APRICOT

All Purpose Radio Imaging Cameras On Telescopes

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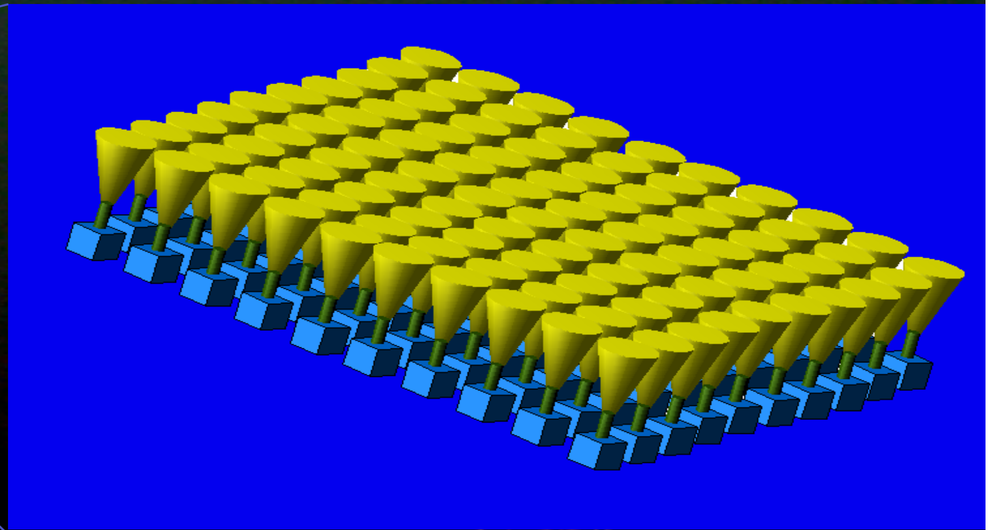


1) Design studies & sub-system prototyping for future large-format Q-band FPA "cameras" on large telescopes

2) MIC + MMIC devices from within Europe.

APRICOT Partners

- University of Manchester (UMAN)
- Max Planck Institut fűr Radioastronomie (MPIfR)
- Instituto Radio Astronomia Bologna (IRA)
- Centro Astronómico de Yebes (CAY)
- Torun Centre for Astronomy (TCfA)
- Universita di Roma Tor Vergata (UTV)

EC Framework7 "RadioNet" Instrumention R&D

APRICOT : Q-band camera subsystems + European MIC/MMICs

(Caltech/JPL MMIC array spectrographs & NRAO FPA goals overlap with APRICOT)

AMSTAR+ : mm/sub-mm cameras subsytems (SIS, MMIC)

(W-band FPAs overlaps with APRICOT)

(UNIBOARD: multi-purpose digital backends)

Some European Q-band telescopes

Science Strategy

- "Cameras" enable these telescopes to make new surveys in scientifically rich range 33-50 GHz –
  - In "intermediate" gap between SKA and ALMA
  - Follow-up with EVLA, VLBI, VSOP-2, ALMA Band 1
  - Continuum and spectroscopy: observations in different weather conditions
  - Complement other mm→sub-mm observations
  - Complement CMBR observations e.g. Planck

APRICOT: Basics

- Operating range: 33-50 GHz
  - spectrally rich + many continuum applications

- All Stokes parameters + spectroscopy at same time
  - Continuum band split into (n x few GHz) sub-bands for atmospheric & spectral discrimination.
  - Broad-band IF output selected from anywhere within overall band, sent to high-speed digital FTS

Molecular Line Spectroscopy

- Star-forming regions & circumstellar envelopes
  - Imaging plus modelling → temperature & density
  - Many carbon-chain species in the 30-50 GHz band (HC_nN n=3,5,7; C_nH n=5,6; C_nS n=1,3,5) diagnostic of cold dense quiescent gas
  - Other species:

With large format cameras could survey complete clouds in one day

- Blind surveys in redshifted CO (1-0)
  - Distances & mass estimates of dusty galaxies

