Workshop "Detection and measurement of RFI in radio astronomy"

Yebes Observatory (IGN, Spain), June 8-9, 2017

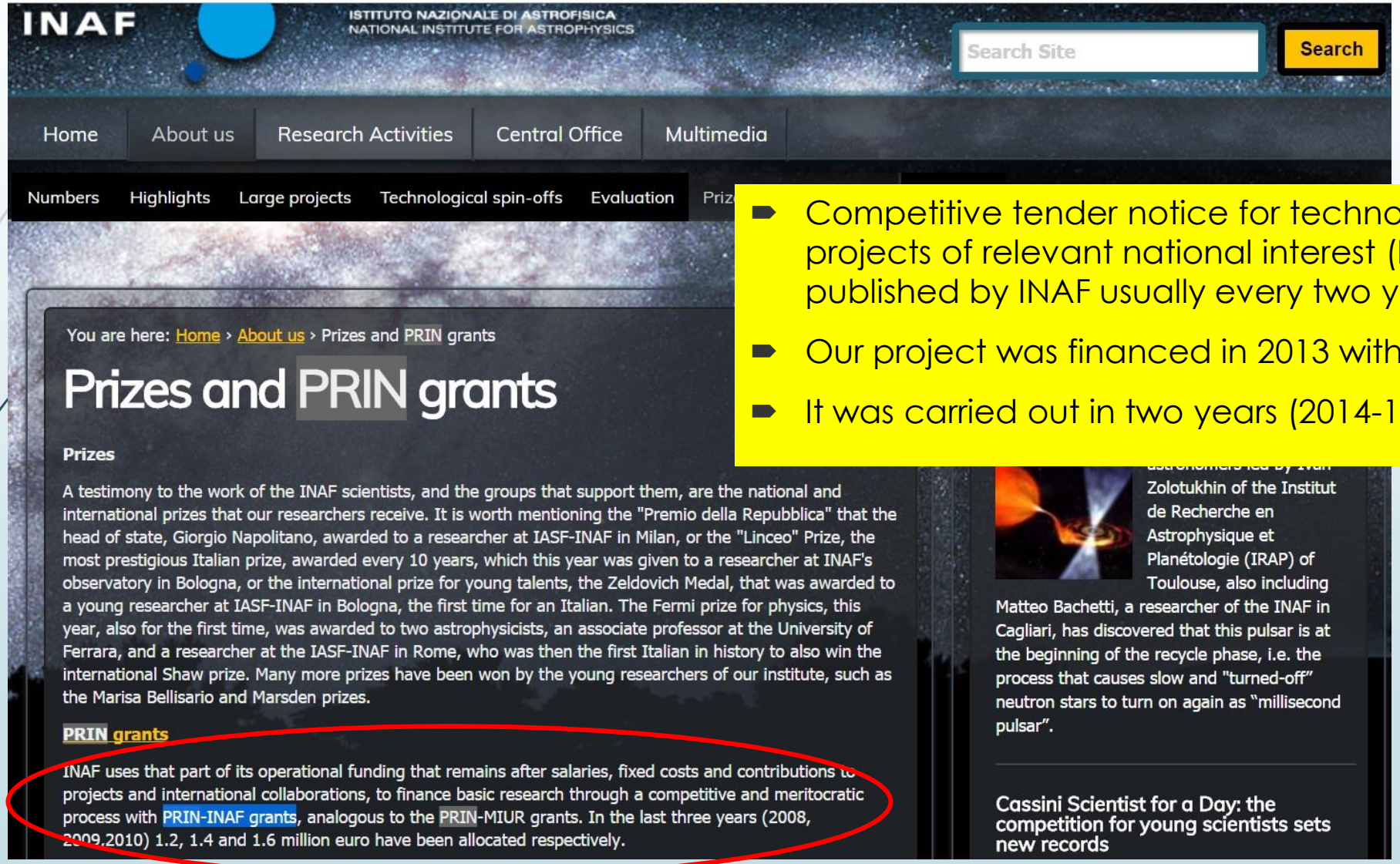
RFI Mitigation Project at Italian Radio Telescopes

G. Serra and many other people
from Italian National Institute for Astrophysics
and other Institutes

Outline

- Introduction (Techno INAF-PRIN)
- RFI facilities at the Italian radio telescopes (IRTs)
- Project tasks for RFI monitoring: some examples of RFI at the IRTs
- Project tasks for RFI mitigation
  - WBLGB spectrometer
  - Off-line Dish Washer
- Tests of mitigation tools at the Sardinia Radio telescope
- Summary and ongoing developments

Intro: Techno INAF-PRIN



- Competitive tender notice for technological projects of relevant national interest (PRIN) published by INAF usually every two years
- Our project was financed in 2013 with 173 K€
- It was carried out in two years (2014-16)

Intro: Reserarch units and people

IRA-Medicina staff
K-H. Mack (P.I.), A. Zanichelli, M. Bartolini, C. Bortolotti, M. Roma, A. Orlati, S. Righini, R. Ambrosini

IRA-Noto staff
G. Nicotra,R. Platania

Non-staff people
M. De Biaggi, F. Cantini, E. Favero (research grants with the project funds)

OA-Cagliari staff
S. Poppi (Local Coordinator)
G. Serra, F. Gaudiomonte
M. Buttu, C. Migoni

OA-Catania staff
C. Trigillio (Local Coordinator)
P. Leto, C. Buemi

External collaborators
R. Prestage (NRAO), W. Baan (ASTRON), A. Jessner, A. Kraus, P. Muller and B. Winkel (MPIfR), G. Busonera (CRS4)

Intro: Research Units and tasks

OA-Cagliari, IRA-Noto and – IRA-Medicina (RFI teams)	Characterization of the RFI situation at the three Italian radio-observatories
IRA-Medicina, IRA-Bologna (backend team)	Development and implementation of the FPGA firmware for on-line mitigation (WBLGB spectrometer)
IRA-Bologna, IRA-Medicina, OA-Cagliari (software team)	Development of an off-line mitigation tool (Dish Washer)
OA-Cagliari, IRA-Medicina (RFI and backend teams)	Verification of the on-line mitigation algorithms
INAF people and external collaborators	Verification of the mitigation tools and observational tests using telescopes

RFI facilities & ordinary actvities at IRTS

32-m Medicina telescope & Northern Cross array

Fixed station: 0.3 -12 GHz
Mobile lab: 0.3 - 40 GHz

64-m Sardinia Radio telescope
Mobile lab: 0.05 - 40 GHz

32-m Noto radio telescope
Fixed station: 0.1 -3 GHz

Project tasks: RFI campaigns at IRTs

@ IRA- Medicina

Dedicated RFI meas. in the RA bands by fixed station and IRA mobile lab)

