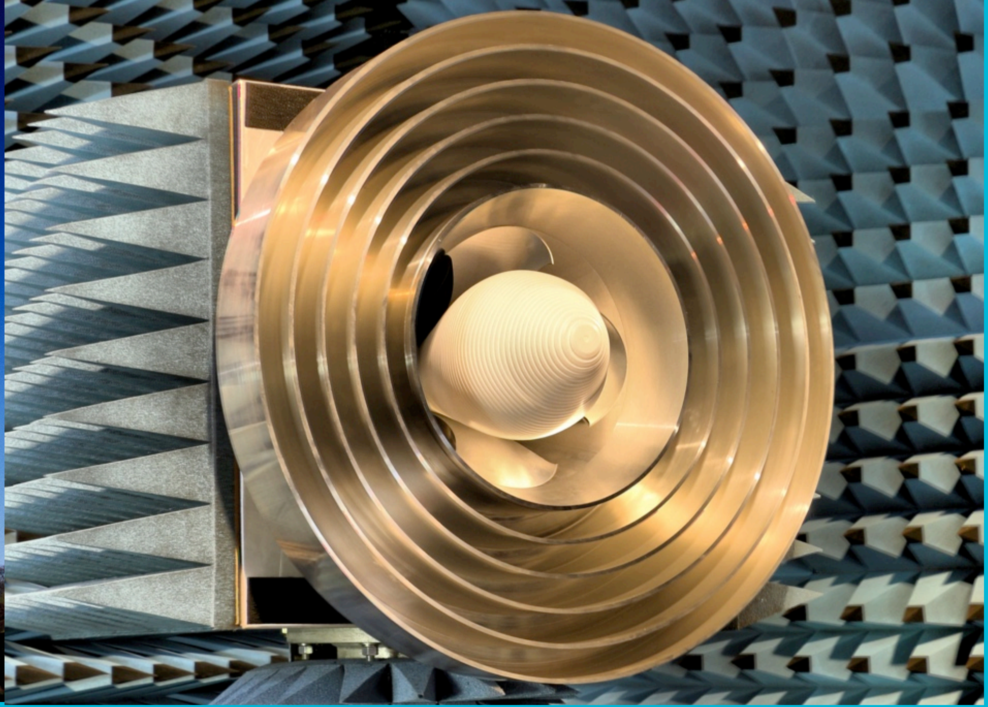



The Parkes Ultra-Wideband Receiver

Dick Manchester

July 30, 2015

CSIRO ASTRONOMY AND SPACE PHYSICS
www.csiro.au

PPTA
SWINBURNE UNIVERSITY OF TECHNOLOGY
THE UNIVERSITY OF WESTERN AUSTRALIA
Achieving International Excellence
THE UNIVERSITY OF MELBOURNE
Curtin University
THE UNIVERSITY OF SYDNEY
Max-Planck-Institut für Radioastronomie
NAOC
CSIRO

Wideband Receivers for Parkes

- Need to improve operational efficiency of Parkes while maintaining high-impact science
  - Pulsar, FRB and HI surveys
  - Precision pulsar timing and polarisation studies
  - Interstellar medium studies: scattering, magnetic fields
  - SETI
- Wideband high-sensitivity receivers needed to minimise receiver changes
- For surveys need high-sensitivity wide-field system
- Planned systems:
  - **UWL receiver: 0.7 – 4.0 GHz**
  - **UWH receiver: 4 – 25 GHz**
  - **Phased Array Feed: 0.7 – 1.7 GHz**
- UWL construction under way. Support from Australian Research Council, Australian universities and international collaborators. Completion ~end 2016
- PAF design study commenced. PAF for MPIfR will be installed at Parkes for ~12 months
- UWH receiver may be supported by Breakthrough Prize Foundation for SETI search
- All systems will use a common GPU-based signal processor

