Laboratorio di Radioastronomia

Scientists-Technologists

- Gianni Comoretto
- Renzo Nesti
- Andrea Lorenzani
- Antonietta Russo (2 Yrs)

Technician

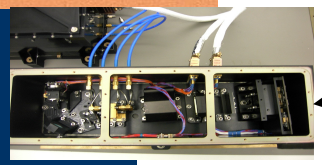
- Dario Panella
- Luca Cresci
- Salvatore di Franco (UniFi)
- Luca Carbonaro (Shared with other OAA Tech. groups)
- Piero Curioni (retired but still alive....)

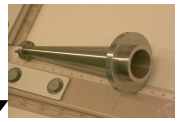
In 2007 team staff of 11 people

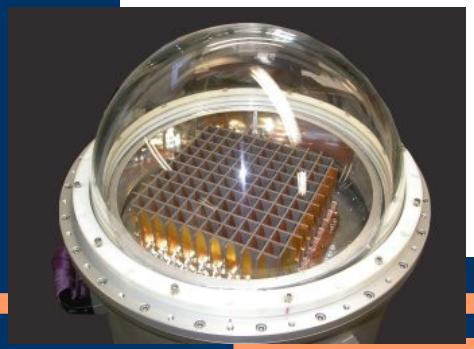
Activities

- RF optics design and testing
  - Feed horns
  - New techniques for waveguide components
- Receivers for cm-mm bands
  - Cryogeny
  - Low noise measurements
  - Large vacuum windows for RF wavelengths
- Back-end electronics
  - Fast (GHz) signal processing
  - Large programmable logics, GPUs

Activity synopsis







1980 1990 2000 2010 2020

Digital backends

Arcos

Doppler receiver (DTE)

Multibeam FFT backend

ALMA sampler

ALMA correlator

Herschel WIFI AOS

DBBC (Noto)

Uniboard (FP7)

SKA correlator

Feeds & EM Optics

Medicina 3cm 20cm 1.3cm

5cm

PLANK LFI

ALMA

SRT 5cm

32–45 GHz (FP7)

Compon. HTS

SRT 6mm

SKA

Receivers

350 GHz

43 GHz

18–26 GHz (FP5)

5–7 GHz (FP6)

18–26 GHz (Medicina)

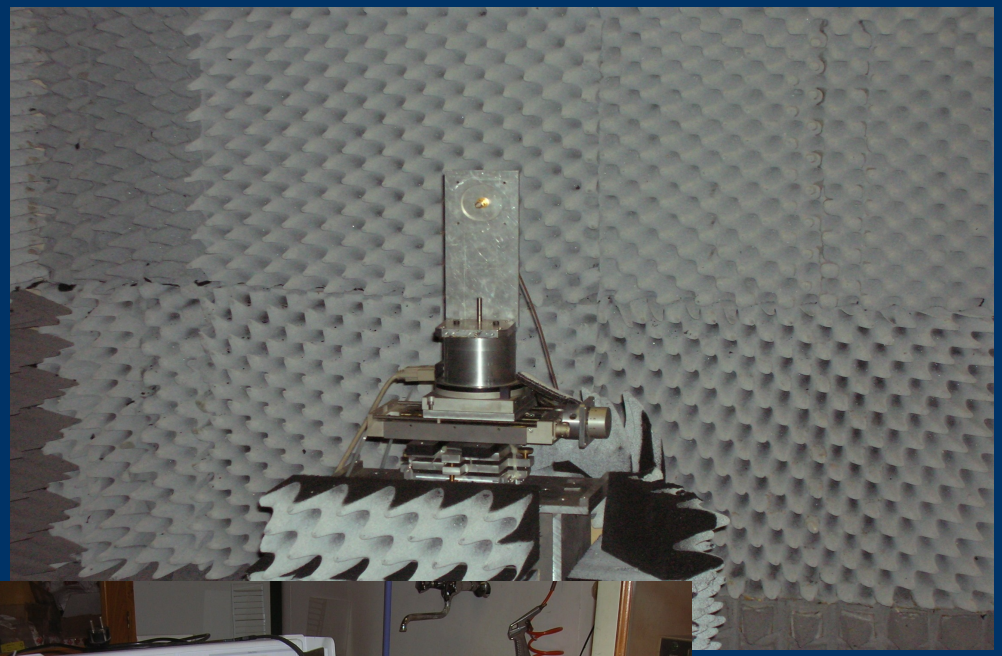
SRT 38–50 GHz

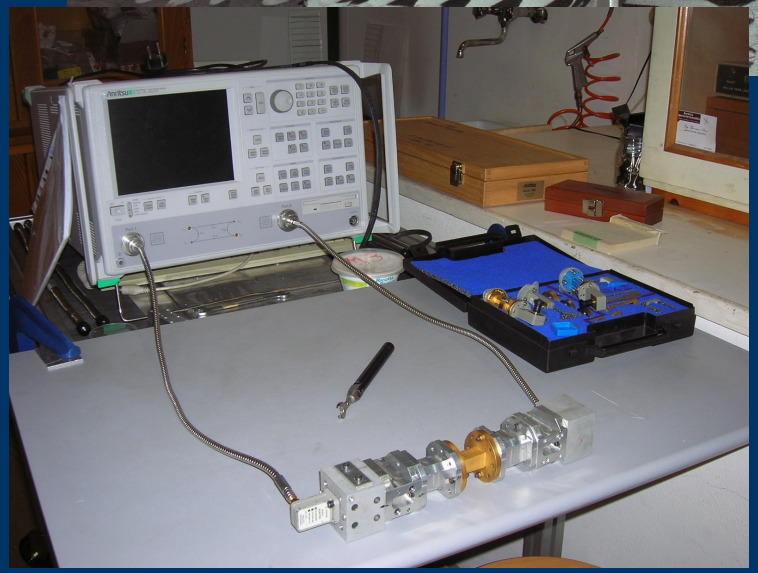
Telescopes

- Sardina Radio Telescope
  - Italian 64m radiotelescope
  - Begin commissioning phase
- Atacama Large Millimetre Array
  - Large mm wave interferometer
  - ESO-USA-Japan consortium
- Square Kilometre Array
  - Very large VHF-UHF-cm interferometer
  - Worldwide consortium
  - Design phase starting now

Laboratories

- Mechanic shop for prototyping, adjustment
- Small anechoic chamber for feed testing
- Microwave lab & Digital electronics lab

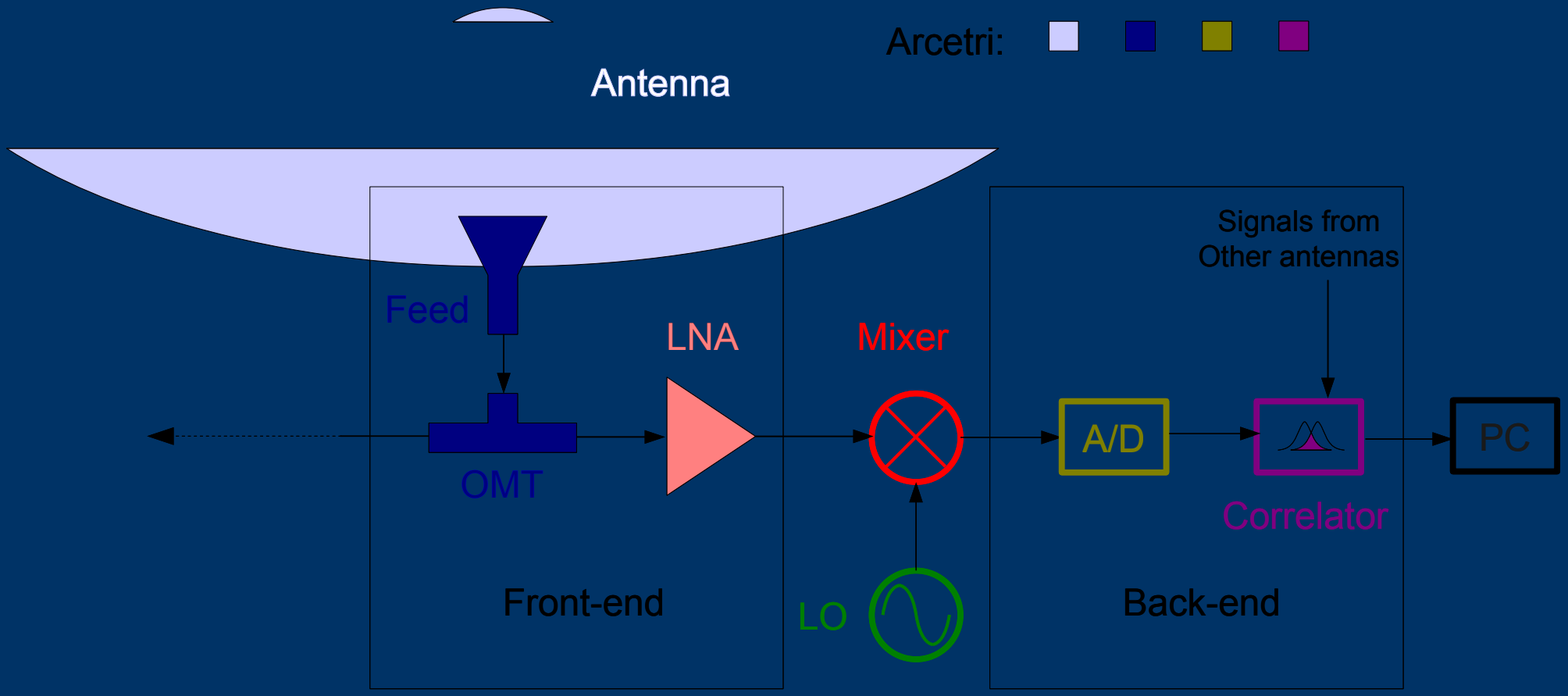




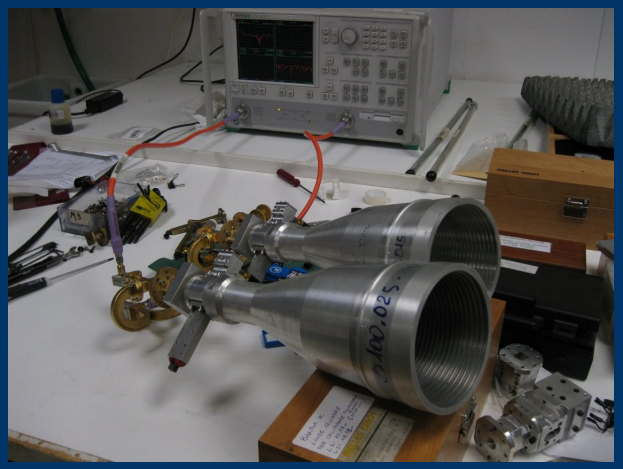
Front end receivers

- 0.3 – 90 GHz receivers for the Italian radiotelescopes
  - First light receivers for SRT
- Multibeam receivers
  - Gregorian 7-beam receiver for 18-26 Ghz
  - Focal plane phased arrays
- Microwave optic design and testing
  - Current research in easy to manufacture & cheap components for multibeam receivers
  - Technology transfer to industries