@ IRA- Noto

2 RFI meas. campaigns in freq. range 0.05-40 GHz (in 2014 and 2016)

(by **OA-Cagliari mobile lab**)

@ SRT

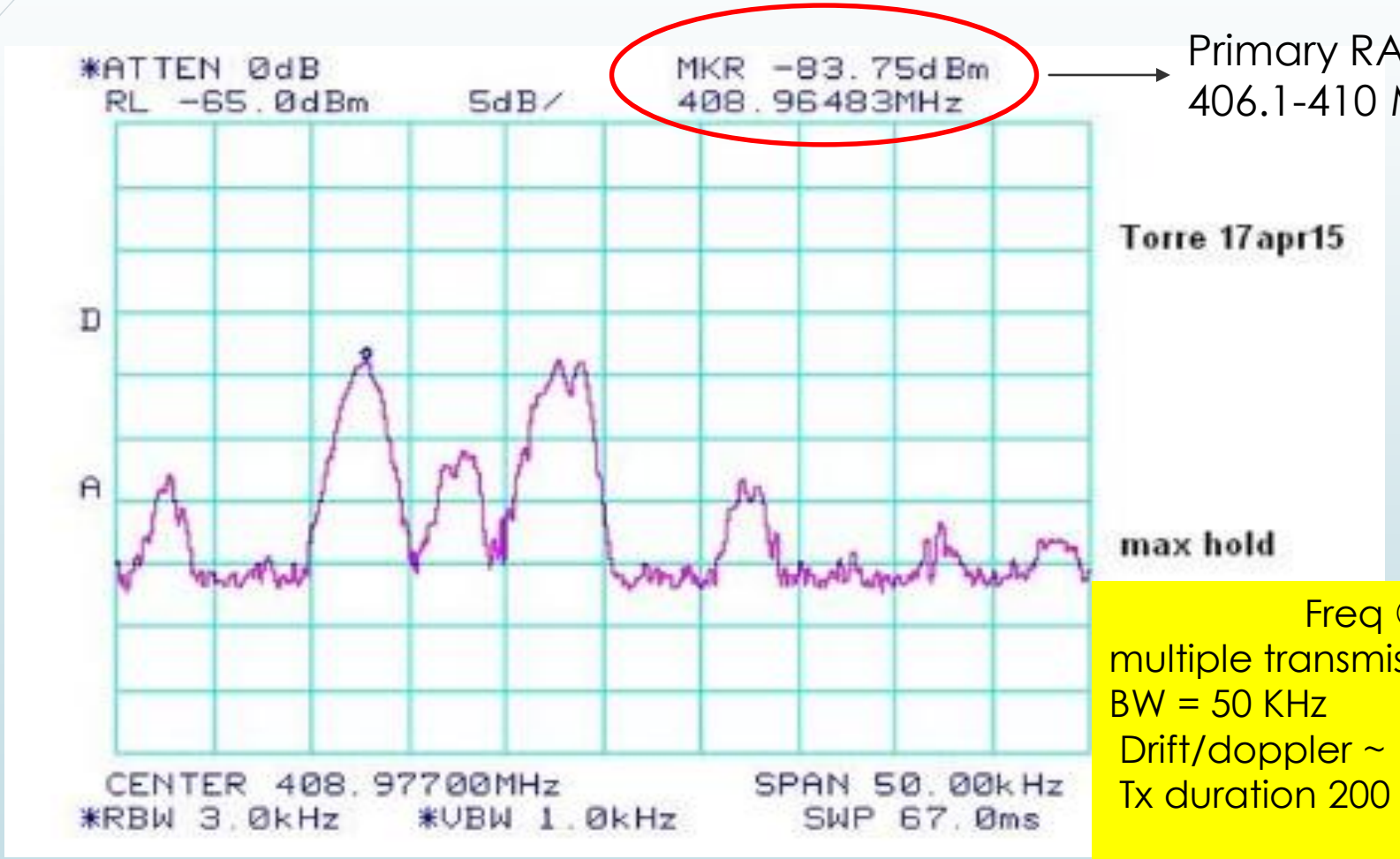
1 RFI meas. campaign (in 2015)

freq range 0.05-40 GHz

(by **OA-Cagliari mobile lab**)

Example of RFI @ Medicina

Satellite signal in the Best2-Northern Cross band (400-416 MHz)



