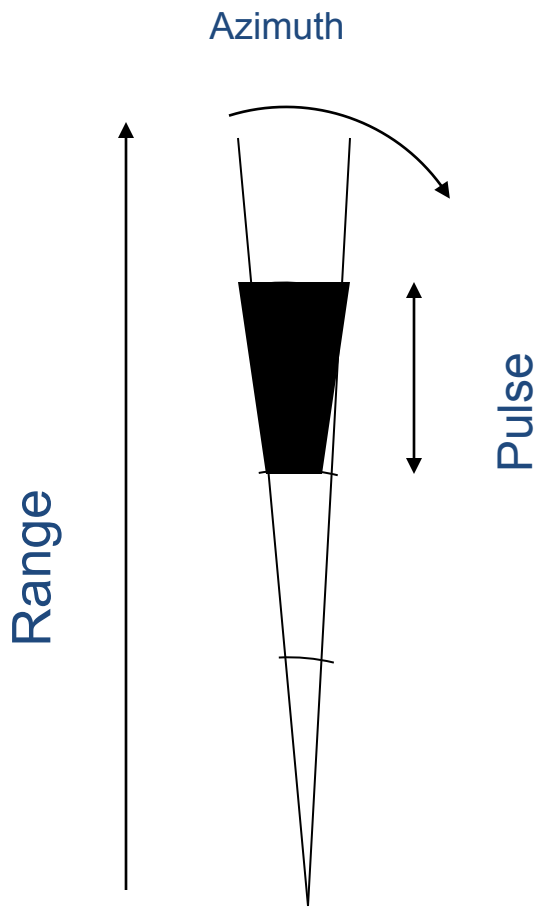
Super-resolution processing at the UK Met Office

Can signal processing techniques improve rainfall estimates for urban catchments?

CONTENTS

Fine scale resolution – weather radars limiting factors

- Weather radars measurement are collected in polar coordinates
- Range gate resolution is limited by the transmitted pulse length.
- The angular resolution is mostly limited by the beam width of the antenna at the transmission frequency.

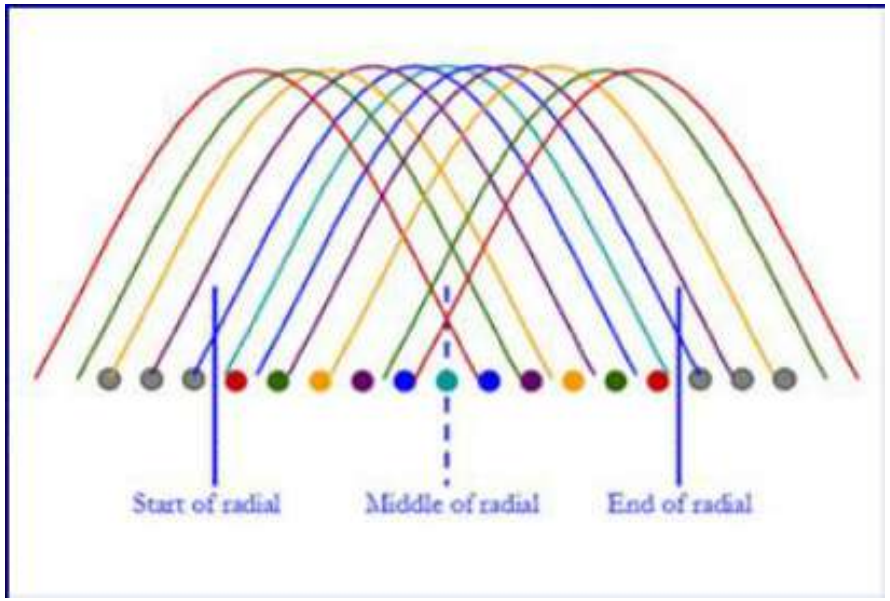


Fine scale resolution – weather radars limiting factors

- Intrinsic Angular resolution:
  - Inversely proportional to the size of the antenna
    i.e. bigger antenna → finer angular resolution
  - And proportional the radar wavelength
    i.e. smaller wavelength or higher frequency → finer angular resolution.