Radio Astronomy Receiver

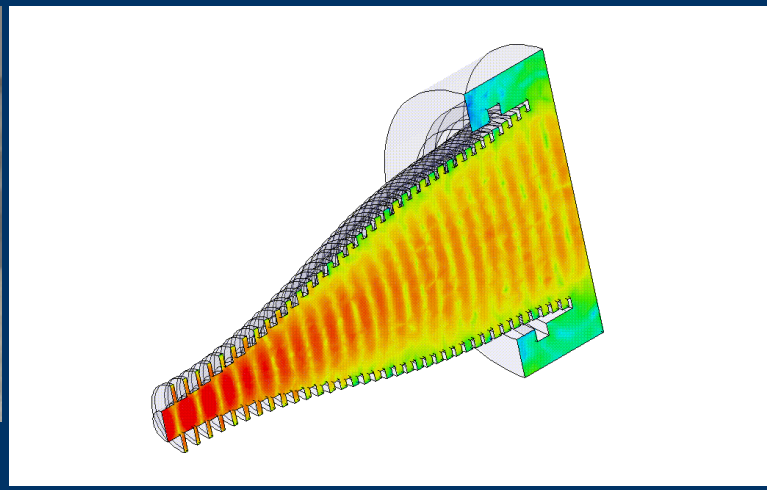


Circular Corrugated Feed Horns

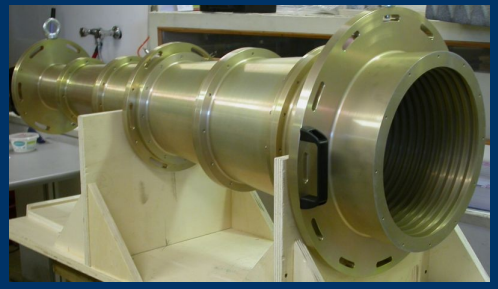


Med 22GHz

SRT 22GHz

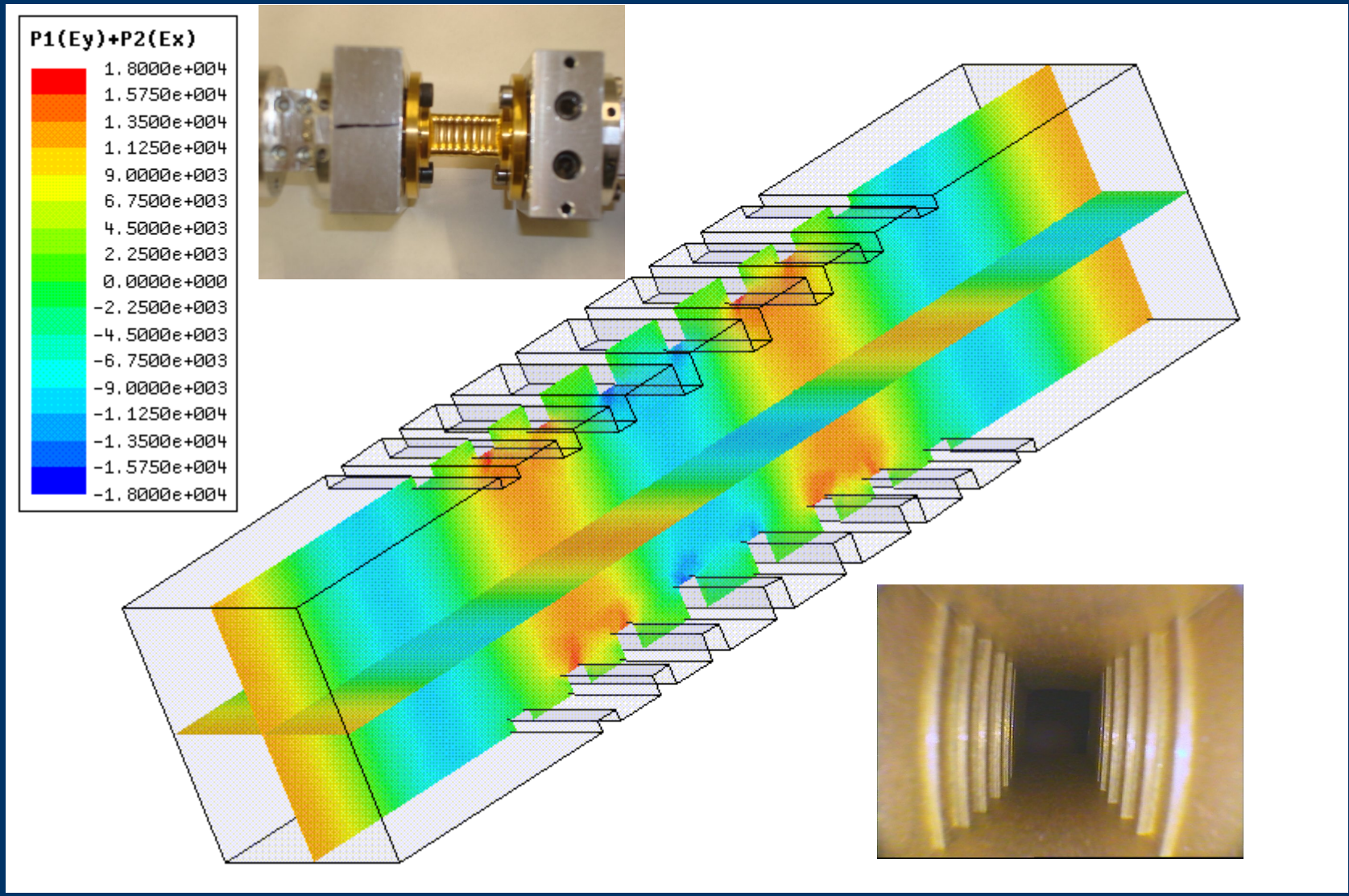


Array 43GHz



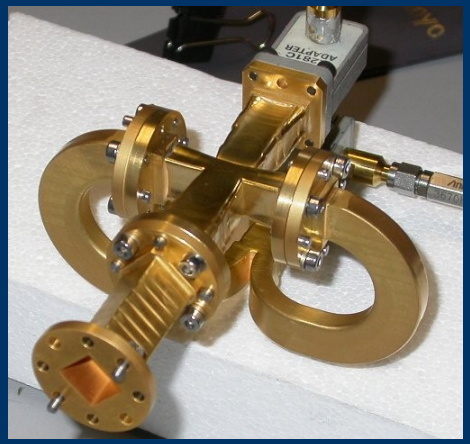
SRT 6.7GHz

Double Circular Polarization: Polarizer

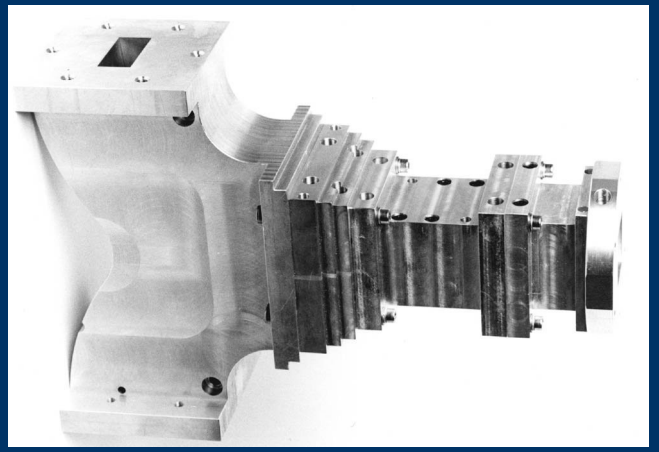


Orhomode Transducers

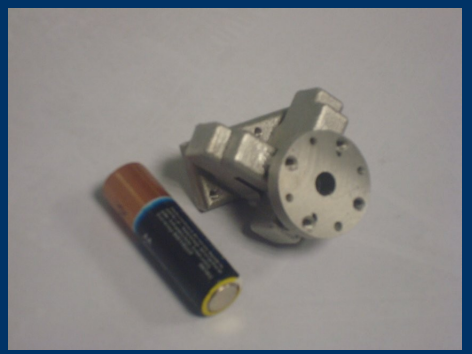
Med 22GHz



SRT 22GHz

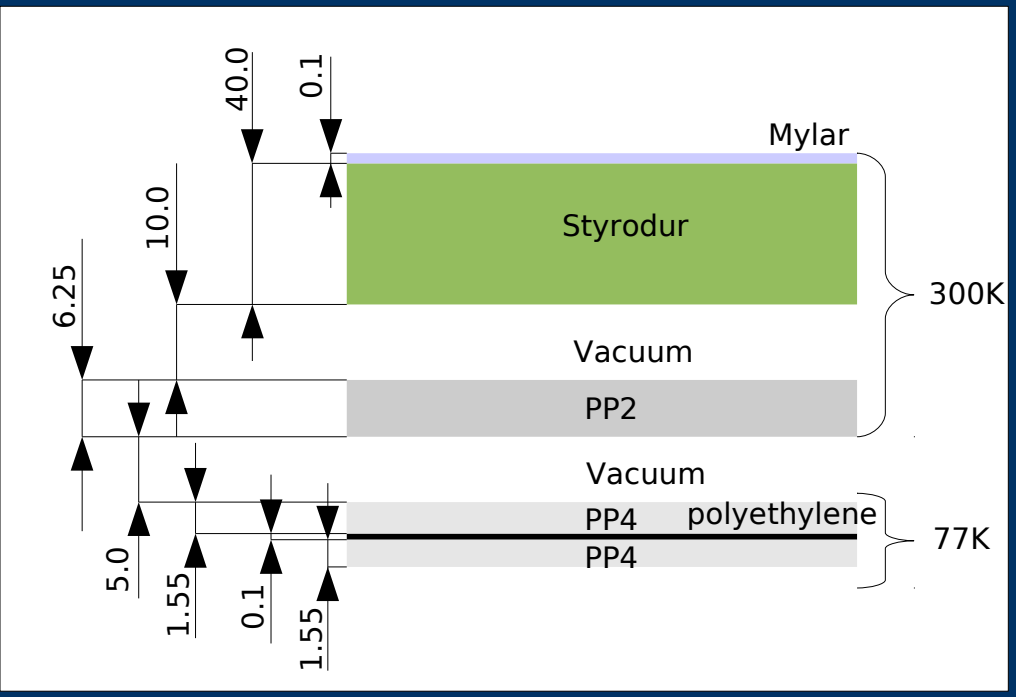


Noto 6.7GHz (Pol.)

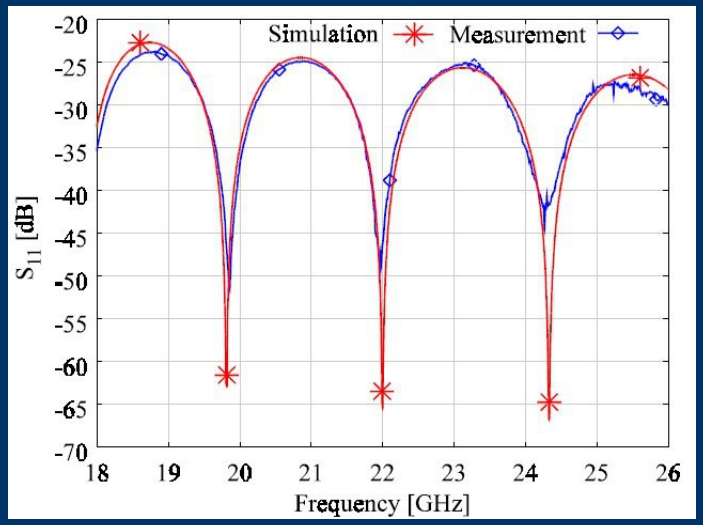


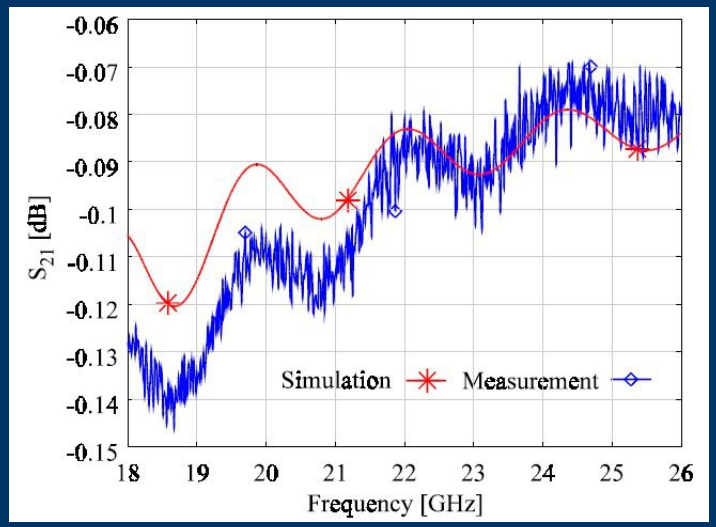
43GHz: Platelet Electroformed 3D Laser Melting

Dielectric characterization of vacuum window materials



Amplitude Reflection/Transmission Measurement





	Electrical properties	
Material	ε_r	$tan\delta \cdot 10^2$
Mylar(2)	3.5	8.0
Styrodur(2), 3035CS, 5000CS	1.045, 1.050, 1.070	0.007, 0.003, 0.003
PP2	1.04	0.02
Vacuum	~1	~0
PP4	1.08	0.1
Polyethylene	2.24	0.2

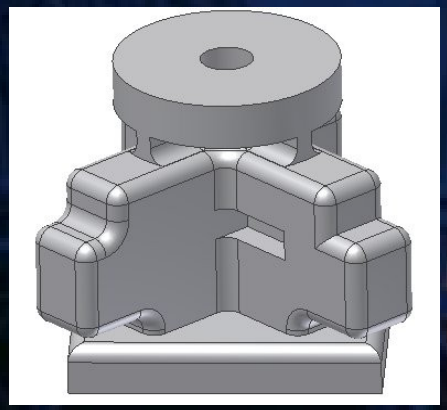
Radionet FP7 *APRICOT*

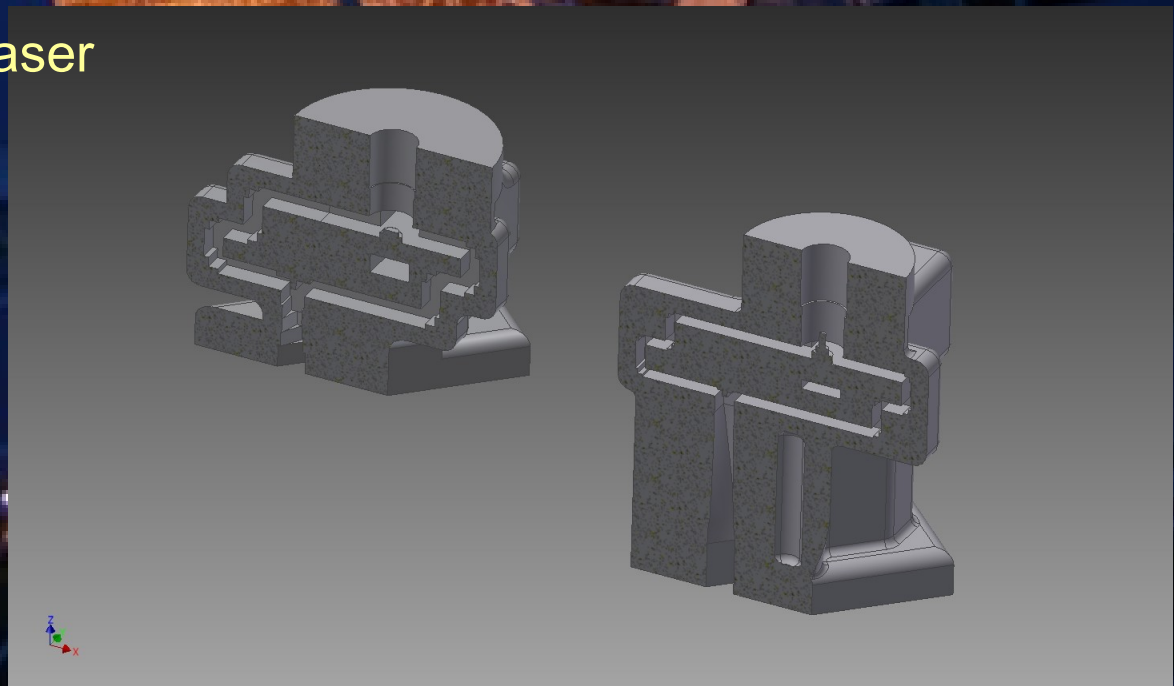
Multifeed 43GHz (Q-Band)