Primary RAS band
406.1-410 MHz

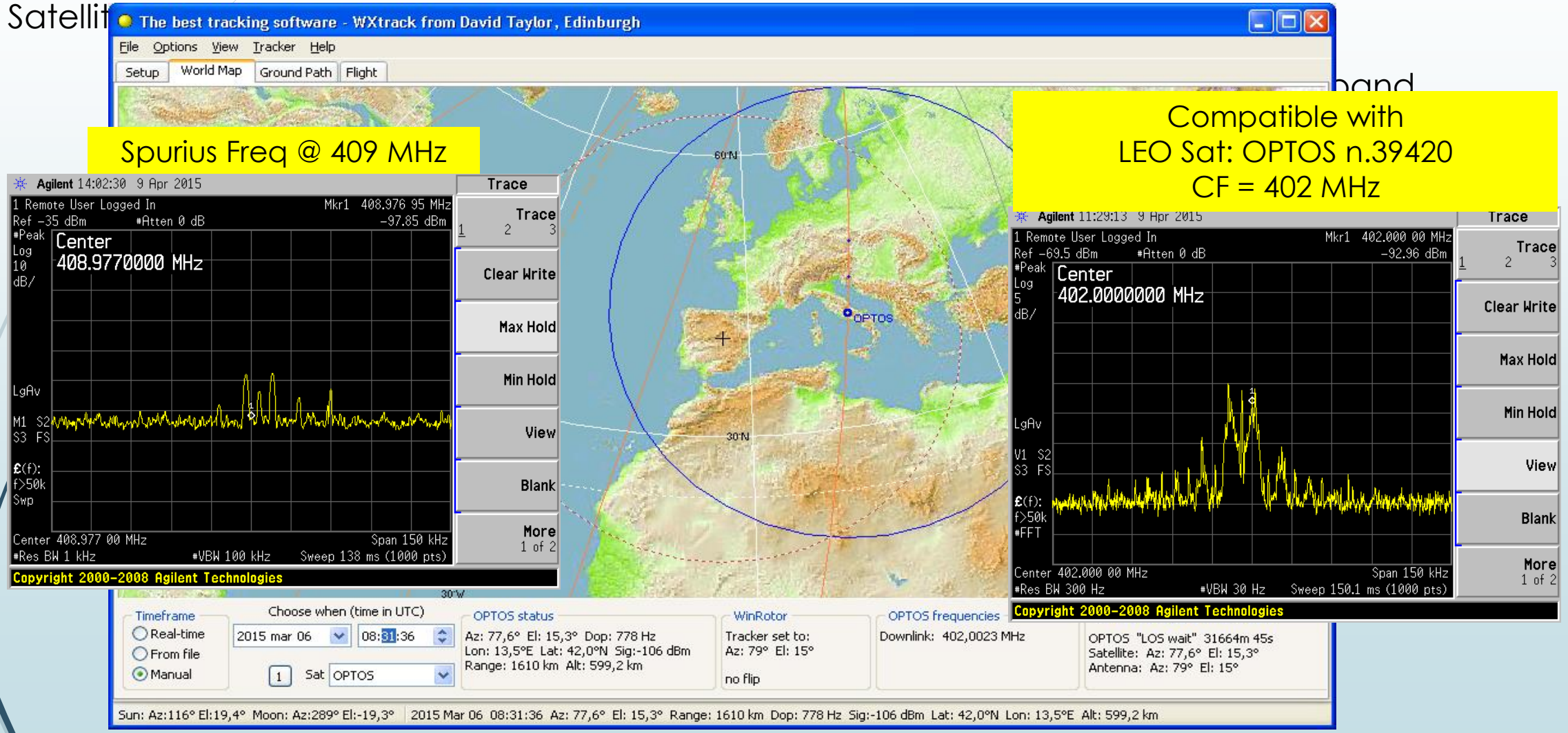
Freq @ 409 MHz
multiple transmissions every 5 KHz
BW = 50 KHz
Drift/doppler ~ +/- 9KHz
Tx duration 200 ms every 10-20 s

Example of RFI @ Medicina (@SRT as well)

