Technologies for Radio Astronomy

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CSIRO ASTRONOMY AND SPACE SCIENCE
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Outline

Current Projects

- CABB
- ATCA C/X Upgrade
- FAST

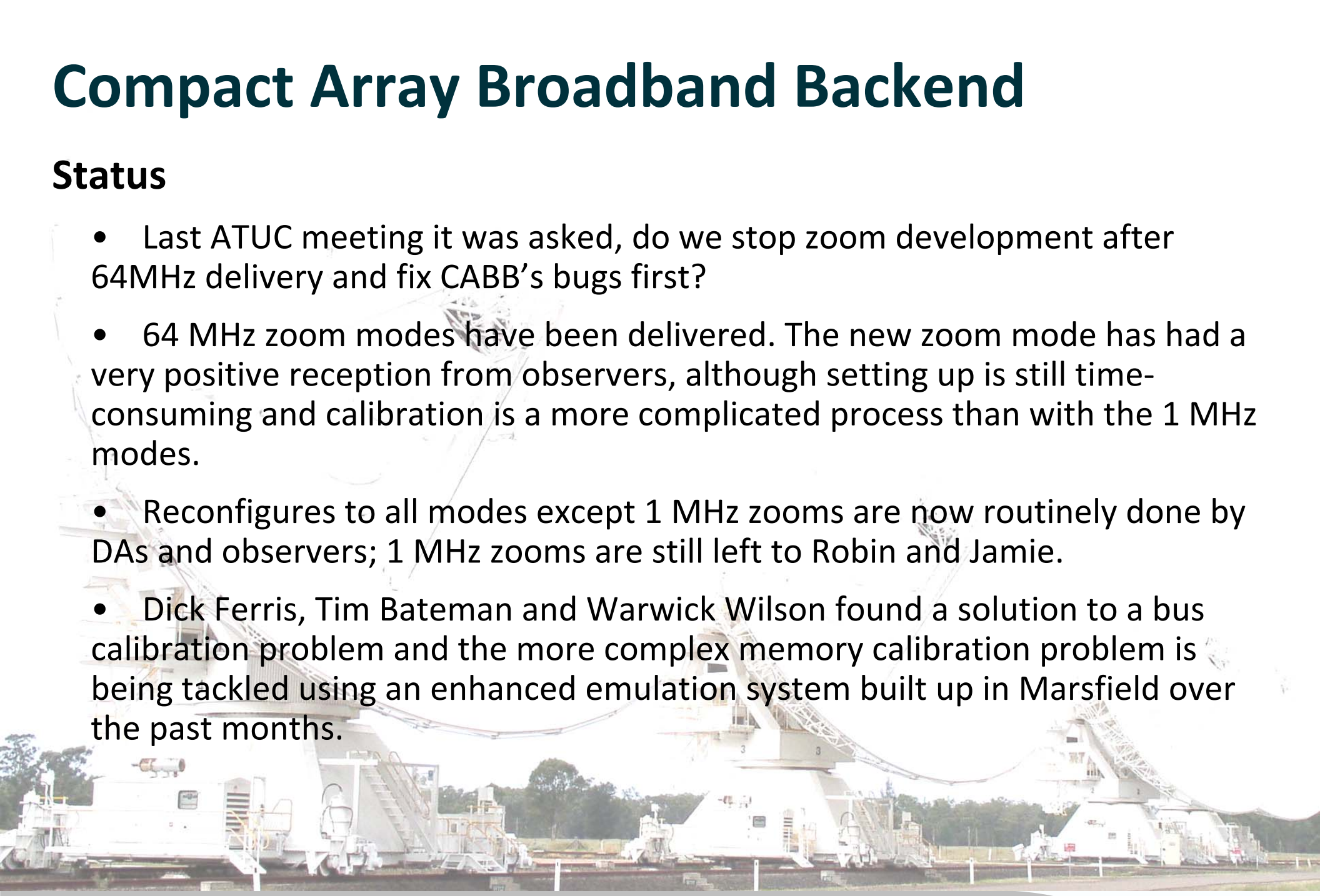
Parkes – Future Receiver Systems

- Wideband Receiver Systems
- PAFs

Compact Array Broadband Backend

Status

- Last ATUC meeting it was asked, do we stop zoom development after 64MHz delivery and fix CABB's bugs first?
- 64 MHz zoom modes have been delivered. The new zoom mode has had a very positive reception from observers, although setting up is still time-consuming and calibration is a more complicated process than with the 1 MHz modes.
- Reconfigures to all modes except 1 MHz zooms are now routinely done by DAs and observers; 1 MHz zooms are still left to Robin and Jamie.
- Dick Ferris, Tim Bateman and Warwick Wilson found a solution to a bus calibration problem and the more complex memory calibration problem is being tackled using an enhanced emulation system built up in Marsfield over the past months.

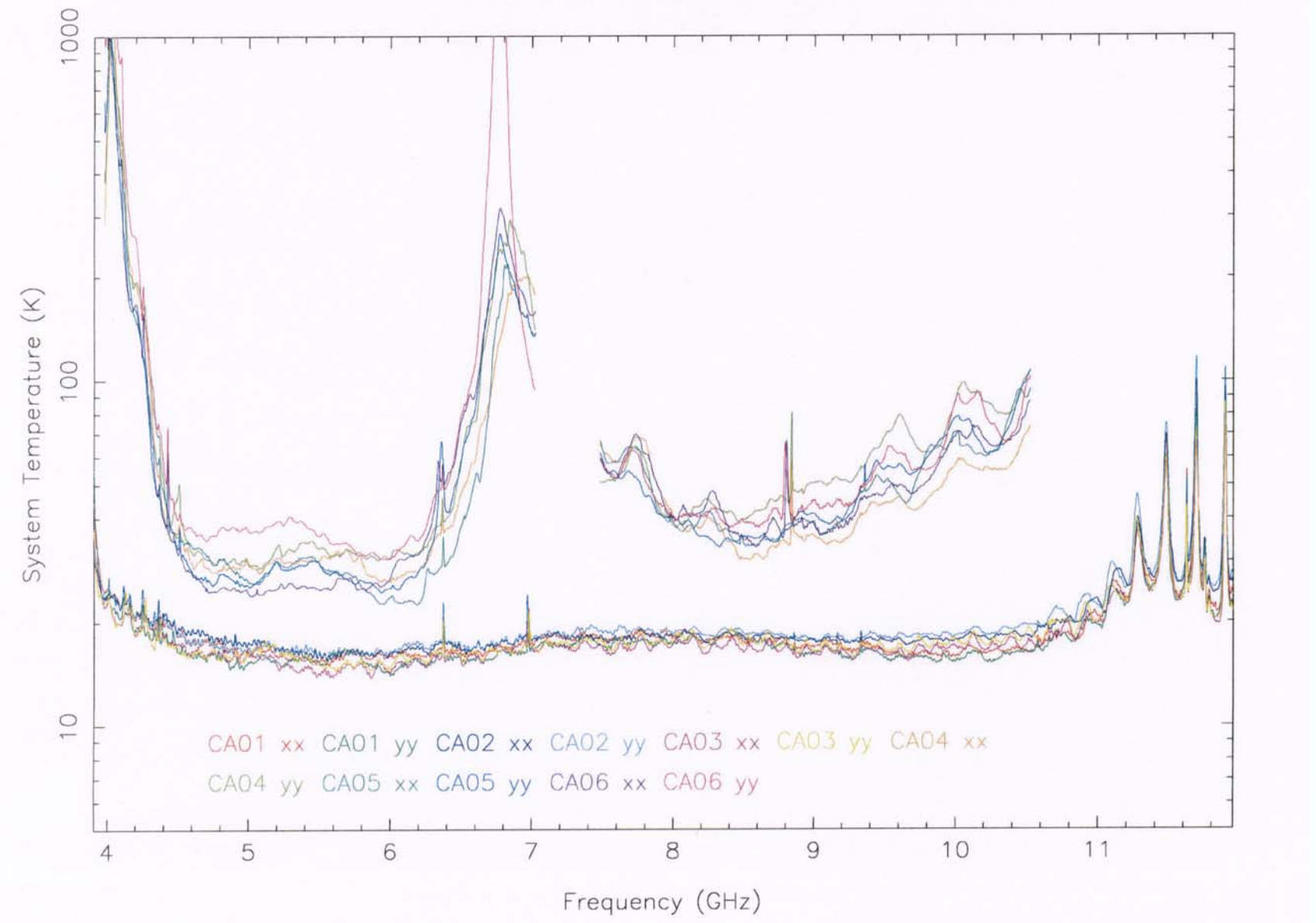


ATCA 4 – 12GHz Receiver

Status

- Australian Astronomy Ltd. funded program - upgrade funding continues until June 2013.
- The manufacture of hardware and components for the production receivers is ongoing.
- The first two receivers (production) were installed on the ATCA during Aug – Sep 2012.
- The next two receivers (3 and 4) are currently in the Marsfield laboratories undergoing modification.
- Installation of receivers 3 and 4 is scheduled for end of November 2012.
- The plan is to have all ATCA receivers (excluding spare) completed in Feb – Mar 2013.