7 Corrugated Horns - Low cost (5.3K€)

Orthomode Transducer Array

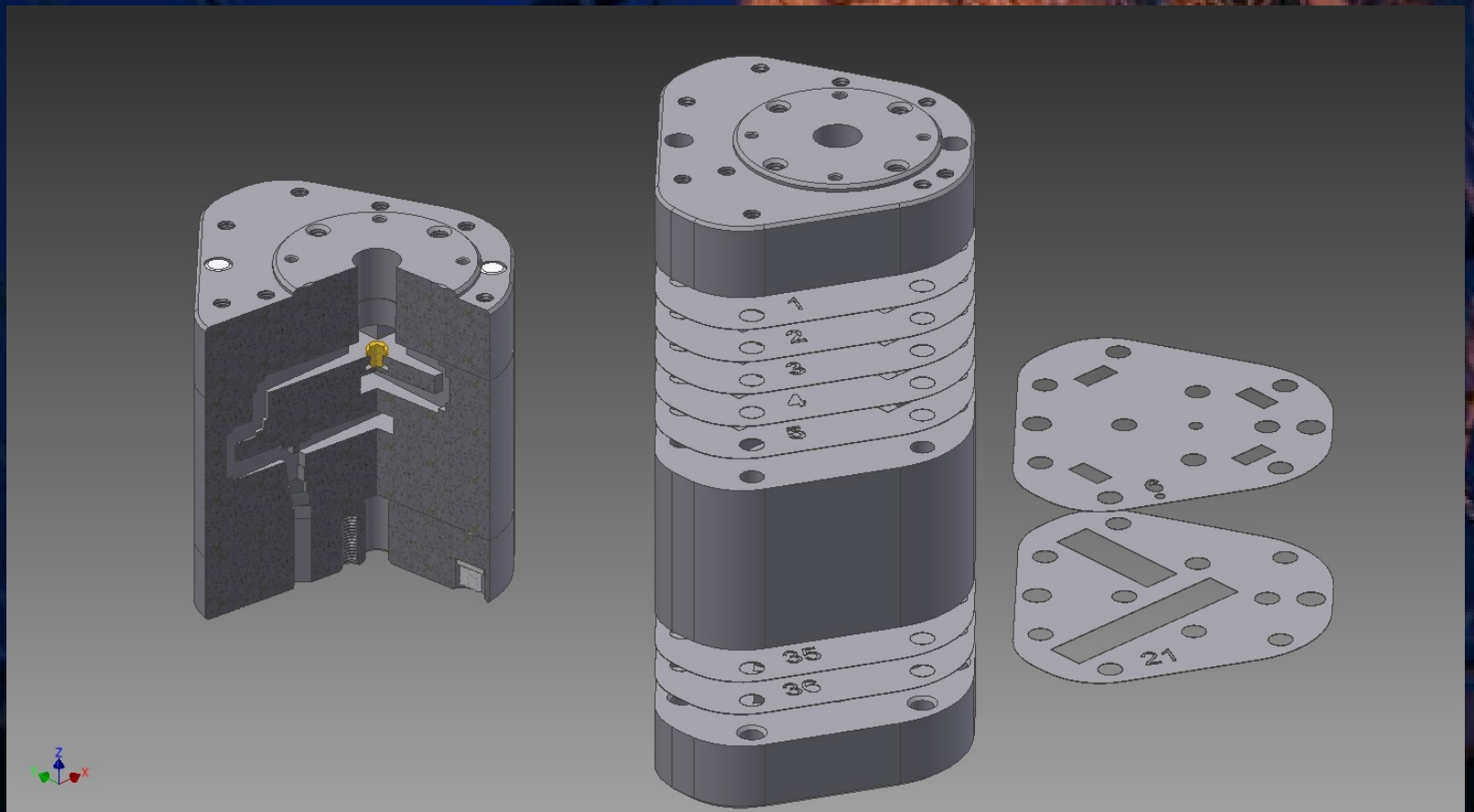
- EM Design for High Performances – Low cost
- Cost-Estimate: 0.5K€ x 7
- Mechanical 3D-model for 3D-laser prototyping





ASI-2007
Progetti di sviluppo Tecnologico

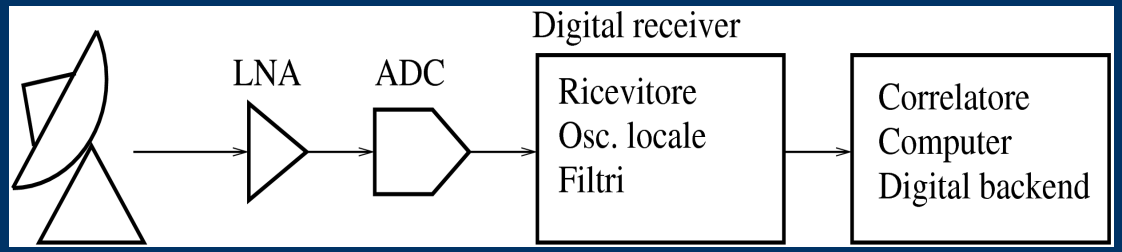
- Low cost (4.3K€+7x0.6K€) Q-Band Orthomode Junctions
- High Performances
- Designed for SRT Receiver



Radioastronomy backends

- Digital backends for Italian radiotelescopes
  - Medicina & Noto ACF spectrometers
  - 16 ch. FFT spectropolarimeter for multibeam receiver
- Participation to ALMA correlator
  - TFB upgrade: x32 spectral resolution
- Fast wideband platforms for general purpose backends
  - DBBC (VLBI standard backend)
  - Uniboard (FP7)

Digital radioastronomy



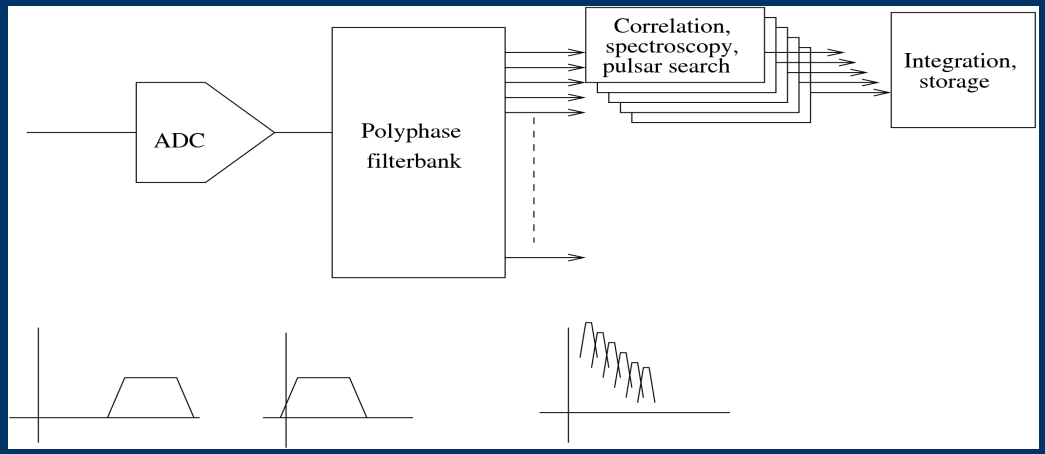
- Digital receiver
  - Wideband input
  - Limit: RF = only the LNA
  - Digital output (10G Eth) for recording or on-line processing (GPUs)

- Digital backend
  - Spectropolarimety
  - Interferometry, beamforming
  - RFI mitigation

Advantages: uniformity e predictability, high insulation (RFI) , compact
Same instrument reprogrammed for different functionalities
Exploit Moore law

Digital radioastronomy

- Typical processing
  - Wideband ADC: 1-20 GHz BW, 1-10 GS/s
  - Filterbank: produces several (16-1000) narrow bands, at “reasonable” data rate
  - Processing: heavy parallel, in programmable logic or GPUs
  - Postprocessing and storage on generalpurpose computers
- Problems:
  - Fast data ra
  - Interferometry, beamforming
  - RFI mitigation

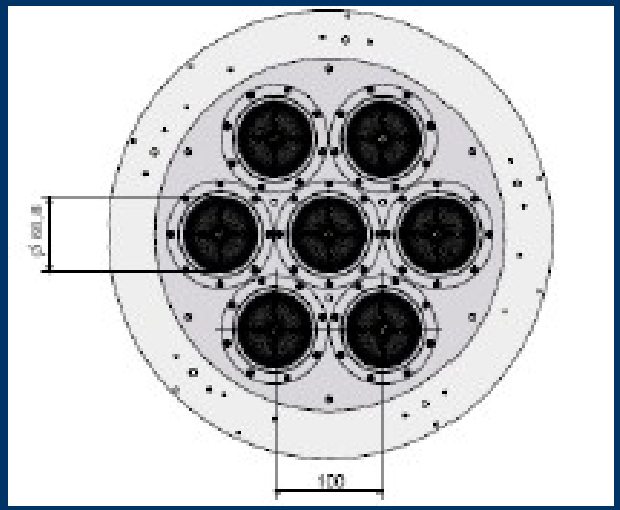


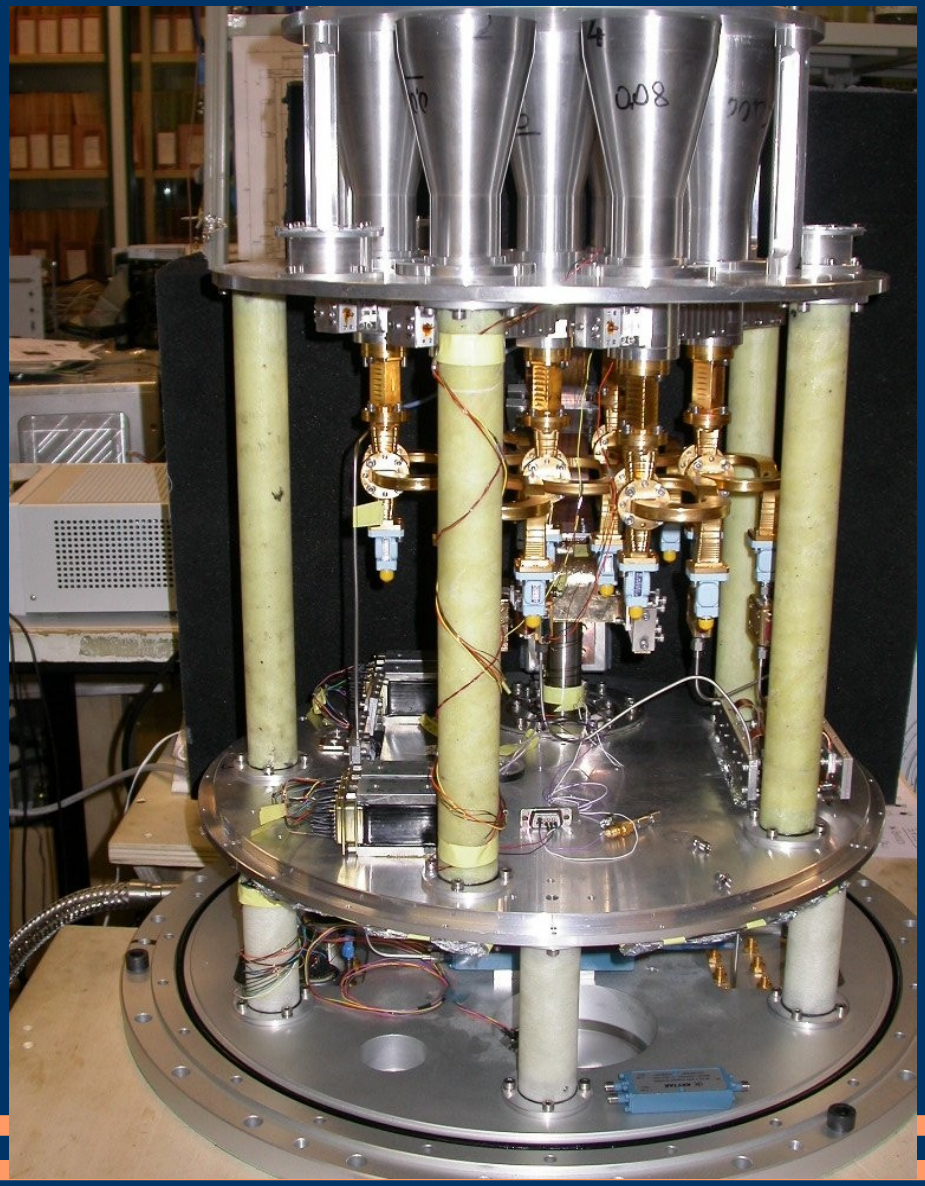
Sardinia Radio Telescope

- 64 m reflector dish antenna
- Frequency range: 0.4-116 GHz
- Active surface control (0.15 mm) – laser ranging, holography
- Three foci: Gregorian, secondary and waveguide
- Science:
  - Pulsar timing and search
  - VLBI
  - Survey of molecular spectral lines
  - Tracking of Interplanetary probes

FARADAY - FP5
18-26 GHz Multibeam

- 18-26 GHz multibeam (Faraday – FP5)
- Based on MMIC InP amplifier
- 20 K T_{sys}, 2 GHz instant. BW