Antenna diameter (m)	S-band – beam width (degree)	C-band - beam width (degree)	X-band - beam width (degree)
8.5	1.0	0.55	
4.2	2.0	1.0	
2.4			1.0
1.0			2.3

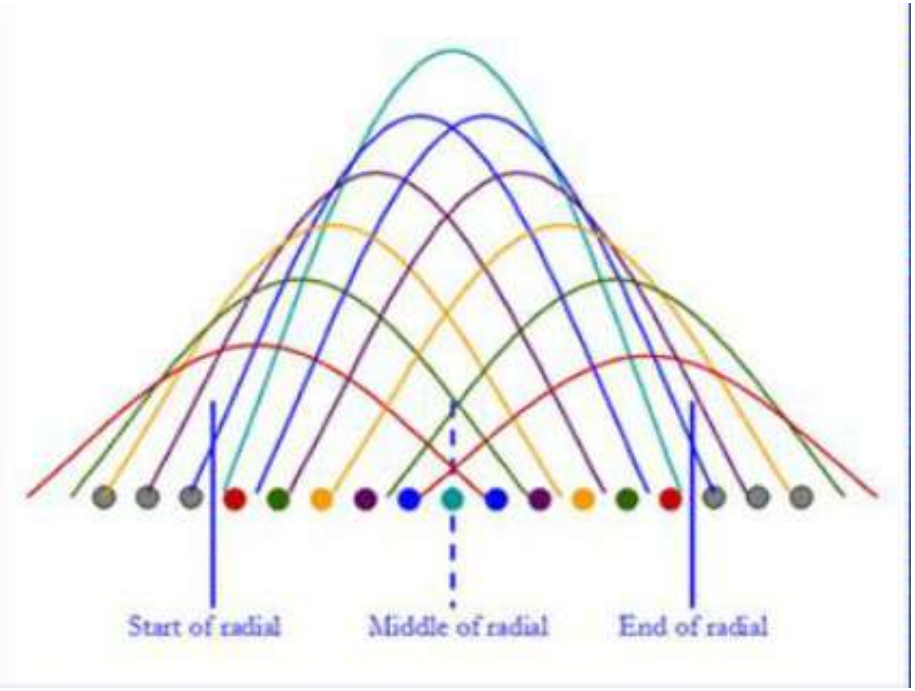
Effective Beamwidth



http://www.wdtb.noaa.gov/courses/dloc/topic3/lesson2/player.html

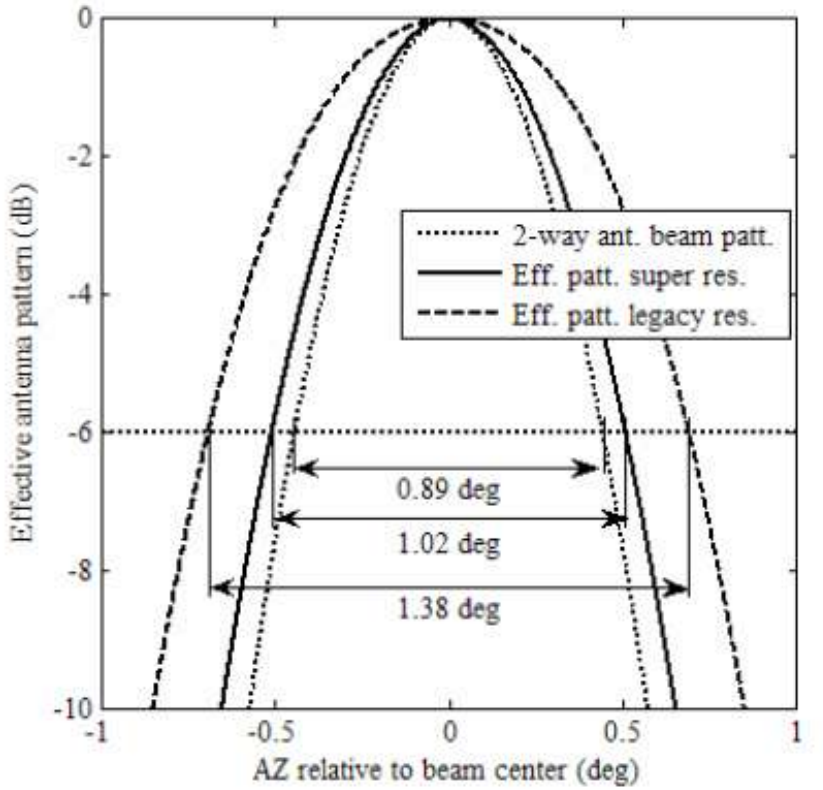
- Beam width is degraded by scanning motion of antenna
- Beam broadening due to scanning is rotation rate independent
- Effect of convolution of intrinsic beam pattern with (usually) 1 degree integration period rectangular window