Continuum Studies

- Surveys for discrete sources (in polarisation)
  - Find new types of AGN e.g. youngest CSOs
    - follow-up with mm-VLBI & VSOP-2 imaging
    - follow-up of GLAST transients
  - Provide net of calibration sources for EVLA and mm-VLBI
  - Support of *Planck* and all high-sensitivity CMBR experiments
- Surveys for/of clusters of galaxies via the S-Z effect
- Surveys of diffuse Galactic emission (in polarisation)
  - Synchrotron; free-free; anomalous dust; thermal dust
  - Need to dissect out the contributions: for ISM astrophysics and CMBR polarised foregrounds
  - In compact regions e.g. YSOs - diagnostics of dust agglomeration in protoplanetary disks

WP1 Receiver Architecture

MPIfR; IRA, UMAN, CAY, TCfA

Architectures for highly integrated multi-pixel receivers

WP2: passive components

IRA; MPIfR, UMAN

Highly integrated low-cost low-loss chain

Deliverables - design study reports
- few pixels hardware comparing performance of conventional and "innovative" approaches

WP3: MIC/MMIC development

UMAN; IRA; MPIfR; CAY; URomeTV

To develop and secure European supply of world-standard MMIC devices for astronomy (Fraunhofer; OMMIC)

To seek improved noise performance (Manchester)

Link with AMSTAR+

WP4: Device Testing

CAY; UMAN; MPIfR, IRA; URomeTV

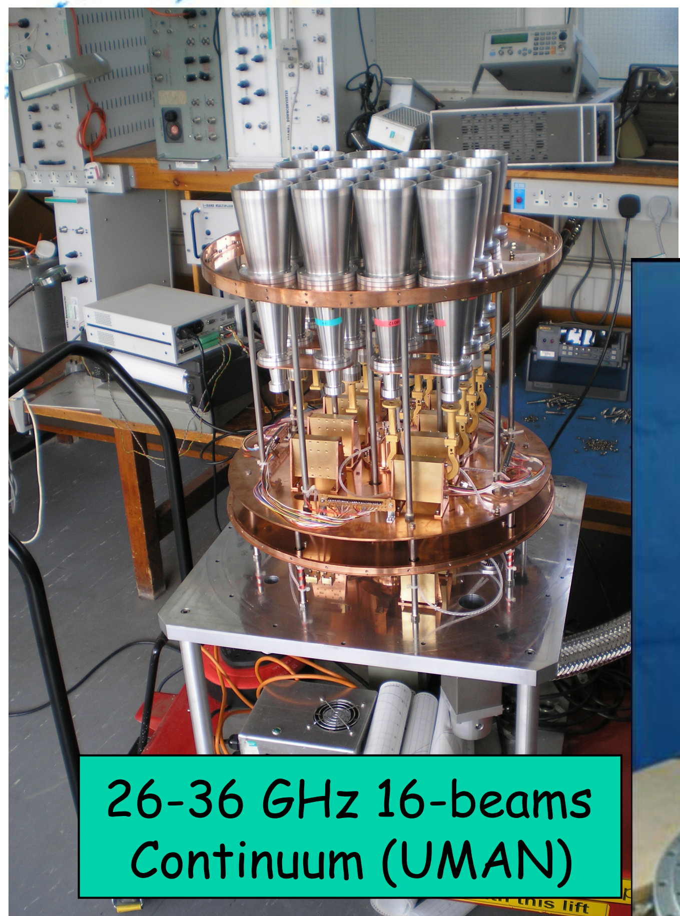
Accurate measurement of noise temperature and gain fluctuation of devices at cryo temperatures

