RainGain Workshop Briefings
April 16, 2012 Leuven, Belgium

CASA perspective on X-Band radar technologies

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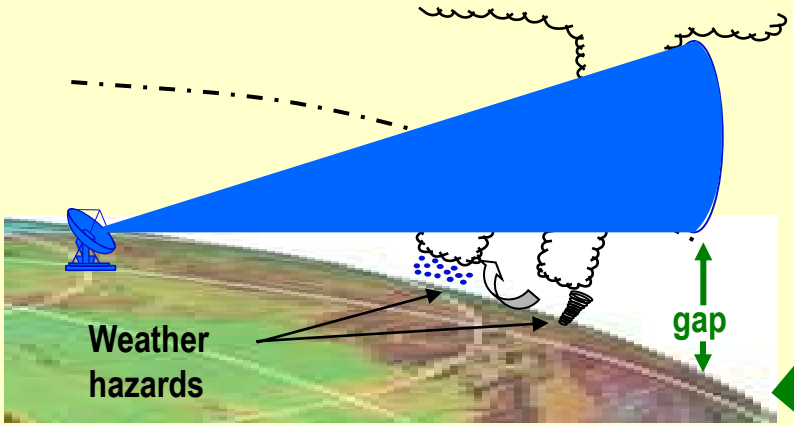
UMASS AMHERST

CASA Engineering Research Center



Solution

Numerous inexpensive, closely-spaced radars

Data

Tasking

Multiple end users

Observe, understand, predict and respond to hazardous weather events

Some theoretical numbers

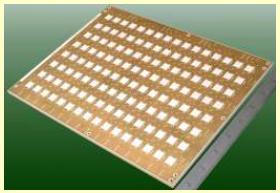
Assumes regular grid 230km(S), 150km(C), 30 km (X)

	"Blanket Coverage"		15% Coverage*
	Large Radar (S/C Bands)	Small Radar (X Band)	Small Radar (X Band)
USA/CONUS	145	8,511	1,277
Europe/OPERA	217	5,416	812
France	28	712	107
UK	11	270	41
Belgium	2	42	6

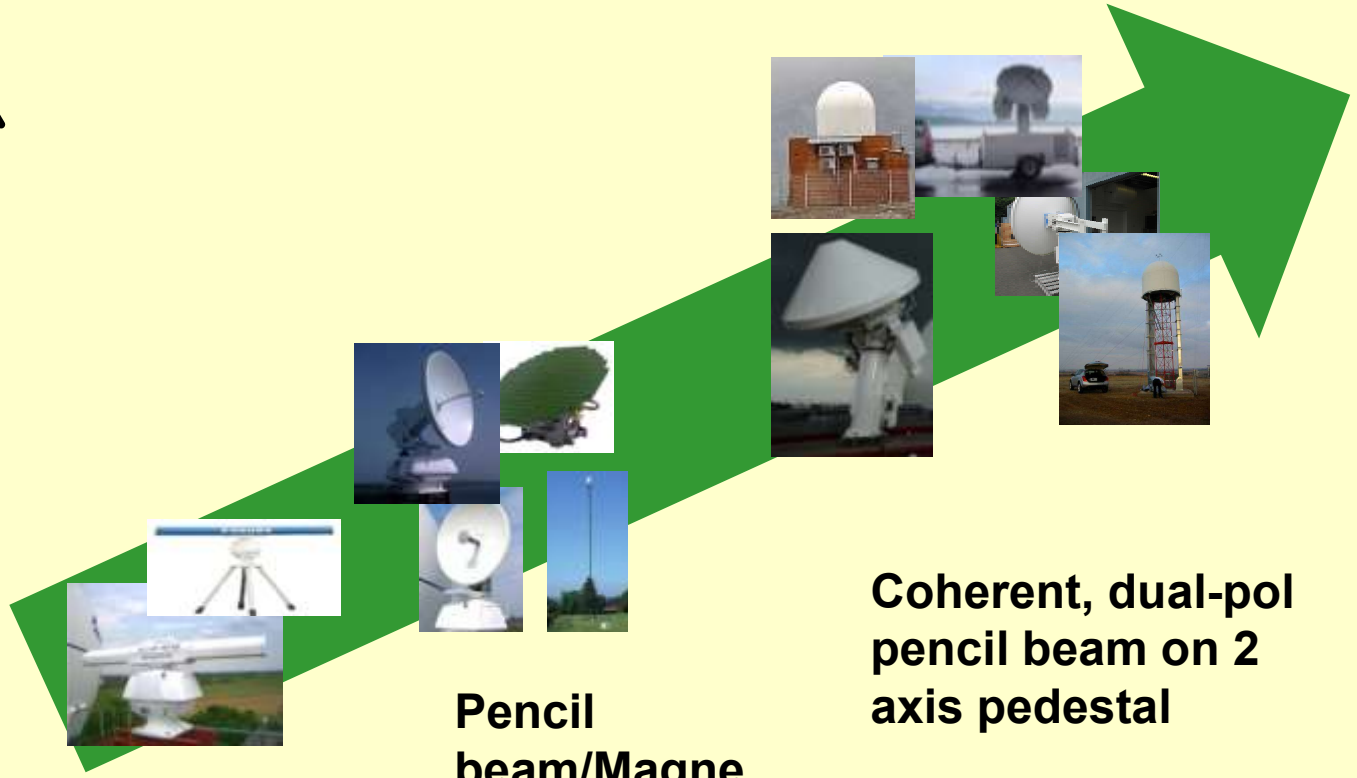
***Critical infrastructure, population centers, borders, etc…**

Large numbers of small radars –must be inexpensive, easy to deploy

X-Band Weather Radar Technologies deployed over past decade



Performance
(Resolution, Doppler, Dual-pol, Sensitivity, Clutter rejection)