4 – 12GHz Receiver - Performance

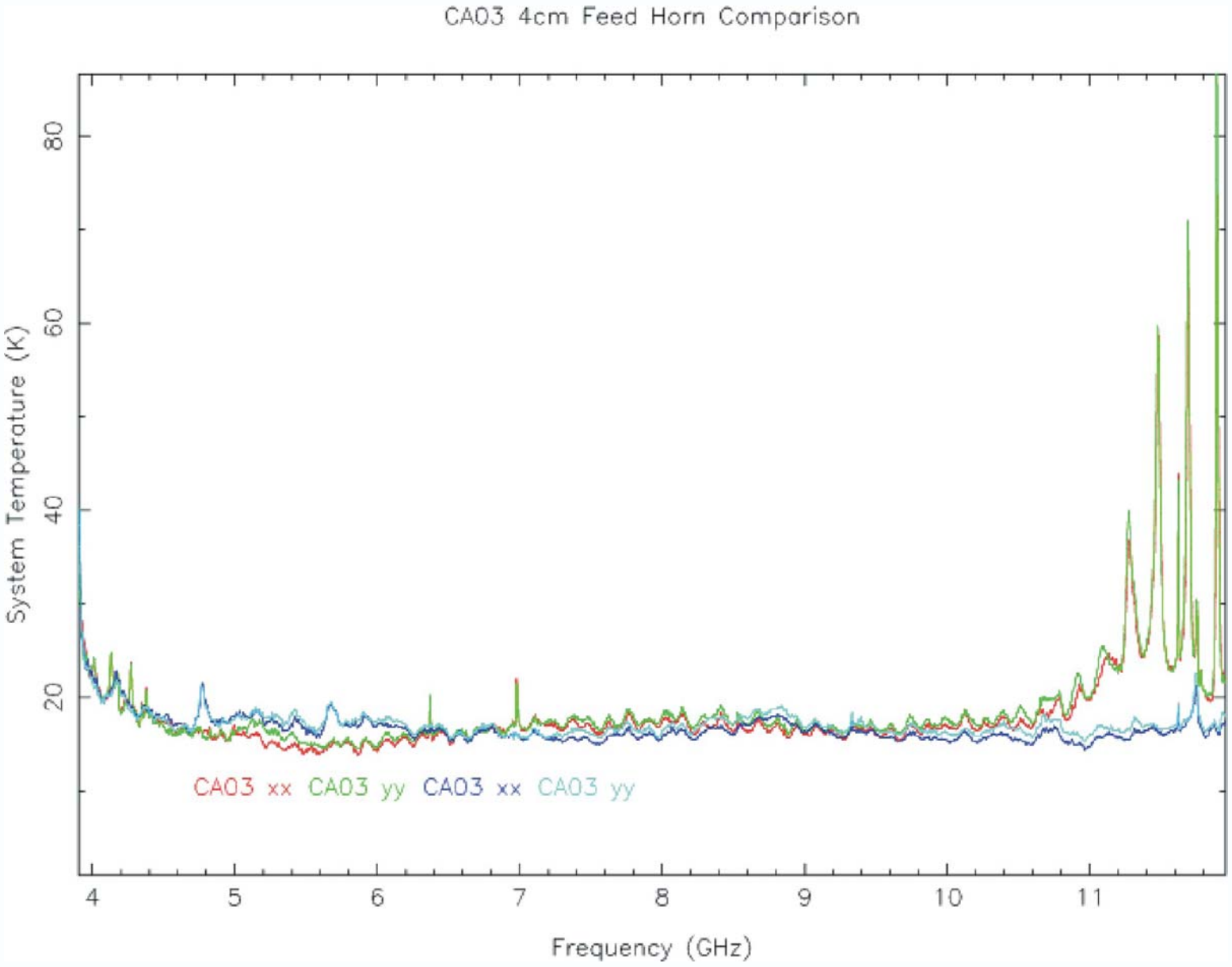


4.0 – 12.25GHz Feed Horn Development

Status

- Existing C/X feed horn does not work above 10.8GHz.
- Two prototype 4.0 – 12.25GHz feed horns were delivered by BAE Systems in Jul – Aug 2012.
- Feed tested on the ICT Centre antenna range during Aug – Sep 2012.
- Single feed installed on the ATCA (CA03) for evaluation during September 2012.
- Preliminary Tsys results (up to 12GHz) are promising.
- Evaluation of beam patterns, polarisation performance, sensitivity, etc. underway.
- Evaluation of performance above 12GHz requires modification to CABB.

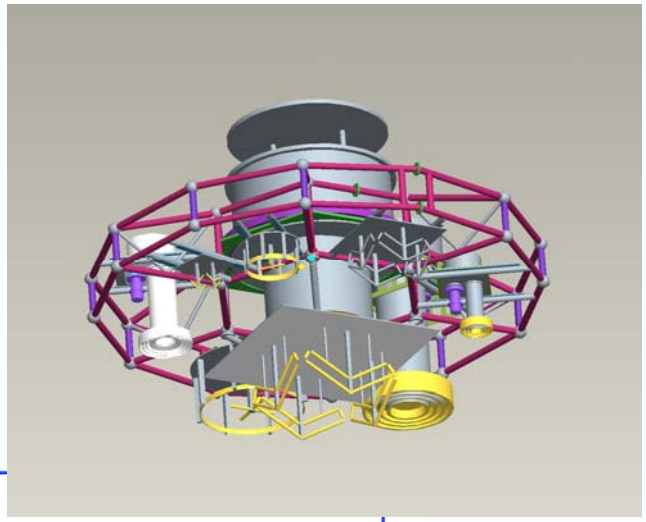
Prototype 4 – 12.25GHz Feed - Performance

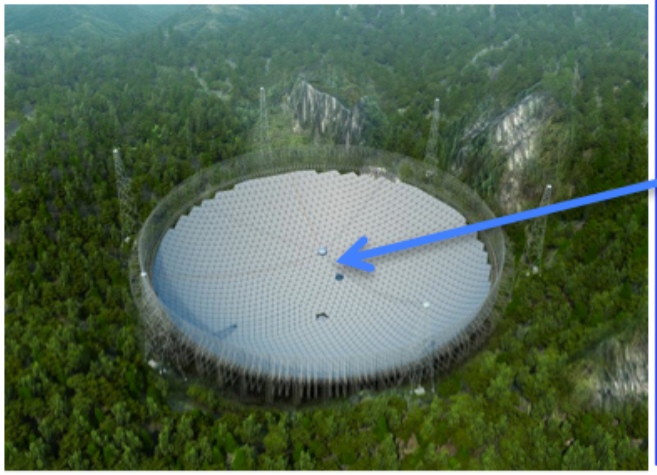


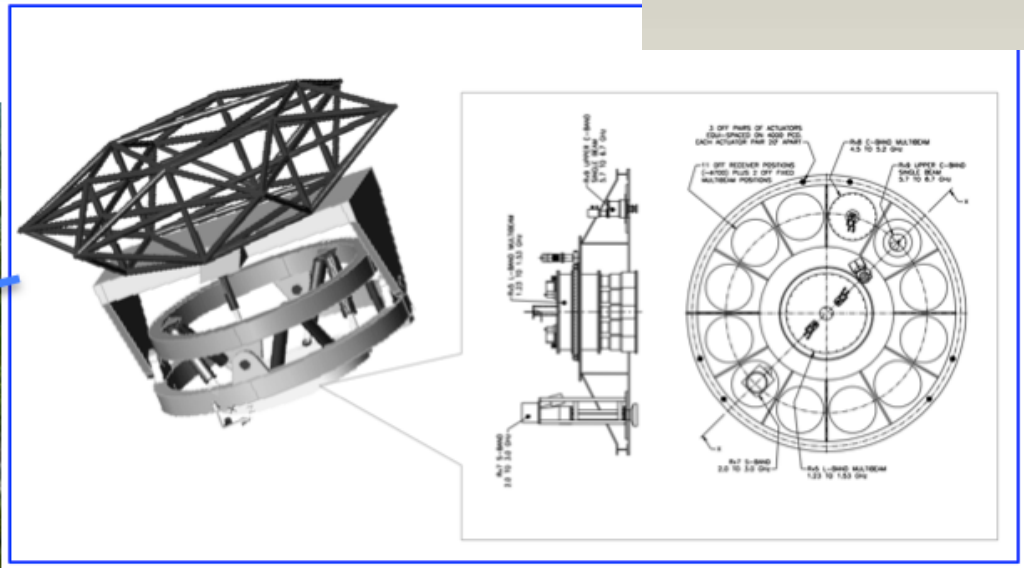
FAST Multi-beam Receiver - Feasibility Study

Background

- Joint feasibility study involving NAOC, JBCA and CSIRO.
- CSIRO and JBCA developing a cryogenic LNA and OMT.
- CASS working in collaboration with CSIRO ICT Centre for feed and Ortho-mode Transducer design.
- CASS conducting a design study for the cryogenic receiver system.