WP5: Data handling

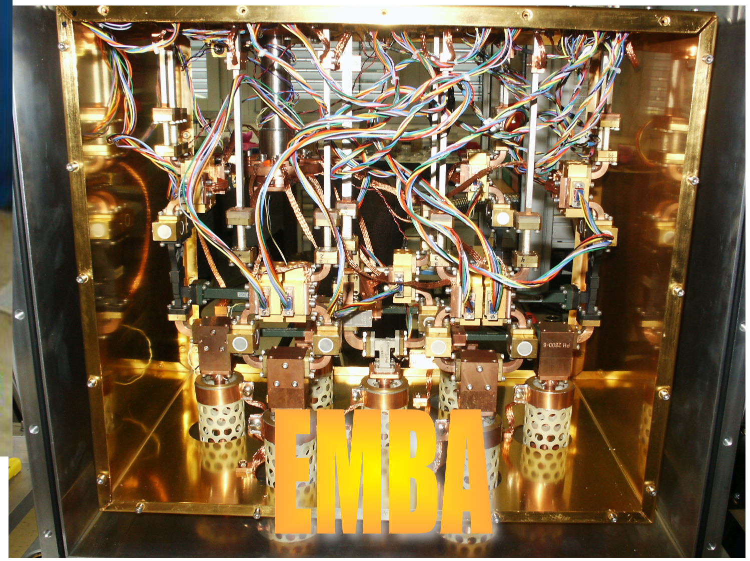
TCfA: UMAN, IRA, MPIfR

Algorithms using the multi-pixel and multi-spectral data to reduce effects of 1/f noise and atmosphere ("on the fly-mapping")

Status Quo



7 - 16 pixels typical
Horns 300K, 70K
special purpose RX



Wiring discrete
Assembly of Components

Goals of this study

- Define boundary conditions
  - No. Of pixels
  - Cooling
  - Wiring
- Find the right architecture
  - Down conversion scheme
  - LO & Cal distribution
  - Mechanical setup
- Find solutions for components
  → See WP description

Observation Modes I

- Observation Mode Capabilities
  - Spectroscopy:
    - Bandwidth,
    - Flatness,
    - Polarization?
  - Continuum:
    - No. Of Channels, Bandwidth,
    - Polarization,
    - Stability,
    - Polarimetry?

Observation Modes II

- Observation Mode Capabilities
  - Pulsars:
    - Bandwidth,
    - what else?
  - VLBI: applicable?

Architecture Concepts:

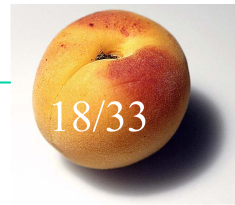
- Signal Chain:
  - Straight forward
  - Pseudocorrelation Concept (switched)?
- Down Conversion:
  - Cryo or Room Temp. 1st Mixer:
    - Output WG or koax
  - No. of IF's per Polarisation
    - Channels for Continuum
    - Bandwidth of IF

Mechanical/Geometrical

- Footprint of pixel = Feed apperture
- How to Assemble / Maintainability
- Mechanical Design:
  - Cartridge (ALMA)
  - Line (AMSTAR)
  - Flat (FARADAY, EMBA)

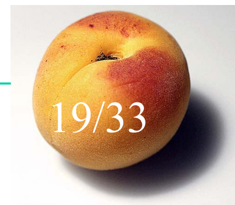
Cryo Aspects

- Feeds:
  - 300K: small windows, easy cooling, noise penalty
  - 70K: big window, moderate cooling, sub optimal noise
  - 15K: big window, difficult cooling, optimal noise
- Thermal decoupling at dewar output
  - Waveguide output / koaxial
  - Mixer inside/outside dewar



DC Supply

- MMIC DC supply:
  - single voltage: performance payoff
  - bus controled: safety issues
- PCB DC supply:
  - Single voltage, low current
- IF cabling:
  - Minimize interconnects
  - Cheep but reliable