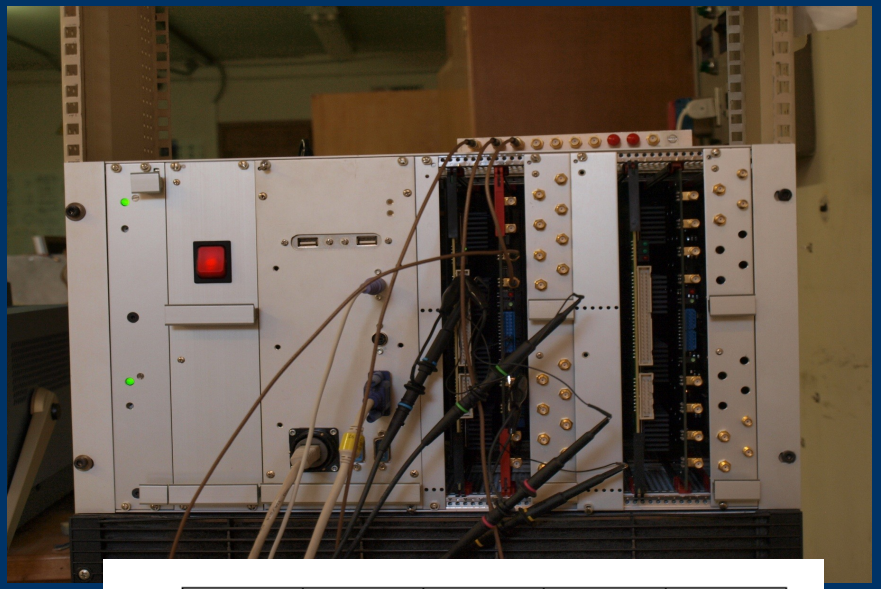


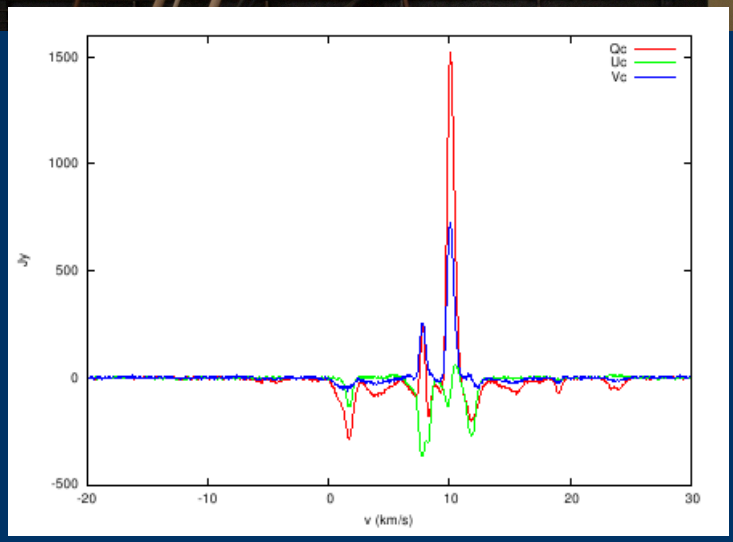


Multibeam spectrometer for SRT

- 16 channel spectrometer
  - 8 ch full polarimetric
- 0.5-80 Mhz bandwidth
- 2048 spectral points

- Based on tunable filter boards from ALMA correlator

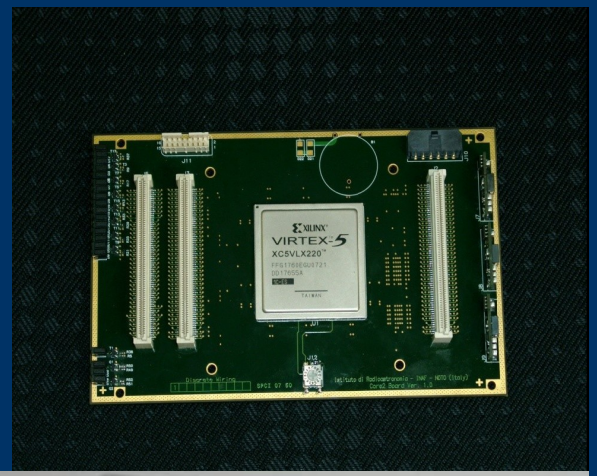


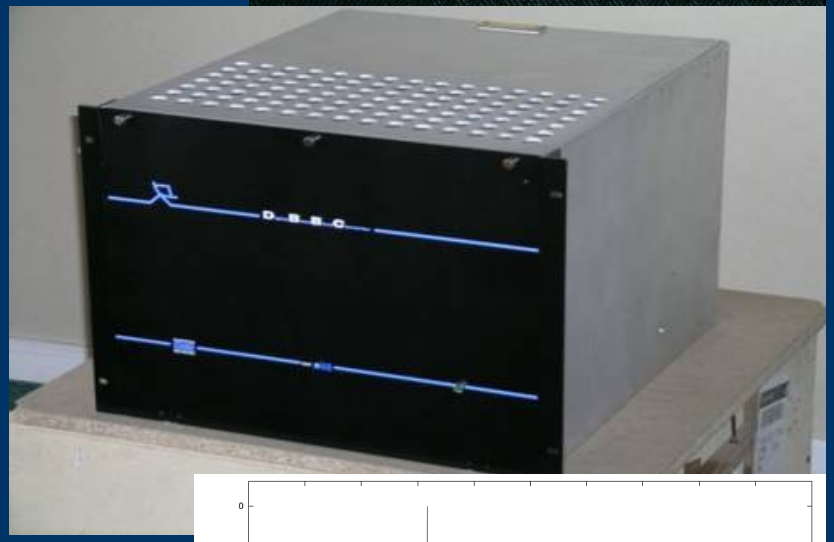


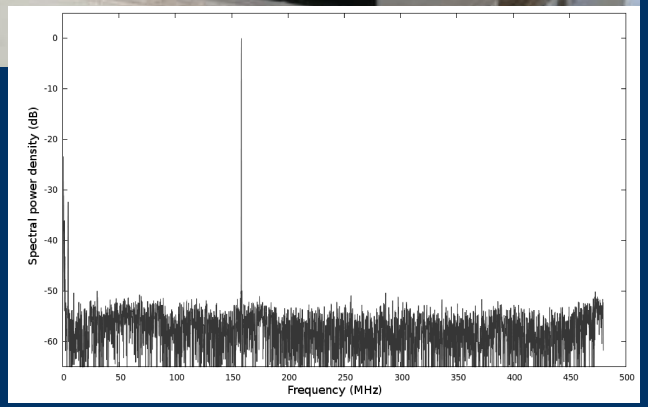
Polarized emission from Orion H2O maser

Digital BBC

- Standard for digital VLBI
- Modular system: small boards for ADC and processing
- Work in Arcetri:
  - Standard application (VLBI receiver)
  - 500 Mhz spectrometer
  - 32 channel polyphase filter

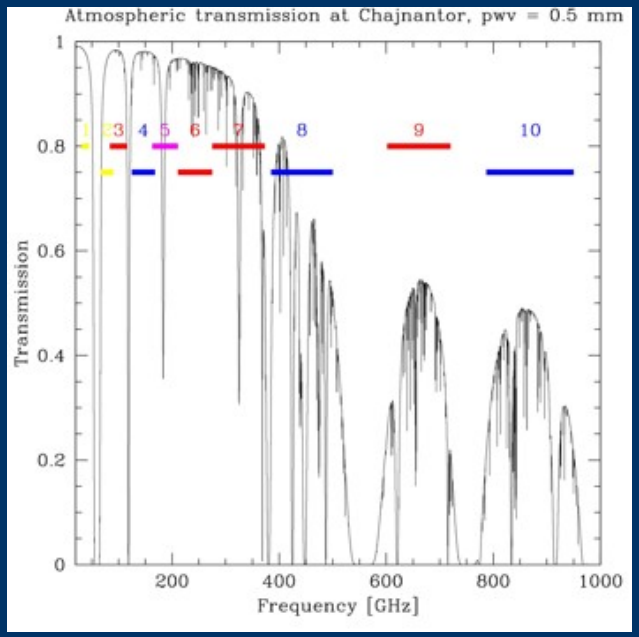


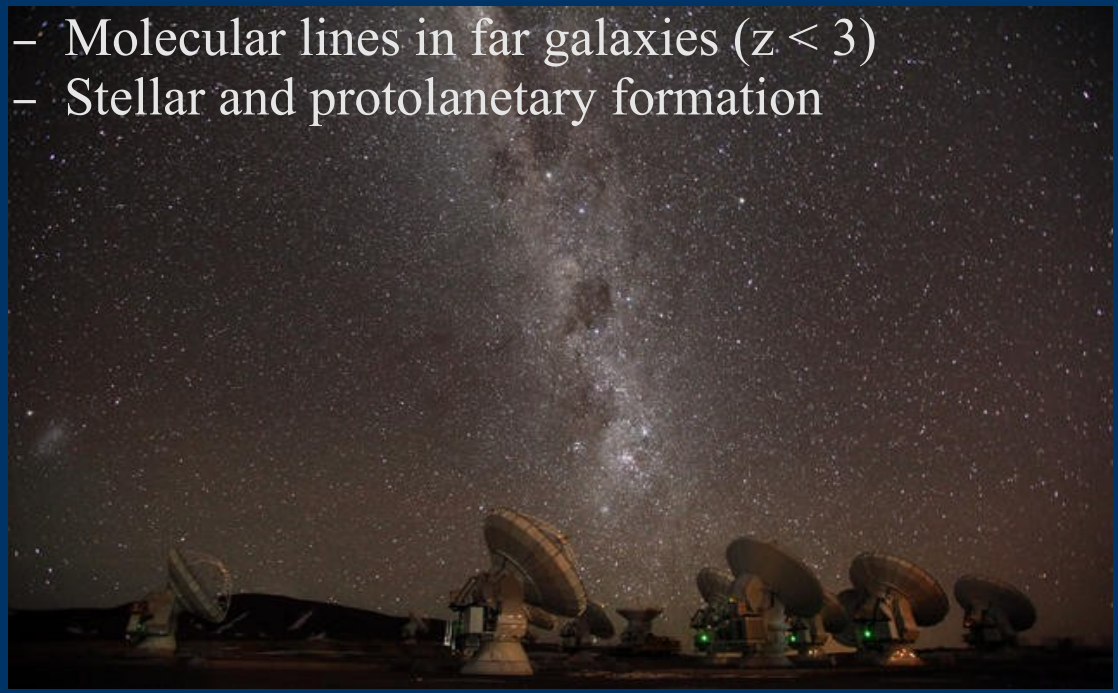




ALMA interferometer

- 60x12m antennas + compact array of 12x7m antennas
- Variable configuration: 150m – 17 km
- Site at 5000m elevation at Chajnantor plateau (Chile)
  - Frequency range: 40-950 GHz (0.3-7.5 mm)
  - Angular resolution: 6 mas-0.7 arcsec
  - Spectral resolution 3.8 KHz-15 MHz (10 m/s)
- Science:
  - Molecular lines in far galaxies (z < 3)
  - Stellar and protolanetary formation





ALMA correlator

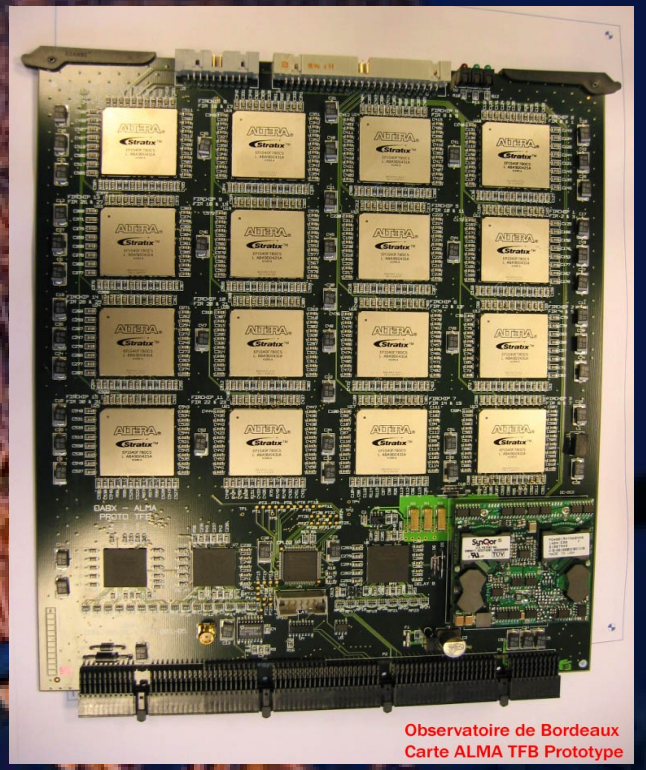
- Original correlator: 1024 points over 8 GHz
  - 4x 2 GHz correlator, time multiplexed
  - 32 correlator planes analysing same data in parallel: limited resolution
- Proposed modification: 32K points over 4 GHz
  - No extra cost - substitutes a band delimiting filter with an array of digital tunable filters
- Accepted in 2003
- Not a INAF *institutional activity*

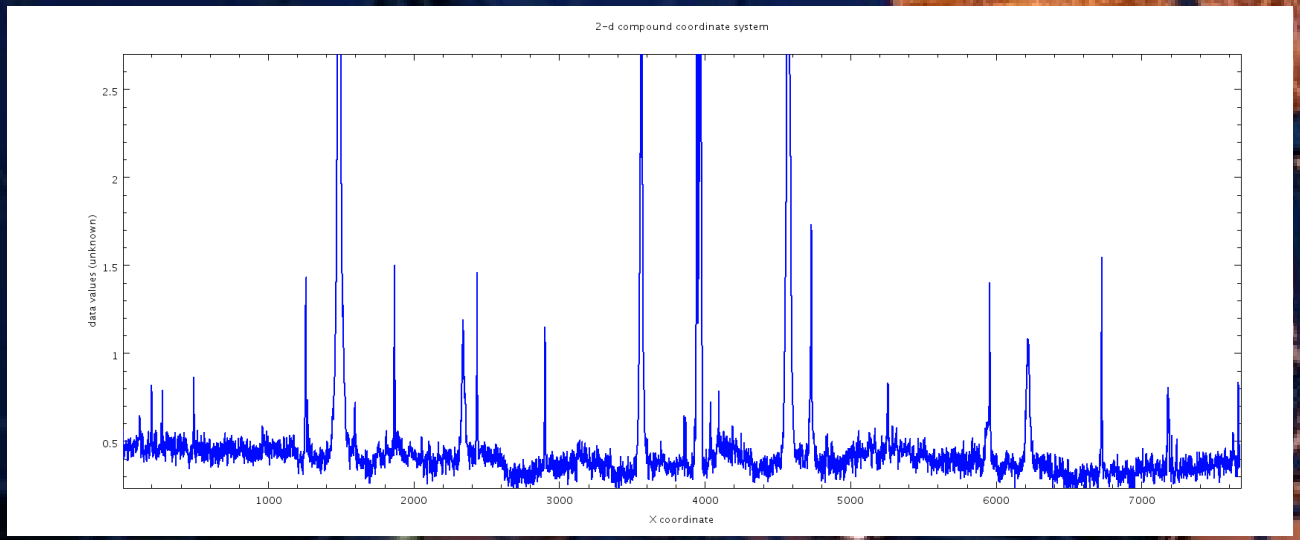
ALMA correlator

Digital receiver bank to improve correlator resolution

32x resolution at 2 Ghz

Independent sub-channels at lower bandwidth





Banda SiO in Orione – 2 GHz

Square Kilometre Array (SKA)