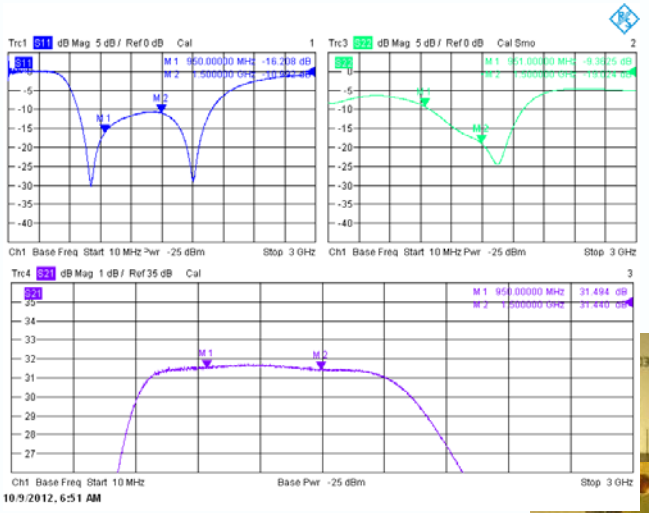


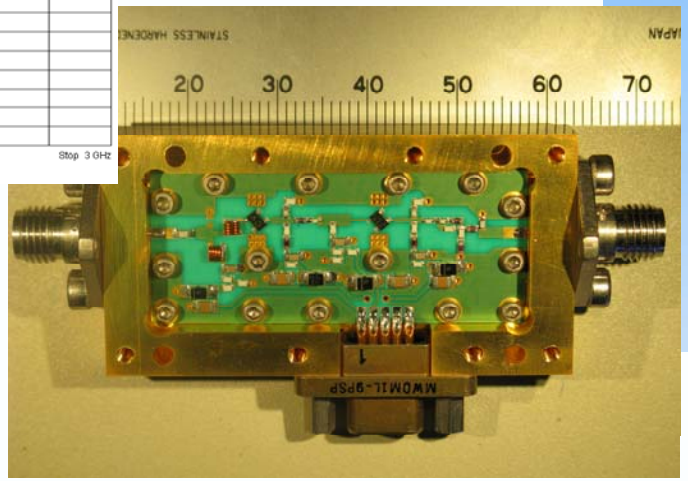


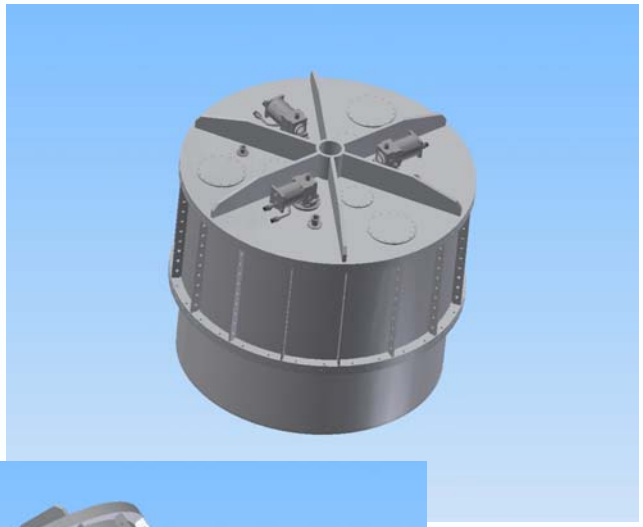
FAST Multi-beam Receiver - Feasibility Study

Status

- ICTC feed electromagnetic design almost complete.
- CASS LNA and cryostat design underway.
- CASS prototype LNA assembled and under test.







Parkes Technology Upgrades

Initial stage of developing a long term plan – Options:

Wideband Receivers

- 700 MHz to 4 GHz
- 4 – 12 GHz (16GHz) (18GHz) (20GHz) (24GHz)?

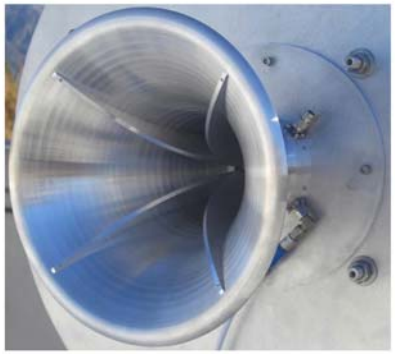
PAFs

- Frequency coverage comparable to ASKAP Mk II PAF.
- Room temperature or Cryogenic?

Wideband Receiver Development

Status

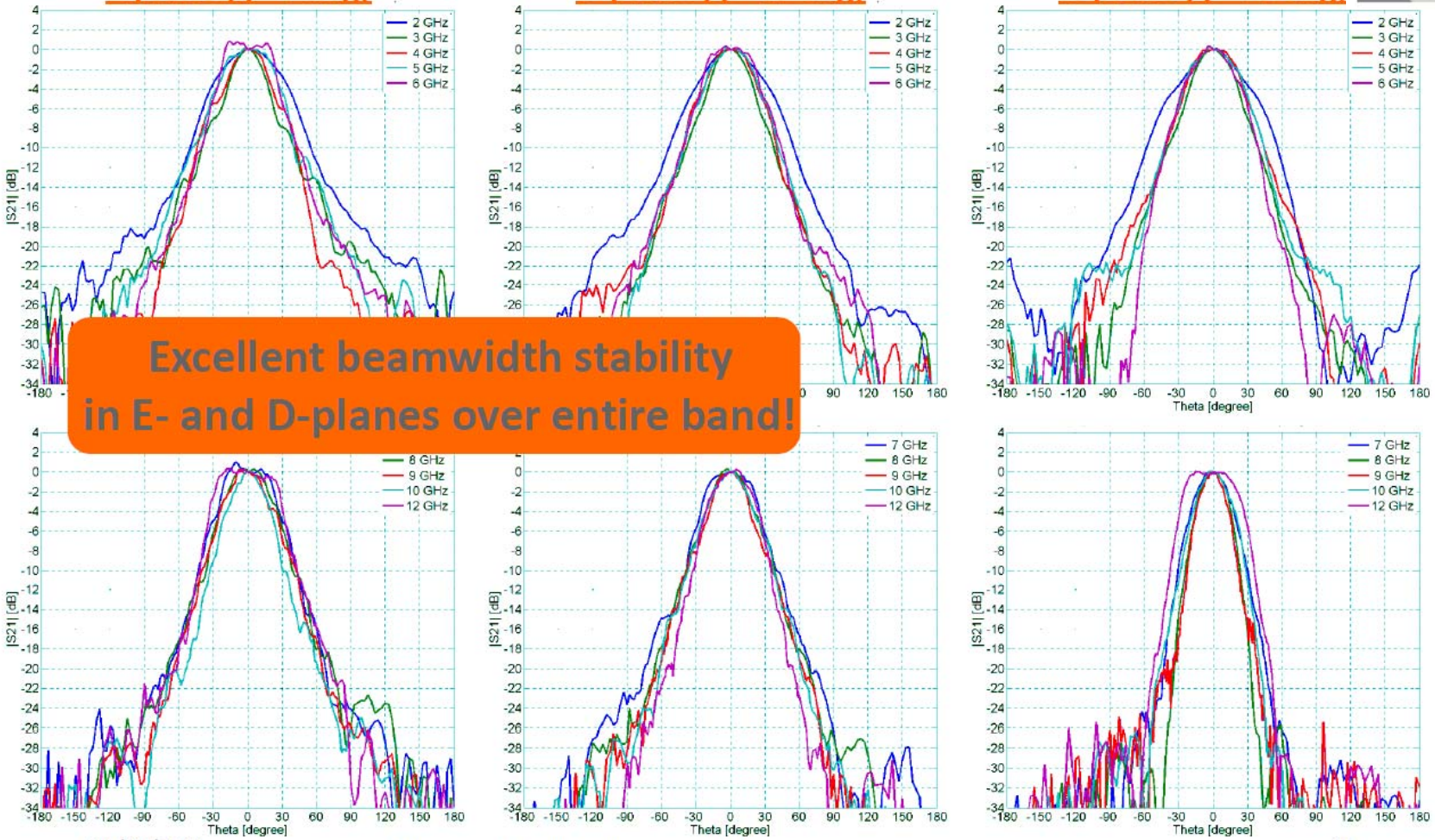
- A feasibility study to determine the design, performance and compromises and address some of the challenges commenced.
- Preliminary feed designs for 3:1, 5:1 or 6:1 bandwidths are well advanced.
- Preliminary results of modeling appear challenge the assumption that scaling a single feed design would produce the best scientific and operational outcome.
- Development of preliminary project plan and scoping work commenced.
- Discussion CASS scientific staff and broader user community underway.
- Manpower, existing project commitments are constraints (ASKAP, ATCA cm upgrade, CABB, SKA).