Integration Density

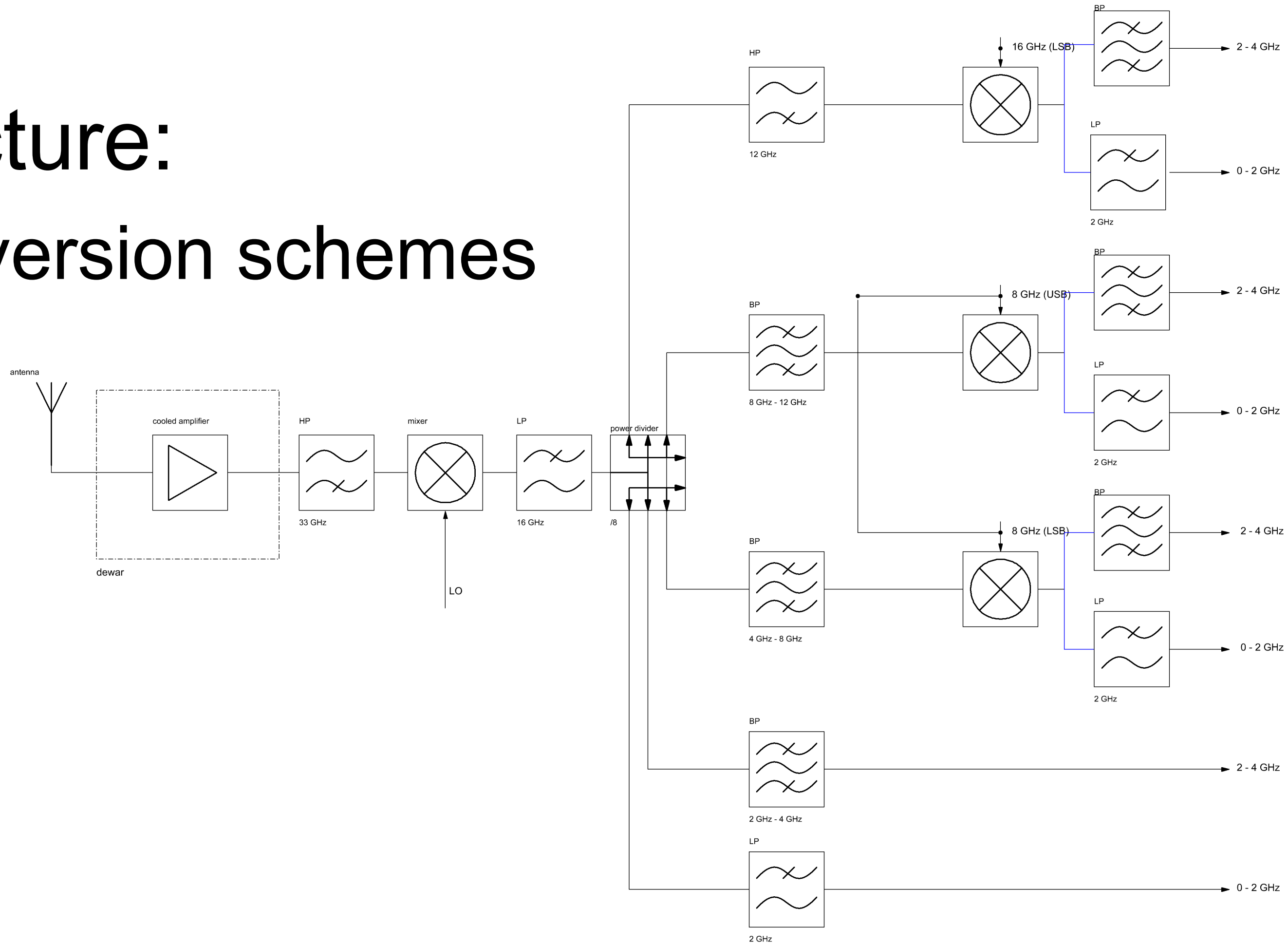
- WG Split Block
  - Feed
  - OMT
  - Active Components
- MMIC
  - LNA only
  - Down converters
  - Cal Source
- All in one Front End

Results

- Workshop “Science on Q-Band”
- Architecture Studies
- Component Developments
- Software Development

