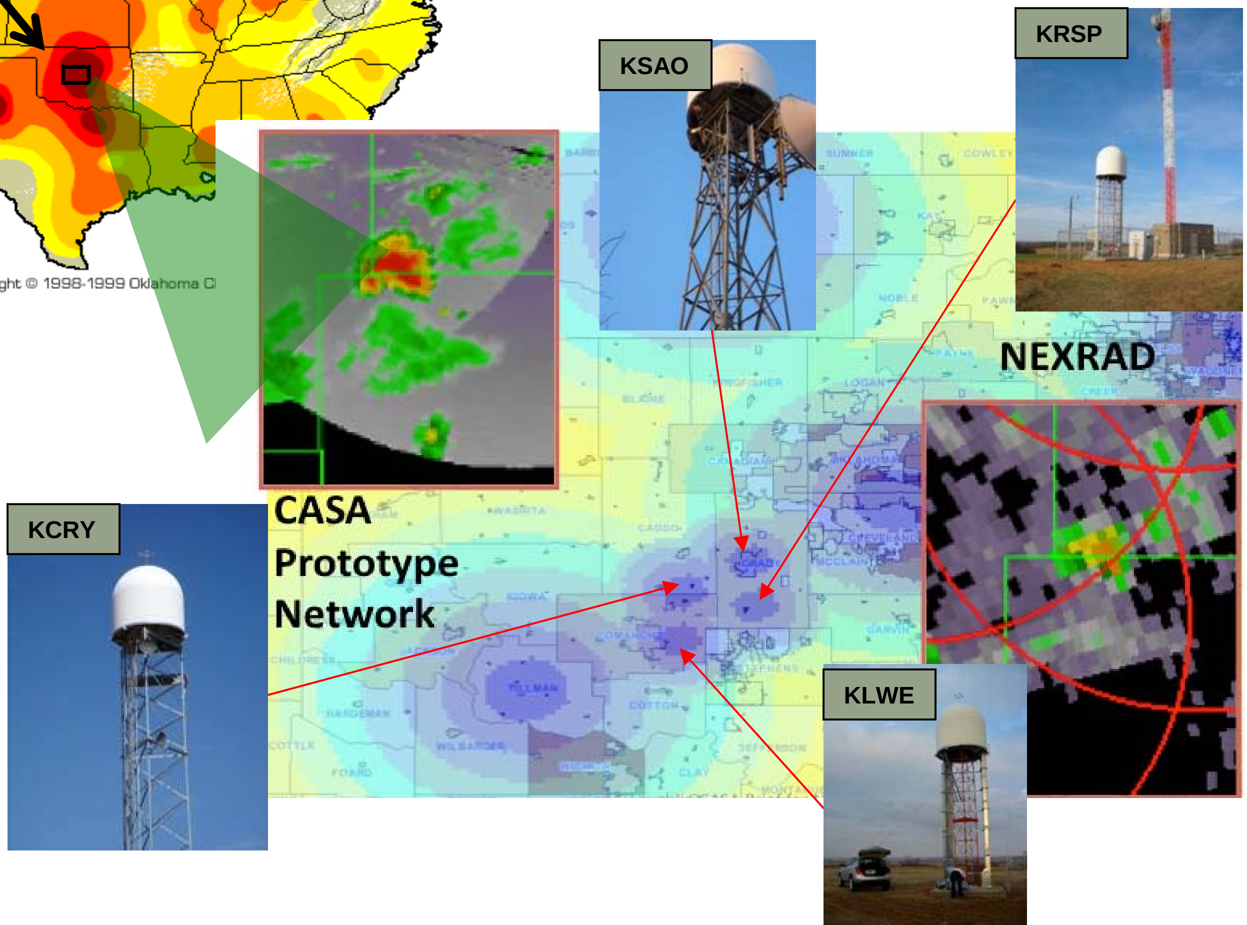


Floods and Tornadoes

- #1 and #2 weather hazard for injuries and deaths
- occur at ground level
- occur on very short time scales
- occur on very small space scales