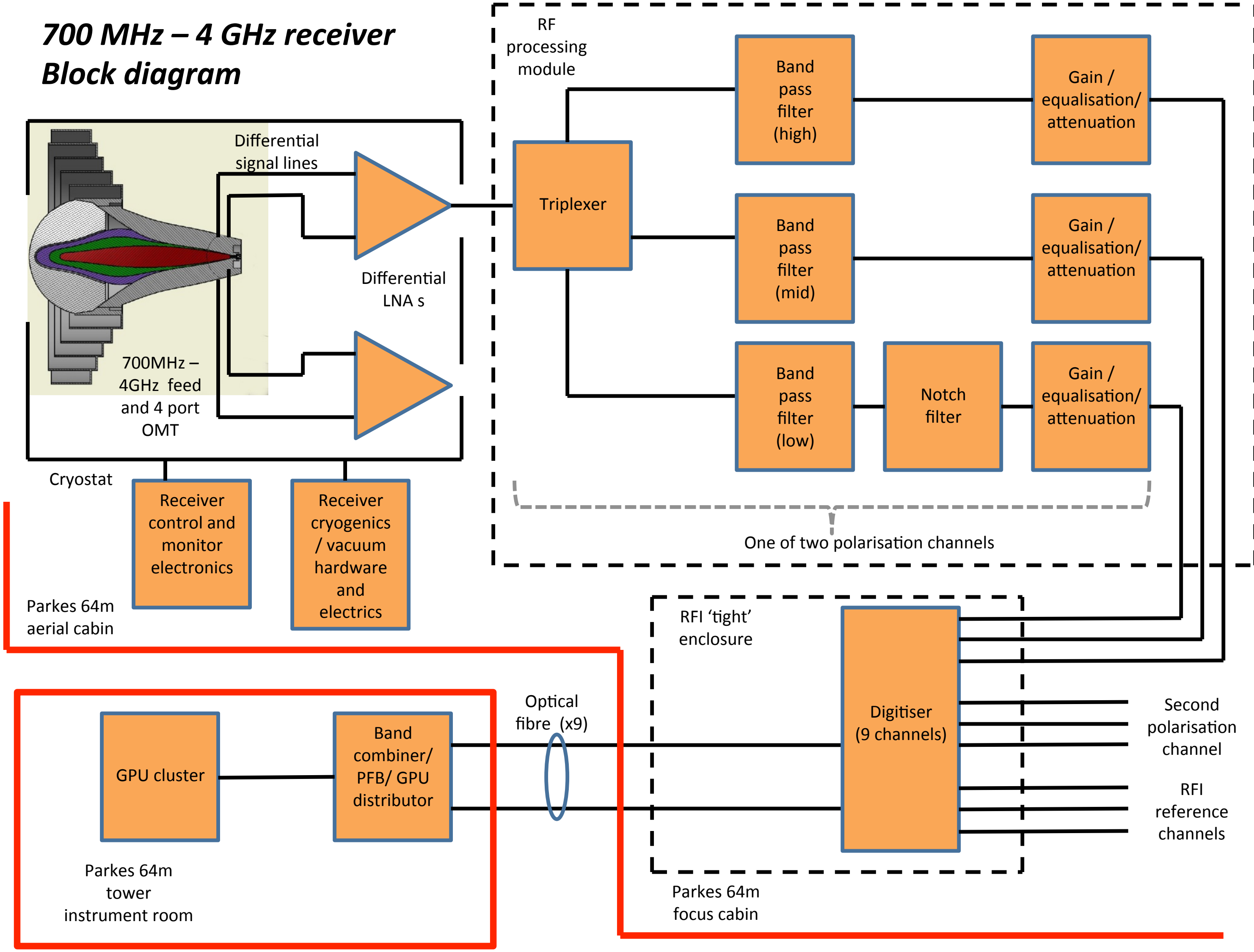
Main Science Goals for the UWL Receiver

- Pulsar timing – PPTA, relativistic binaries, Fermi counterparts, magnetars
- Pulsar emission mechanism studies, intermittent pulsars, etc
- Interstellar medium – Faraday rotation, dispersion, scattering
- Spectral lines – HI, OH, CH (methyladyne)
- Continuum background polarisation, RM synthesis
- VLBI – "L-band" (20cm, 18cm) and "S-band" (13cm)
- Low spatial-frequency data for ASKAP/SKA imaging
- The PAI – a real-time interferometer between Parkes and ASKAP
- Other things we haven't thought of yet!

Large-single-dish systems are versatile and are easily adapted to new developments