Measurements

Port 1 Patterns (Co-pol)

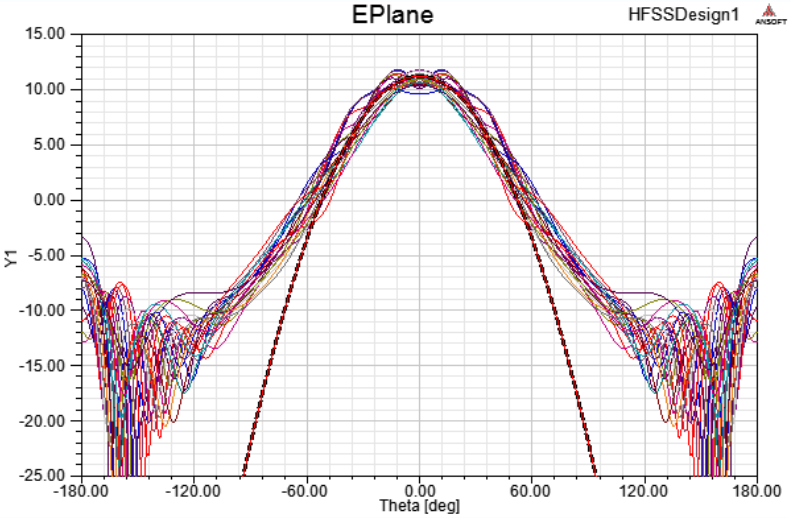
E-plane (ϕ=0 deg) | D-plane (ϕ=45 deg) | H-plane (ϕ=90 deg)

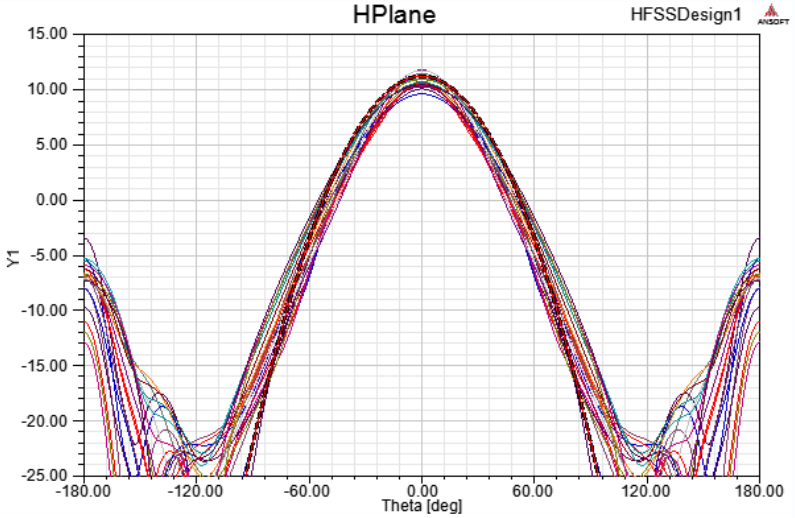


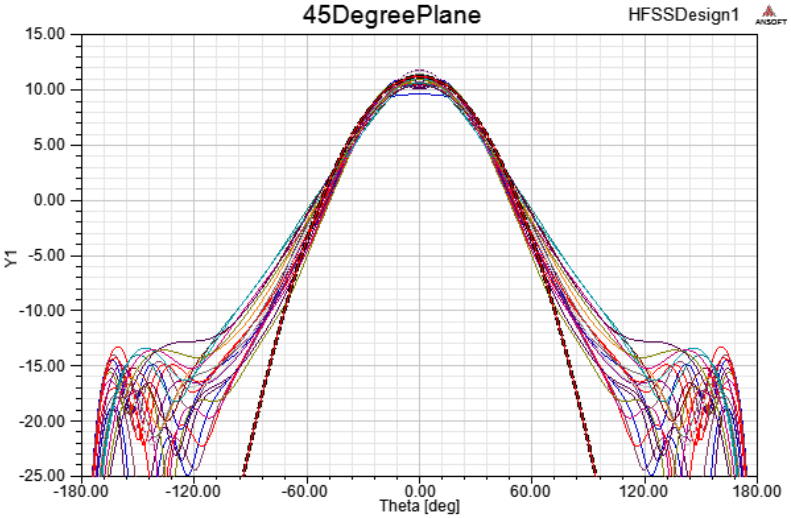
Excellent beamwidth stability in E- and D-planes over entire band!