CASA Network

- 4 Radars integrated with NEXRADs
- Prototype network data compared to NEXRAD only
- CASA produces detailed weather

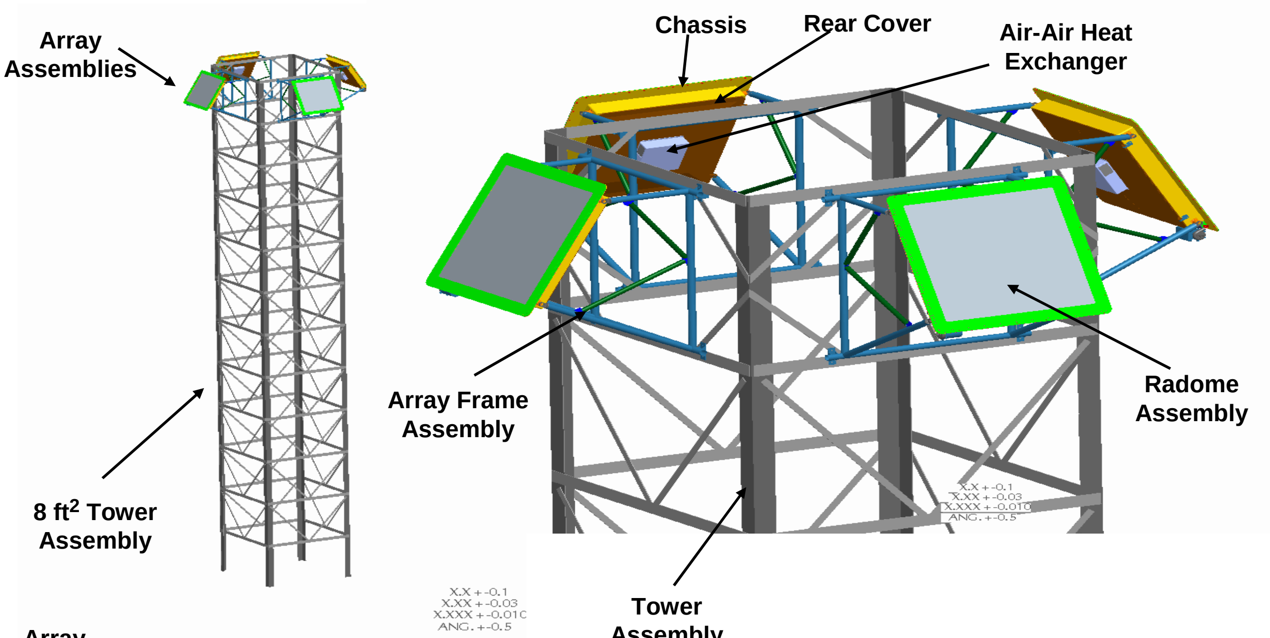


Typical Radar Performance - Weather

Parameter	Value
Center Frequency	9.6 GHz
Operating Bandwidth	80 MHz
Instantaneous Bandwidth	6 MHz
PRF	3.4 kHz
Peak Transmit Power	100 W
El Beamwidth (Broadside)	~2°
Az Beamwidth (Broadside)	~2°
Elevation Scan Range	0-30°
Azimuth Scan Range	±45°
Antenna Gain (Broadside)	39 dB
Maximum Range	30 km
Range Resolution	25 m
Pulse Width	4.16 – 41.67 μs
Duty Cycle	20-30%
Noise Figure	5 dB
System Losses	5 dB
Minimum Detectable Signal	~ -100 dBm

X-Band Radar Technology Application

Future Weather System Technology-Elec Scan (2010)