Satellit band

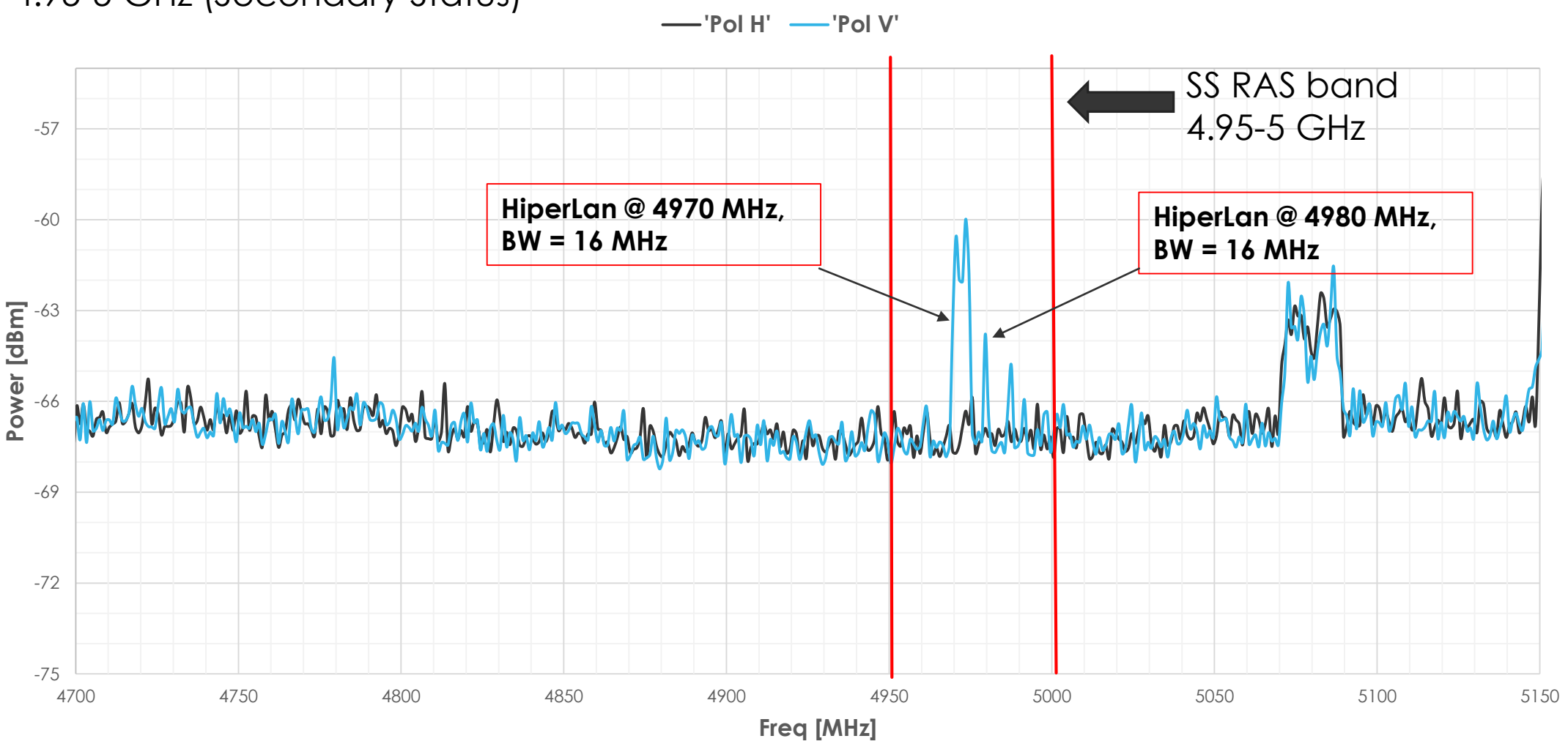
Spurius Freq @ 409 MHz

Compatible with
LEO Sat: OPTOS n.39420
CF = 402 MHz



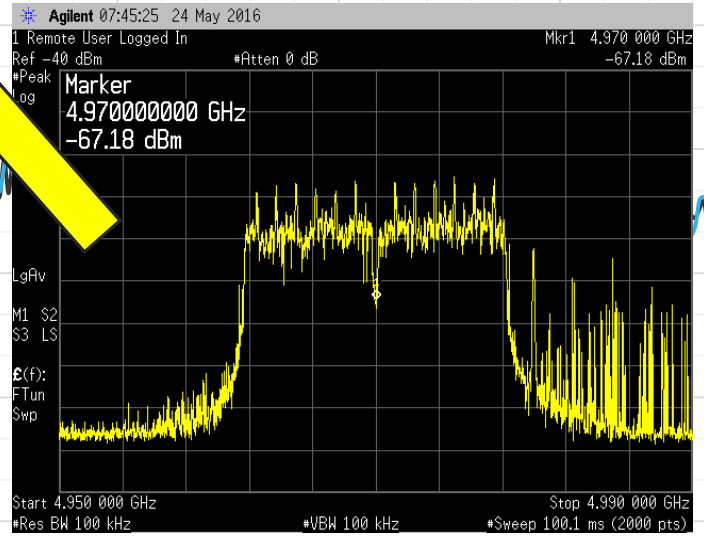
Example of RFI @ Noto

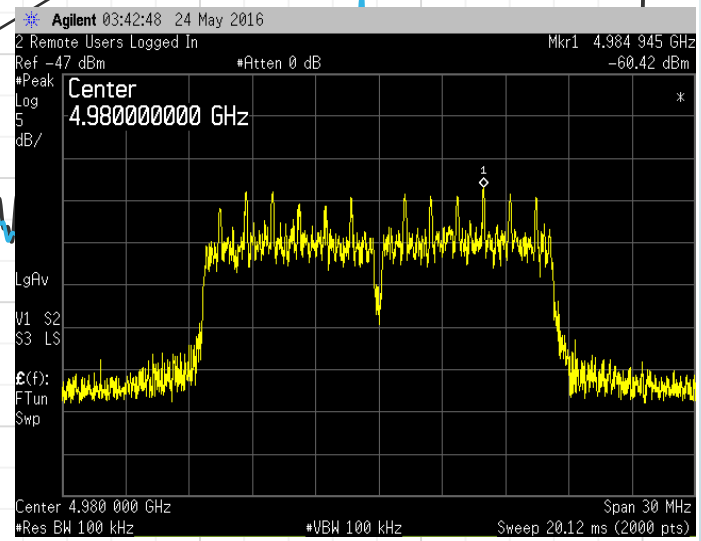
Low-C receiver band: two HiperLAN signals in a non-allocated band inside the RA band 4.95-5 GHz (Secondary Status)



Example of RFI @ Noto

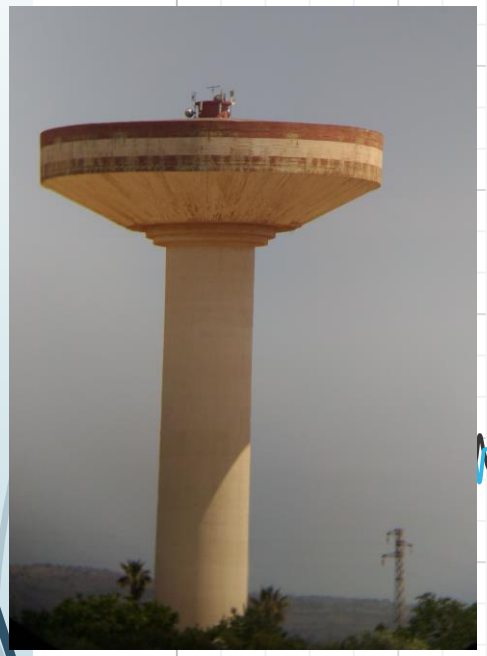
Low-C receiver band: two HiperLAN signals <u>in a non-allocated band</u> inside the RA band 4.95-5 GHz (Secondary Status)