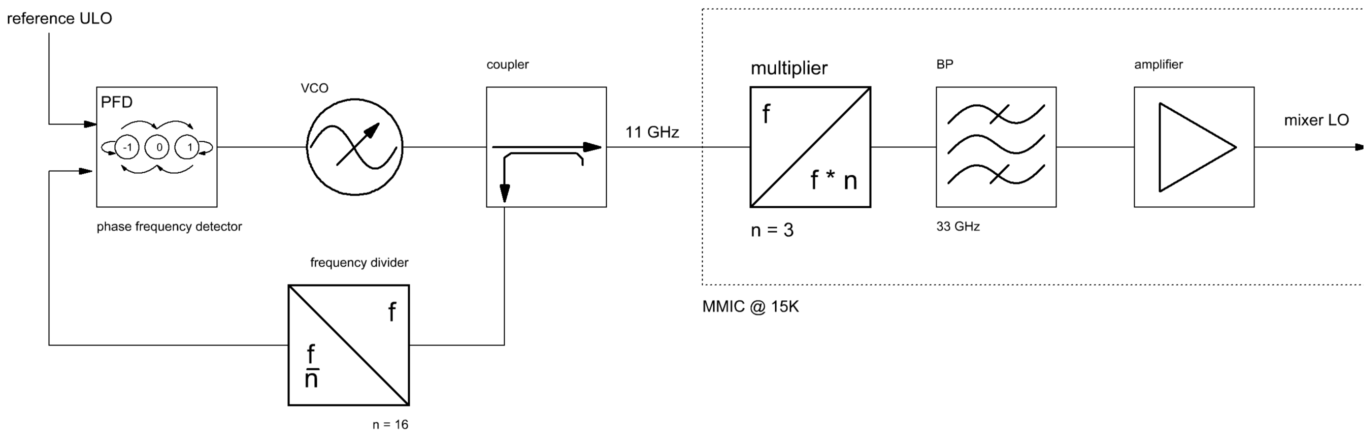
WP1: Architecture

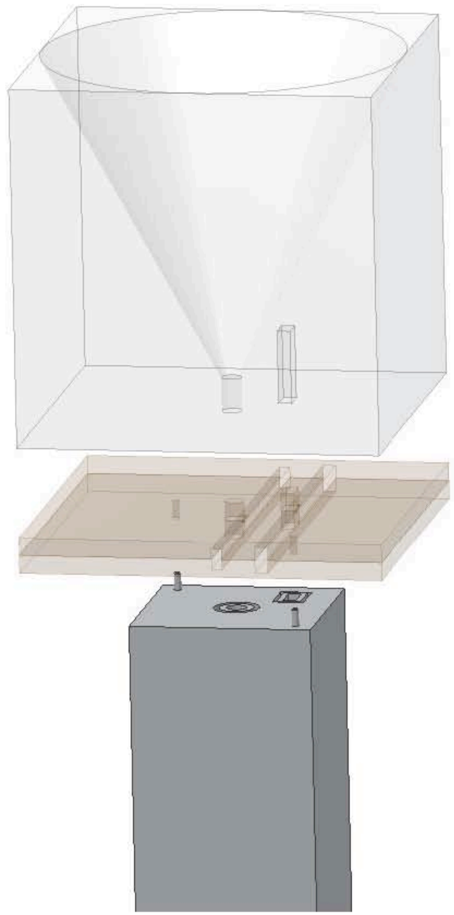
- RF Architecture:
  - Down conversion schemes



WP1: Architecture

- RF Architecture:
  - Calibration distribution
  - LO distribution





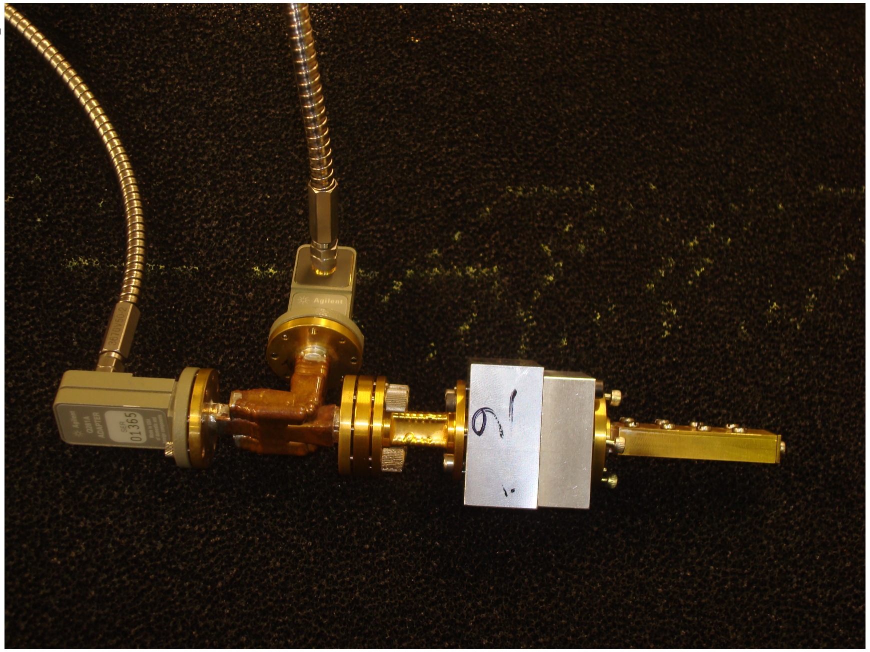
WP1: Architecture

- Mechanical Architecture
  - Horn arrangement
  - Pixel modules
  - Cryo aspects

WP2: Passives

1. work done on the classical solution of feed system chain: to be used as reference performance for comparison with the new solution in dense multifeed. We produced and tested a prototype of polarizer+omt in the 36-50GHz band (see picture 1). A corrugated horn has been designed and has to be constructed and tested.