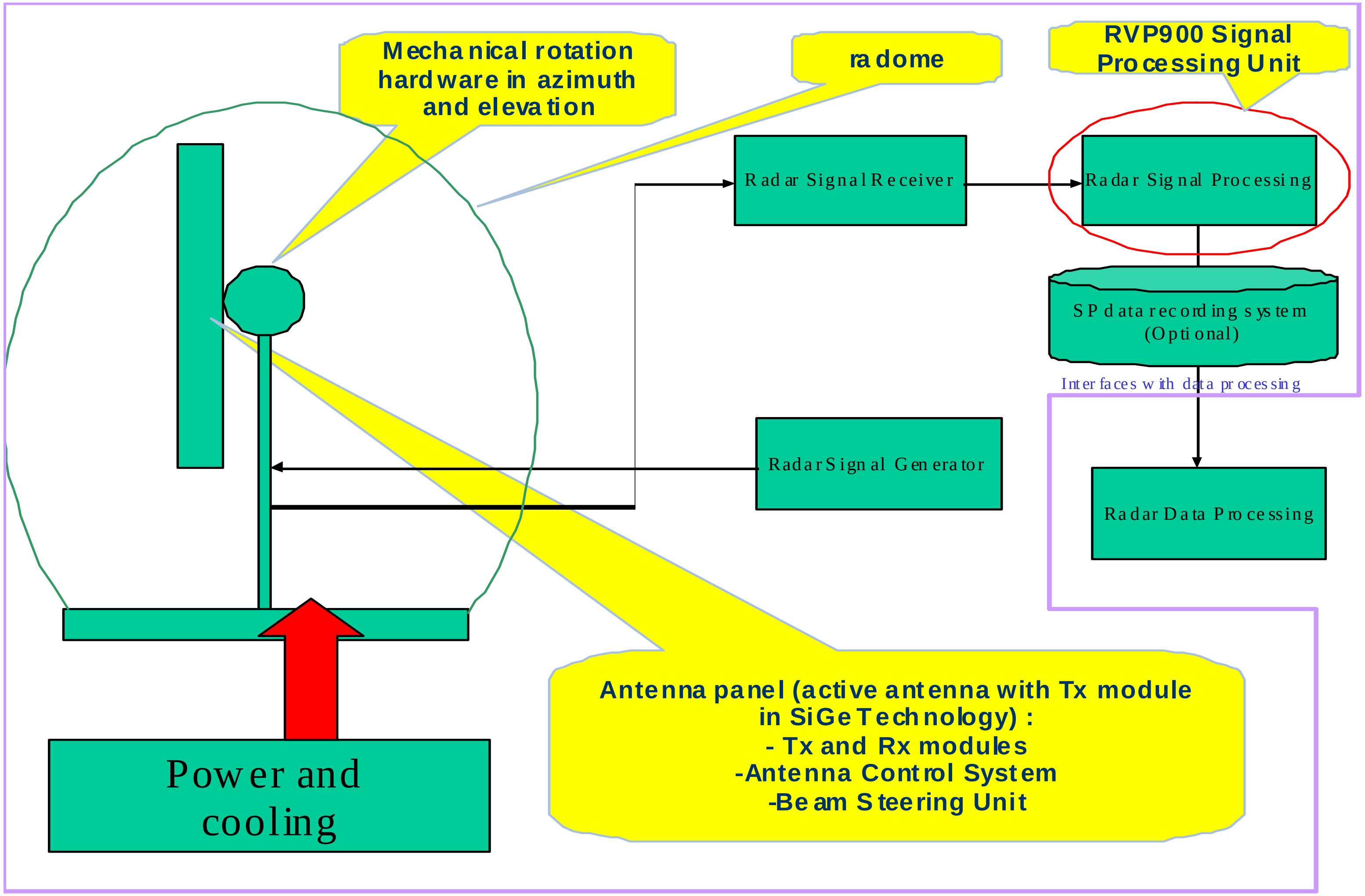
Characterstics:

- 1 m x 1 m X-band antennas
- 2 degree pencil beam
- Single and dual V & H polarization configurations
- 10's Watt average power