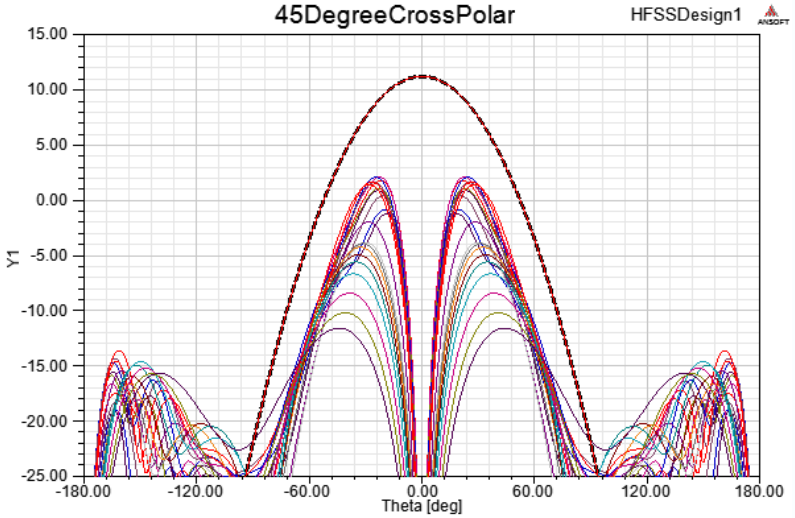
Normalized to boresight gain

3.3:1 Bandwidth Quad Ridge Horn

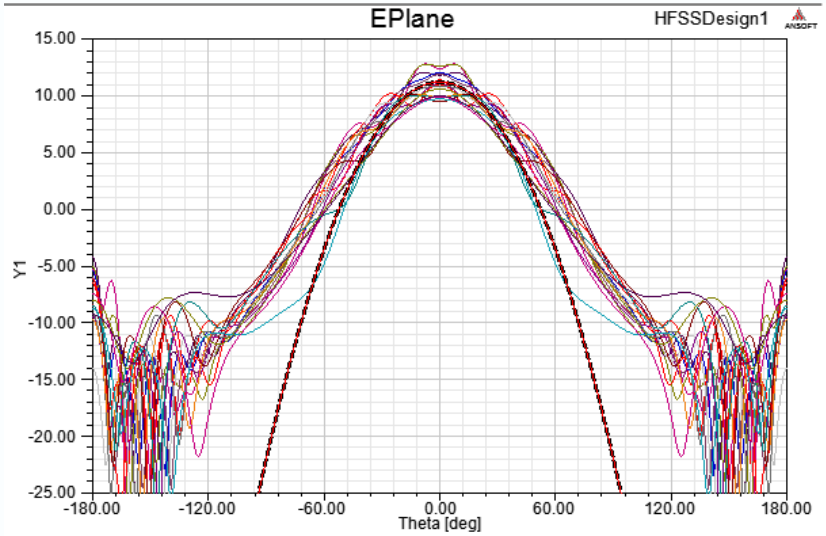


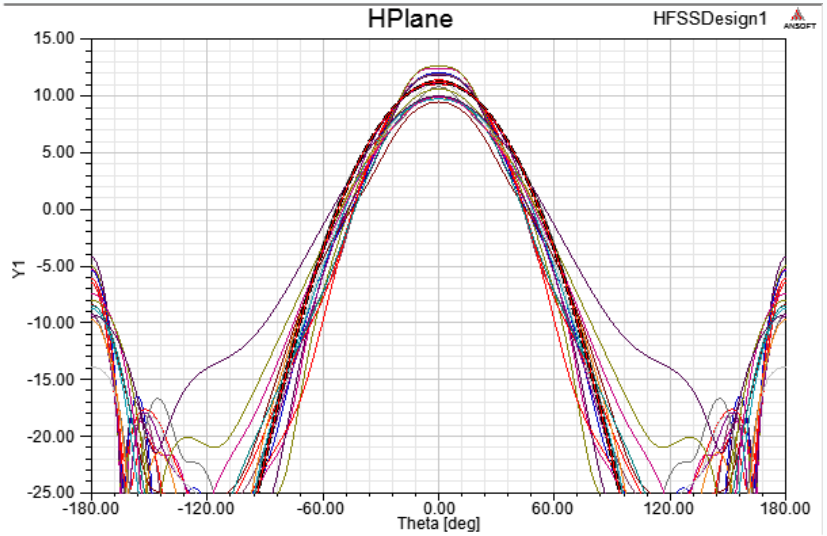


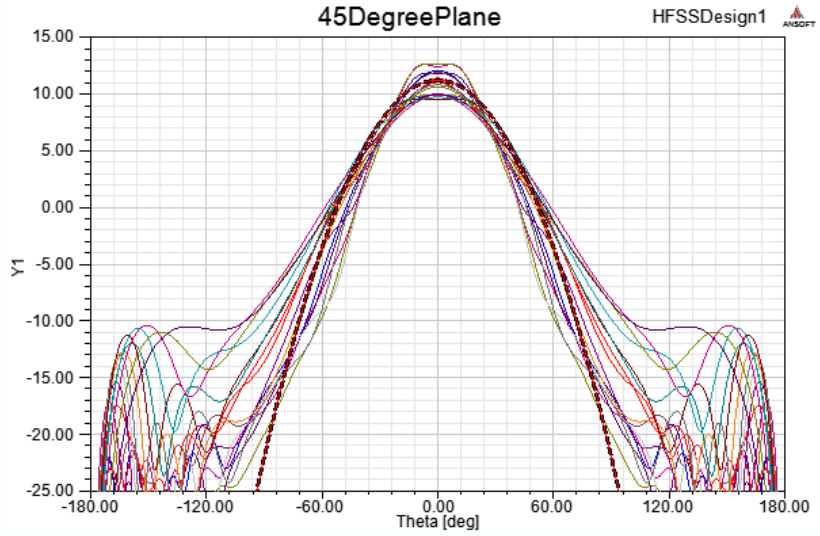


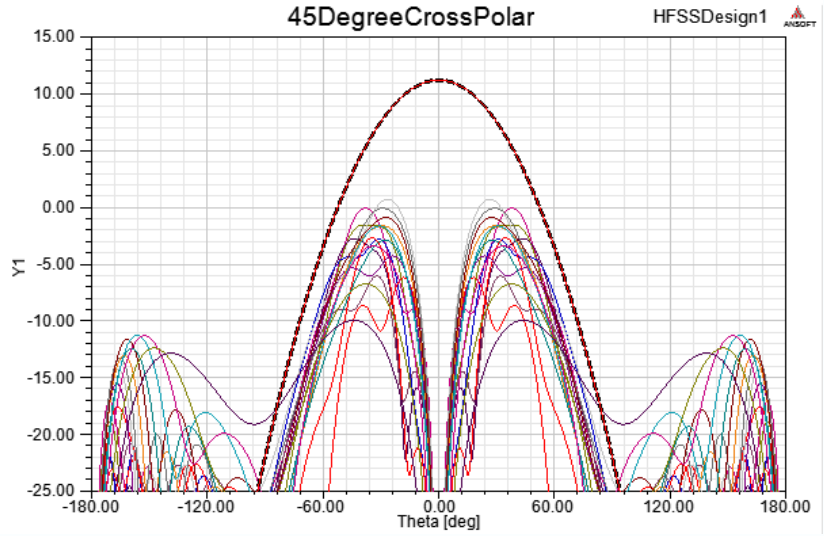


5:1 Bandwidth Quad Ridge Horn

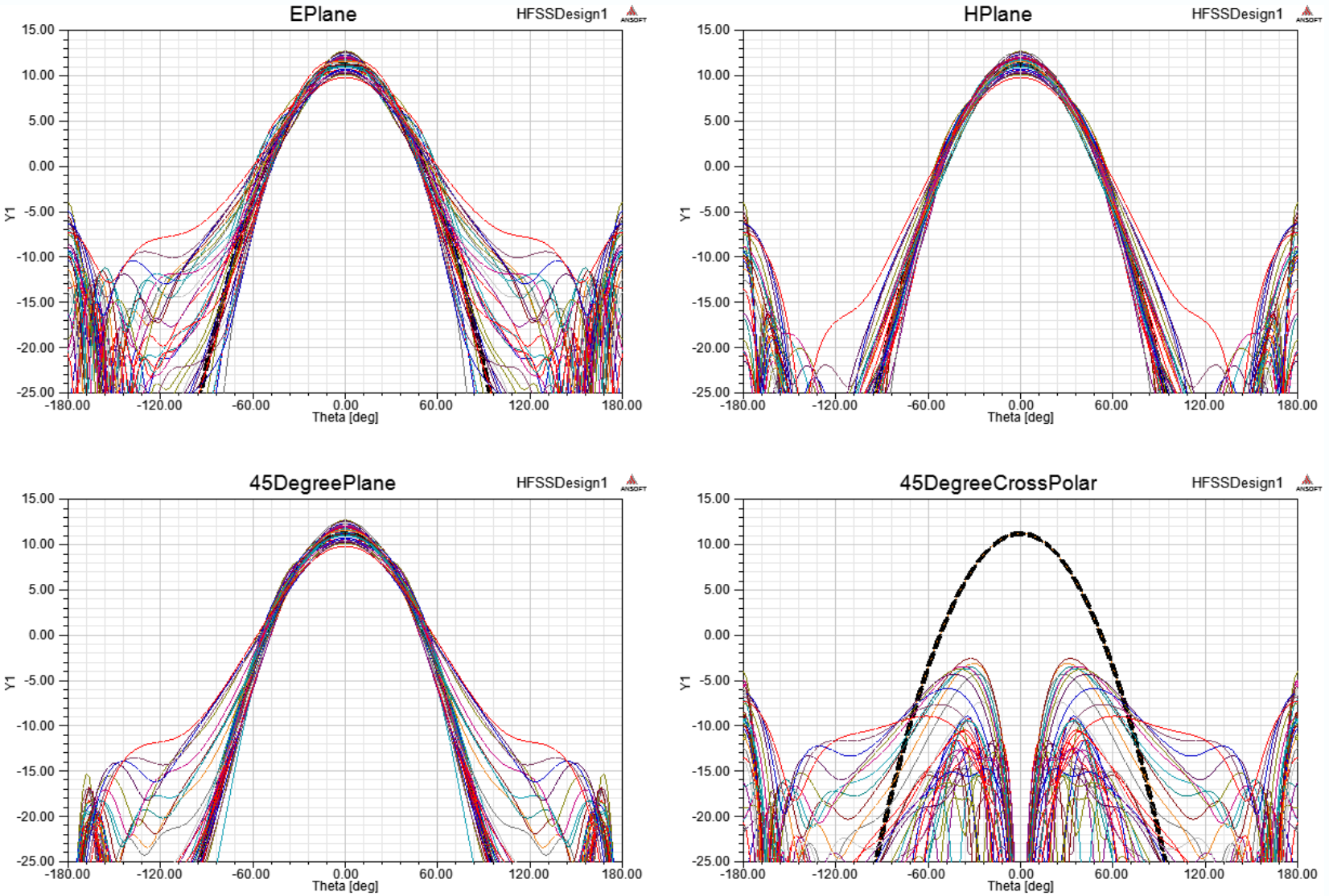








6.7:1 Bandwidth Quad Ridge Horn

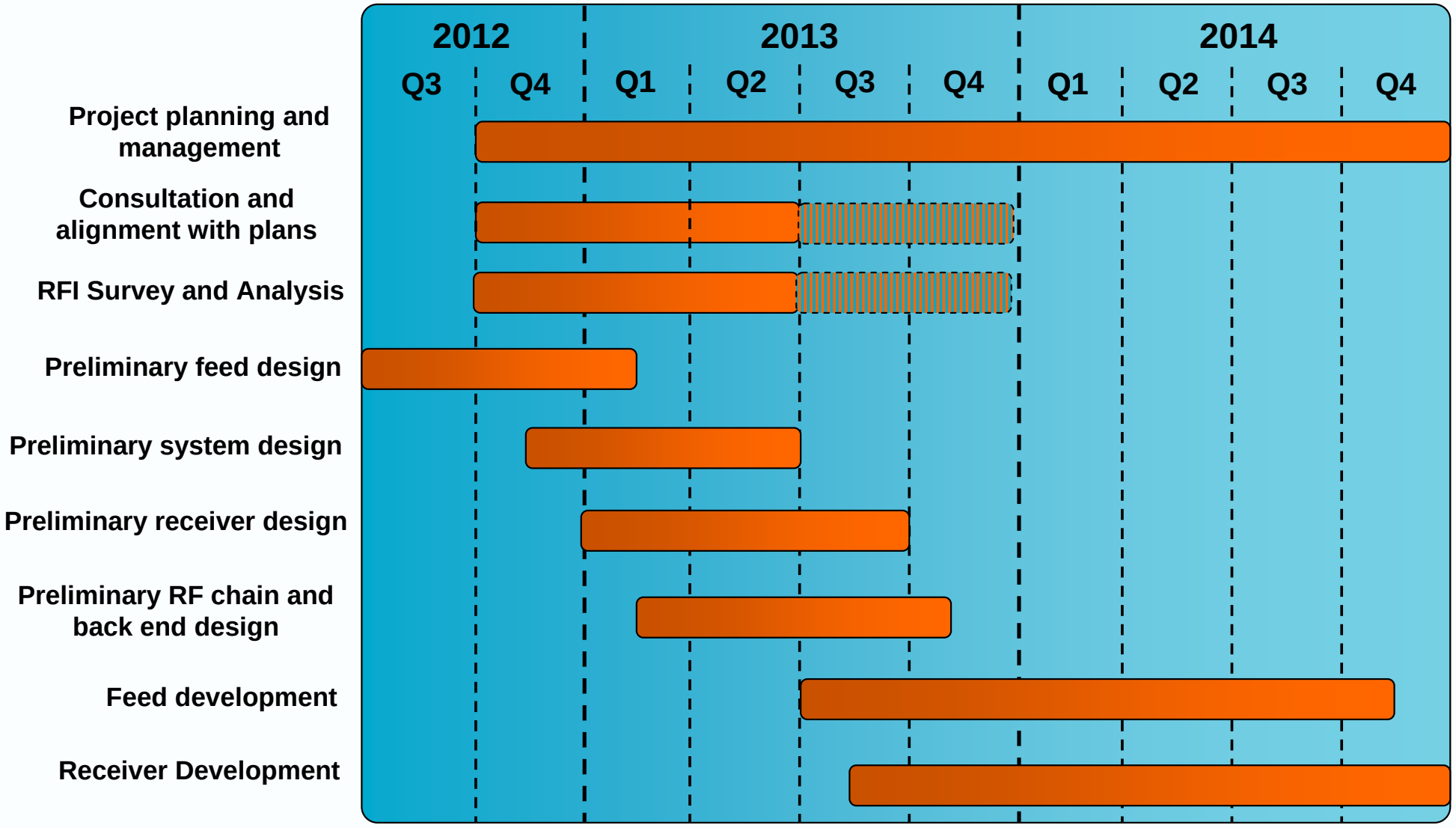


Wideband Receiver Development

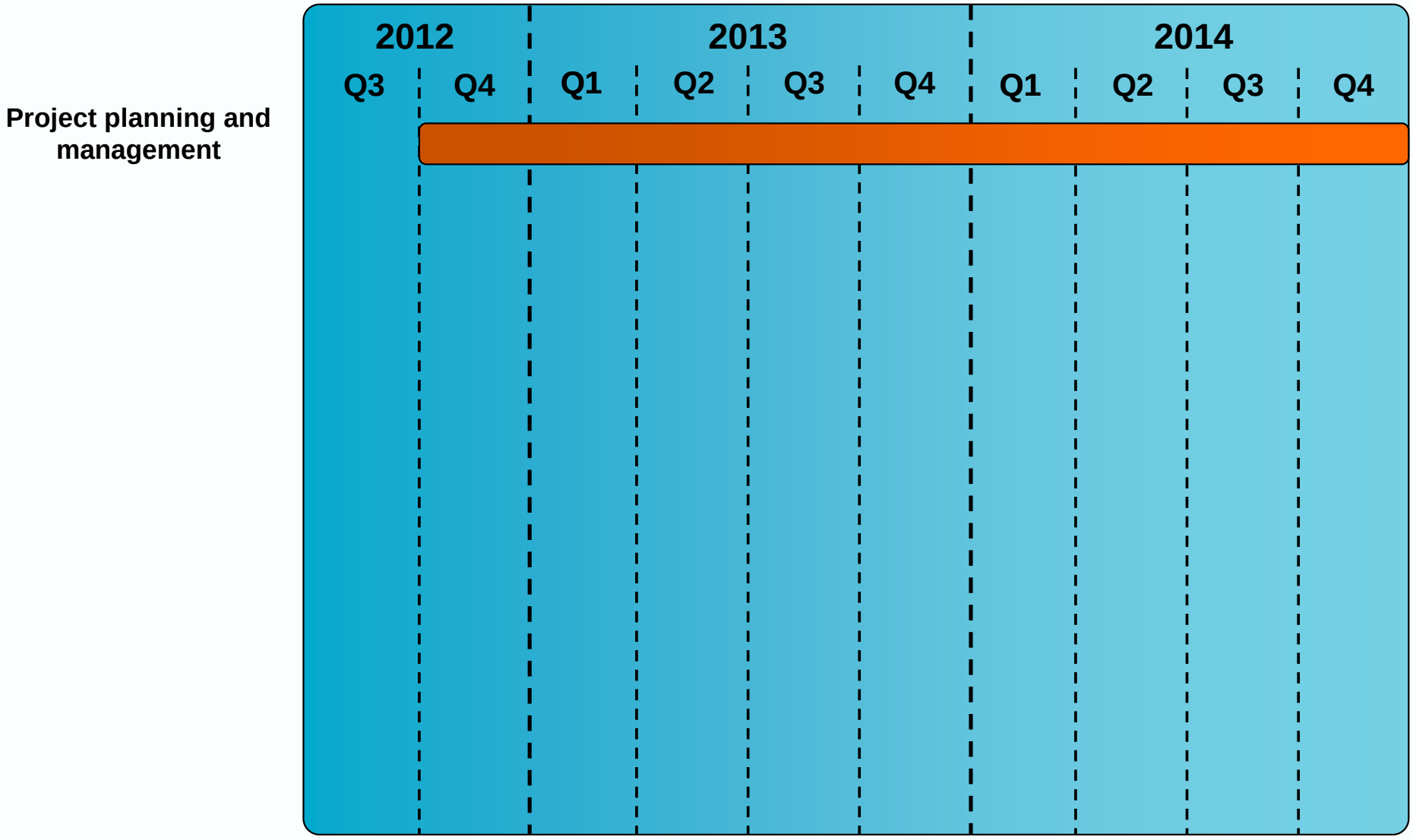
What have we learnt?

- The beam symmetry, polarisation performance, illumination characteristics of wide band feeds are not as good as “traditional” feed horns.
- A simple scaling of a single design is possible but unlikely to be optimal.