Super angular resolution



- By weighting values in azimuth we can recover some of the angular resolution
- Downside
  - Loss of information
    – Higher variance measurements

Effective beam width



Effective antenna patterns corresponding to legacy- and super-resolution processing for a Gaussian intrinsic antenna beam pattern with a two-way 6-dB beam width of 0.89 deg. *

Range	Intrinsic beam width 0.89°	Effective beam width 1.38°
10km	~150 m wide	~240 m
25km	~400 m wide	~600 km

* **Design considerations for improved tornado detection using super-resolution data on the NEXRAD network** **Sebastian Torres, Christopher** Curtis

Fine scale resolution – weather radars limiting factors

- Range resolution:
  - Proportional to the pulse length
    - i.e. shorter pulse leads to finer range resolution.
  - Not related to the radar frequency or to the transmitter power.

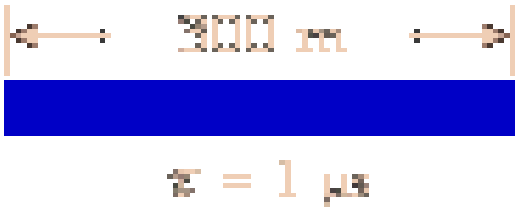
Pulse width (us)	Range resolution (m)
0.5	75
2	300
3.3	500

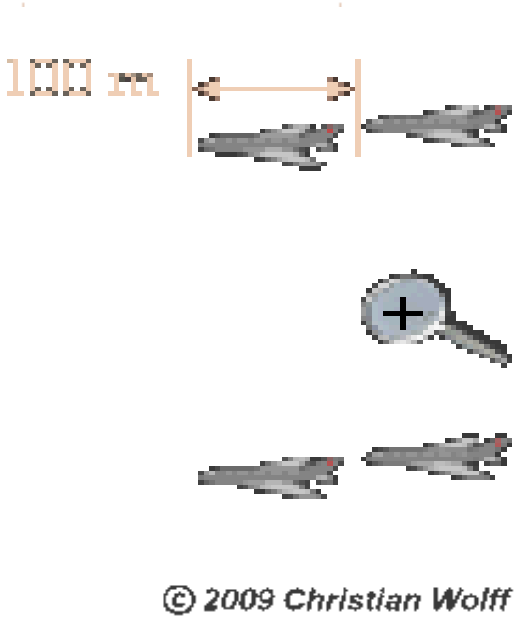
Typical selectable pulse length for S, C and X radars

- Why not always use a short pulse for max range resolution?