Current Weather System Technology

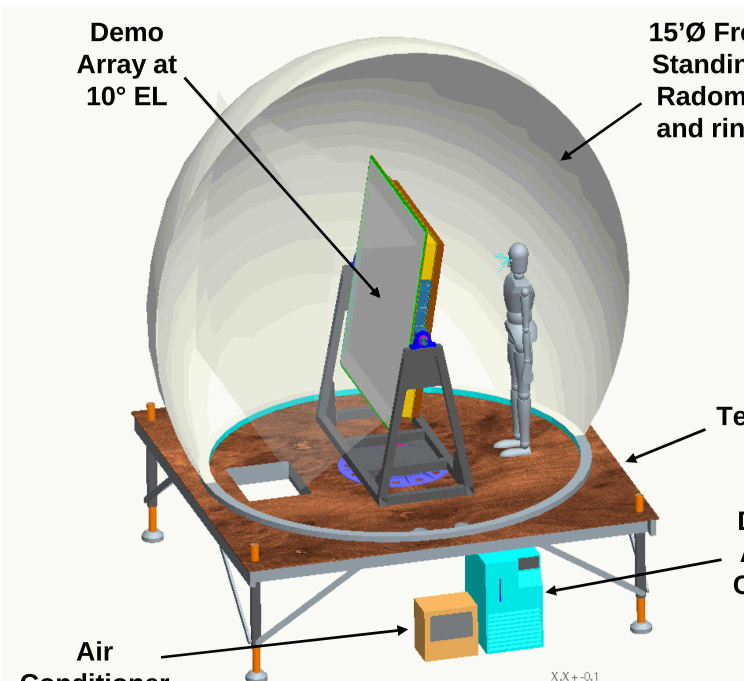
-Mech Scan (2005)