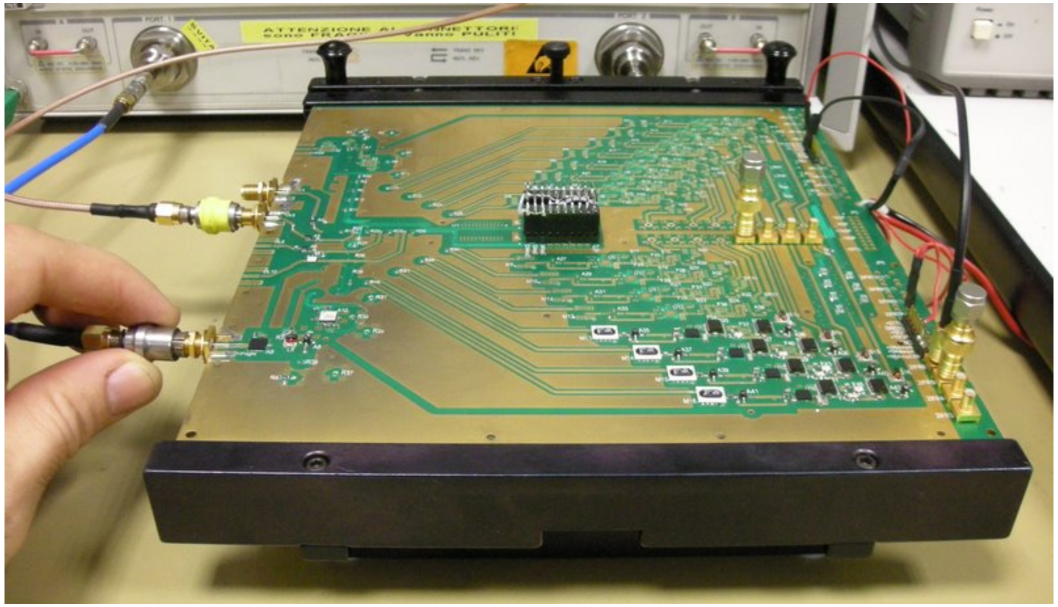
2. work done on acquiring information about the integration of a huge amount of identical feed system chains. The “platelet” technique is already in use, especially in challenging radio-astronomical projects related to CMB measurements, and it seems to be very attractive. Besides a look into a plastic-metallized feed system has started to be into consideration.



Test of a prototype of a Q-band polarizer+omt

WP2: Passives

3. work done on developing a new receiver architecture for the just completed Mfeed system in the 18-26.5GHz band, in order to exploit the 8GHz instantaneous band, splitted into 8x1GHz sub-bands, and on integrating in the receiver a continuum back-end with total power + polarimeter (see picture 2). The board contains down conversions and back-ends for all sub-bands for each pixel.



Prototype of a 3 to 11GHz multilayer board

WP3: Actives

- Major work in WP3 at Manchester is fabrication and testing of new InP transistor architectures. However because of delay in funding it has not been possible to start this activity at all as it relies on recruiting an RA to do the work
- Only related work was making noise measurement from 16 to 26.5 GHz using Manchester set up on Sergio's Mariotti's LNA. This proved to be quite good and gave confidence that the noise set up equipment is adequate.