- A mix of wideband (6:1) and ~octave band (2:1, 3:1) feeds may be the way to achieve the best science and operational outcomes.
- It should be possible to include more than one band in a single large receiver package (subject to physical limitations).
- Modelling indicates that we have designs that should have better polarisation and illumination properties than current quad-ridged feed designs.
- Cryogenic cooling of the feed is still a viable option.
- The feed development remains the largest risk.

Wideband Receiver Development - Planning



Wideband Receiver Development - Planning



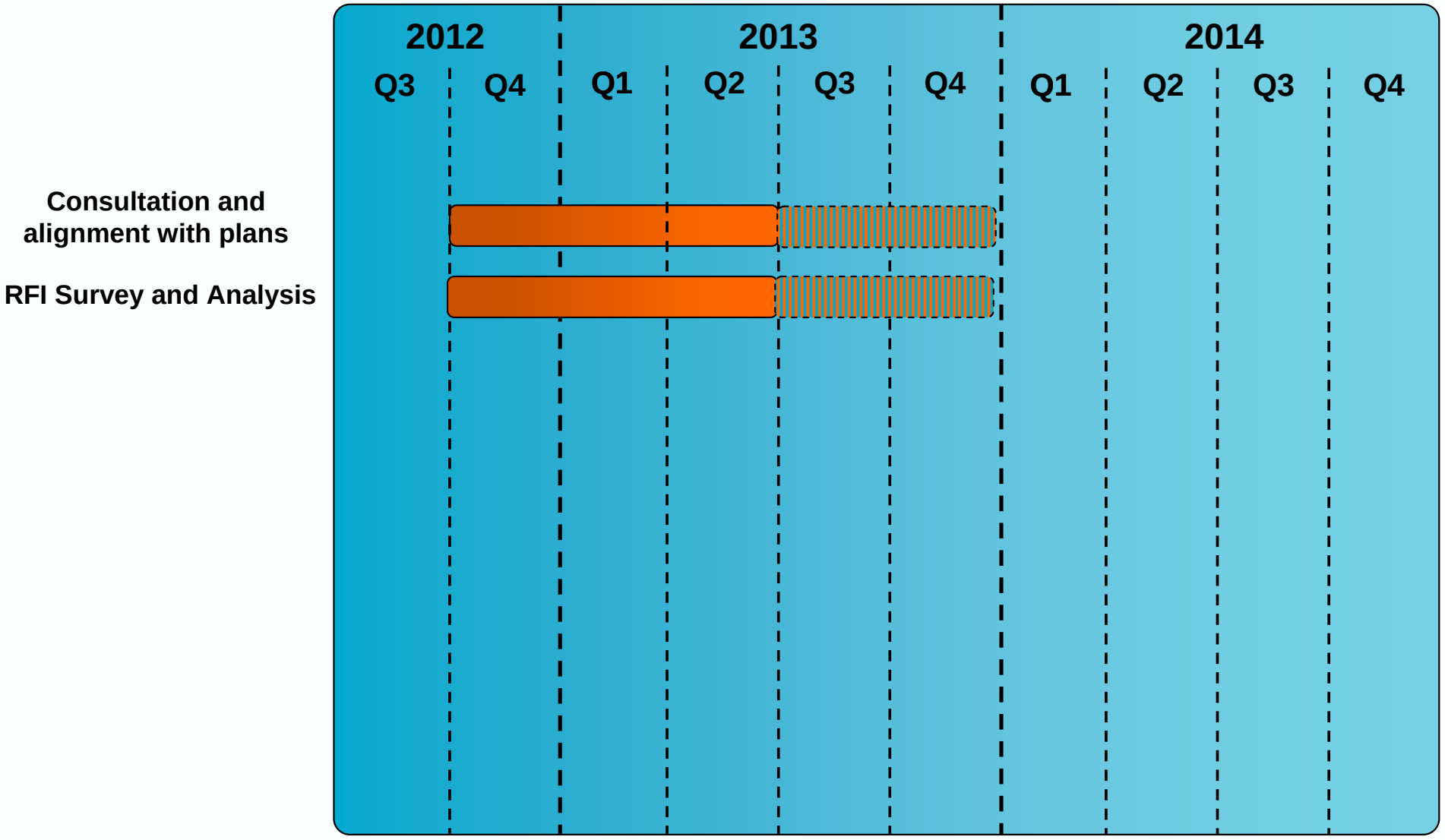
Wideband Receiver Development - Planning