Weather / Wake Vortex X-Band Radar Package

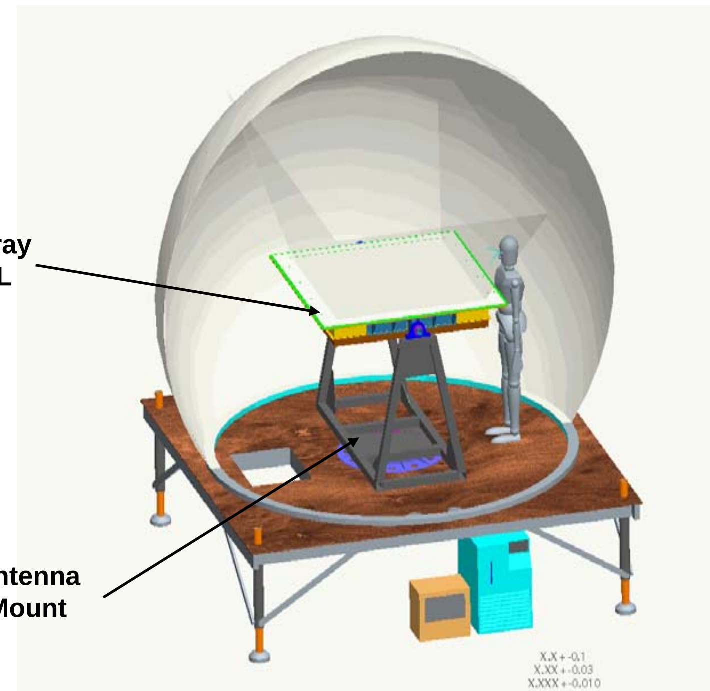


Weather / Wake Vortex Demo Configuration

Weather Test Configuration

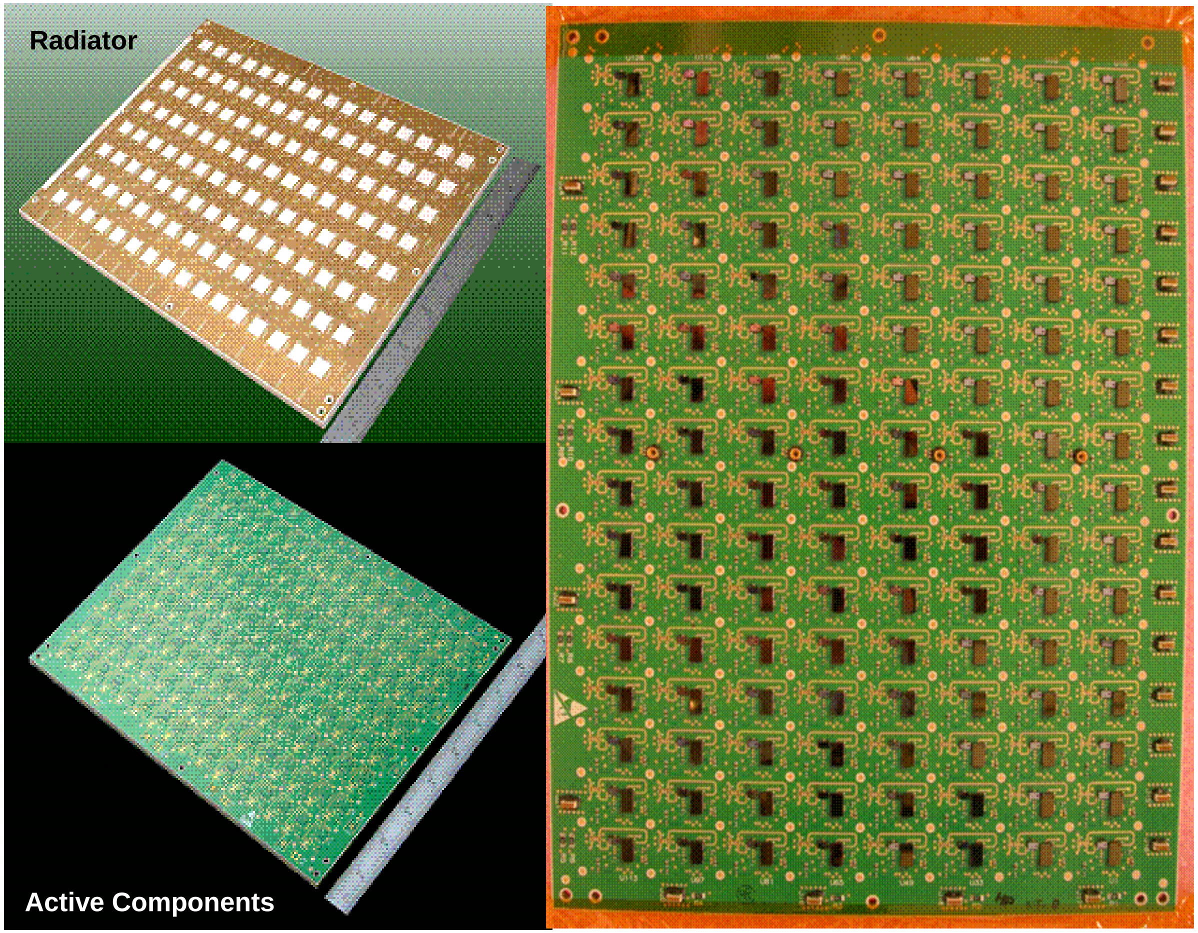


Wake Vortex Test Configuration



Demo Array – Panel CCA Assembly Overview

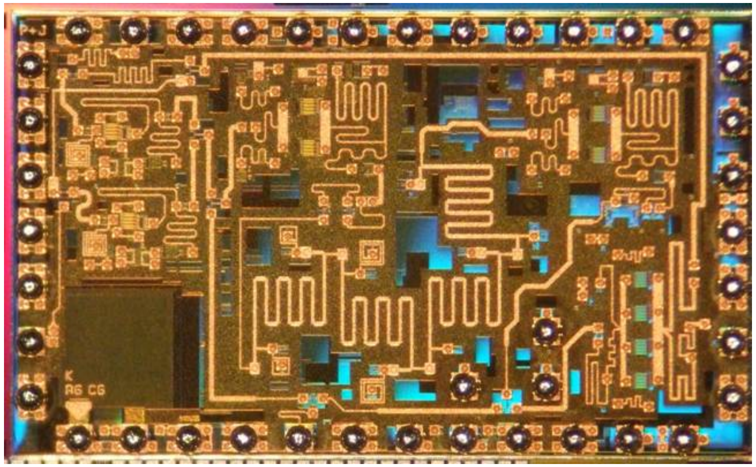
- Building Block Panel PWB consists of 128 identical unit cells
  - 18 layer board
  - Slot fed single Patch Radiator
- Each unit cell contains single SiGe Flip Chip, Linear Regulator, and associated Caps / resistors
- 4 Power, 4 Logic connectors and 1 RF Connector