Fan beam/ Magnetron

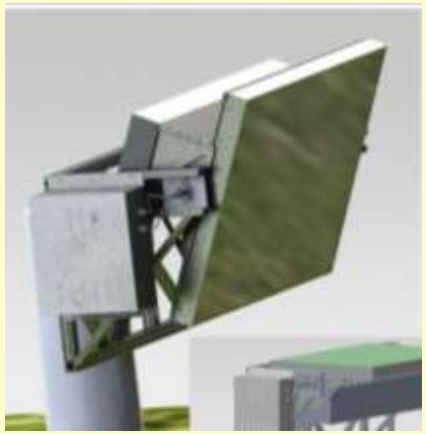
Pencil beam/Magne tron

Coherent, dual-pol pencil beam on 2 axis pedestal

Size, Weight, Cost, Complexity

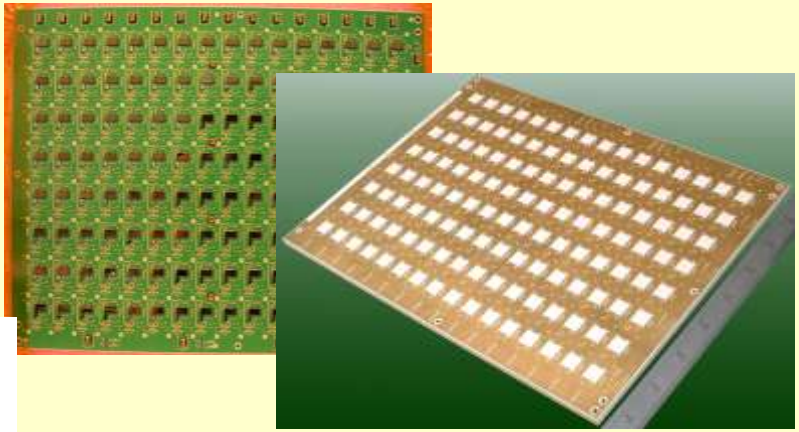
E-Scanned Antenna Technologies

First RF Corp



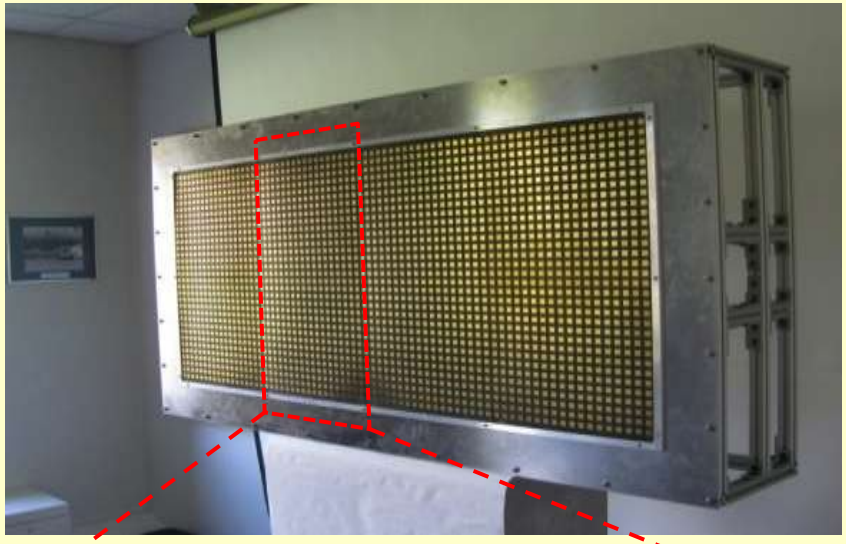
- Phase steer – azimuth
- Mech tilt – elevation
- 1.5 meter x 1 meter
- 70 W peak, 30% duty

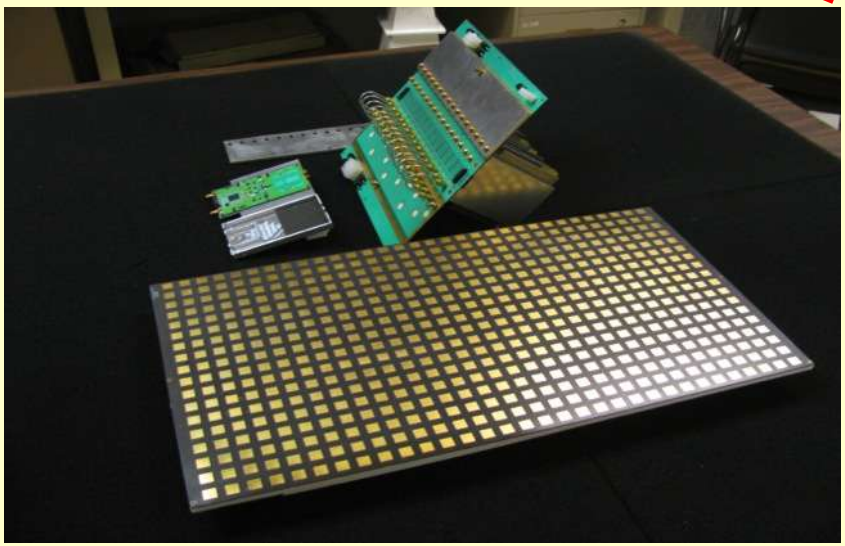
Raytheon

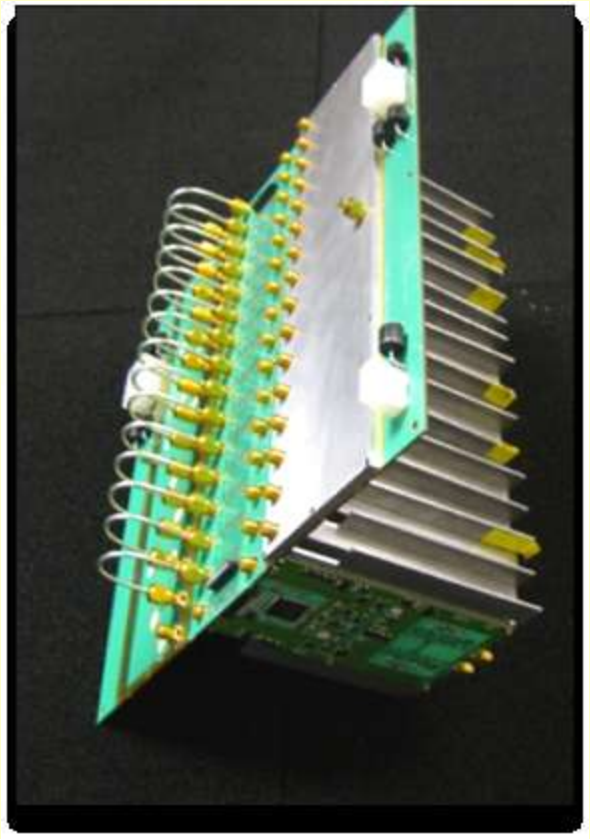


- 2D phase-phase array
- 1 meter x 1 meter
- ~ 100 W peak, 30% duty
- 3,000 T/R channels using SiGe instead of GaAs