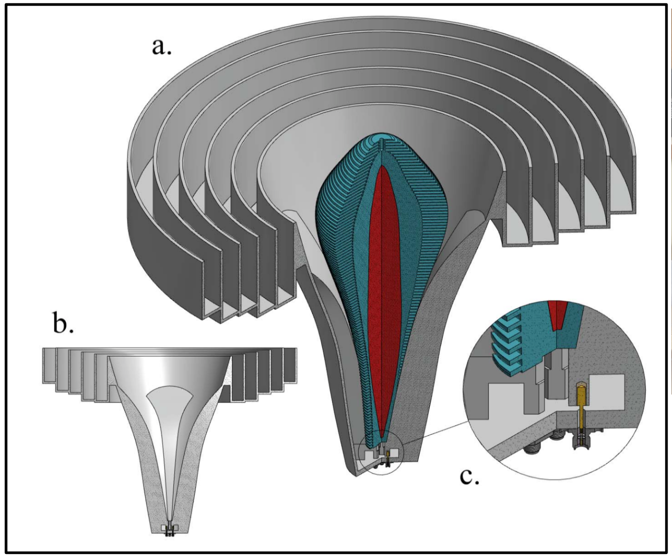
CSIRO

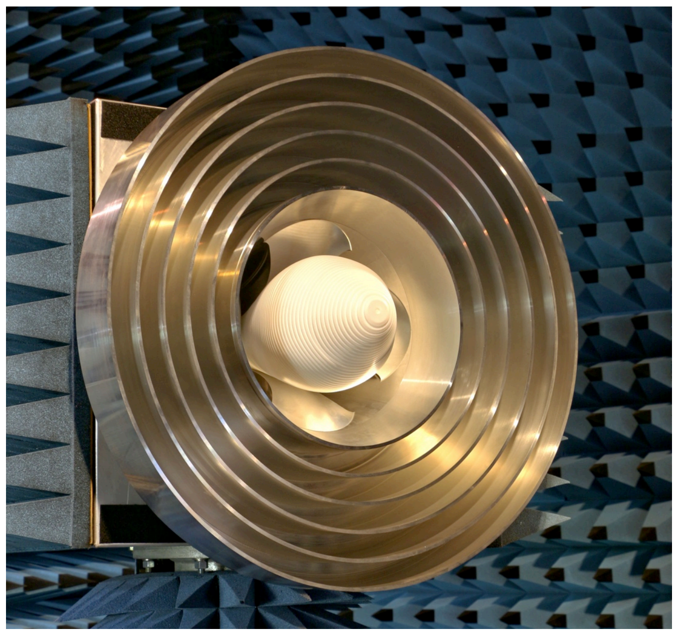
700 MHz – 4 GHz receiver Block diagram

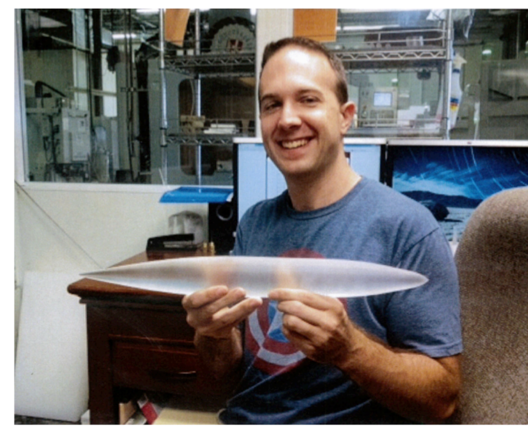


UWL Feed Progress

- Design by Alex Dunning (patent applied for)
- Bandwidth 0.7 – 4.5 GHz
- Quad-ridge horn with outer rings and graded dielectric insert
- Overall diameter 737mm
- Horn and dielectric insert cooled to 70K
- Almost constant beamwidth over whole band
- Exceptional polarisation performance
- Ambient-temperature version tested at CASS