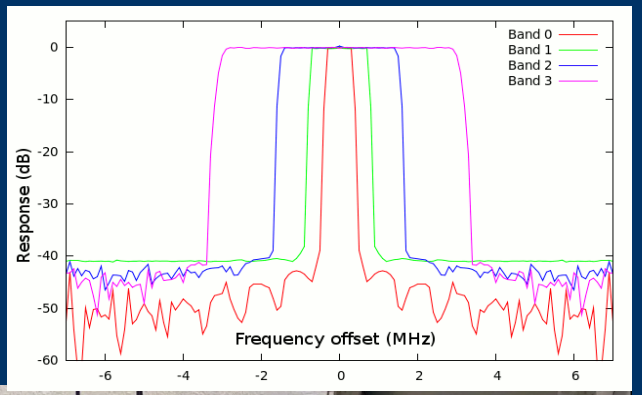
- 10^6 m^2 collecting area – sited in South Africa & Australia
- Frequency range: 60MHz-16GHz
- Low frequency using aperture arrays
- High frequency using small (~10m) dishes
- Multiple (~1000) beams for fast surveys
- Science:
  - Pulsar search and accurate timing (GR tests)
  - H survey up to the “dark age” (z= 20)
  - Galaxy formation and evolution
- Technology
  - Cost effective (1000's antennas)
  - Correlator: scales as n^2
  - Data transport and storage

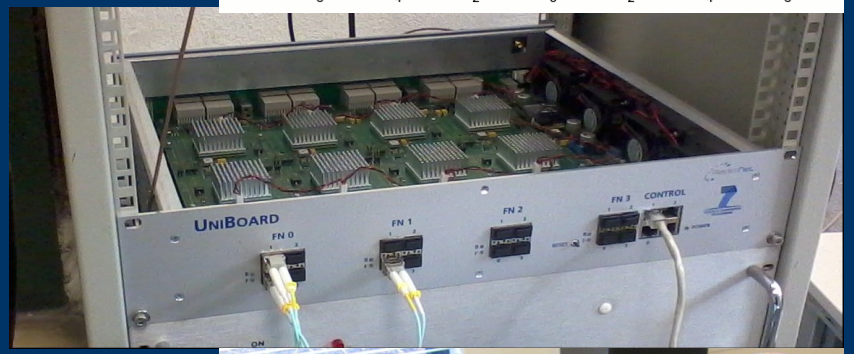
Uniboard

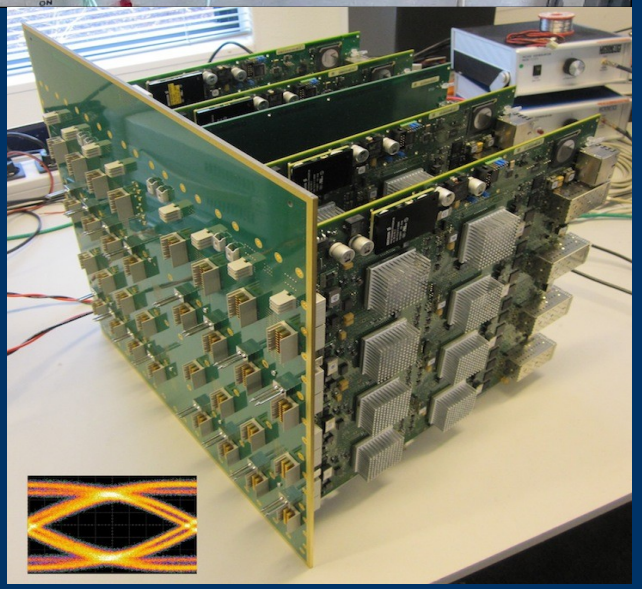
High performance platform for correlators & LOFAR beam former
Potential SKA physical platform

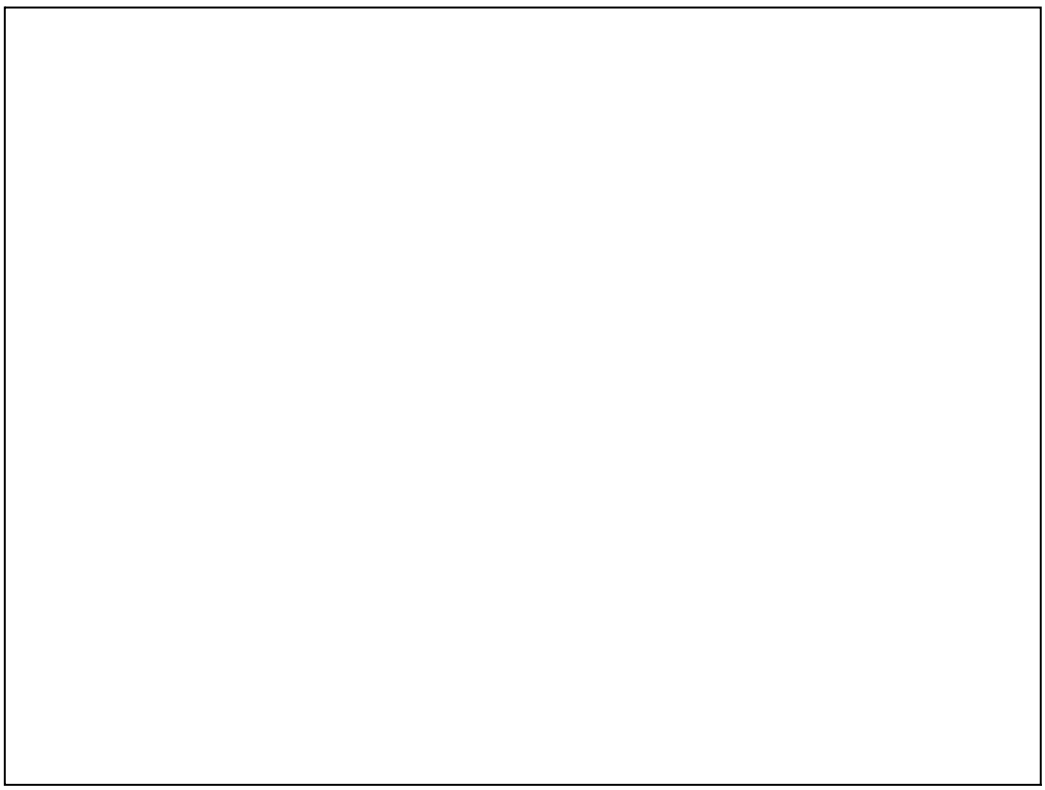
Work in Arcetri

- Digital receiver
  - 4 Ghz BW input
  - 64 output channels, tunable, band 1-128 MHz
  - Output on 8 10G Ethernet
  - Used as a component for pulsar receivers, RFI mitigation, etc