UMass Laboratory prototype



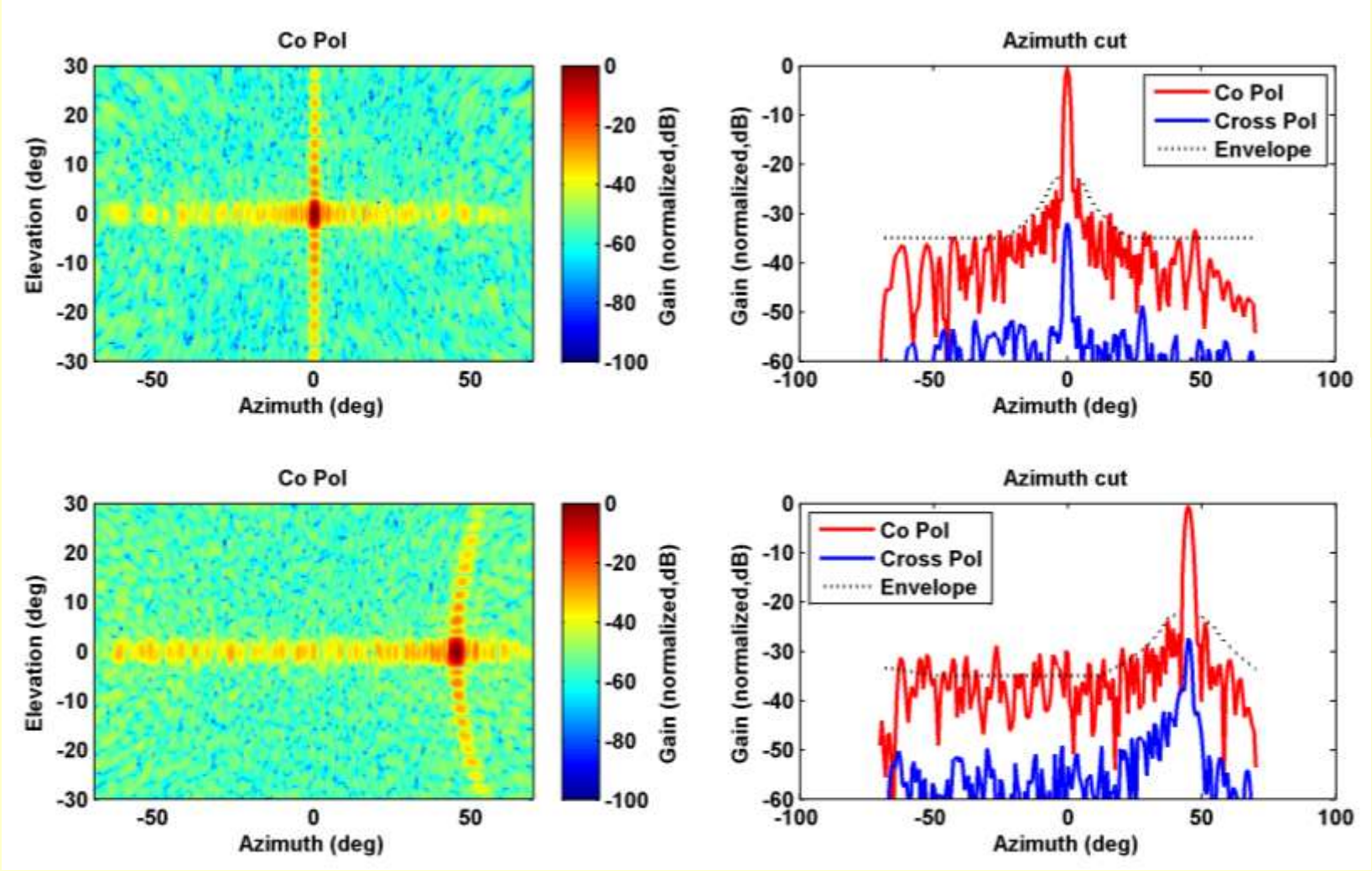




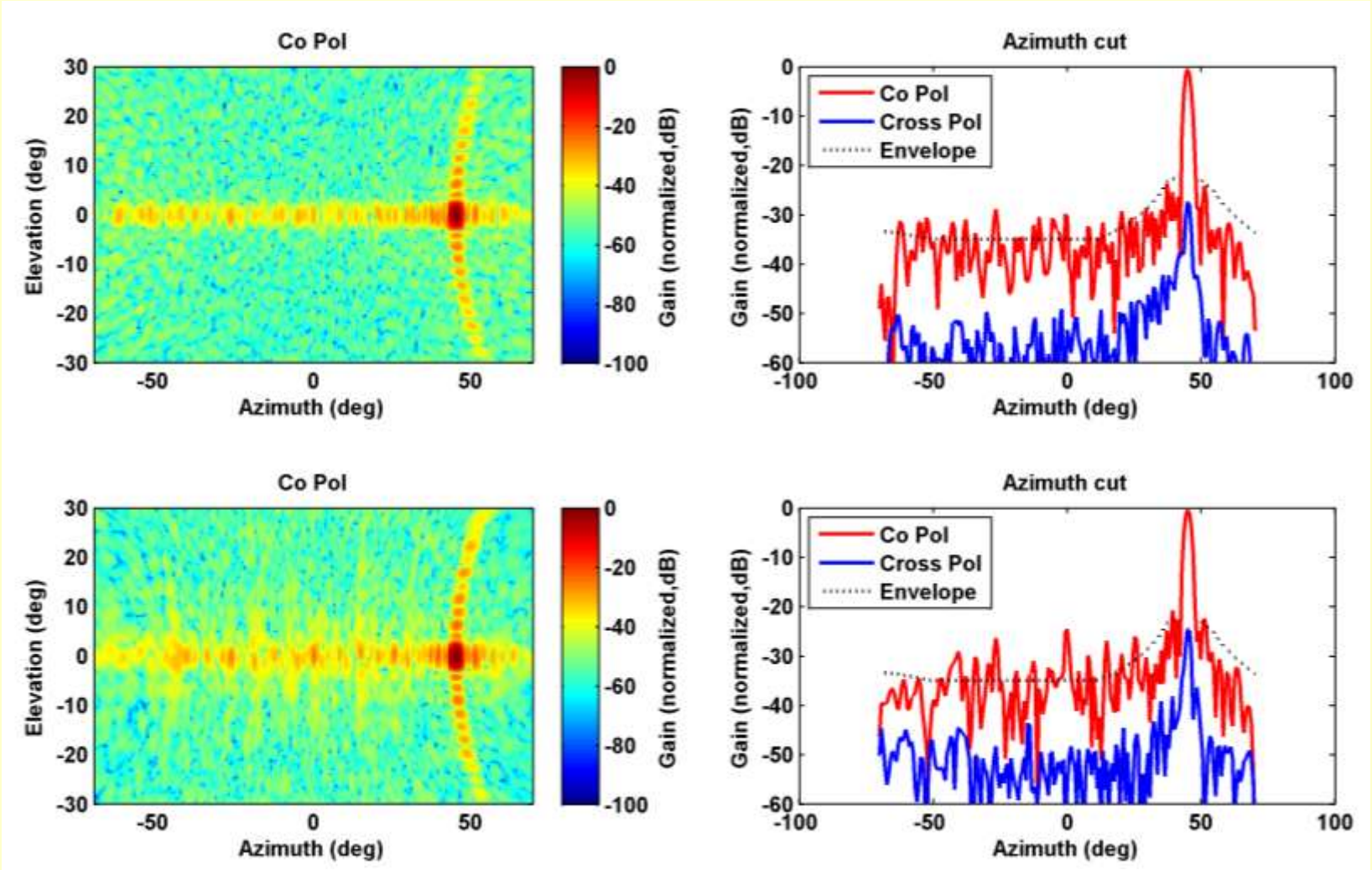
University of Massachusetts prototype demonstrating ~$10k (US) per LRU

Manufactured Product FRF – 166

V pol beam patterns (0 & 45 degrees)



Vertical (upper) & Horizontal (lower) Patterns at 45 degrees

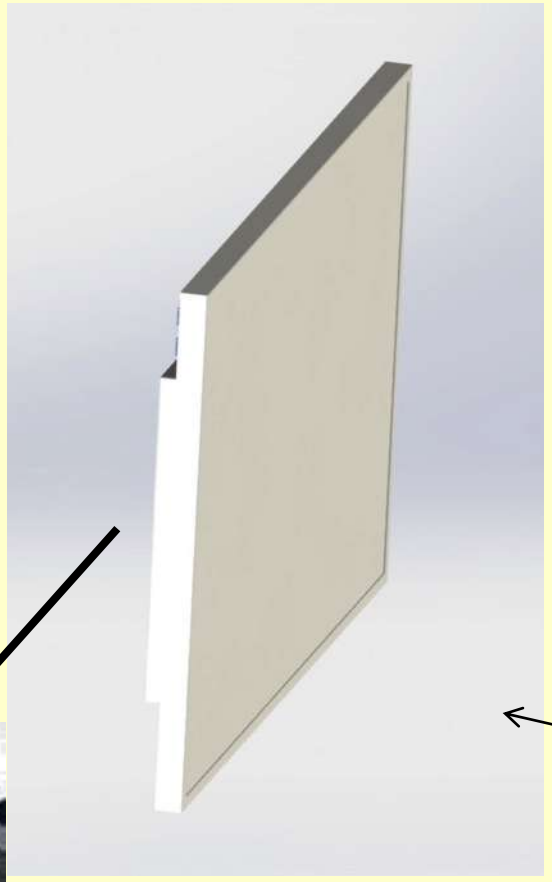


Toward a “Flat Screen TV” Antenna

	First System	Intermediate	Next configuration
	Unit 001	Unit 002A	Unit 002B
aperture dimensions L x h x D (m)	1.3 x .9 x .7	1.3 x .8 x .3	1.2 x .8 x .1
aperture weight (kg)	125	80	<60
Power (includes power supply and motor)	600	600	600
AZ beamwidth (deg)	1.5	1.5	1.5
EL beamwidth (deg)	2.5	2.5	2.5
Elevation Mechanical Pointing range (deg)	-15 to 90	-15 to 90	-15 to 90
Azimuth scan range (deg)	>+/- 45	>+/- 45	>+/- 45

FIRST RF Corporation

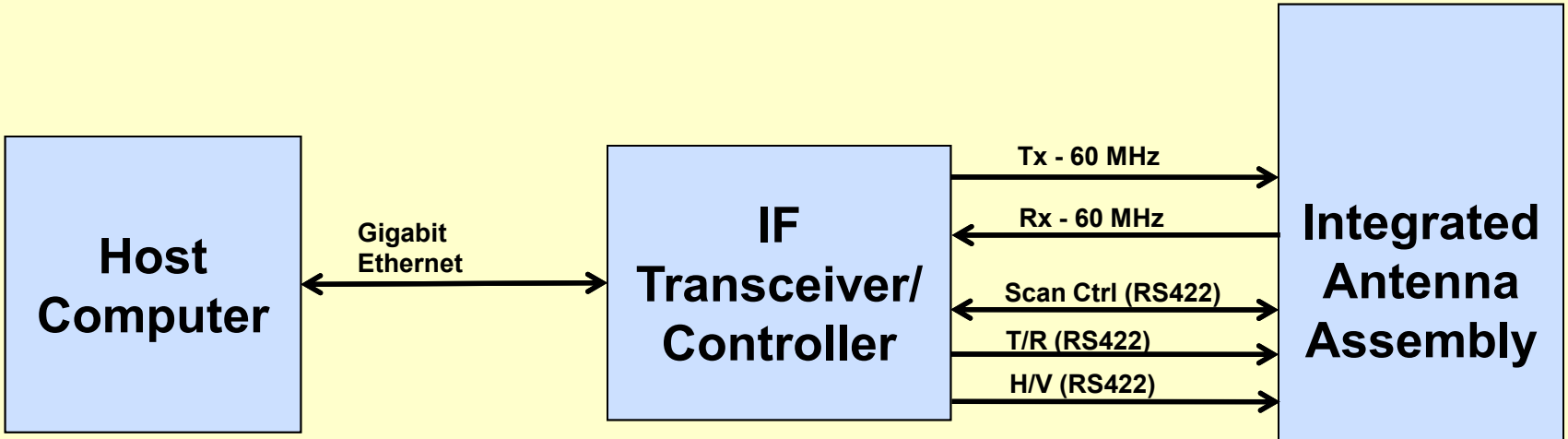
Towards a “Flat Screen TV” Phased Array



Rear face
Radiating face (front)