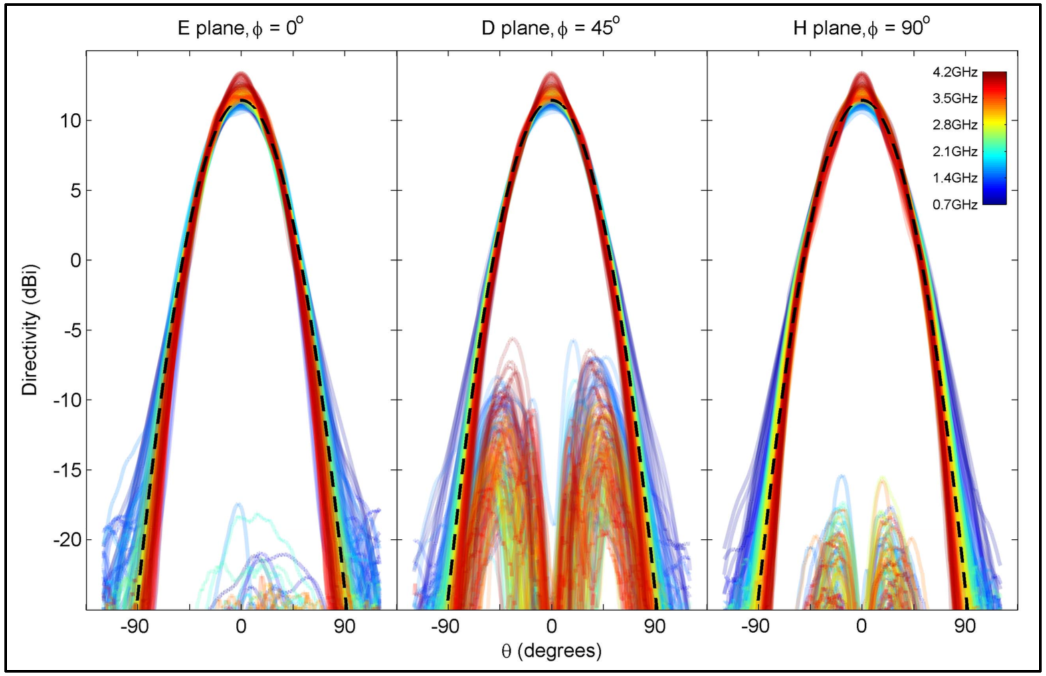


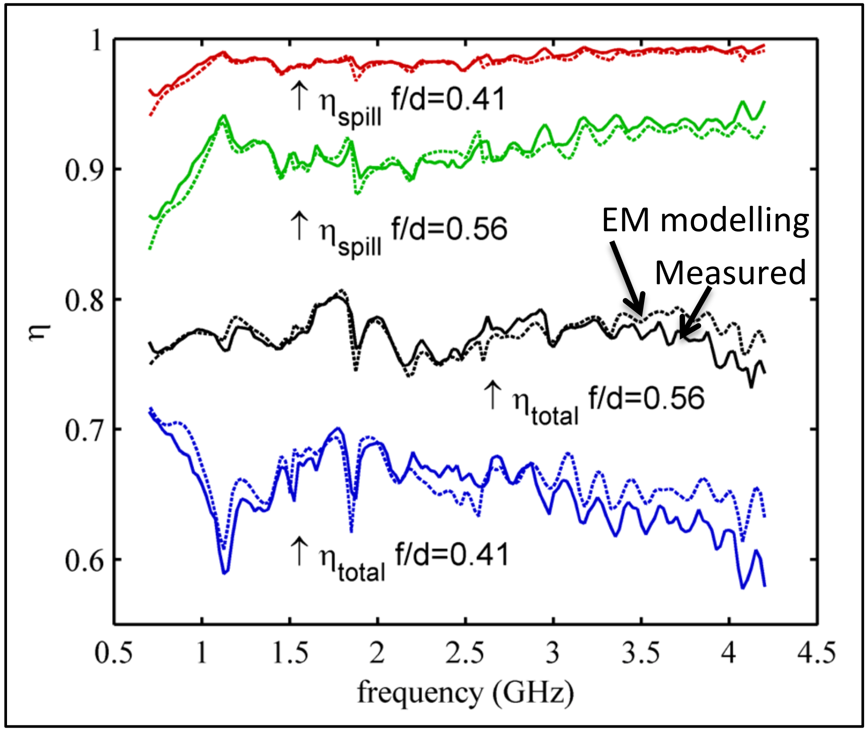




UWL Feed – Measured Properties

- Anechoic chamber measurements
- Beam pattern almost independent of frequency and close to gaussian over whole range!
- Cross-polar <-20db over whole range!



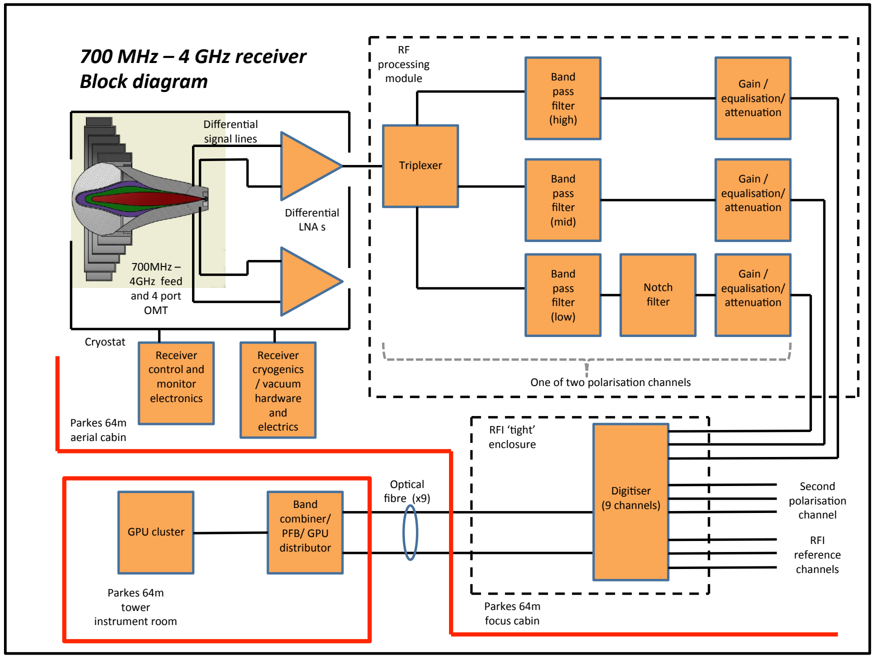


- Focal position essentially independent of ν for ν>1.7 GHz; max deviation ~ 80mm at 1.15 GHz
- With optimal position at high ν, efficiency at low ν not greatly affected (< -1%)
- Maximum efficiency at f/d = 0.56; minimum T_{sys}/η at f/d = 0.41 (Parkes f/d = 0.43)