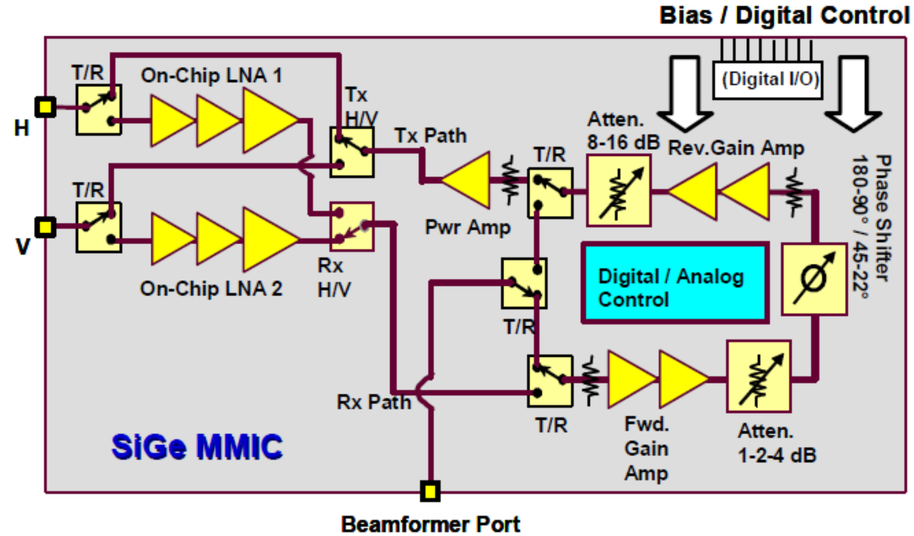
SiGe T/R MMIC Description

- The Wake Vortex / Weather Radar T/R MMIC is a mixed-signal circuit containing Microwave, Analog, and Digital circuitry.
- The T/R MMIC provides the full functionality of a T/R module on a chip, providing final output power in Transmit, setting noise figure in Receive, and amplitude/phase control for beam steering.
- The T/R MMIC has been designed for IBM's SiGe 7HP BiCMOS process followed by proprietary Topside post-processing.
- The microwave circuitry consists of:
  - Power Amplifier (PA)
  - Low Noise Amplifier (LNA)
  - Common Leg Circuit (CLC) containing two Gain Amplifiers, a 4 bit Phase Shifter, a 5 bit Attenuator, and a Transfer switch
  - Transmit/Receive (T/R) switches
  - Horizontal/Vertical (H/V) Polarization switches
- The analog circuitry consists of bias controls to support the amplifiers of the RF functions as well as the internal digital requirements.
- The digital circuitry decodes the incoming digital commands and provides the logic controls for the phase shifter, attenuator, and switches.

Silicon Germanium Transmit/Receive MMIC



5.7 mm x 3.5 mm



Weather Radar Transceiver MMIC design optimized for low power Wake Vortex and Weather radar requirements

- 0.18 μm IBM SiGe 7HP BiCMOS
- Selectable H/V polarization
- 4-bit phase shifter/5-bit attenuator
- Ultra low-power CMOS switches
- Selectable LNA front-end
- 125 mW power amplifier
- 128 bit SRAM
- Designed for flip-chip assembly

The RVP900 Vaisala Sigmet Digital Receiver and Signal Processor

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Features

The RVP900TM provides comprehensive digital IF and signal processing functions on an open Linux PC platform