Notional dimensions:
1.2 m length
0.8 m height
0.1 m (10 cm!) depth

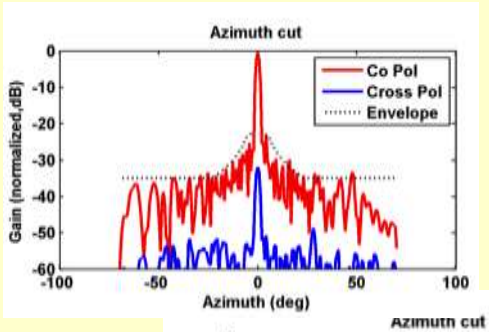
Phase-tilt Weather Radar System

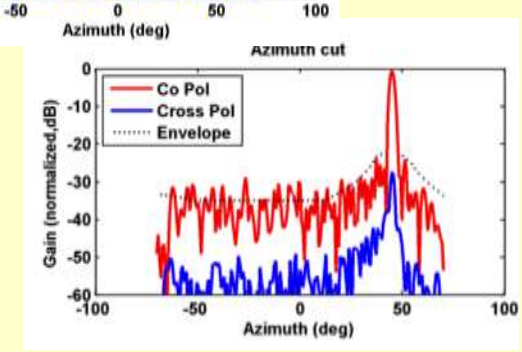


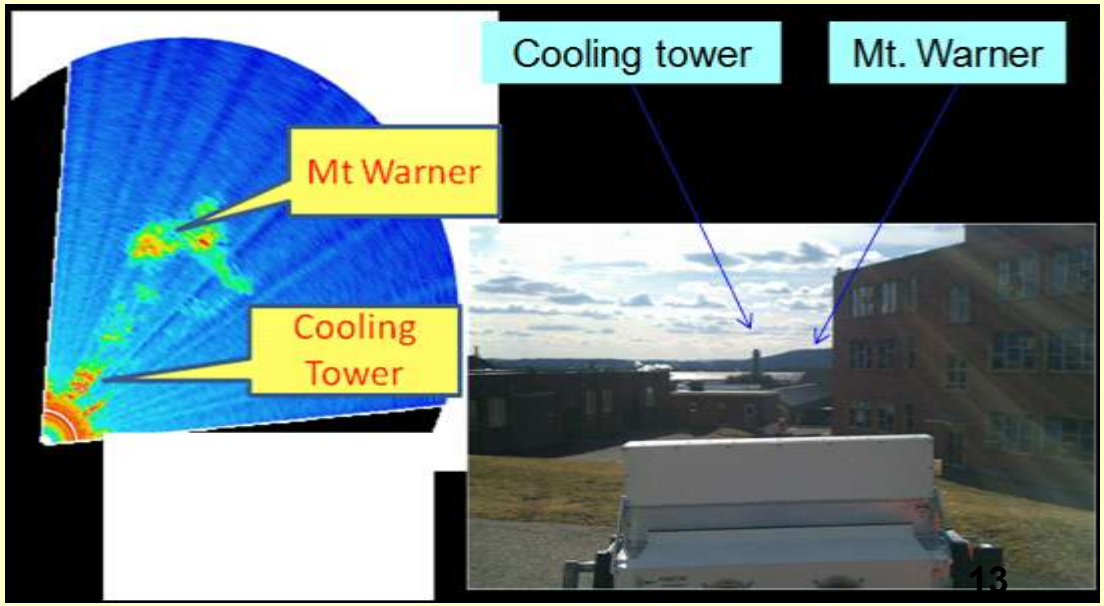
3 components, 2 cables, + software comprise the entire radar system!

CASA's Phase-tilt Weather Radar Demo

- **Electronic Steering Az $\pm 45^0$**
- **Mechanical Steering El -5 to 90^0**

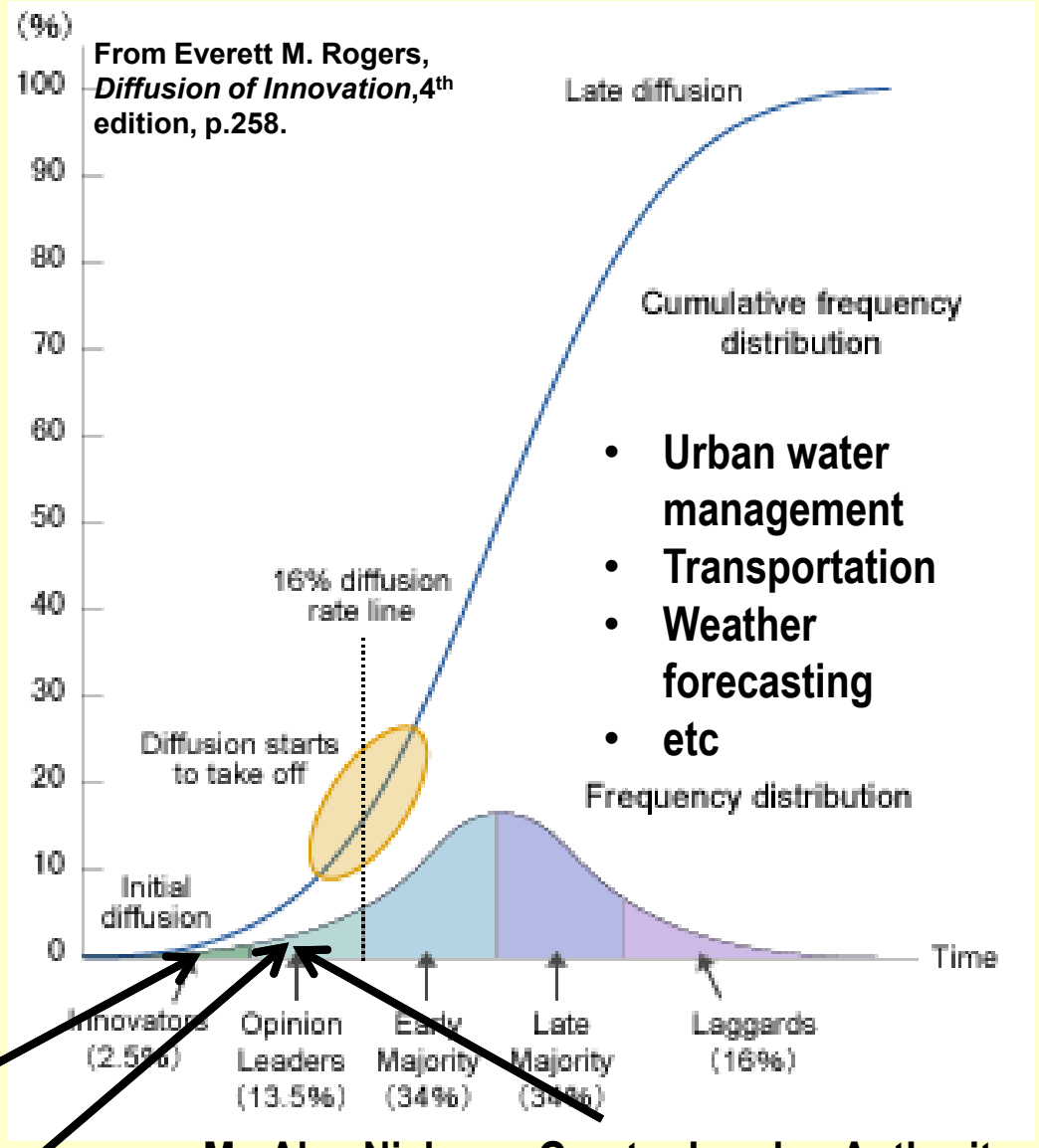






Diffusion of Innovation

- Innovators: venturesome, seek new ideas
- Early adopters: respected and influential leaders
- Early majority: deliberate, size creates critical mass
- Late majority is skeptical
- Laggards are traditional