  - Sensitivity is related to power in one pulse

Range Resolution



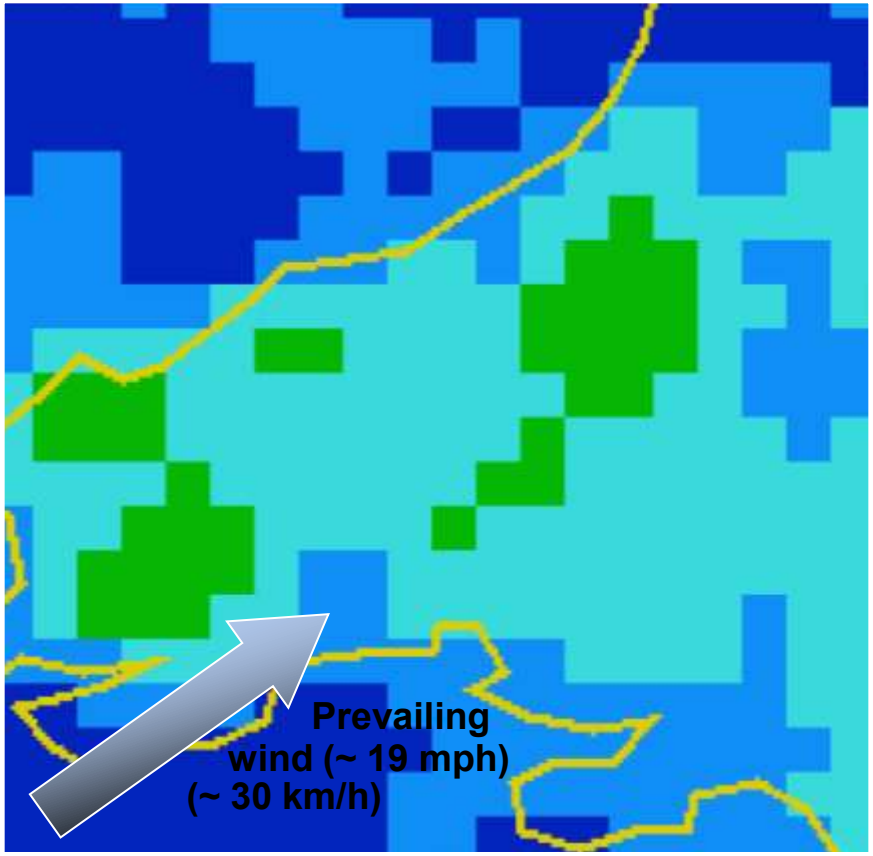


Range Super-resolution

- To be investigated by Imperial College London
- Oversampling based
  - Whitening transform
    - Produce more independent samples to compensate for effects of angular windowing – reduce variance again
  - De-convolutional processing
    - Could give improved range and azimuth processing , in one.
    - Highly sensitive to noise – research required