WP3: Actives

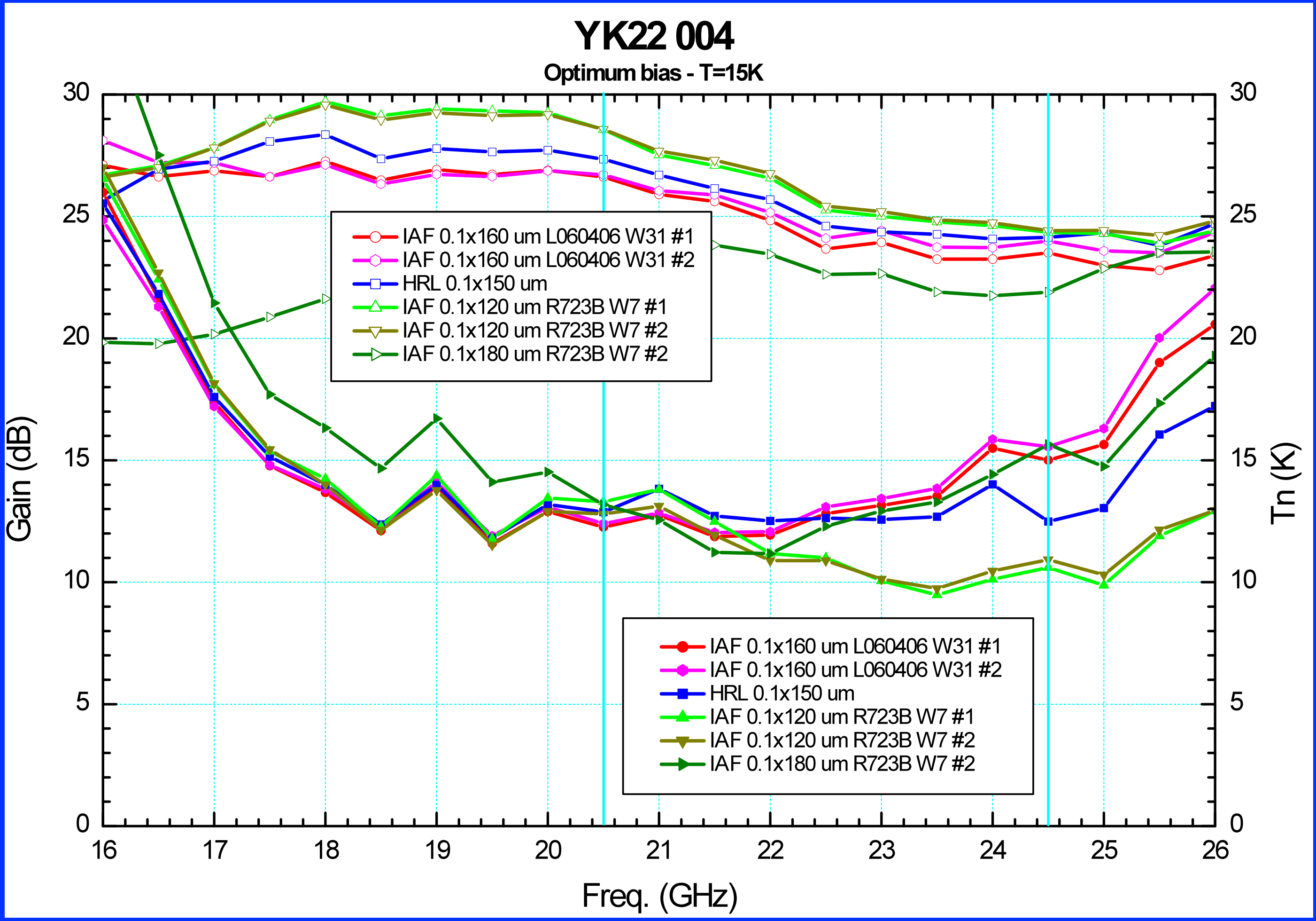
- We were hoping to provide Yebes with some 1um gate transistors from SKADS programme but these got delayed . Still planning on delivery some.

- Short term Plan is also for Andrea Cremonini to come and use cryogenic noise facilities in Manchester in readiness for when we make APRICOT specific transistors.

WP4: Measurements

- Recruits: 1 Engineer hired since Jan 2009. 1/3 of the time will be for APRICOT
- Agreements with Universidad de Cantabria (UC) and IAF signed for the development of cryogenic low noise technology. 1 post-doc position (own funds) already working at IAF.
- Cryogenic evaluation of some runs of IAF discrete mHEMT devices (see figure in next slide) with good noise results
- Cryostat recently modified for noise and gain stability measurements in coaxial up to 40 GHz
- Circulation of "standard amplifiers" for noise calibration comparison within different labs started with INAF

Cryogenic noise obtained with IAF mHEMT in a 20-26 GHz MIC amplifier. Comparison with HRL InP HEMTs.