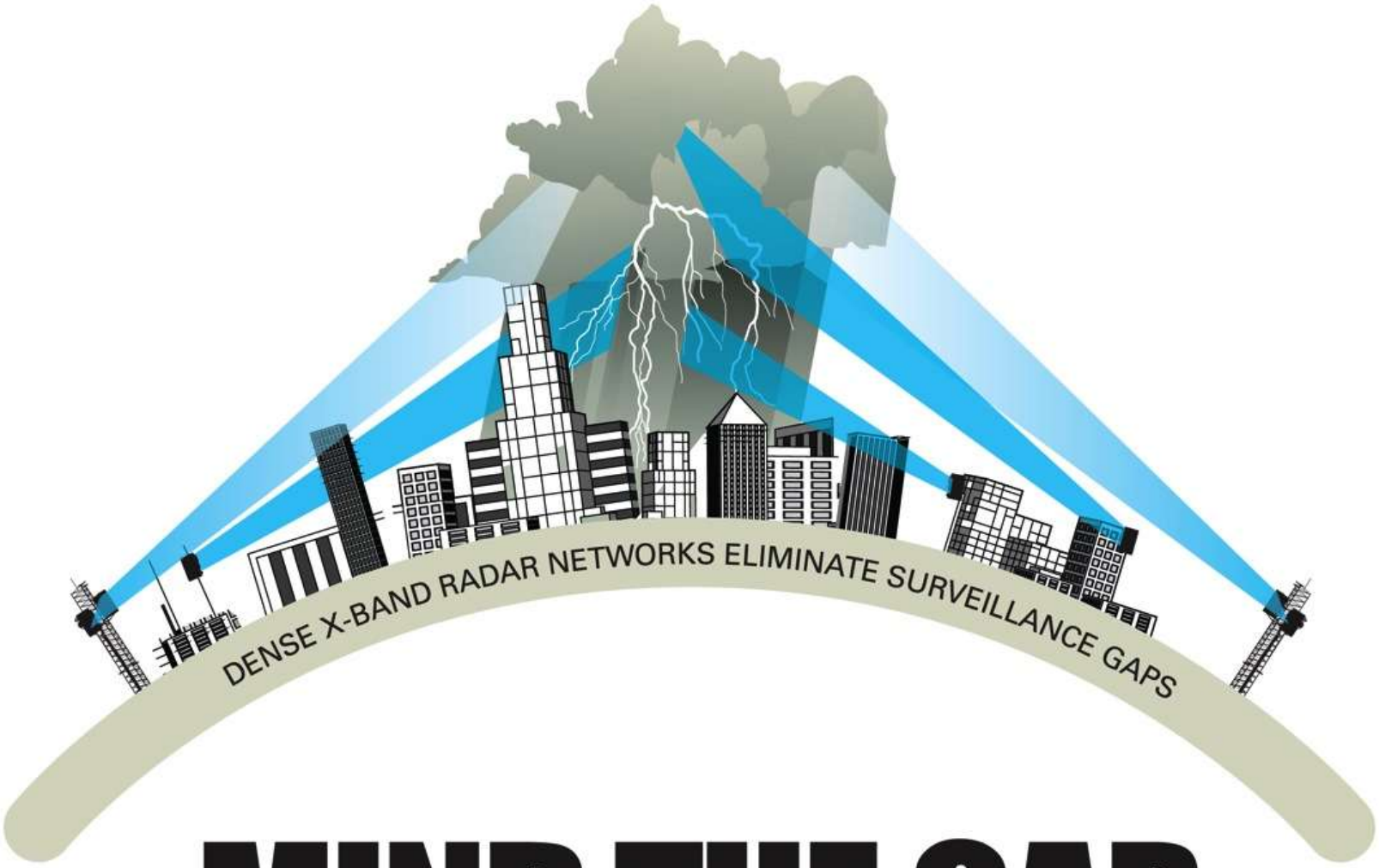
Commercial phased array technology

X-Band Weather Radar

eg, Mr. Alex Nickson, Greater London Authority; Mr. Daniel Goedbloed, City of Rotterdam

Upcoming Demos & Booths

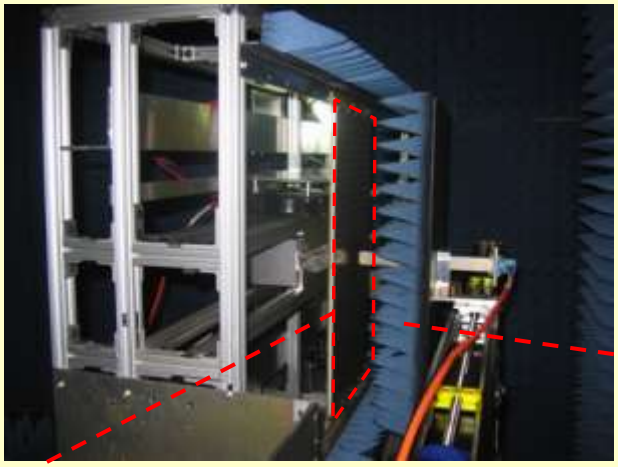
- 6/2012 Toulouse: European Wx Radar Conf
  - UMass, First RF, Raytheon
  - Show design issues & performance data
  - Gather key “care-abouts” from prospective users/customers
- 10/2012 Brussels: Meteo Tech International
  - UMass, First RF, Raytheon
  - Present radar hardware/mockup & performance data
  - Discuss options for purchase, lease, research demos of Phase Tilt Weather Radar Systems



MIND THE GAP

Detect weather where it matters—in the low atmosphere.