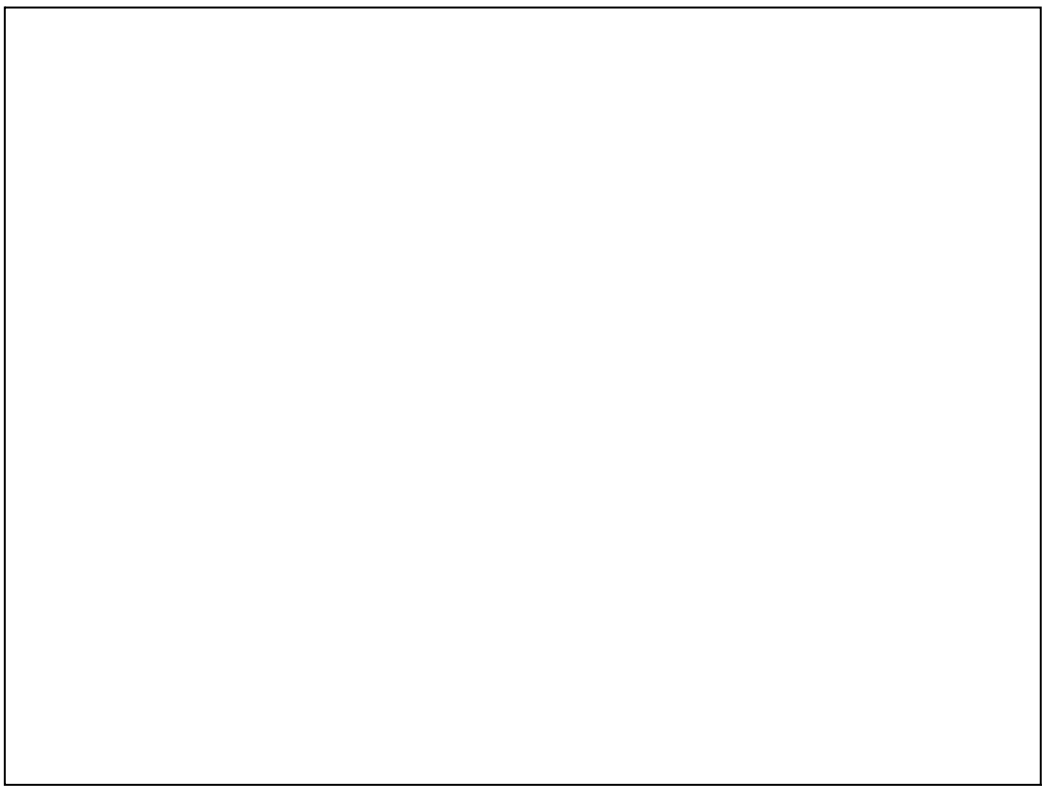




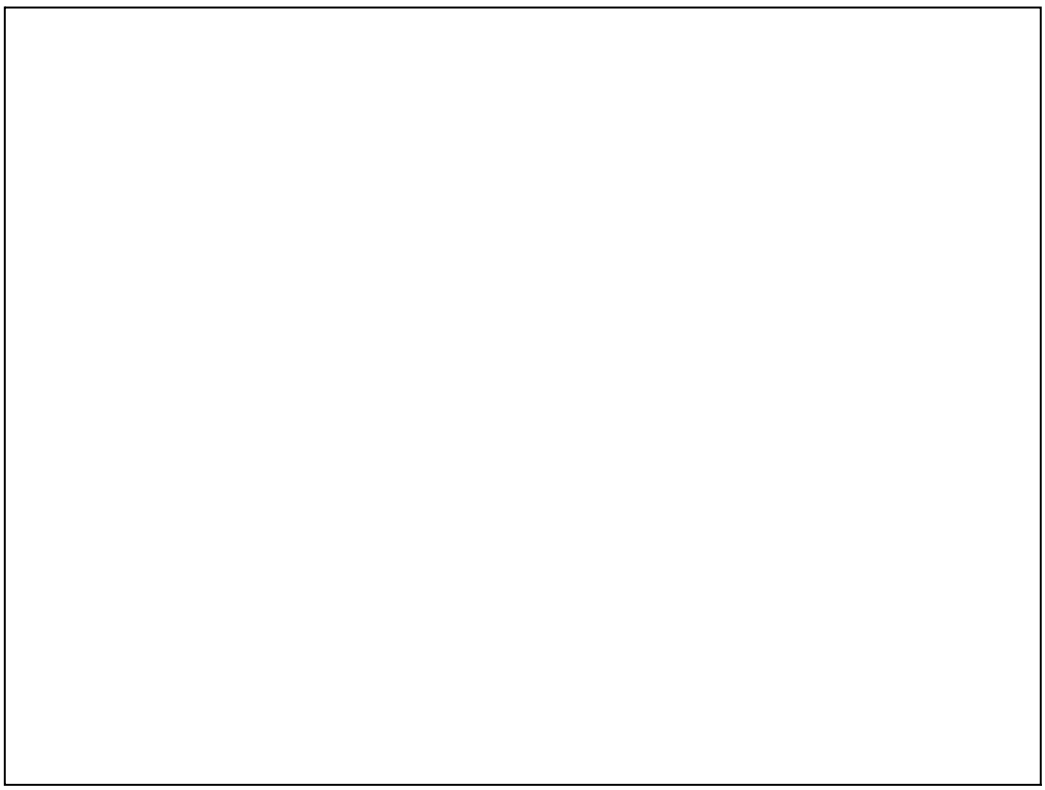




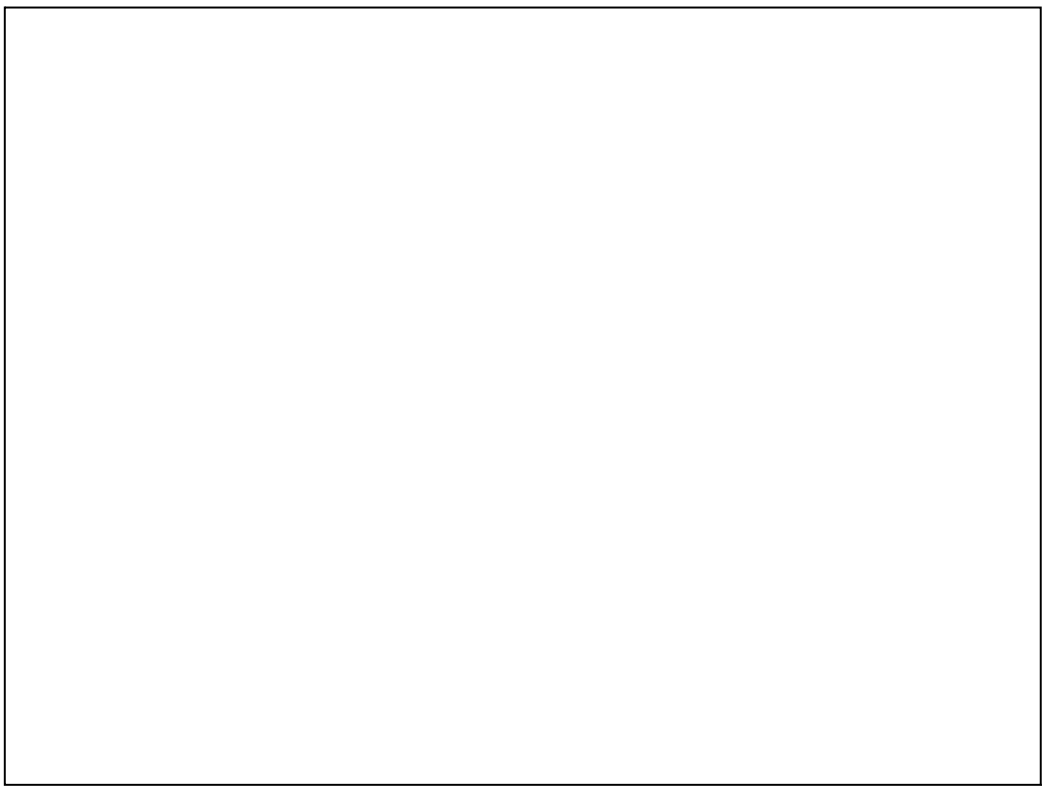
Small group. Works seamless with IRA-FI
One researcher. IRA FI group shrinking due to retirements
Limited funding



Laboratory: prototyping and mechanical design
Fabrication done externally (electroforming, machining)
Same for electronics, capability to mount SMD but on small scale.
Microwave testing: used by the Florence university



Synopsis activity:
2 main areas, digital electronics and microwave optic design



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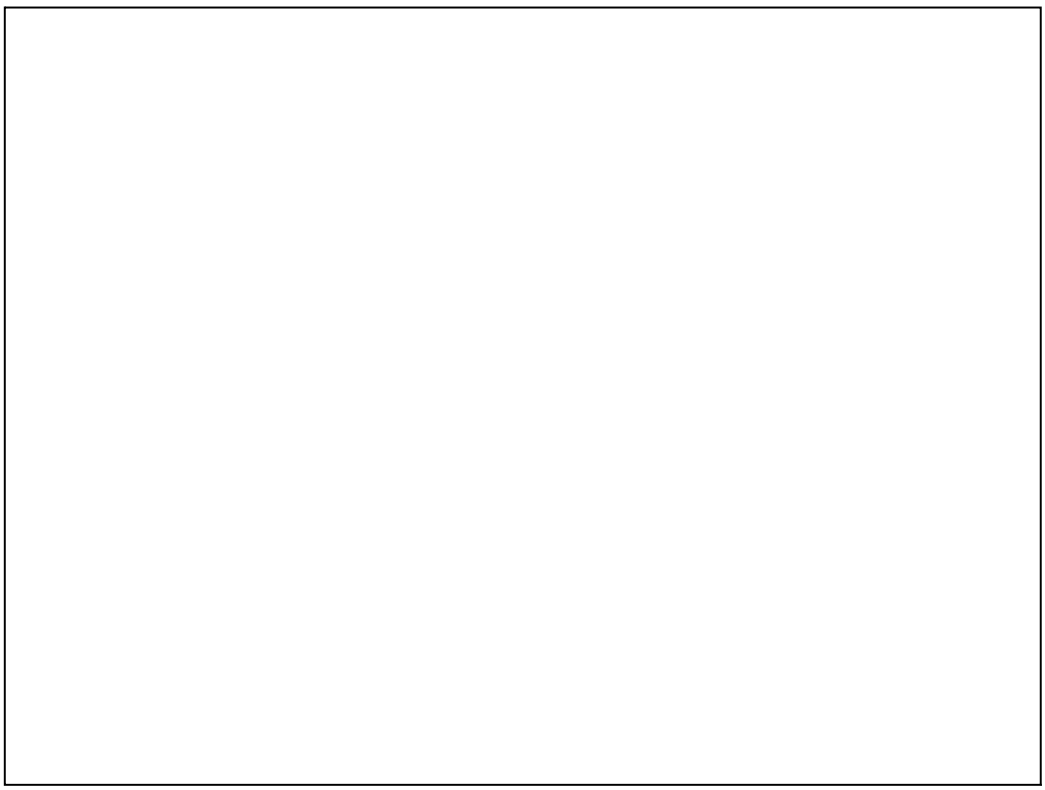

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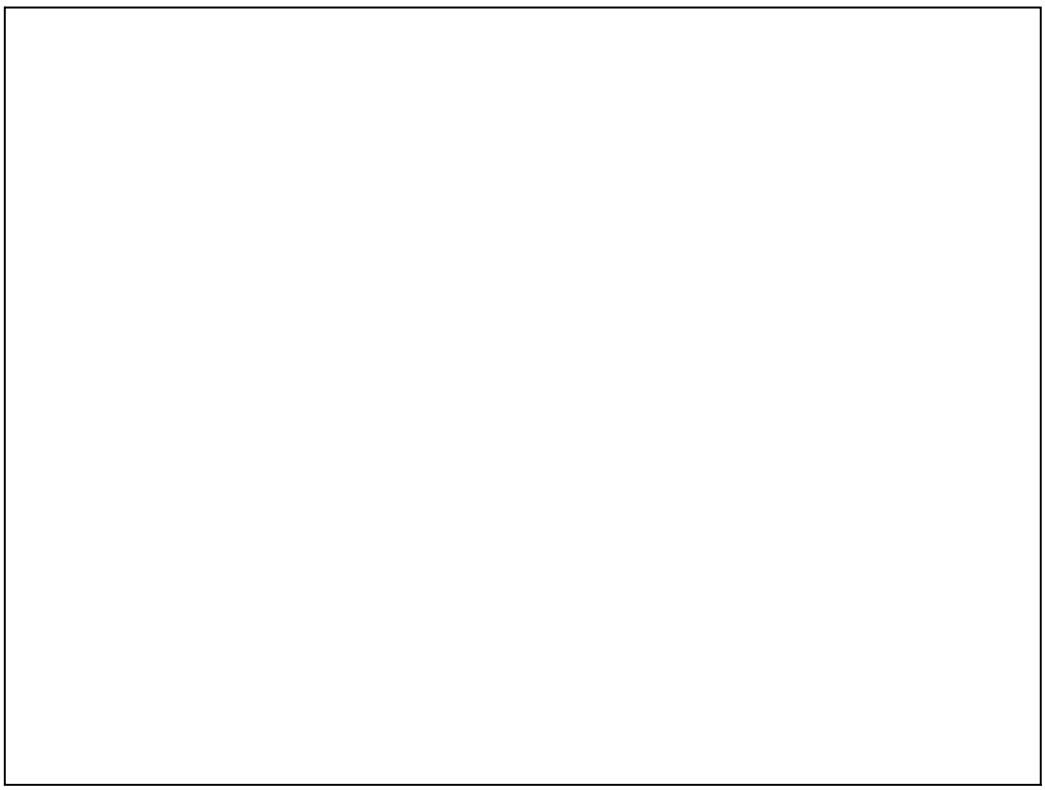
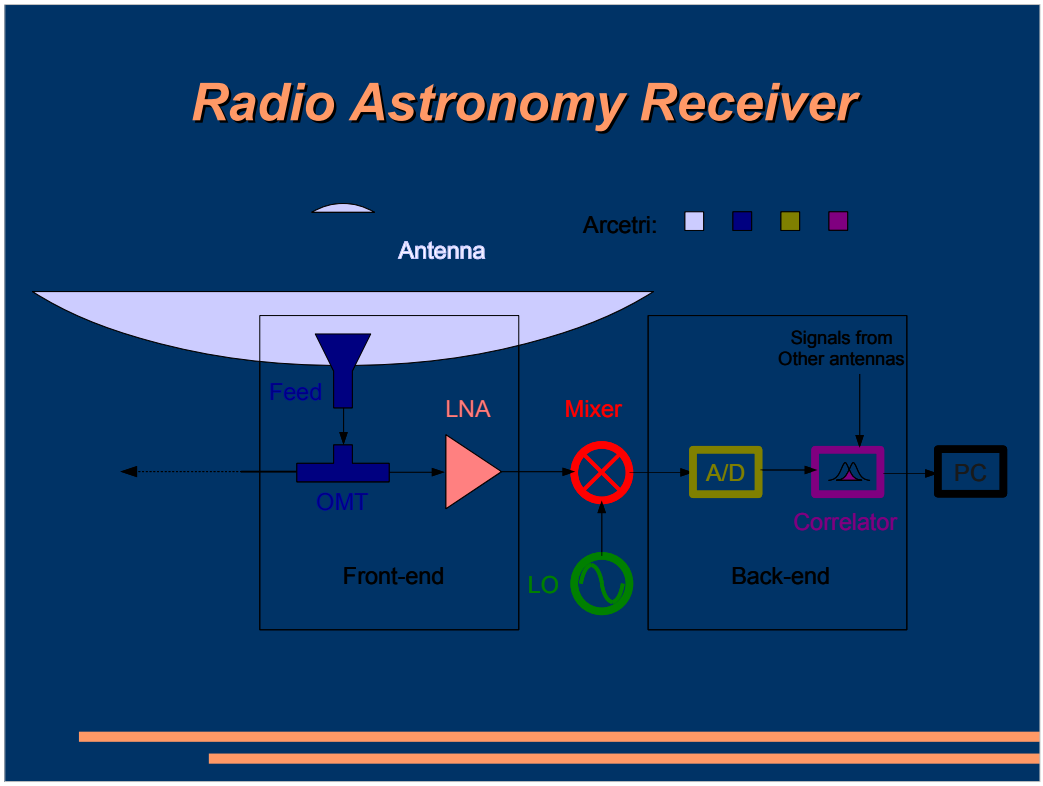
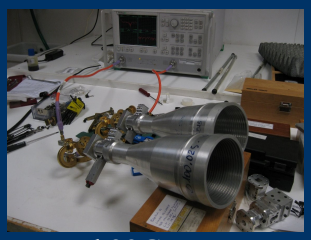


Historically main expertise on electromagnetic optic design & testing
Collaborations with Florence & Pisa Universities
Design & construction of several receivers from 6 to 350 GHz
43 GHz cooled receiver for Noto
Recently multibeam receivers, because single receiver approaching quantum limit
Problems of large cryostats, vacuum windows, compact and economic design
Simple to build, reproduce

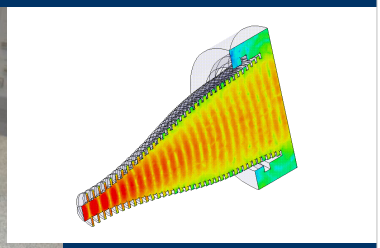
Radio Astronomy Receiver



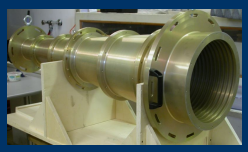
Circular Corrugated Feed Horns



Med 22GHz

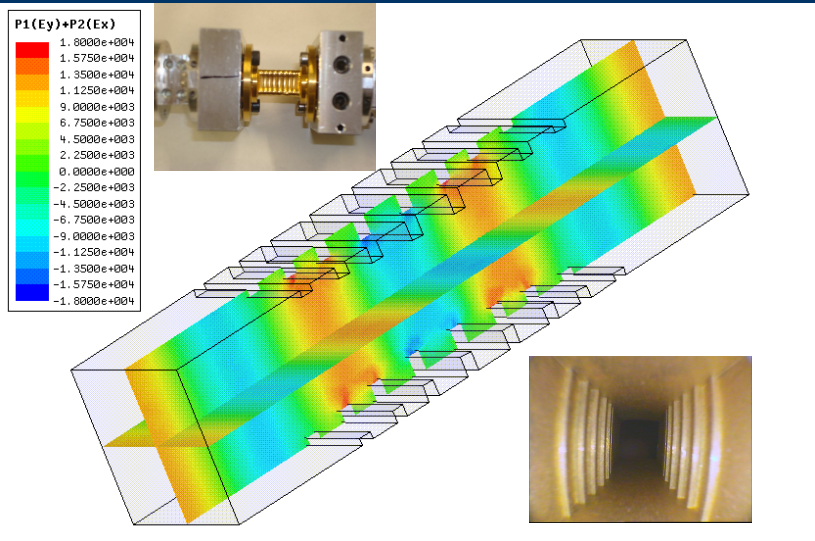


Array 43GHz

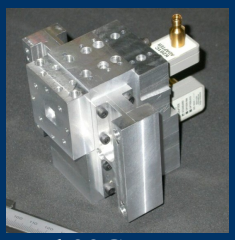


SRT 6.7GHz

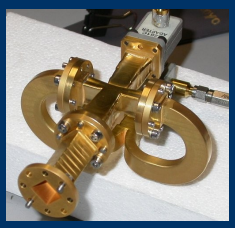
Double Circular Polarization: Polarizer



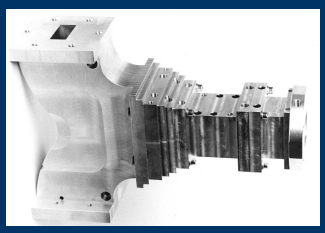
Orhomode Transducers



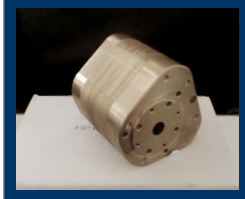
Med 22GHz

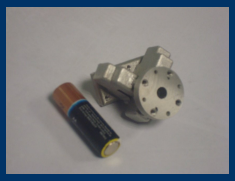


SRT 22GHz



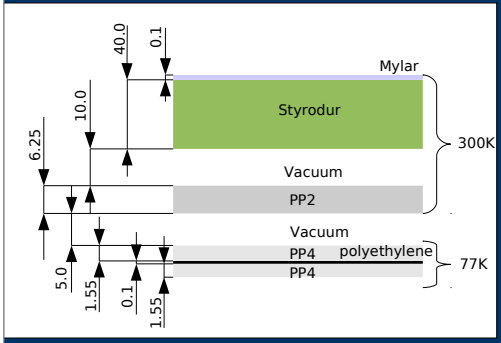
Noto 6.7GHz (Pol.)