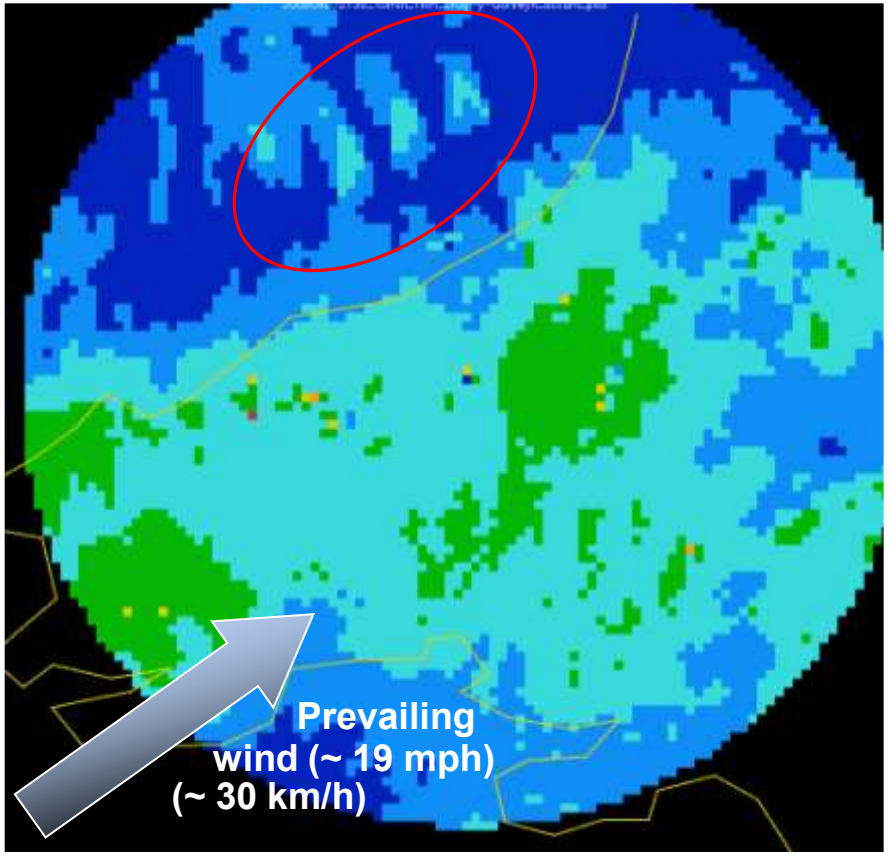
A problem of temporal resolution

15 min accumulation for Crug-y-Gorllwyn, 07-04-2009 (2130)



5 km

Not noticeable



1 km

Highly noticeable

Temporal Resolution improvement

- Currently UK Met Office has 5 minute repeat cycle
  - 5 volumes for Doppler measurement
  - 5 Volumes for Reflectivity
- Can this be reduced to 2 ½ minutes ?

Possibilities

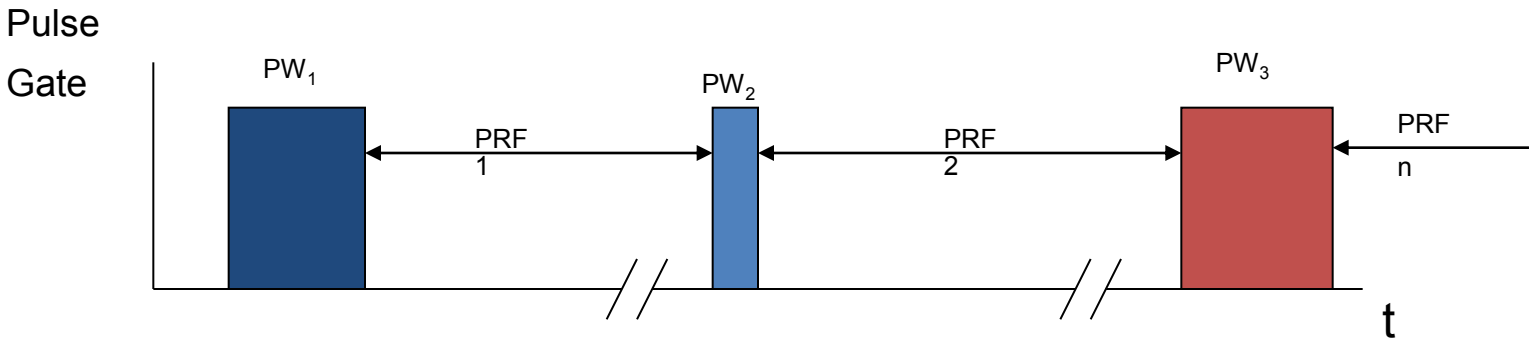
- Are all 5 beams of each type essential?
- Reduced number of Doppler scans
  - Doppler data only really used by NWP community for wind assimilation
  - Data denial experiments planned to determine impact of reduced beam numbers / which beams give most benefit to model

Possibilities 2

- Reduced number of Reflectivity Scans
  - Higher reflectivity beams only used for infilling over severely cluttered regions at the moment
    - Optimise and reduce scan elevations to match infilling requirements
- Faster Scanning by increase rotation rate
  - Currently scanning lowest 2 reflectivity elevations @1.2 rpm with 3 higher elevations @2.4 RPM
  - 1.2 rpm slower than typical
  - Perform all reflectivity scans at 2.4 RPM
  - Impact to be assessed

Possibilities 3

- New Transmitter has novel control interface
  - Trigger pulse from DSP controls pulse length and repetition frequency simultaneously
  - Possibility of Mixed/interleaved pulse lengths and PRFs