Umass Amherst Phase-tilt Antenna Array Prototype Tests

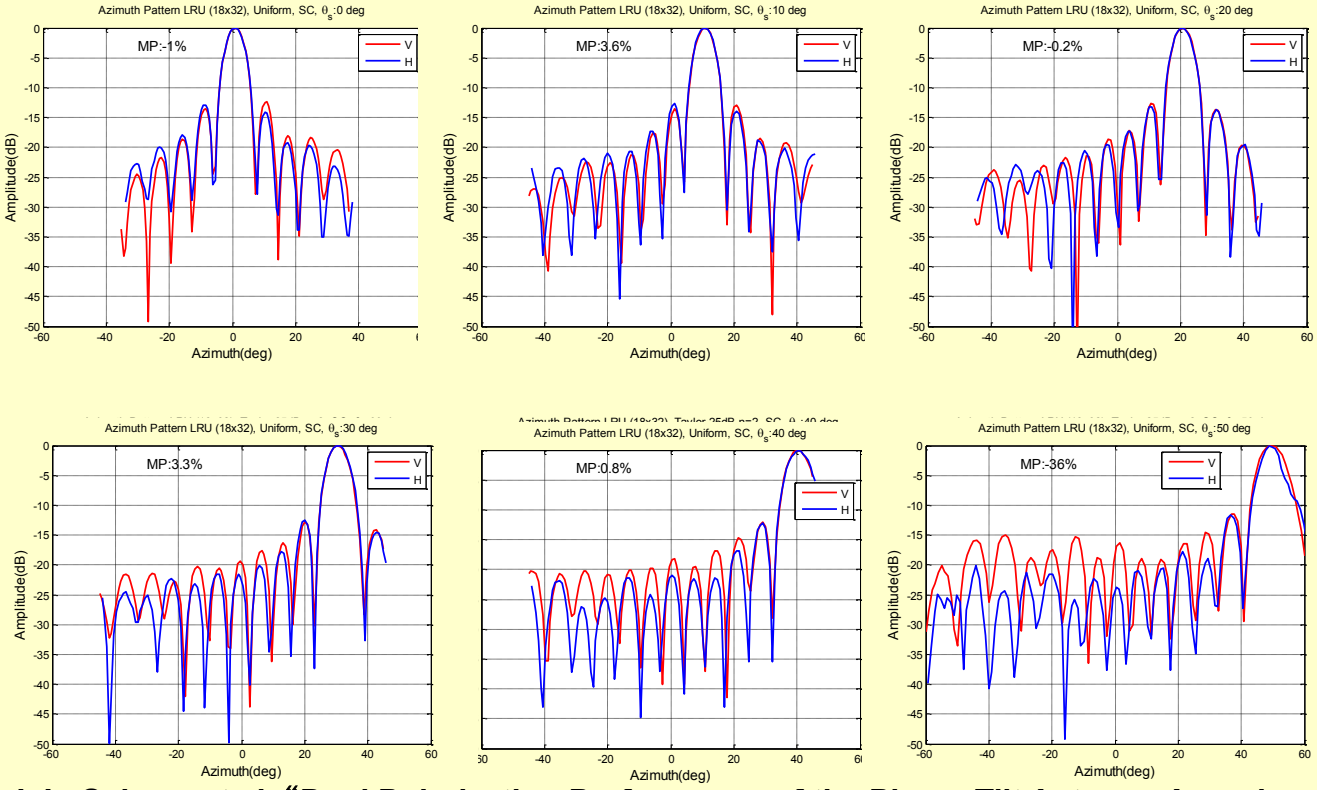


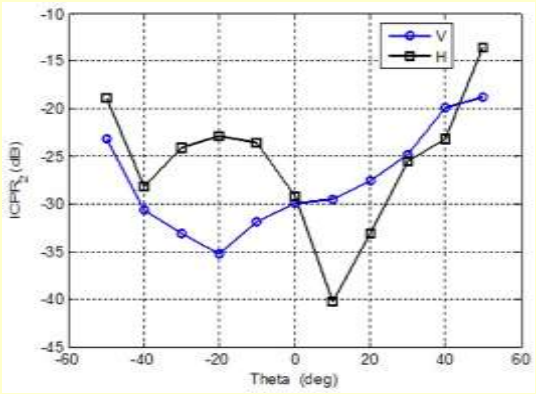
Dual Polarization Performance:

- Co-pol mis-match <5% to 45^0 (based on LRU NF measurements)
- -20 dB Xpol to 45^0 (calculated)

Co-pol

X-pol





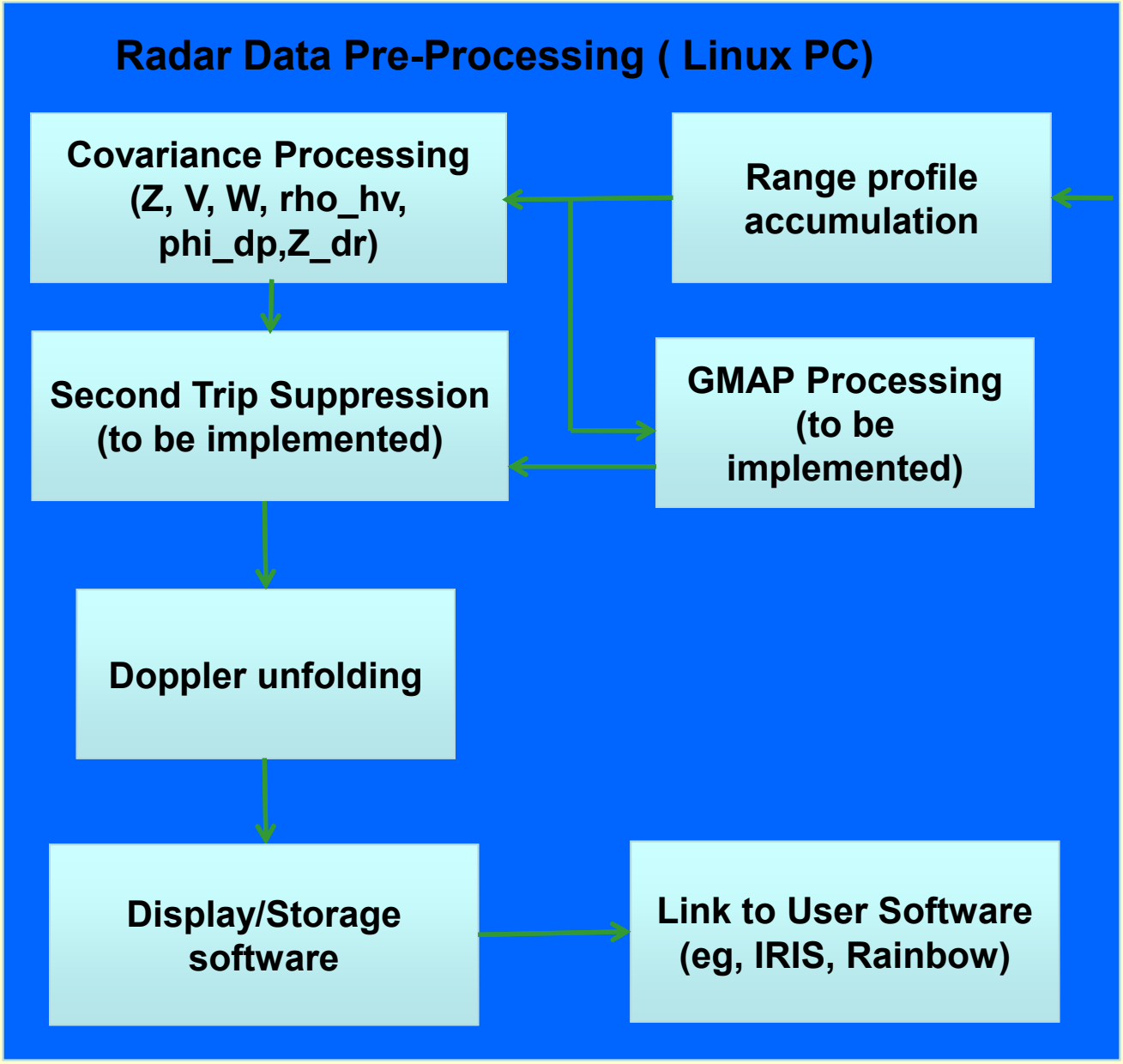
J. L. Salazar et al, "Dual Polarization Performance of the Phase-Tilt Antenna Array in a CASA Dense Network Radar", Proc. IEEE Geoscience Remote Sensing Symposium, 2010.