(Dunning et al. 2015)

Receiver and Signal Processor

- Feed has balanced outputs – greatly assists in achieving beam symmetry and excellent polarisation performance
- Differential preamplifiers based on MMIC technology for high sensitivity – expect 20K system temperature across most of band
- Triplexer – split each polarisation band into three sub-octave sections to improve linearity and avoid spurious second-harmonic responses



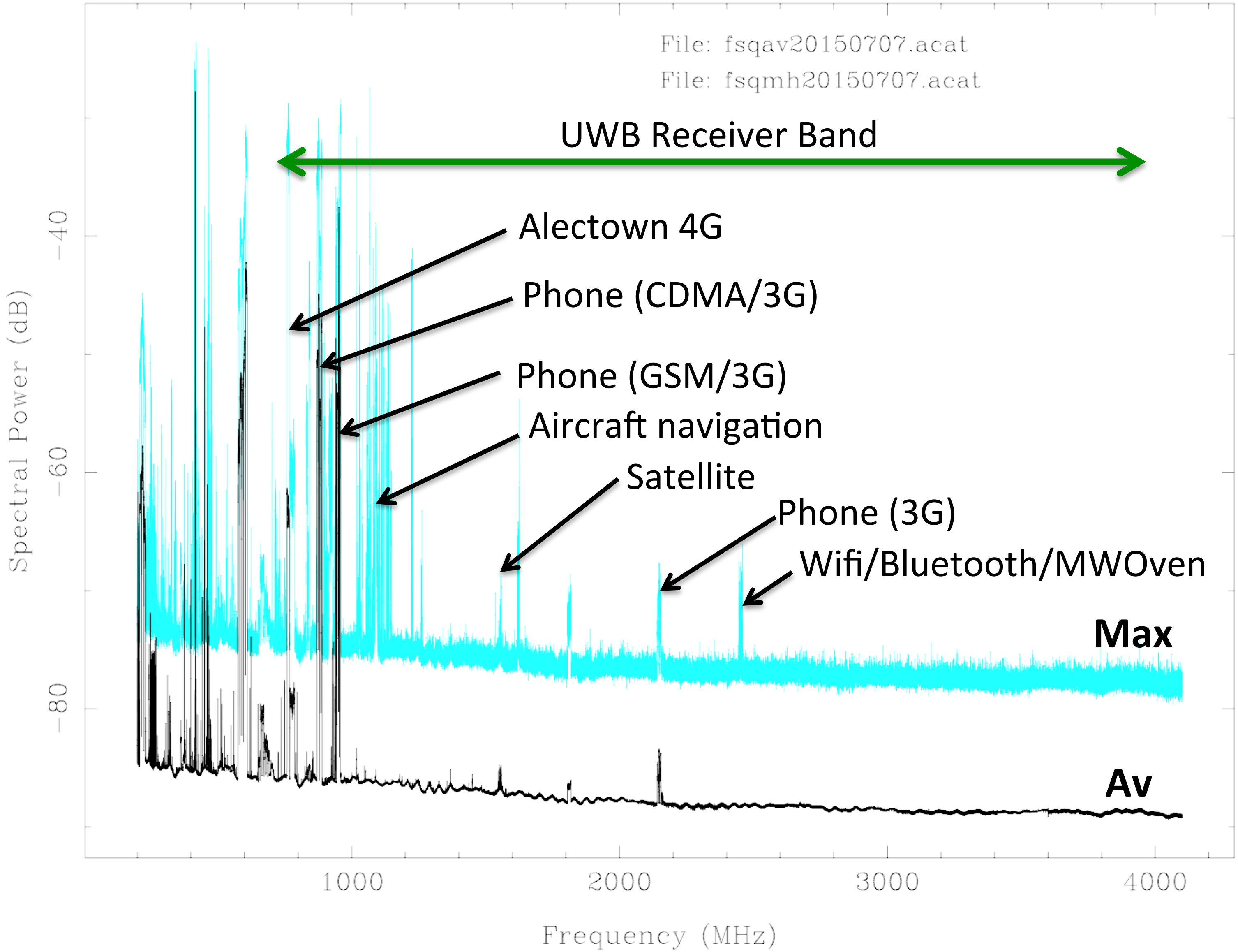
- Antenna(s) and amplifier chain(s) for RFI reference signals
- 5 GSamp/sec 12-bit digitisers for receiver and RFI reference signals – all at RF (no analogue down-conversion). In focus cabin for stability – triple-shielded RFI enclosure
- Single-mode fibers to tower receiver room
- FPGA band combiner, RFI mitigation and CPU/GPU distributor
- Versatile GPU processor – used for all Parkes receivers and science outputs.