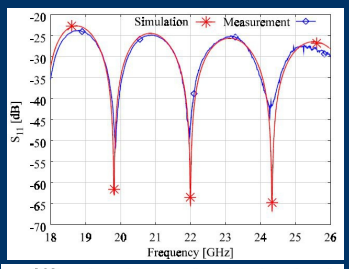


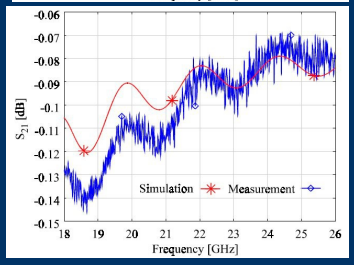
43GHz: Platelet Electroformed 3D Laser Melting

Dielectric characterization of vacuum window materials



Amplitude Reflection/Transmission Measurement





	Electrical properties	
Material	ε_r	$tan\delta \cdot 10^2$
Mylar(2)	3.5	8.0
Styrodur(2), 3035CS, 5000CS	1.045, 1.050, 1.070	0.007, 0.003, 0.003
PP2	1.04	0.02
Vacuum	~1	~0
PP4	1.08	0.1
Polyethylene	2.24	0.2

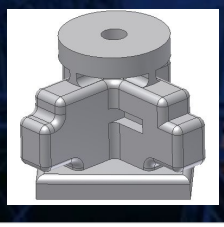
Radionet FP7 *APRICOT*

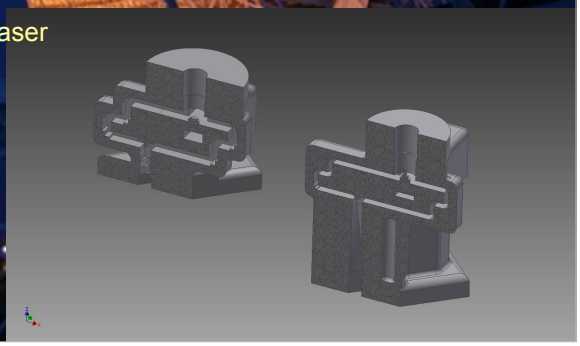
Multifeed 43GHz (Q-Band)

7 Corrugated Horns - Low cost (5.3K€)

Orthomode Transducer Array

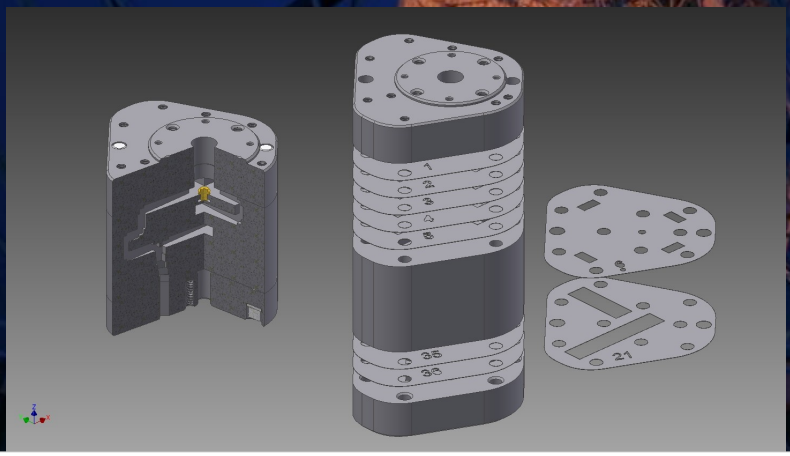
- EM Design for High Performances – Low cost
- Cost-Estimate: 0.5K€ x 7
- Mechanical 3D-model for 3D-laser prototyping

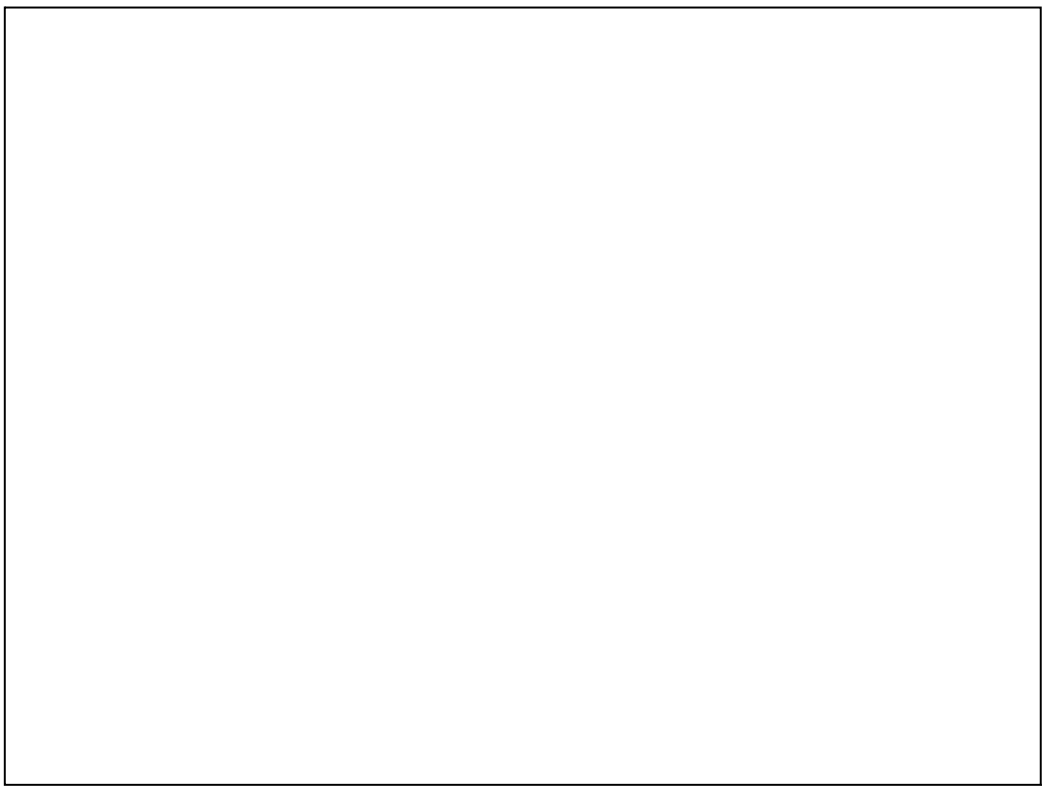




ASI-2007
Progetti di sviluppo Tecnologico

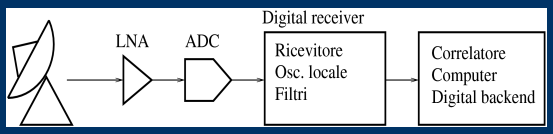
- Low cost (4.3K€+7x0.6K€) Q-Band Orthomode Junctions
- High Performances
- Designed for SRT Receiver





25 years of digital spectrometers
Autocorrelation spectrometers for Medicina and Noto telescopes. 20+ years of H2O maser monitoring up to current FFT 16 channel spectropolarimeter for the Pharos receiver
Digital receivers for Doppler tracking, GW search using interstellar probes, radio science
Experience used to participate to ALMA: proposal of a hybrid FXF modification for the ALMA correlator
Future projects: involvment in SRT backend
FP7 proposal on fast digital backends

Digital radioastronomy



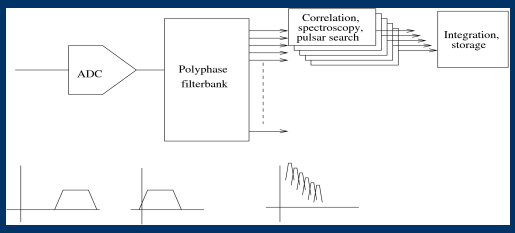
- Digital receiver
  - Wideband input
  - Limit: RF = only the LNA
  - Digital output (10G Eth) for recording or on-line processing (GPUs)

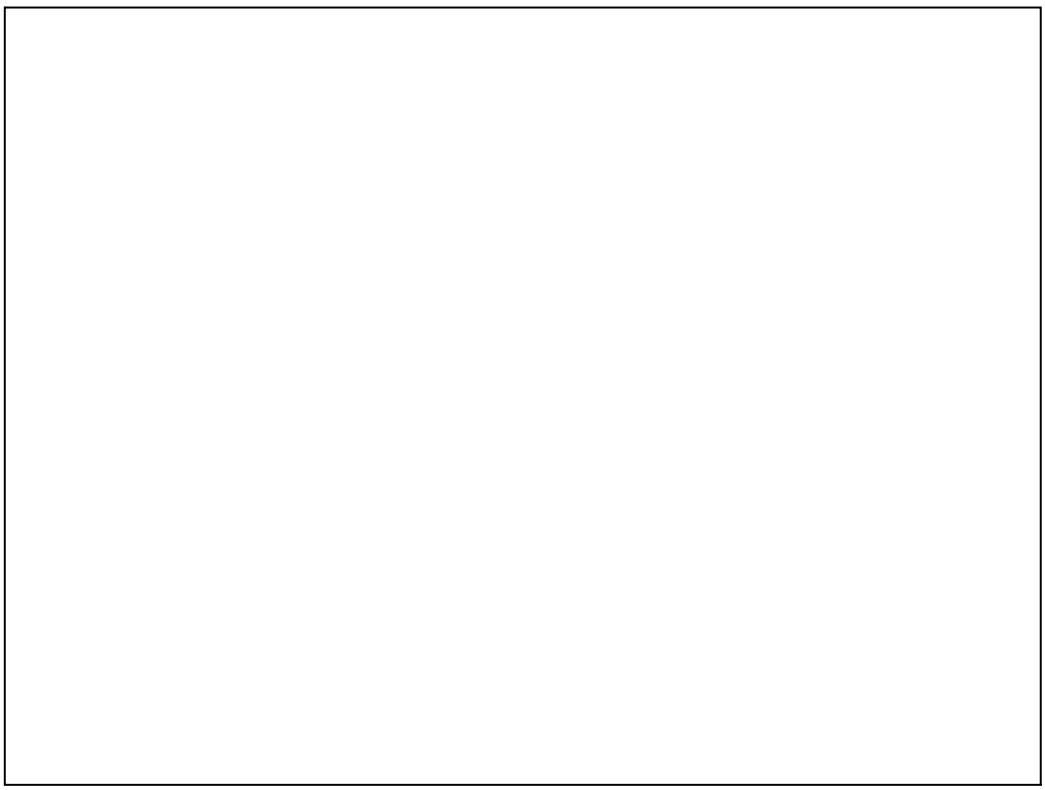
- Digital backend
  - Spectropolarimety
  - Interferometry, beamforming
  - RFI mitigation

Advantages: uniformity e predictability, high insulation (RFI) , compact
Same instrument reprogrammed for different functionalities
Exploit Moore law

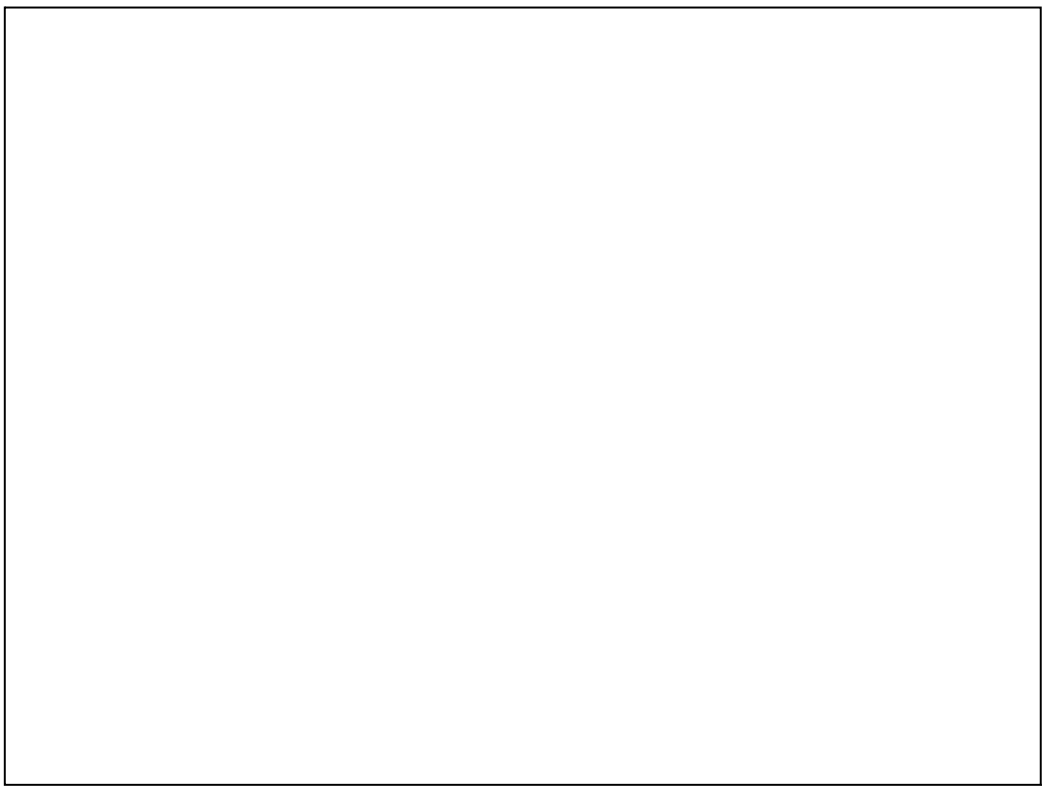
Digital radioastronomy

- Typical processing
  - Wideband ADC: 1-20 GHz BW, 1-10 GS/s
  - Filterbank: produces several (16-1000) narrow bands, at “reasonable” data rate
  - Processing: heavy parallel, in programmable logic or GPUs
  - Postprocessing and storage on generalpurpose computers
- Problems:
  - Fast data ra
  - Interferometry, beamforming
  - RFI mitigation