WP5 contributions

Bartosz Lew – TCfA, Toruń Poland

Implementation of:

- sky motion simulator
- variety of sky Scanning trajectories (variations of rectangular grids, Lissajous trajectories etc)
- Scan Realizations with simulated orientation of rotatable matrix with arbitrary number and configuration of receivers
- Variety of scan trajectory visualizations
- GUI prototype

Development of:

- Optimization routines for improving scan time efficiency w.r.t. scan type and scan parameters
- Scan area uniformity and scan completeness checks (via eg. Monte-Carlo simulations)
- Simulations of high resolution mock radio (CMB) maps for TOD tests
- Simulations of real-life RT dynamics and accuracy tests in realizing assumed scan trajectories

WP5 contributions

Bartosz Lew – TCfA, Toruń Poland

To do:

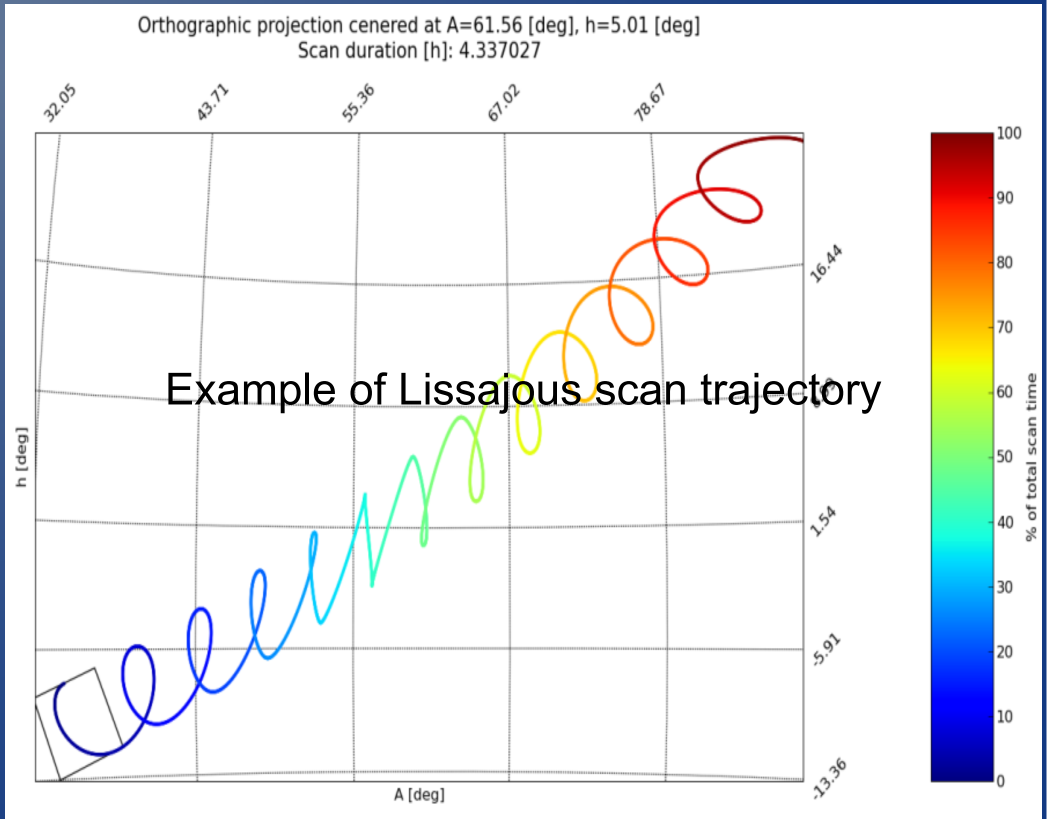
Data acquisition simulations including beam profiles

map reconstruction from TOD data – limits on systematical errors

Software tests on real-life RT (with OCRA-f project)

Include polarization simulations (Q, U and V)

Many other subtleties...



Example of Lissajous scan trajectory

Documentation, updates and tests:

The almost up to data information can be found at:

http://cosmos.astro.uni.torun.pl/~blew/scan_simulator.php

Conclusion

- Study has begun
- Specifications are still open
- Multi Pixel Cameras for
  - Effelsberg Q-Band, K-Band?
  - SRT
  - Yebes