Radio-Frequency Interference Issues

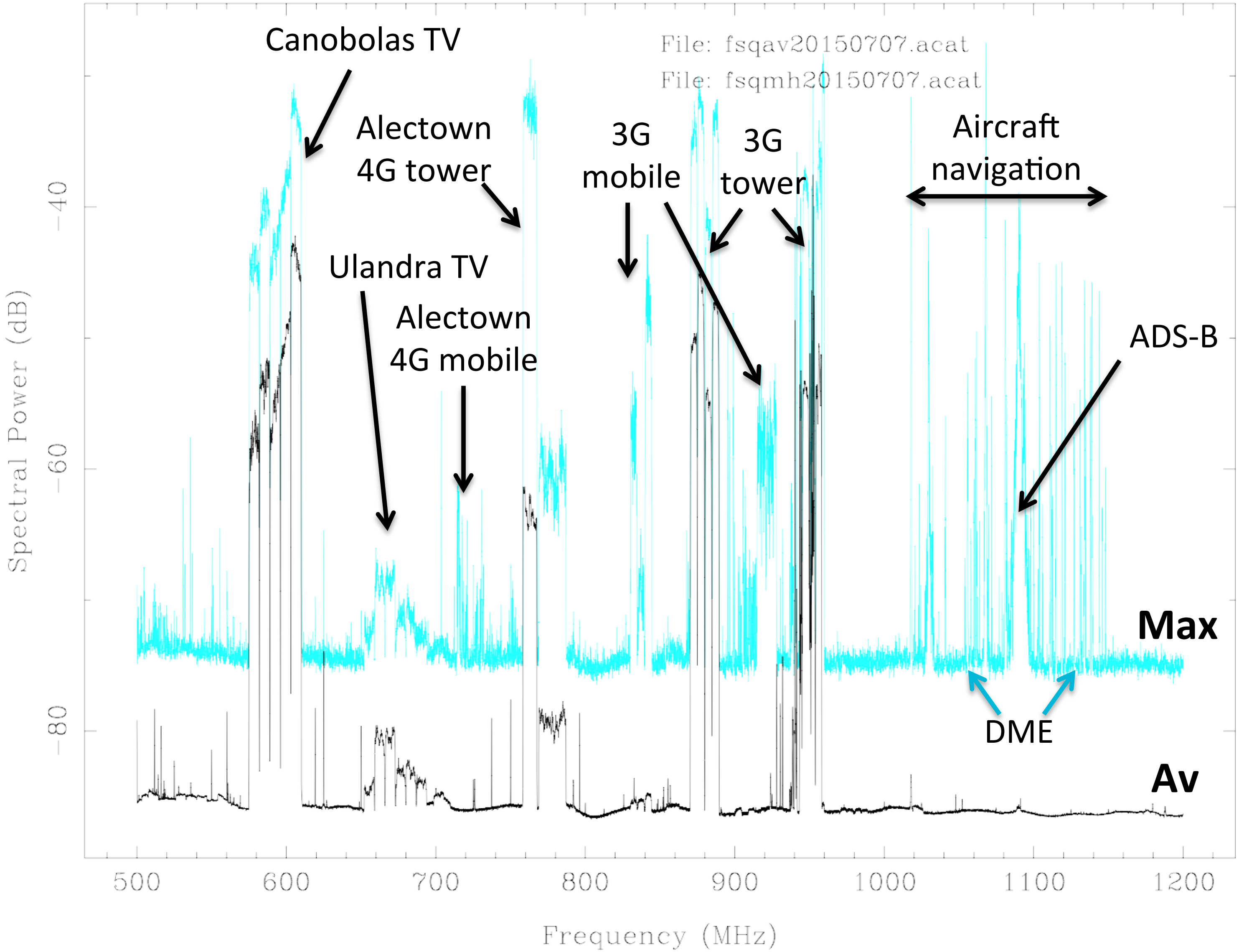
- Very wide band and relatively low frequency of the UWL receiver means that RFI is a significant issue
- RFI comes in two main classes:
  - Band-limited quasi-steady transmissions
  - Broad-band and band-limited transient signals
- Different mitigation strategies:
  - Quasi-steady transmissions:
    - Analogue filters in RF amplifier chain – band excision
    - Digital filters in FPGA preprocessor – band excision
    - Real-time adaptive filtering using reference signal – removal of RFI only
  - Transient emissions:
    - Digital excision in time domain – e.g., kurtosis filtering of baseband data