Historically main expertise on electromagnetic optic design & testing
Collaborations with Florence & Pisa Universities
Design & construction of several receivers from 6 to 350 GHz
43 GHz cooled receiver for Noto
Recently multibeam receivers, because single receiver approaching quantum limit
Problems of large cryostats, vacuum windows, compact and economic design
Simple to build, reproduce



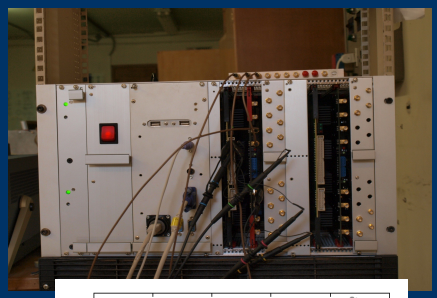
Faraday FP5 project

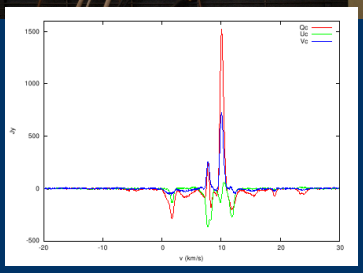
- common access to foundry to build MMIC amplifiers
- Application: 7 beam, double polarization receiver: 14 monolithic amplifiers
- Mechanic problem: small and light (cooling) structure for feed and optic components
- Wideband (30%) performance

Multibeam spectrometer for SRT

- 16 channel spectrometer
  - 8 ch full polarimetric
- 0.5-80 Mhz bandwidth
- 2048 spectral points

- Based on tunable filter boards from ALMA correlator

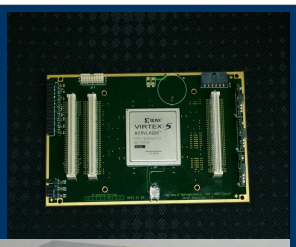


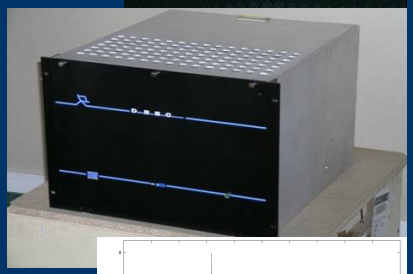


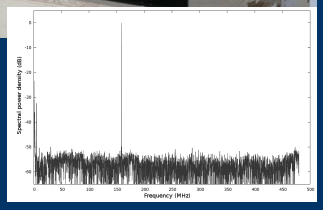
Polarized emission from Orion H2O maser

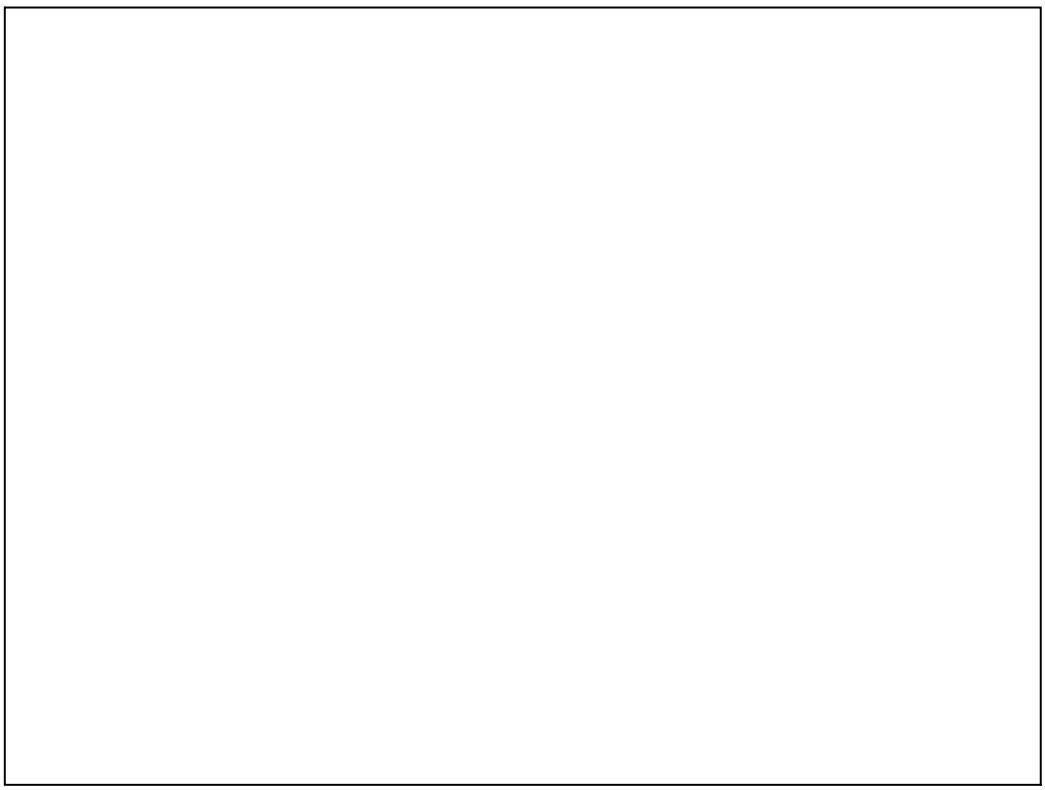
Digital BBC

- Standard for digital VLBI
- Modular system: small boards for ADC and processing
- Work in Arcetri:
  - Standard application (VLBI receiver)
  - 500 Mhz spectrometer
  - 32 channel polyphase filter







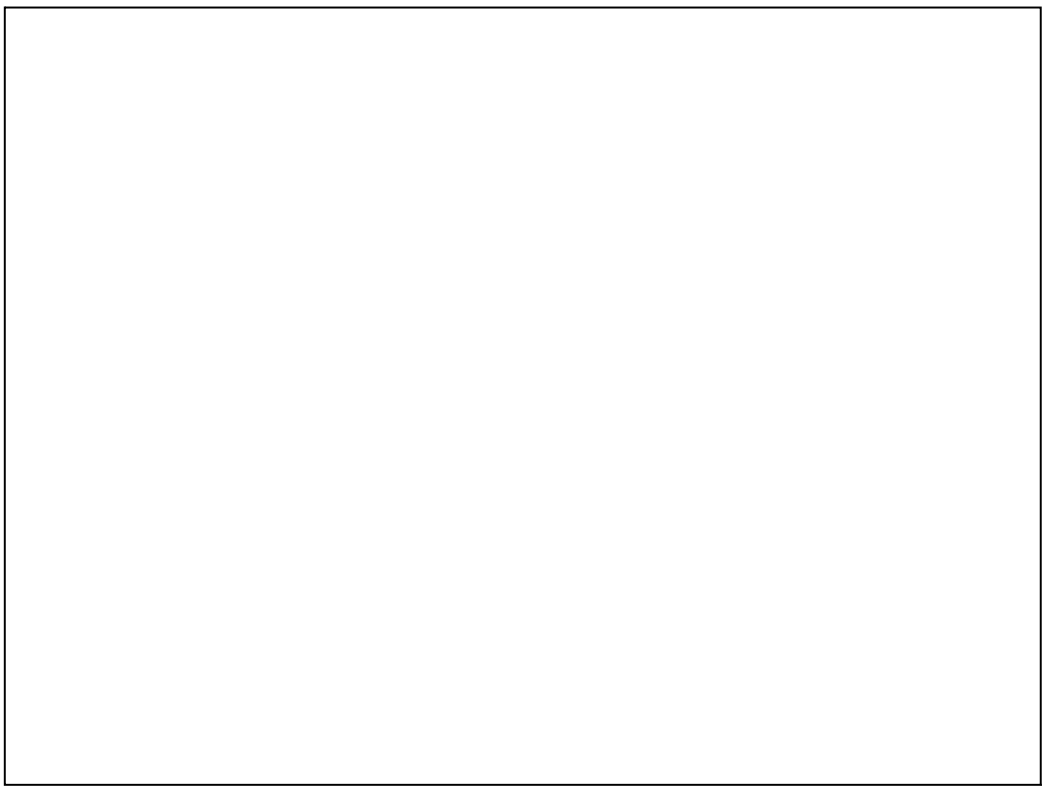


Proposed FXF design for ALMA correlator in 2001-02: more efficient use of correlator HW, resulting in 32x spectral resolution. Extended flexibility, with “zooming” modes over portion of interest of the spectrum

Collaboration with NFRA and OdB for a “2nd generation correlator” based on this design

5/2003: Project asks for a detailed design study for a modification of the existing correlator

9/2003: Design presented at Correlator CDR: limited risk, no cost upgrade



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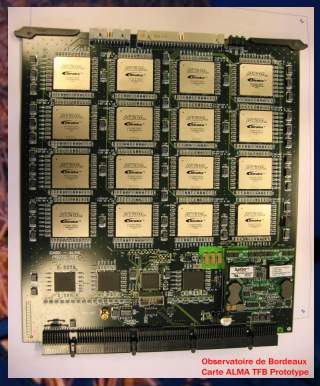
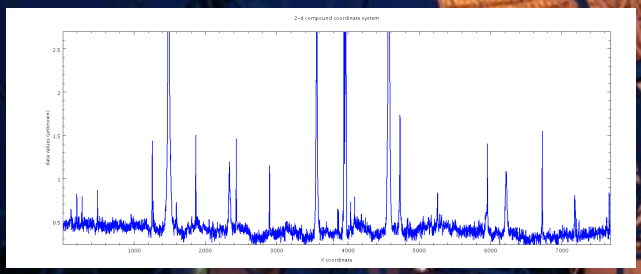
ALMA correlator

Digital receiver bank to improve correlator resolution

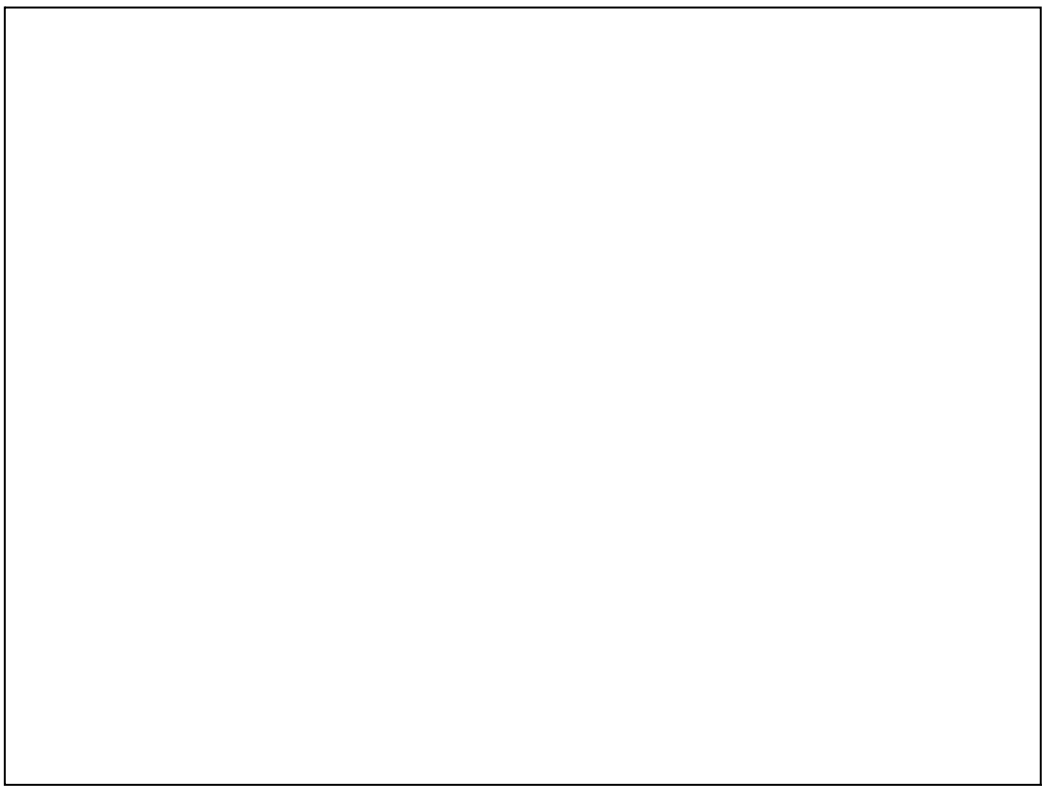
32x resolution at 2 Ghz

Independent sub-channels at lower bandwidth





Banda SiO in Orione – 2 GHz



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Simple to build, reproduce

Uniboard

High performance platform for correlators & LOFAR beam former
Potential SKA physical platform

Work in Arcetri

- Digital receiver
  - 4 Ghz BW input
  - 64 output channels, tunable, band 1-128 MHz
  - Output on 8 10G Ethernet
  - Used as a component for pulsar receivers, RFI mitigation, etc