Project Outline

1. Project planning, project management and system engineering

- Determine project scope and definition.
- Perform preliminary project planning in sufficient detail and depth to allow management and definition of scoping activities.
- Complete preliminary manpower requirements and cost estimates in sufficient depth to allow management and definition of scoping activities.
- Determine user requirements, measures of effectiveness and system requirements – in sufficient detail and depth to enable trade-off analysis and feasibility study.
- Manage preliminary research and definition of scoping activities
- Develop detailed project plan(s).
- Modify project plans, system requirements and measures of effectiveness as necessary to incorporate outcome of consultative processes

Wideband Receiver Development - Planning



Wideband Receiver Development - Planning

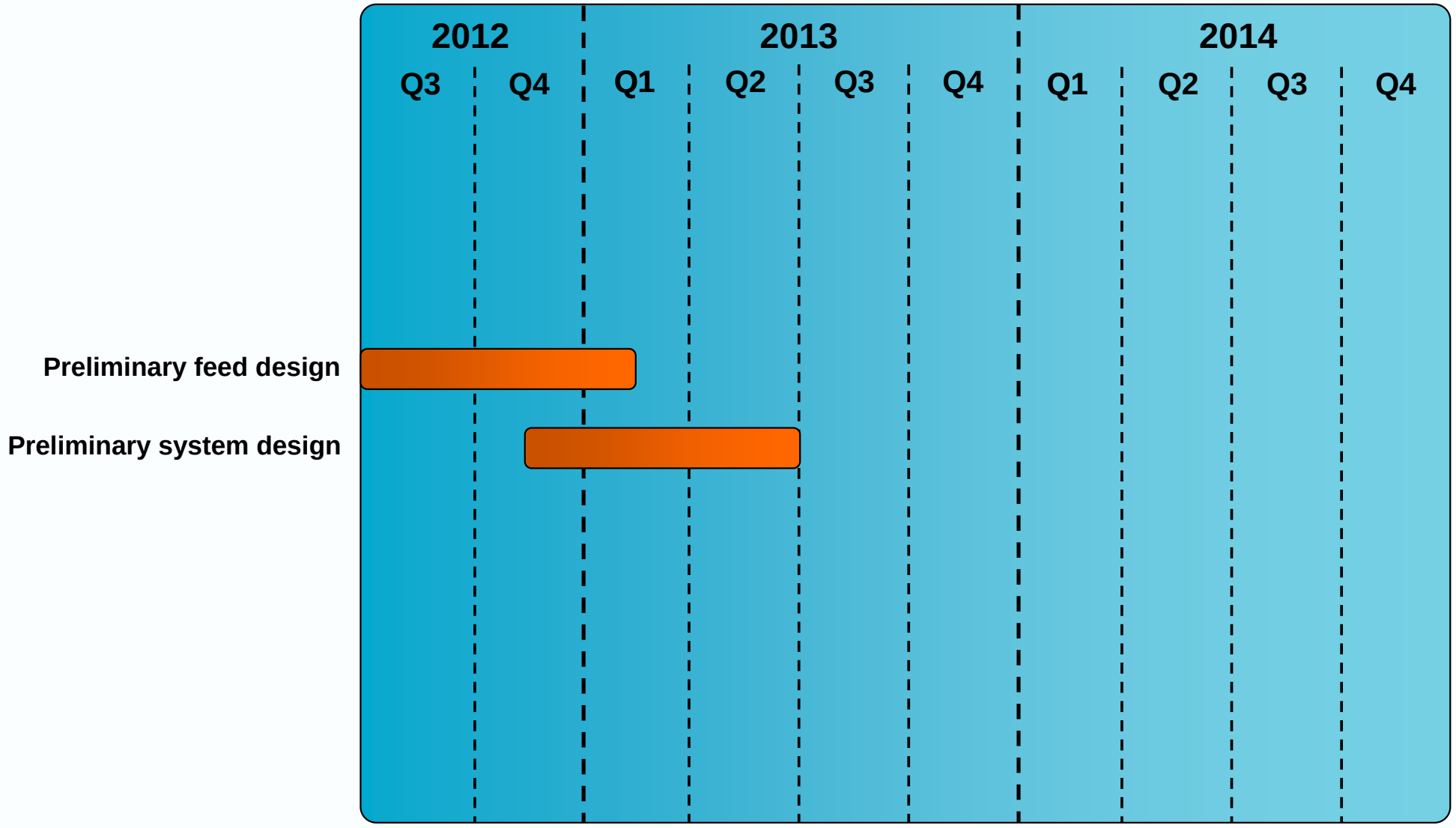
2. Consultation with user community and alignment with operational plan

- Conduct regular briefings and consult user community (eg. CASS Astrophysics and ATUC)
- Present results of trade off analysis and system design activities – at all stages of project development
- Evaluate alignment with long, medium and short term operational plans for Parkes and CASS
- Accept input and feedback and use it to inform project processes

3. RFI survey and analysis

- Survey current RFI environment
- Survey future RFI emissions (ACMA databases, etc.)
- Analyse results of RFI survey in sufficient detail to provide input into RF system design