Essential that RF amplifier chain and digitiser remain linear in presence of RFI

Parkes RFI Spectrum (July 2015)



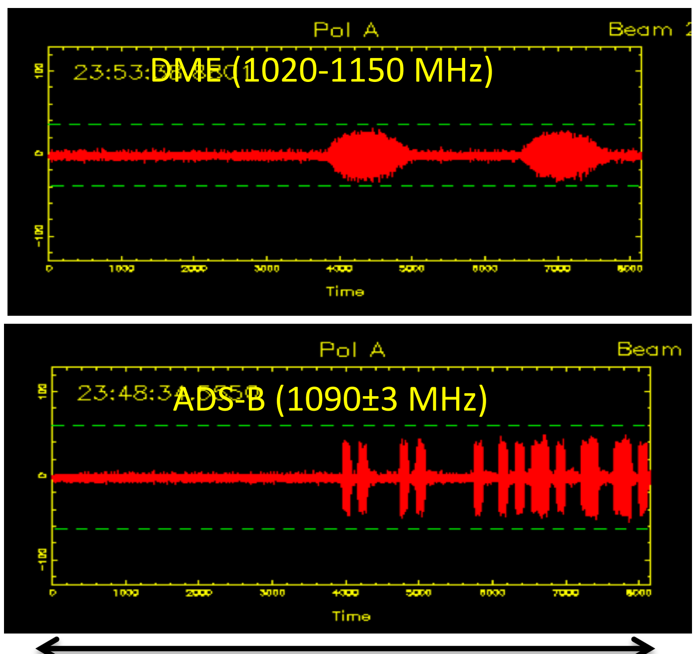
Parkes RFI Spectrum (500 – 1200 MHz)



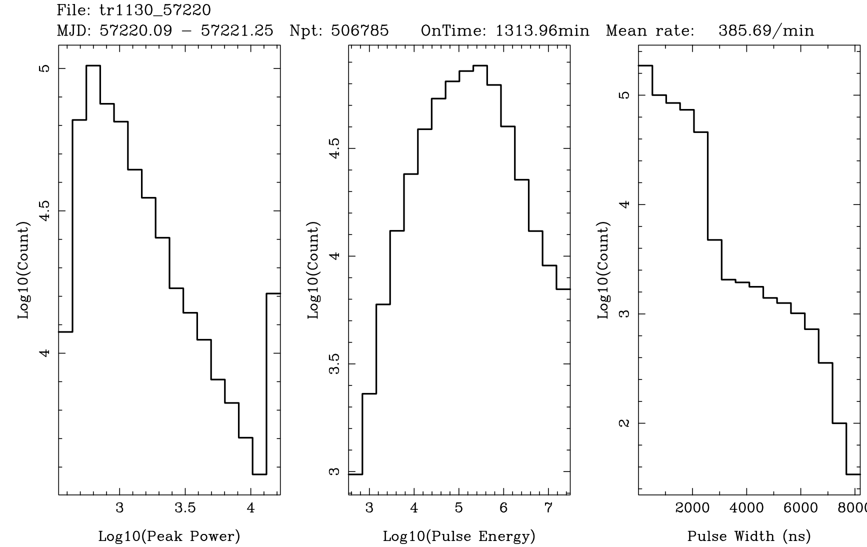
Transient RFI

1. Aircraft navigation: $\Delta\nu \sim$ 1-3 MHz, $\Delta t \sim$ 1 – 128 μs
2. Mobile phones – ~ 1 ms
3. Switching transients: Broadband, $\Delta t <\sim$ 100 ns

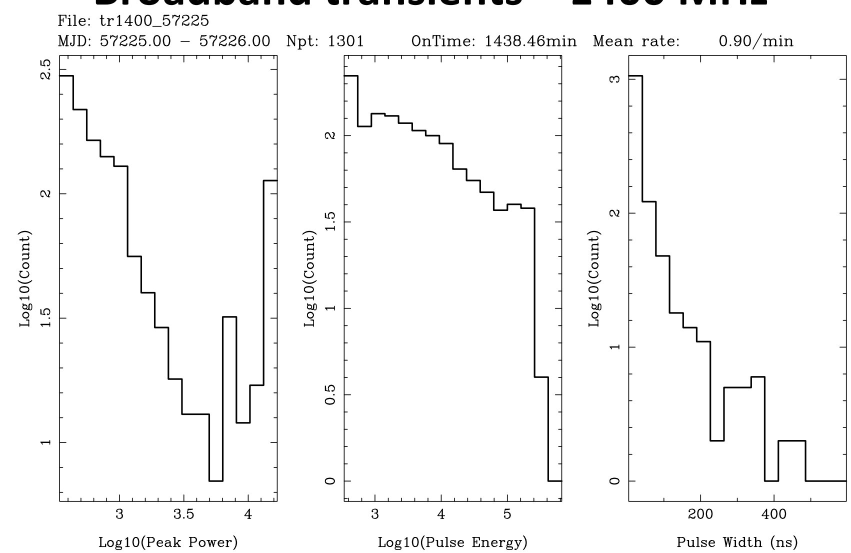
Observed peak flux densities ~ MJy!