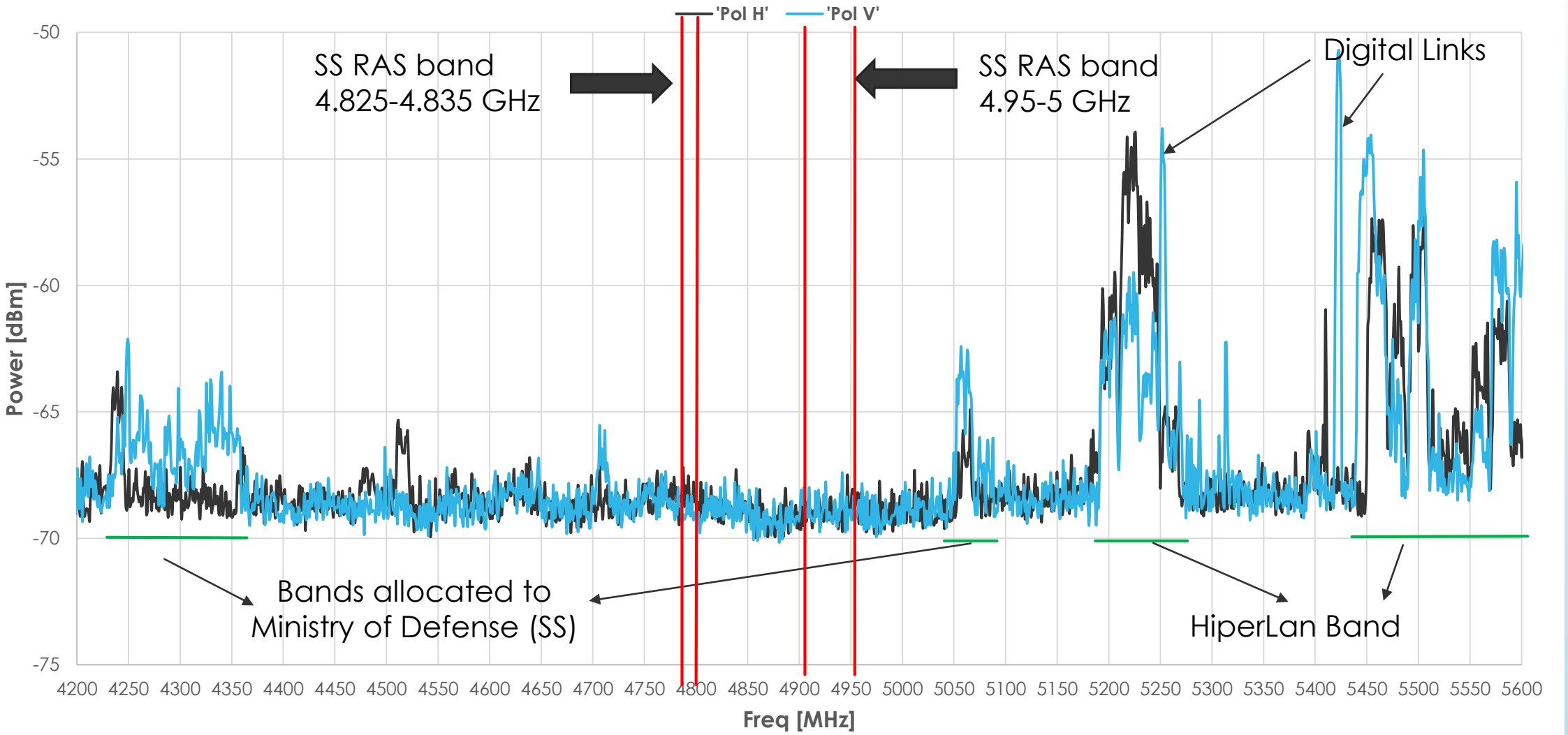
Example of RFI @ Noto

Low-C receiver band: two HiperLAN signals in a non-allocated band inside the RA band 4.95-5 GHz (Secondary Status)



Examples of RFI @ SRT

Low-C receiver (Under costruction) band, no RFI in the SS RAS Bands but…



RFI occupancy* at Italian RTs (in current receiver bands)

Medicina

Receiver (focus)	Freq. Band [GHz]	Occupancy [%]	RFI notes
P BEST – N. Cross (primary)	.400-.416	35	Radio Links, Radiosondes power lines
low-L (primary)	1.35-1.45	15	Radar
high-L (primary)	1.595-1.715	35	Satellite
low-C (secondary)	4.3-5.8	45	HiperLAN Radio links
high-C (secondary)	5.9-7.1	25	Radio links
Coaxial S/X (primary)	2.20-2.36	45	Radio links
	8.18-8.98	5	Radio Satellite
2-beam-K (secondary)	18.0-26.5	5	Radio links

SRT

Receiver (focus)	Freq. Band [GHz]	Occupancy [%]	RFI notes
Coaxial P-L (primary)	.305 - .410	52	Aeronautical digital links, self-RFI, power lines
	1.3 - 1.8	57	Radar, satellite, cell phone, self-RFI
C (tertiary)	5.7 - 7.7	10	HiperLAN, digital links
7 beam-K (Gregorian)	18 – 26.5	7	Cell phone network digital links
Coax. X-Ka (primary)	8.2- 8.6	3	Digital links
	31.85 - 32.35	2	Surveillance radar

Noto

Receiver (focus)	Freq. Band [GHz]	Occupancy [%]	RFI notes
low-C (secondary)	4.70-5.15	4	HiperLAN
high-C (secondary)	6.5-6.8	0	-
Coaxial S/X (primary)	2.189-2.371	11	Digital links
	8.138-8.922	0	-
K (secondary)	21.18-22.46	0	-
Q (secondary)	39.0-43.5	0	Only up to 40 GHz

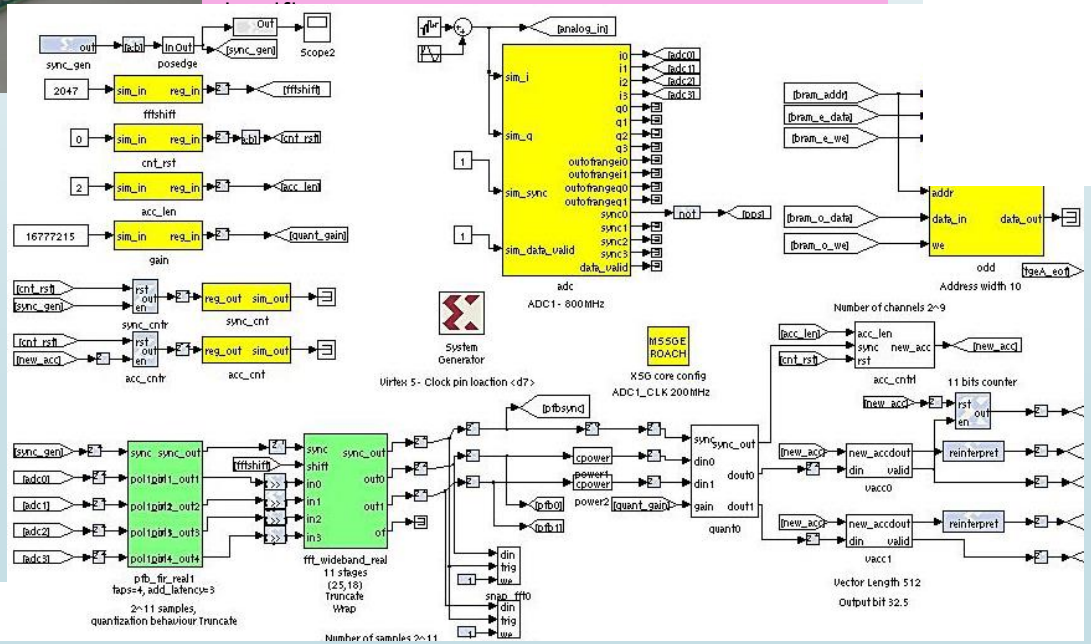
* with respect to the whole bandwidth of each receiver

Project tasks: spectrometer for RFI mitigation

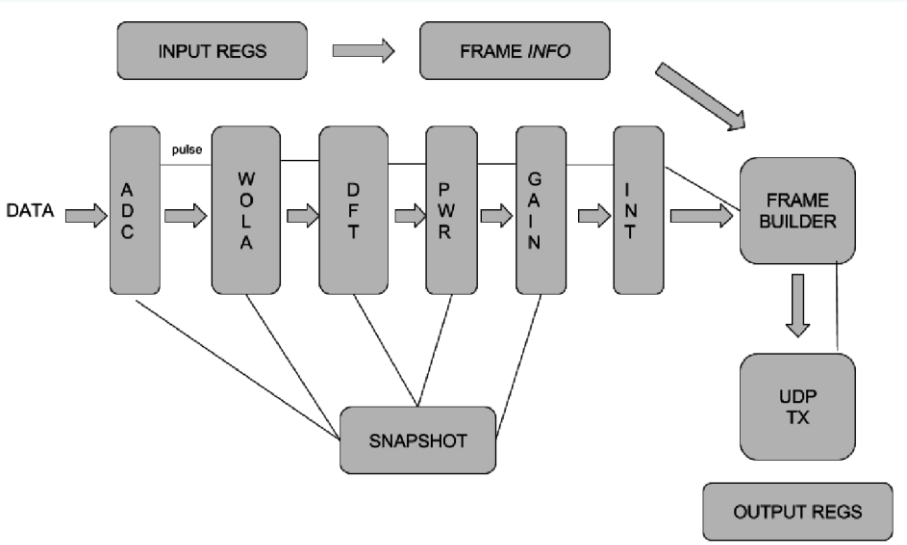
Wide **B**and **L**owpass **G**iga **B**it spectrometer