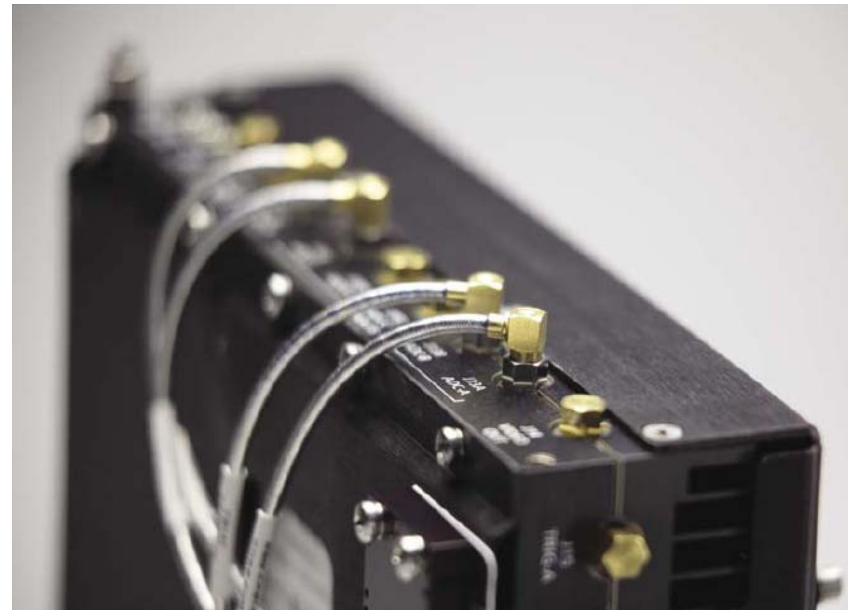
• 100 MHz, 16-bit IF sampling improving sensitivity and dynamic range in 5 independent channels

• 38.4 Billion multiply accumulates cycles per second which is a x5 increase over the RVP8TM

• PCI bus-less architecture allowing the RVP900TM to be PC independent. The next generation hardware is the next faster PC chip.

• Independent and parallel FIR filtering allowing dual pulse width and dual frequency transmit strategies

• Dual Polarization, Wide Dynamic Range, and Pulse Compression ready.



The RVP900 Vaisala Sigmet Technical Data

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Digital Receiver________________________

IF INPUTS
5 separate and identical channels allowing multiple applications such as dual-polarization with ultra-wide dynamic range: 50-Ω, +8.0 dBm

IF RANGES
Selectable: 5-130 MHz

DYNAMIC RANGE
90 to >105 dB depending on matched filter (e.g., >105 dB for 0.5 MHz matched filter). Optional 20 dB ultra wide dynamic range extension using additional IF input channels

A/D CONVERSION
16 Bits at up to 100 MHz with jitter < 1.0 picoseconds

PHASE STABILITY
Klystron: Better than 0.1 degrees
Magnetron: Better than 0.5 degrees (for 1.0 microsecond pulse)

IF WAVEFORM GENERATOR
Dual 16-bit TxDAC at 10-75MHz with 65 dB SNR
10-125MHz on the TxDDS output

Signal Processor__________________________

OUTPUT
dBZ, V, W, Polarization parameters: 8 or 16 bits; I & Q: 16 bits; FFT: 16 bits. Real-time display.

SERVER SPECIFICATIONS
Dual Quad-Core Intel Xeon processors and 1333 MHz System Bus speed offering 5X the processing power of the RVP8TM server.
2 X 250 GB SATA Hard drive
TCP/IP 100/1000 BT Host interface
Remote Intelligent Platform Management Interface (IPMI) with onboard sensors and BITE

Physical and Environmental _______________

PACKAGING
Digital Receiver: 243 x 169.5 x 81.6 mm including fan.
Signal Processor: 1U rack mount chassis.

ENVIRONMENTAL
Digital Receiver: 0 – 50 C operating, 0 – 95% (non-condensing) R.H.
Signal Processor: 10 – 35 C operating, 8 – 90% (noncondensing) R.H.

RELIABILITY
Digital Receiver: >50,000 Hours MTBF (at 25C)