DME – 1130 MHz



Broadband transients – 1400 MHz

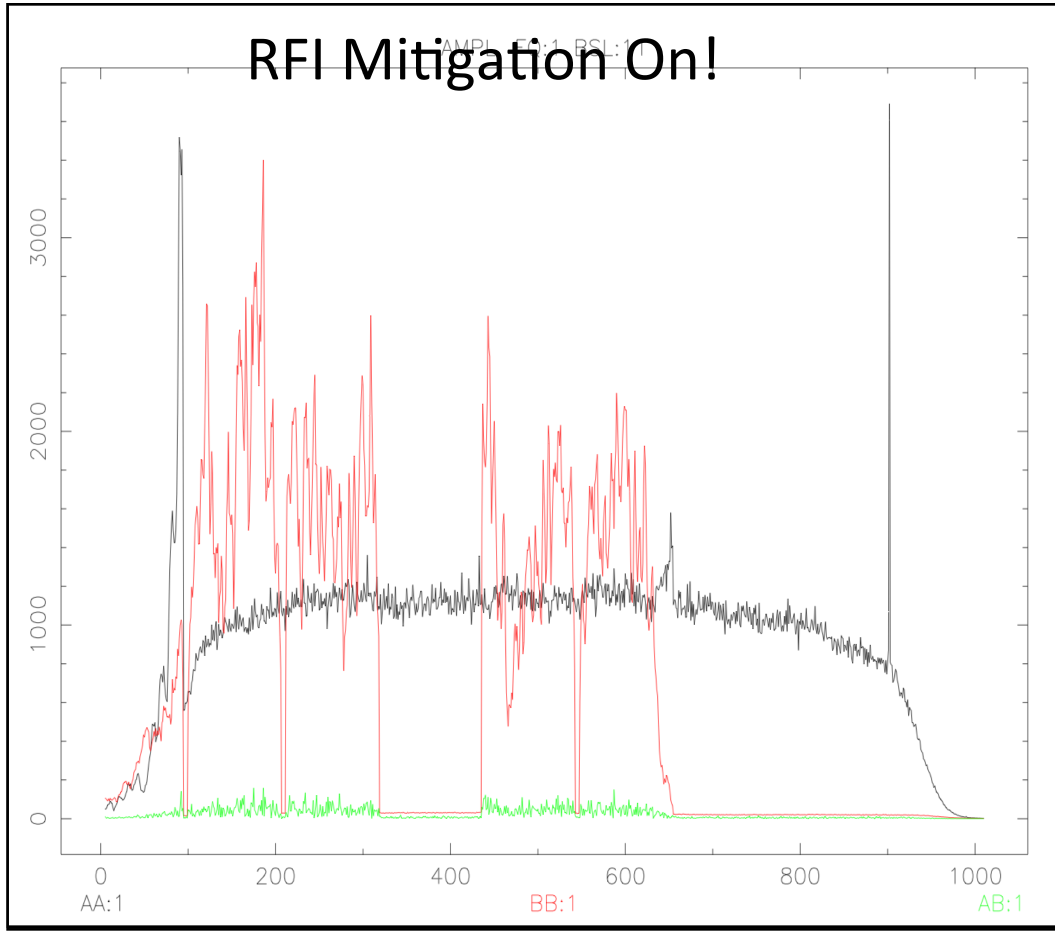


Summary

- Wideband receiving systems are the way of the future
- Digitisation of RF signal near receiver for stability, coupled with powerful and versatile FPGA/GPU signal processors
- For Parkes we are constructing the UWL receiver covering 0.7 – 4.0 GHz
- Expected T_{sys} ~ 20 K across whole band
- Expected completion date ~end 2016
- RFI is a major issue, especially below 1 GHz
- Essential that we learn how to mitigate its effects while maintaining astronomy content

Real-time Adaptive Filtering of RFI

- Parkes – original 50cm band, PDFB3 processor
- Single reference signal used for both polarisations of astronomy signal
- Any signal not in the reference channel is unaffected
- Provided receiver remains linear, bands with strong and near-continuous RFI can be zapped in digital data without major penalty
- Envisage a multi-antenna reference signals
- Can an isotropic refence antenna be used for mobile sources?



System devised by Mike Kesteven, implemented by Andrew Brown and Grant Hampson