Phase-Tilt Weather Radar

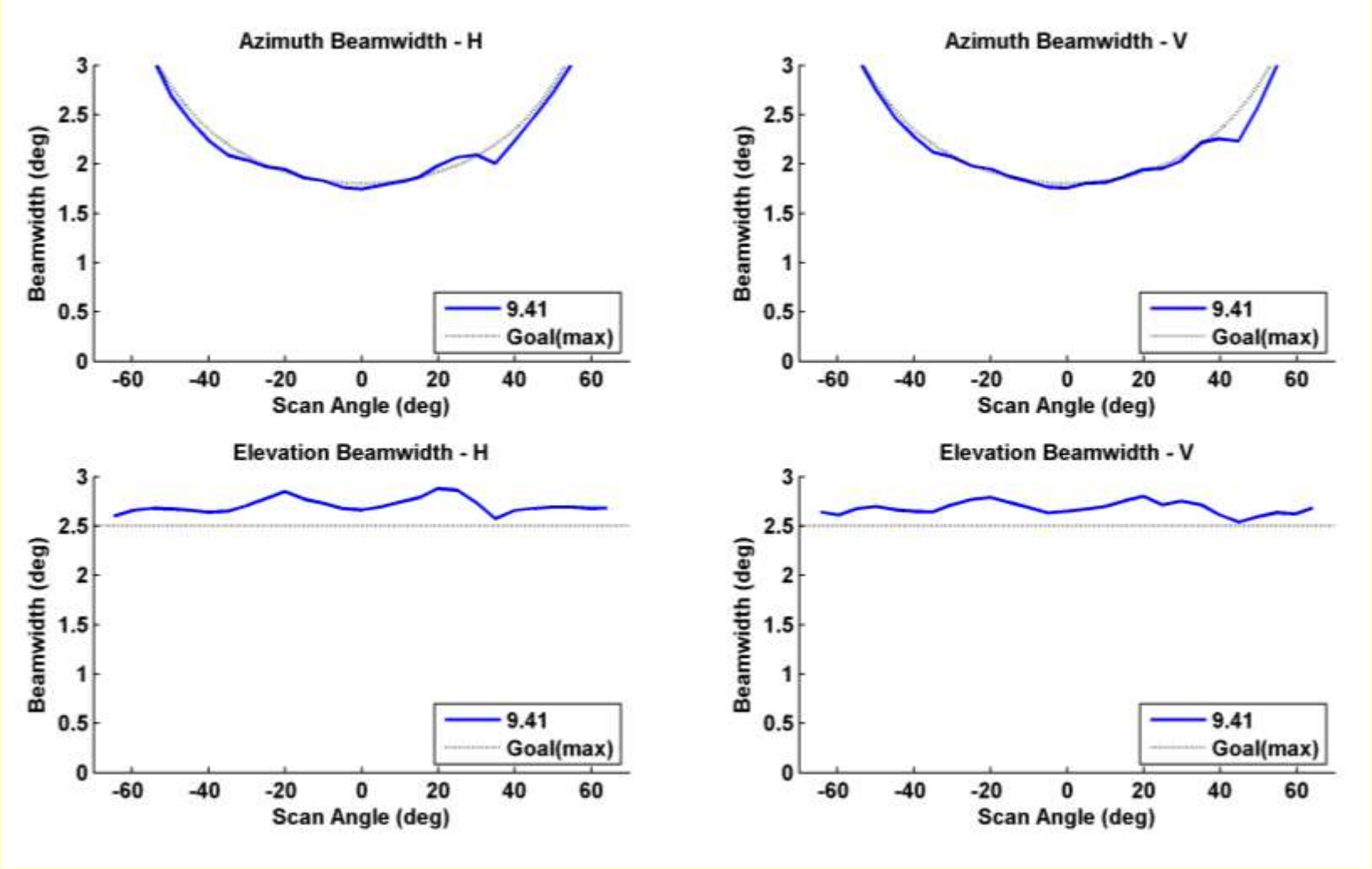
Parameter	Units	PTWR
Frequency Range	GHz	9.3 – 9.5
Tx Power (Peak)	W	70
Pulse Length	µS	.6 - 60
Pulse Compression Gain	dB	Up to 20
Duty Cycle (max)		30%
Unambiguous range @ max PRF	km	31
Unambiguous Velocity @ single PRF	m/s	up to 38
Unambiguous Velocity @ Dual PRF	m/s	57 @ (2:3)
Sensitivity @ 30km	dBZ	18
Elevation Beamwidth	deg	2.8
Azimuth Beamwidth	deg	1.8 -2.4
Polarization Mode		Alternating
Integrated Cross Pol Ratio (max)	dB	-20
Power Consumption		1.5kW peak (600W avg)

Phase-Tilt Antenna

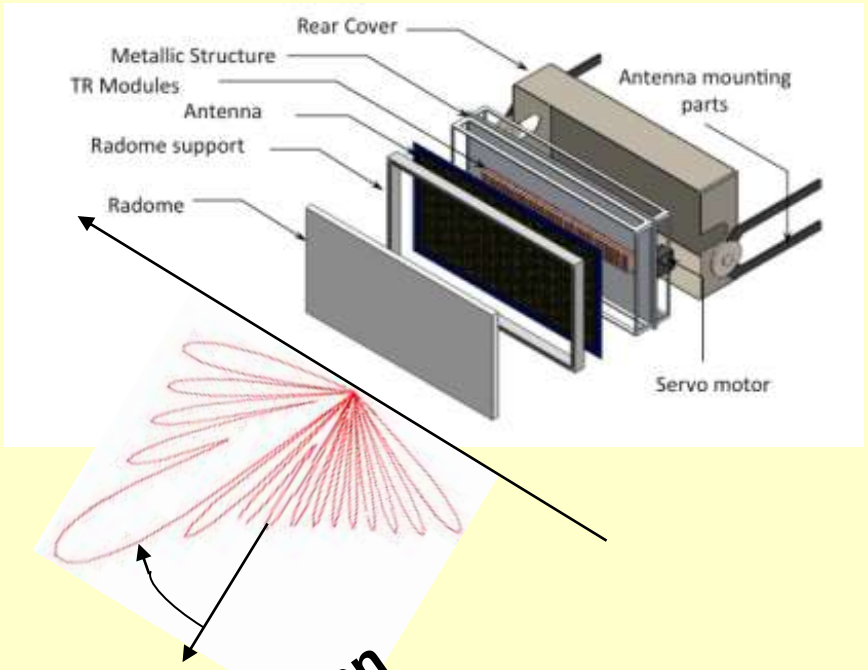
Parameter	Units	PTWR
Antenna Type		1d Phased Array
Polarization		H &V Linear
Scan Type		AZ over EL
Scan range AZ		+/- 45 deg
Scan Range EL		-5 to 90 deg
Azimuth Scan Type		Programmable, discrete positioning
Azimuth Scan Speed		1µS position switching
Elevation Scan Type		Mechanical
Elevation Scan Speed		8 deg/s
Size (array only)	(w x h x d)	1.2m x 0.75m x 0.5m
Weight (array only)		125 kg


Radar Data Pre-Processing (Linux PC)
Covariance Processing (Z, V, W, rho_hv, phi_dp,Z_dr)
Range profile accumulation
Second Trip Suppression (to be implemented)
GMAP Processing (to be implemented)
Doppler unfolding
Display/Storage software
Link to User Software (eg, IRIS, Rainbow)