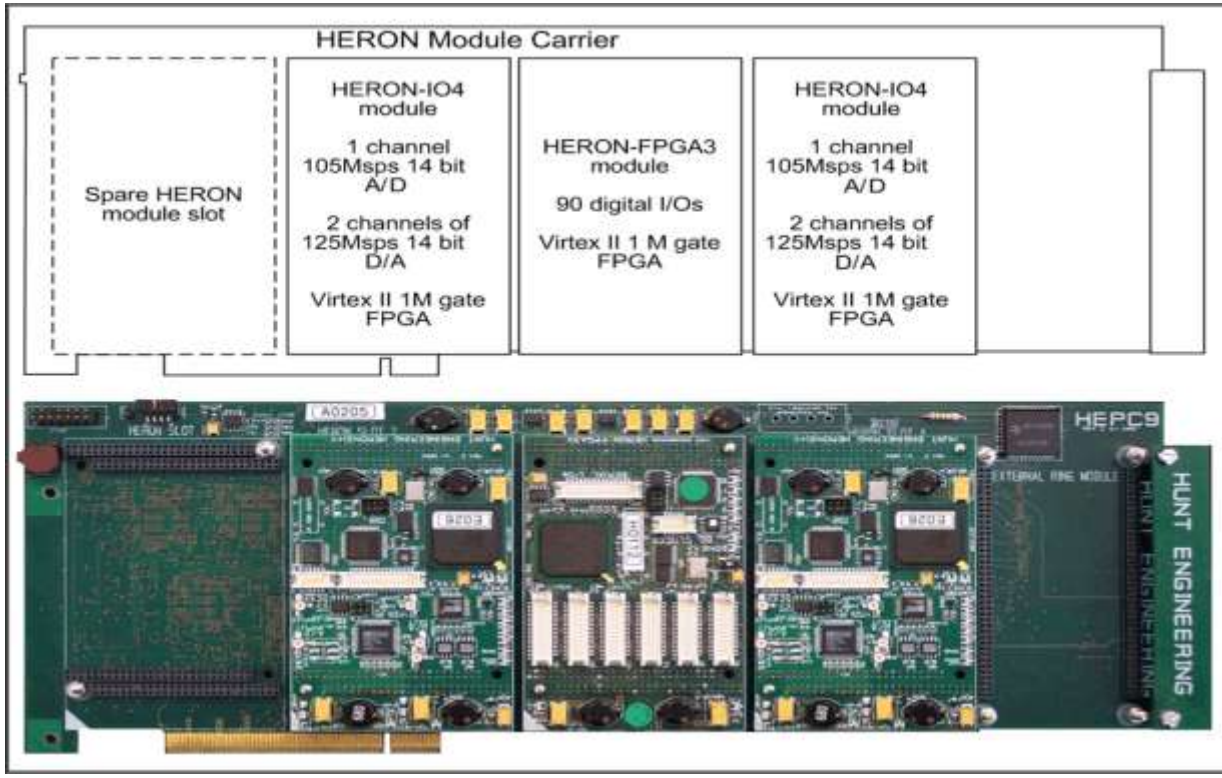
- Can we use this to maximise transmitted power (for best reflectivity) at same time as having high PRF (for best Doppler) within the duty cycle of the Tx?

- Takes advantage of the fact that the rain does not fully de-correlate between pulses

Progress

Current Processing system : Hunt Engineering HEPC9 Based

- Modular design
- 2x 14 bit ADC @100MHz
- Virtex-II FPGAs for control and processing
- > 90 pins programmable digital I/O
- Following down-conversion and filtering I & Q streamed to PC for moment calculation
- ~8 years old now
  - Still quite good
  - Approaching obsolescence issues