Roach Board 1
http://casper.berkely.edu/wiki/ROACH/

implementation by Casper MSSGE



Courtesy of A. Mattana



Spectrometer overview

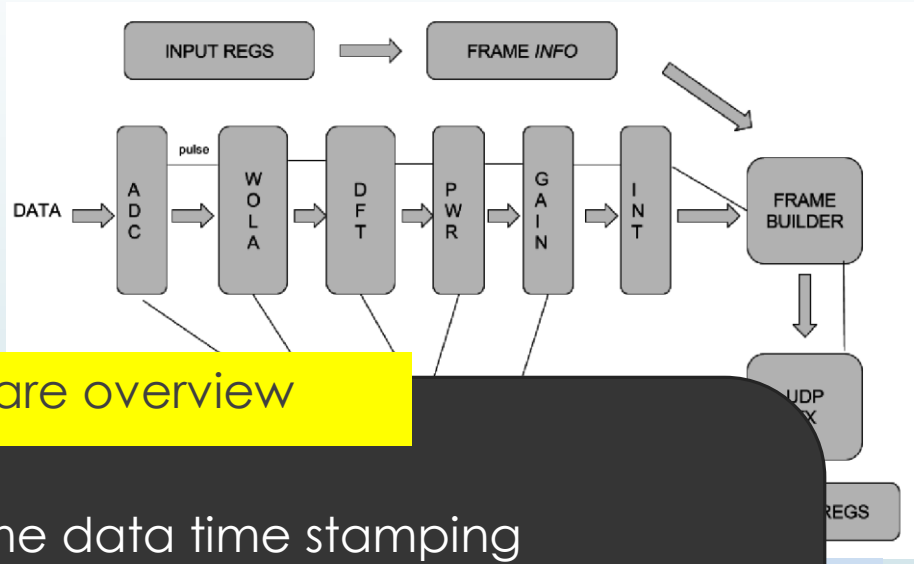
Project tasks: spectrometer for RFI mitigation

Wide **B**and **L**owpass **G**iga **B**it spectrometer

Roach Board 1
http://casper.berkely.edu/wiki/ROACH/

Hardware features

- 8 bit, 1Gsps iADC
- External clock synchronization
- BW = 800 MHz
- integration time = 1ms (minimum for fast RFI detection)
- Data output rate = 1.25 Gbps

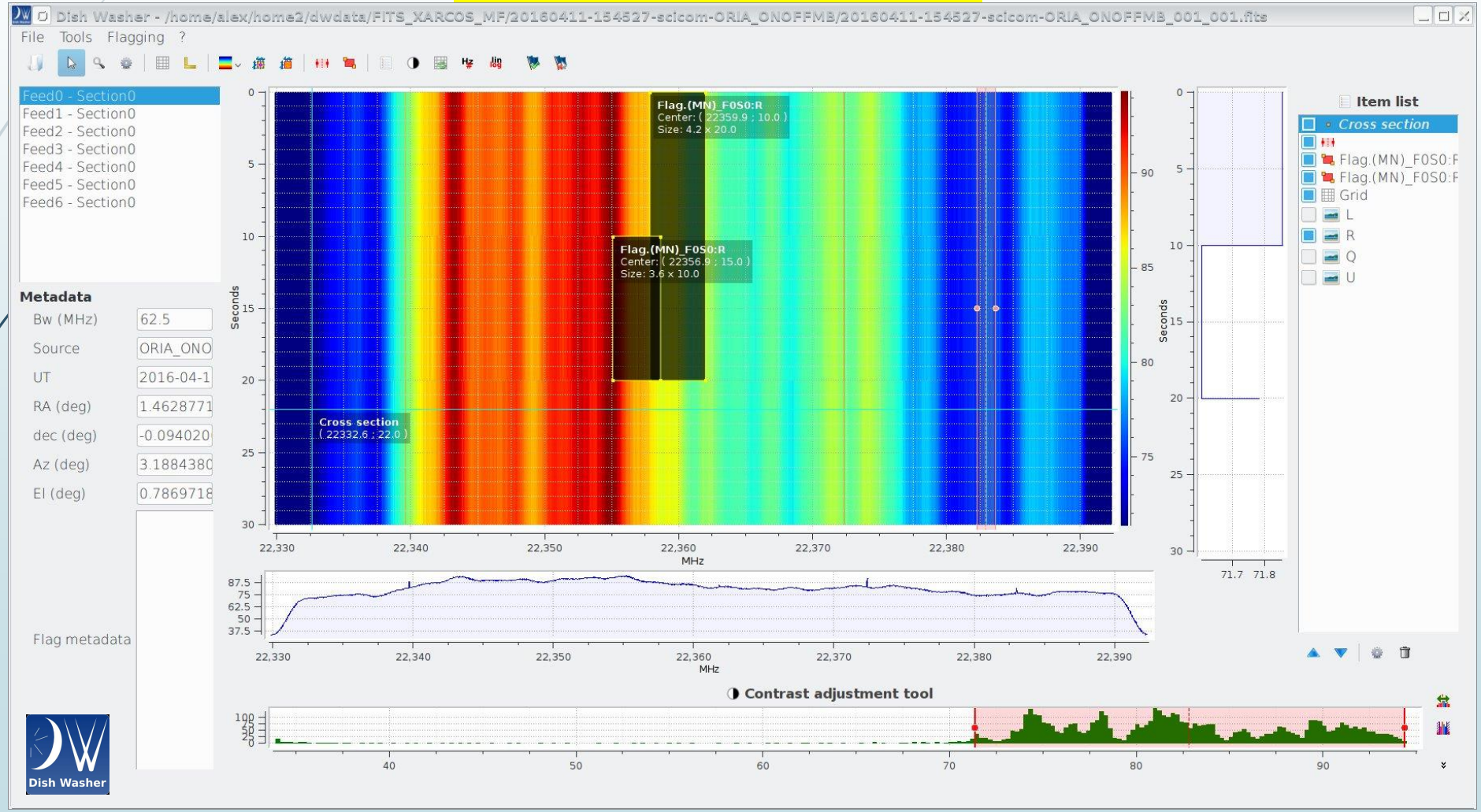


Firmware overview

- Realtime data time stamping
- Freq channels = 4096 (maximum via PFB and DFT)
- Configurable digital gain and DFT shift (robust to RFI signals)
- overflow monitoring
- every stage inspectable via ram blocks