Beamwidth - taylor



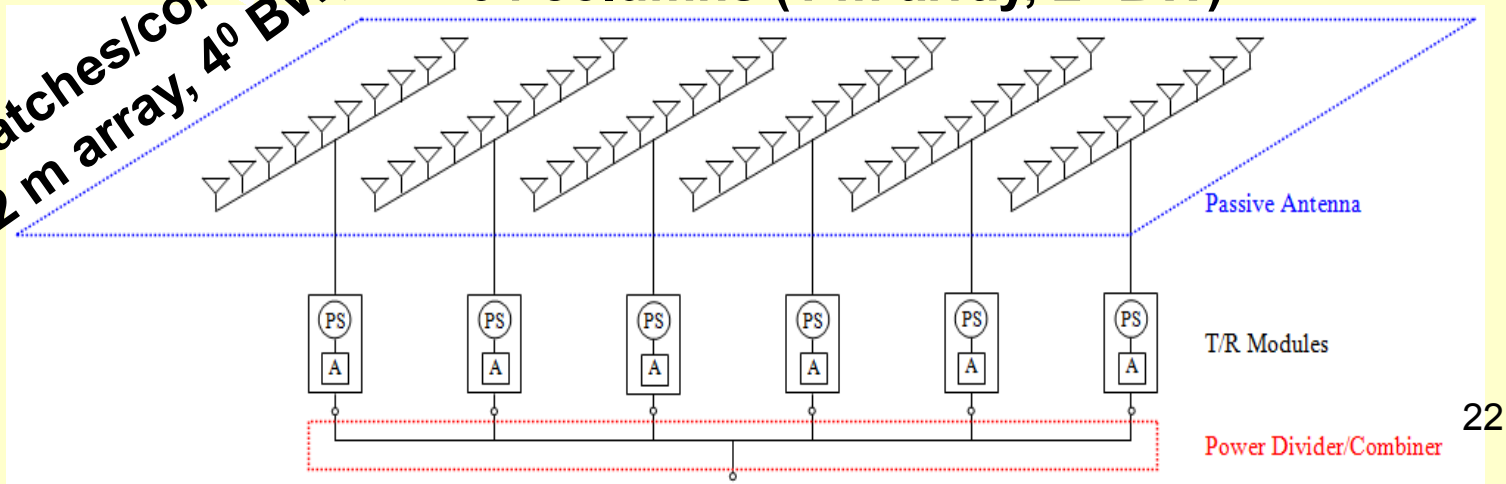
Phase-Tilt Antenna



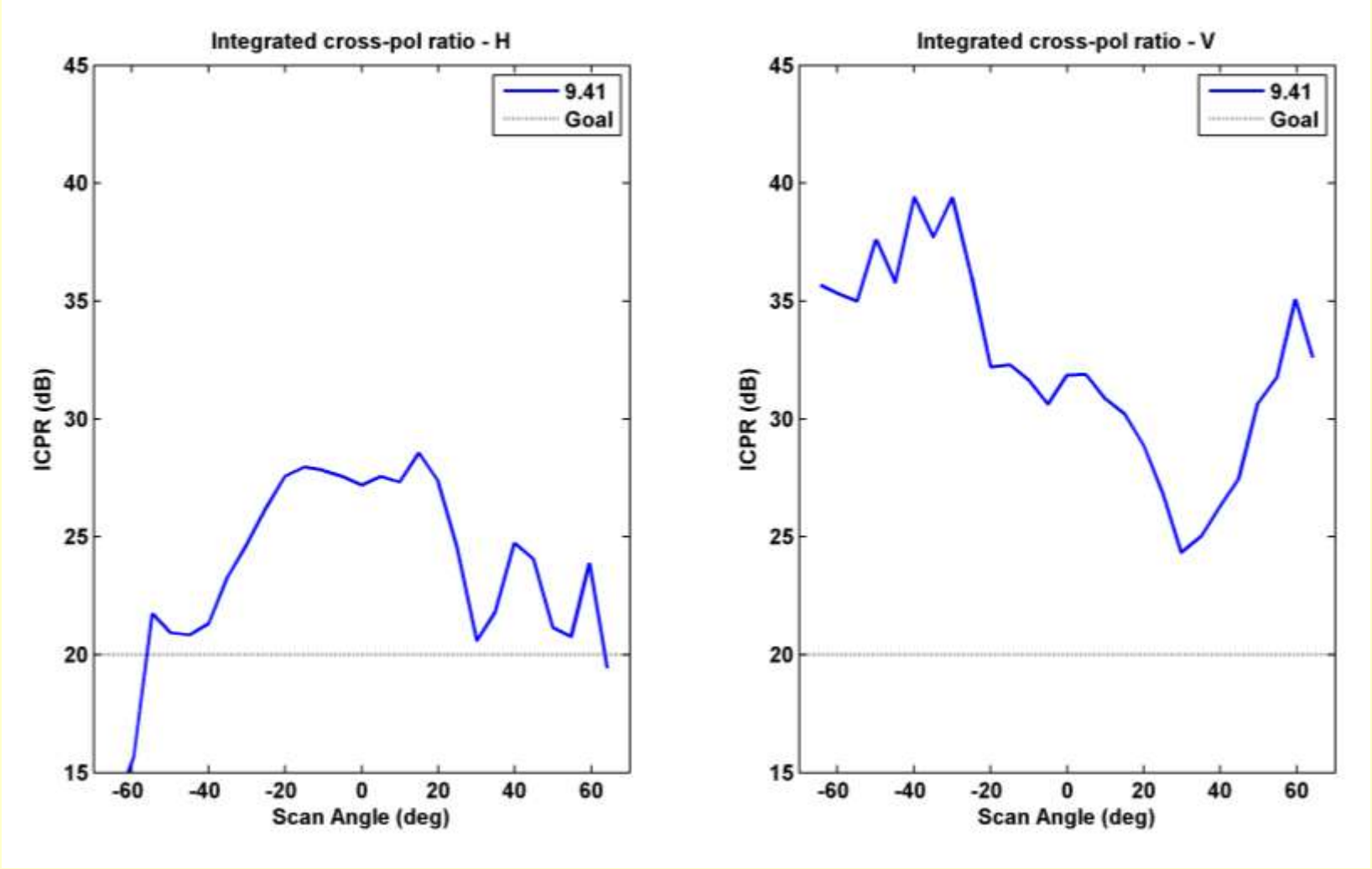
Artist Concepts

64 columns (1 m array, 2^0 BW)

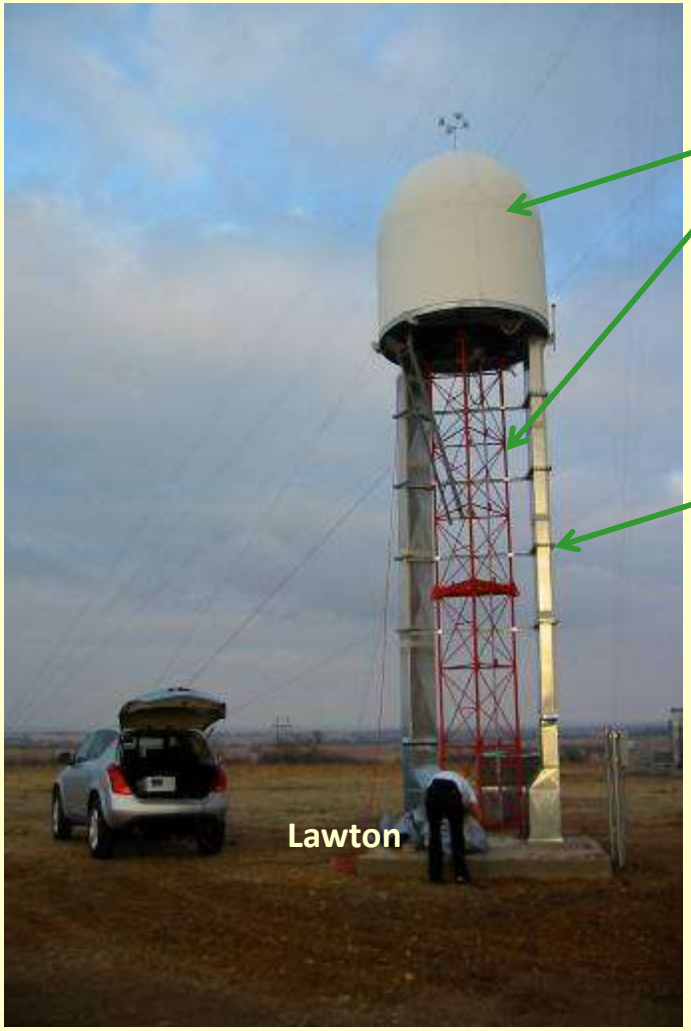
32 patches/column (1/2 m array, 4^0 BW)



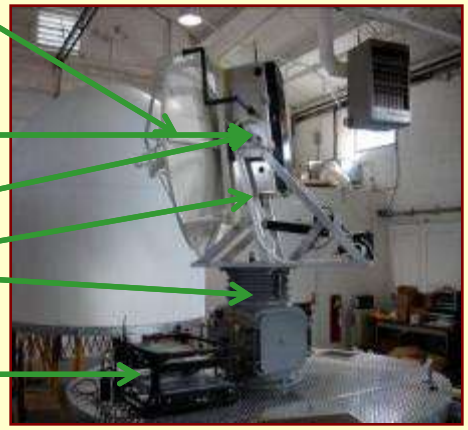
Integrated Cross-Pol Ratio - taylor



CASA's Research Prototype



IP1 Node Component Costs	
Antenna	$8,000
Radome	$20,000
Tower (8m)	$15,000
Data Acq.	$20,000
Transceiver	$30,000
El Positioner	$10,000
Az Positioner	$90,000
Platform, frames	$10,000
Computers, storage	$20,000
HVAC	$6,000
Power line	$500
Total	**$229,500**
Note: 20 m towers cost $120,000	



IP1 Node Yearly O&M Costs	
Electric power	$2,000
Spare parts/repairs	$7,500
Networking	$16,500
Land Lease	$0
Total Annual	**$26,000**

Weight: 12,000 lb for 4 radars – 3,000 lb/radar (1360 kg per radar)

CASA Mechanical Scan - Costing Experience