Wideband Receiver Development - Planning



Wideband Receiver Development - Planning

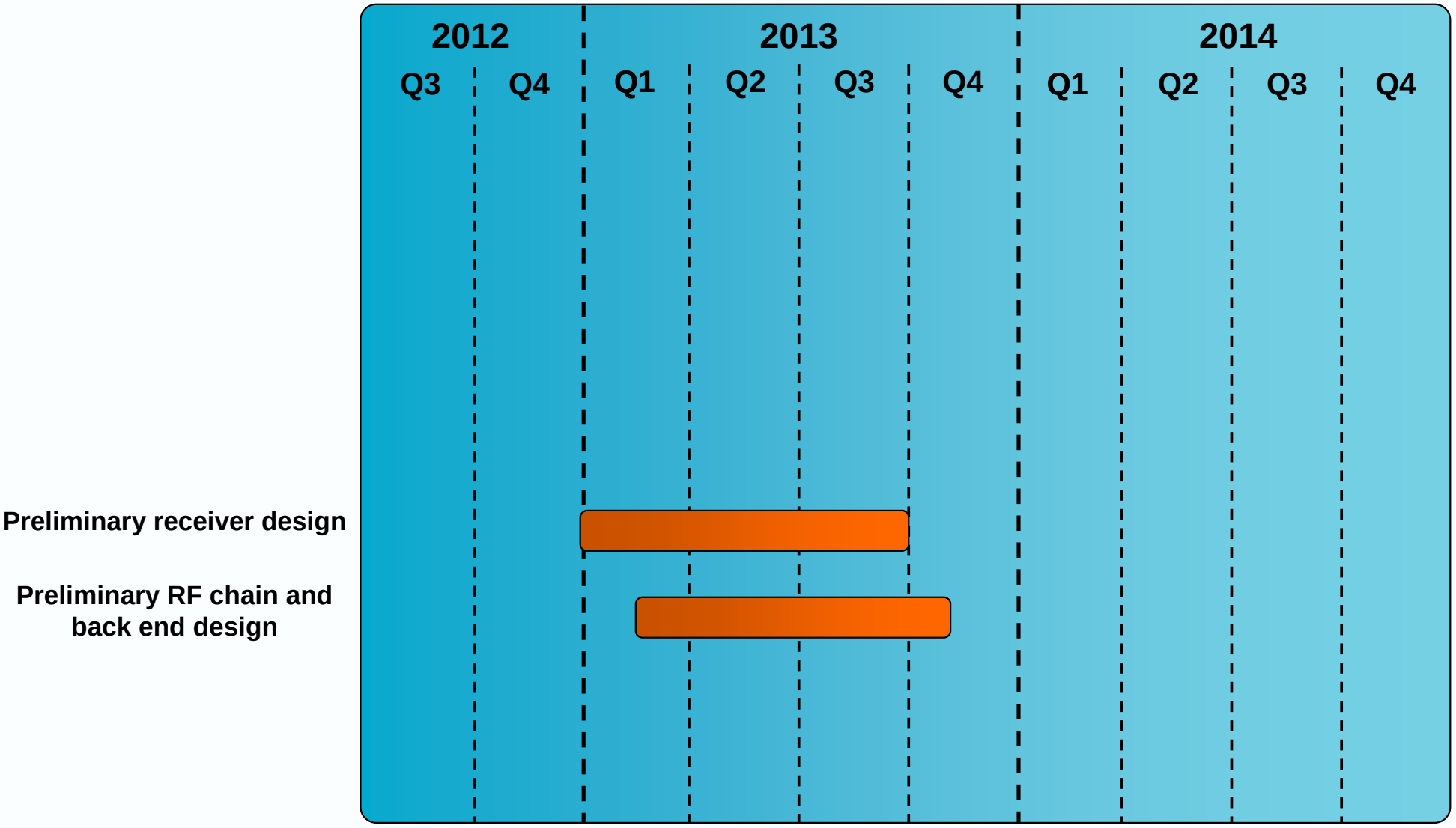
4. Preliminary feed design

- EM analysis sufficiently mature to prove one or more feed concepts
- Designs developed in sufficient detail to enable preliminary mechanical design and FEA analysis of feed/receiver system

5. Preliminary system design

- Define possible observing bands and determine engineering and science implications
- Assess existing Parkes receiver fleet – frequency coverage, science output, estimated lifetime, …
- Trade off analysis – bandwidth, polarisation, Tsys, beamshape, efficiency, sensitivity, …
- Investigate the feasibility of including more than one band in a single receiver package.
- Evaluate alignment with Parkes long term plans

Wideband Receiver Development - Planning



Wideband Receiver Development - Planning

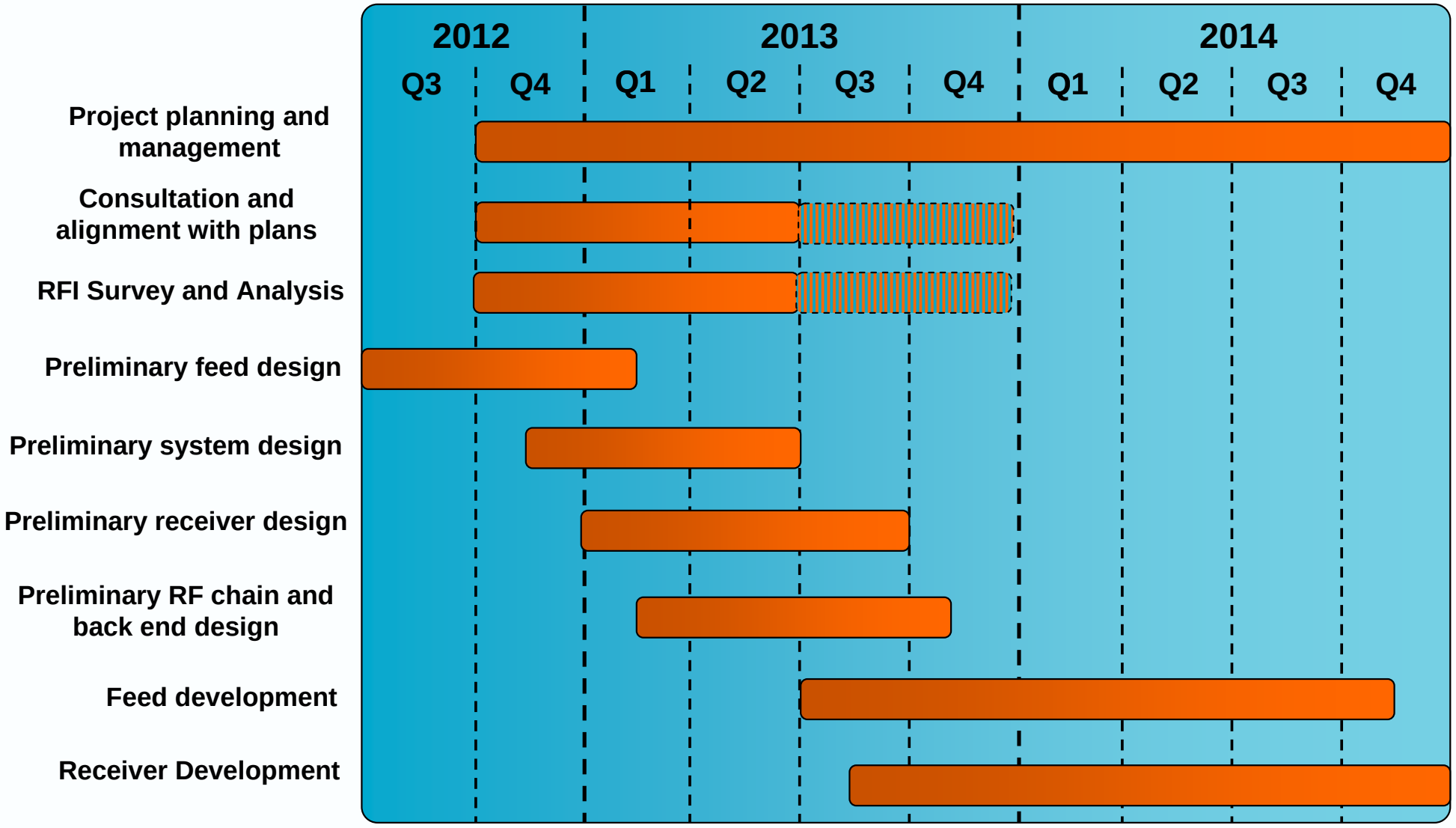
6. Preliminary receiver and vacuum dewar design

- Mechanical design of receiver in sufficient depth to enable the performance of: preliminary FEA, heat load modelling, vacuum leak rate estimation, etc.
- Define dewar RF and electrical interfaces in sufficient depth to enable FEA and other analyses.
- FEA of vacuum dewar, vacuum window and feed to assess feasibility of mechanical design.
- Perform preliminary thermal analysis and assess ability to cool feed/LNAs

7. Preliminary RF chain and backend design

- Evaluate possible wideband sampler architectures and systems in sufficient depth to allow preliminary RF chain design – Sampled bandwidth, direct sampling …
- Evaluate possible RF chain architectures and develop designs - RF over fibre, conversion system, sample at the focus …
- Evaluate alignment with long term operational plans for Parkes

Wideband Receiver Development - Planning



Wideband Receiver Development

Questions

- What RF bands and bandwidths best meet the current and future needs of science with Parkes?
- What performance trade-offs are the user community prepared to accept?
- The relative importance of those trade-offs – what is of greater value bandwidth, sensitivity, polarisation?
- The relative priorities - which receiver do we build first?
- Backend development - does it replace existing backends and/or Parkes conversion system?
- Is it desirable to include more than one band in a single large receiver package? If so which bands?
- How do we carry out the development in alignment with the Parkes operations strategy?
- Funding?

Phased Array Feeds

Status

- A feasibility study to determine the design, performance and compromises and address some of the challenges commenced.
- The feasibility of incorporating BETA and/or ADE PAF structures into Parkes focus cabin is being examined.
- Project scoping work has commenced.
- Discussion CASS scientific staff and broader user community underway.
- Manpower, existing project commitments are constraints (ASKAP, ATCA cm upgrade, CABB, SKA).

Phased Array Feeds

What have we learnt?

- The questions that the user community need to answer are fundamental and have a significant impact upon the project.
- There is no desire to install a PAF that has the limited bandwidth of the Mk.1 receiver – increased performance demonstrated using 5 x 4 PAF.
- The Mk.1 and Mk.2 (BETA and ADE) PAF receivers will NOT fit on the Parkes telescope without significant changes.
- The focus cabin is a controlled environment – potentially makes the PAF receiver simpler.

Phased Array Feeds

Questions

- Does it need to replace the centre beam of the current L-band multibeam receiver?
- How good does the PAF need to be (cryogenic or room temperature)?
- Is it acceptable to install a PAF on Parkes to gain experience?
- Is the development in alignment with the Parkes operations strategy?
- What is the driver for installing a PAF on Parkes?
    - Does it enable new or ground breaking science?
    - An upgrade path for ASKAP PAF systems – towards the SKA?
- A high-frequency PAF?
- Funding and timing – ASKAP delivery?

Technologies for Radio Astronomy

The Future

- The current size of the technologies theme means that it can only support one significant project at any given time.
- Current ATCA C/X receiver upgrade project scheduled for completion in June 2013.
- The C/X upgrade team will be available to commence development of receiver systems for Parkes.
- Backend capability will also be required but ASKAP is likely to still require this expertise.
- Boundaries between analogue and digital systems; hardware and firmware are blurring.
- A system engineered approach is becoming much more important.

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