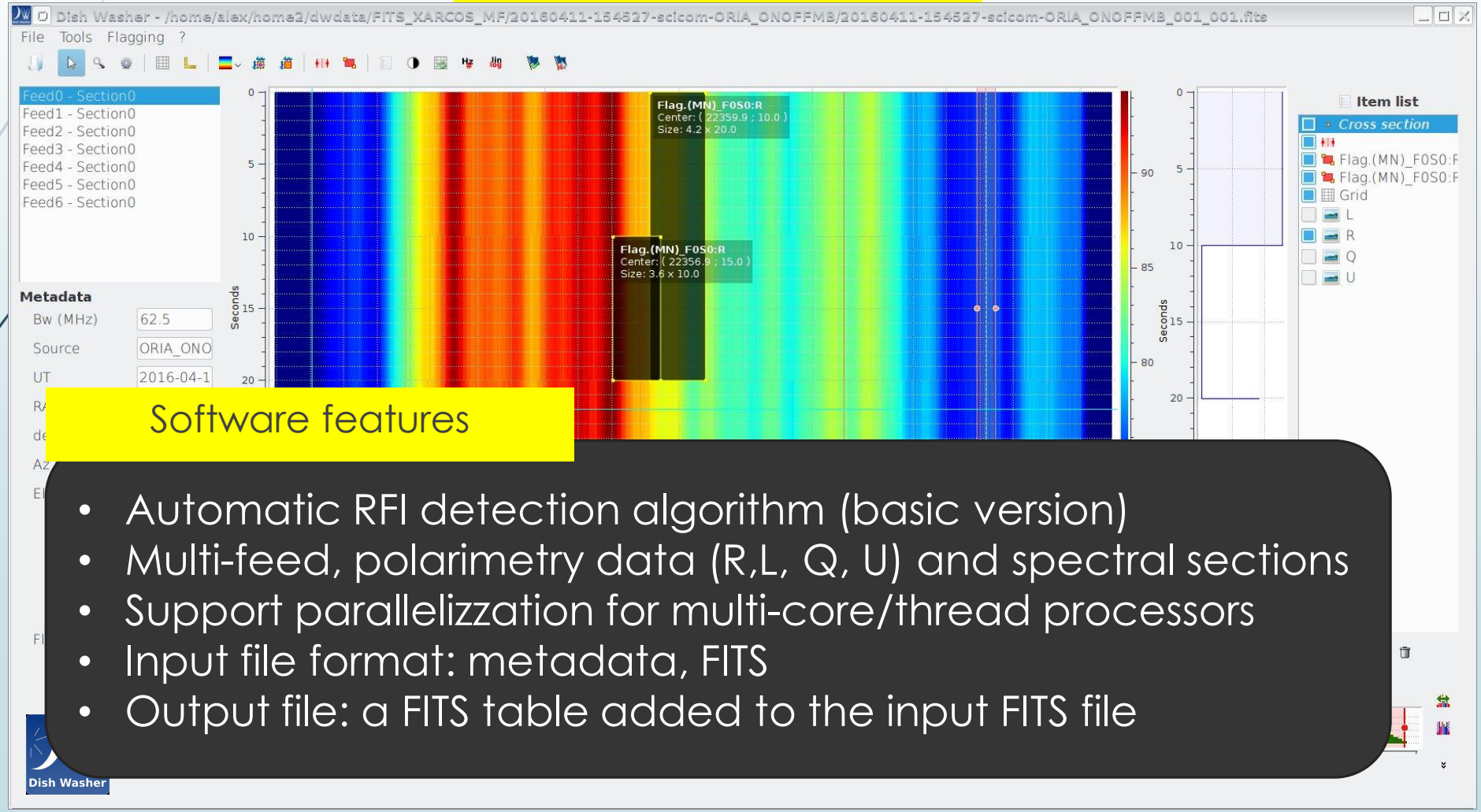
Project tasks: software for RFI mitigation

Off-line Dish Washer (DW)



Project tasks: software for RFI mitigation

Off-line Dish Washer (DW)



Software features

- Automatic RFI detection algorithm (basic version)
- Multi-feed, polarimetry data (R,L, Q, U) and spectral sections
- Support parallelizzation for multi-core/thread processors
- Input file format: metadata, FITS
- Output file: a FITS table added to the input FITS file