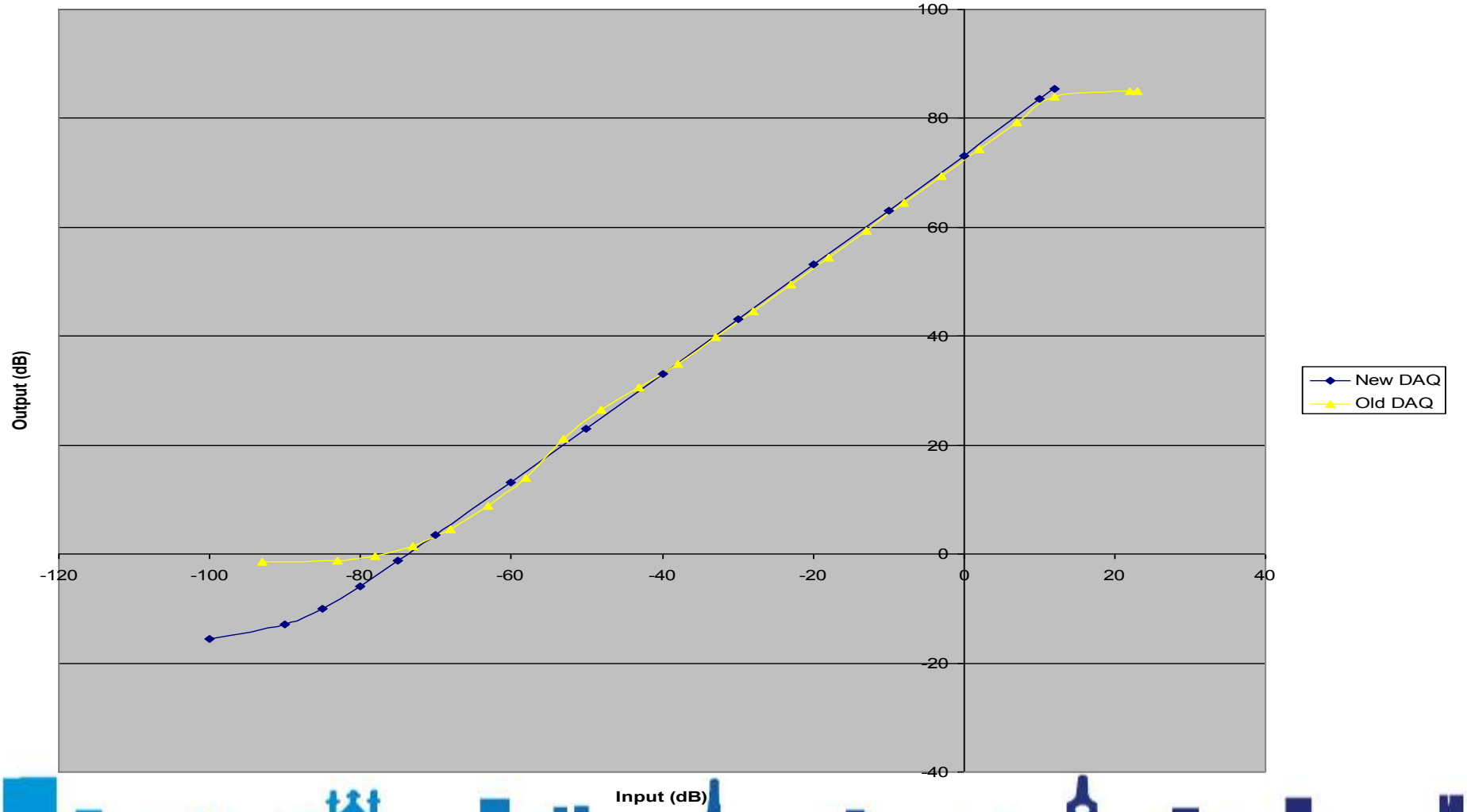


New Processing system

- Pentek Model 71661
- 2x 14 bit ------> 4x 16 bit ADC
- 100 MSPS ------> 200 MSPS
- 3x Virtex II ------> 1x Virtex 6 FPGA
- Implementation into Cyclops now complete

Progress

Comparison of Old and New data aqcuisition cards



Conclusions

- Progressing well
  - Now have platform with which to move forward
  - Live radar testing starts next week
- Angular resolution improvement fairly straightforward to implement
- Questions still to be answered on range and time improvement