Mitigation tools: preliminary tests @ SRT

Set-up and adjustment

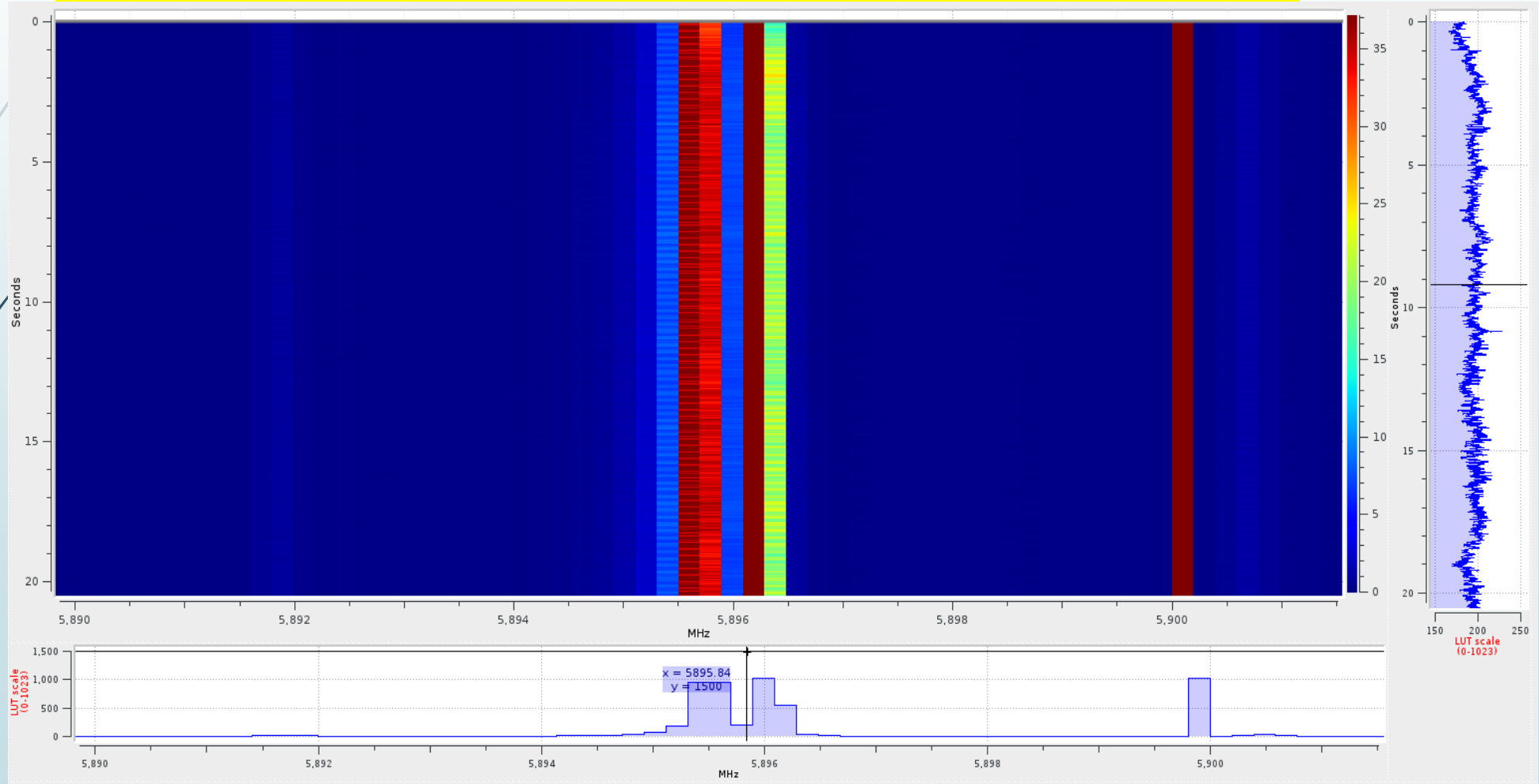
- WBLGB spectrometer firmware was installed on a SRT backend (ROACH 1)

(DW not yet installed @ IRTs but tested off-line with Medicina and SRT dataset)

- Interfacing with the Antenna Control Software (Nuraghe) to get pointing coordinates, source name, UT and receiver setup
- the SRT IF baseband output was connected by a power splitter to:
  - the WBLGB spectrometer
  - spectrum analyzer with for the spectrometer digital gain adjustment (repeated for each SRT receiver band(L-P, C- and K-band)

Mitigation tools: preliminary tests @ SRT

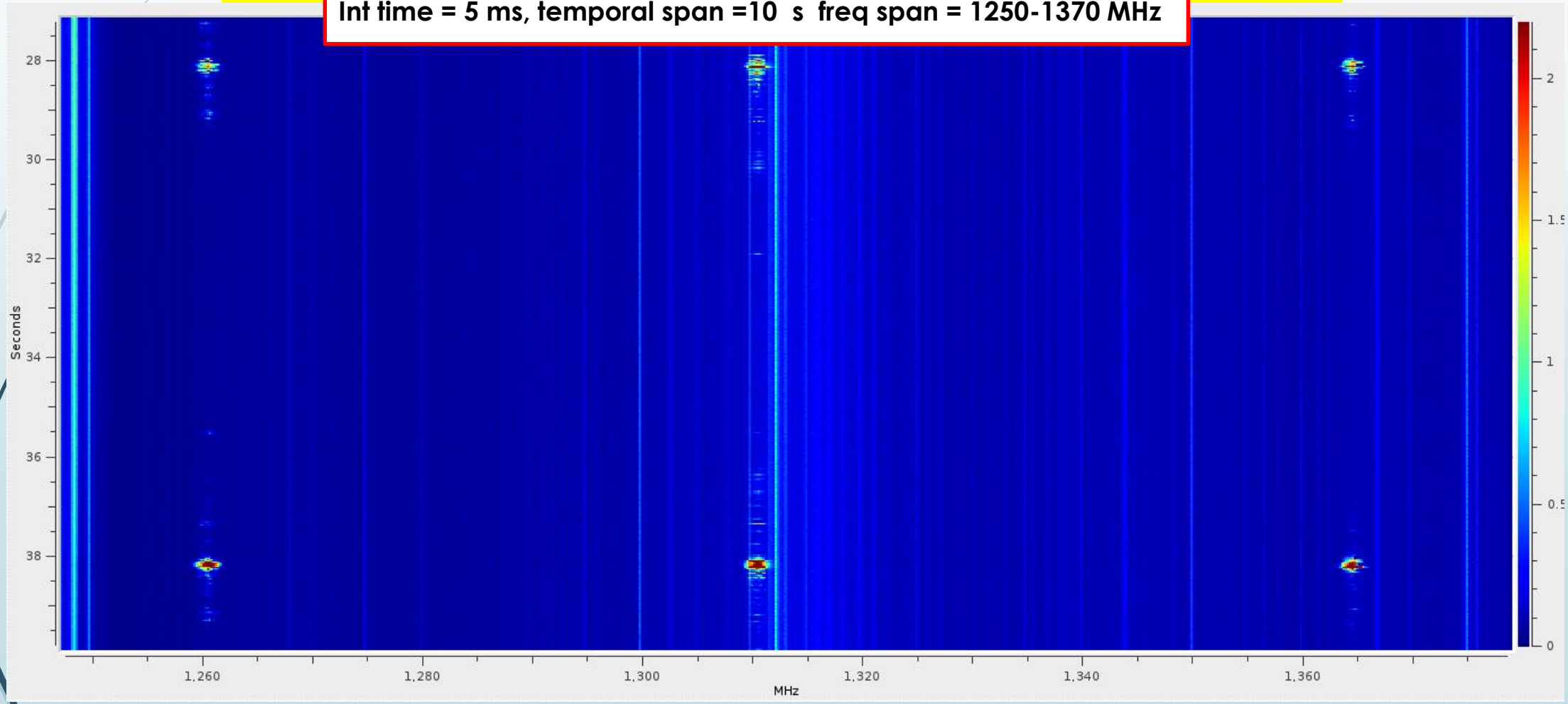
Strong known RFI (digital link) in the C-receiver band (5.7-7.7 GHz)



Mitigation tools: preliminary tests @ SRT

Strong known RFI (radar) in the L-receiver band (1.3-1.8 GHz) :

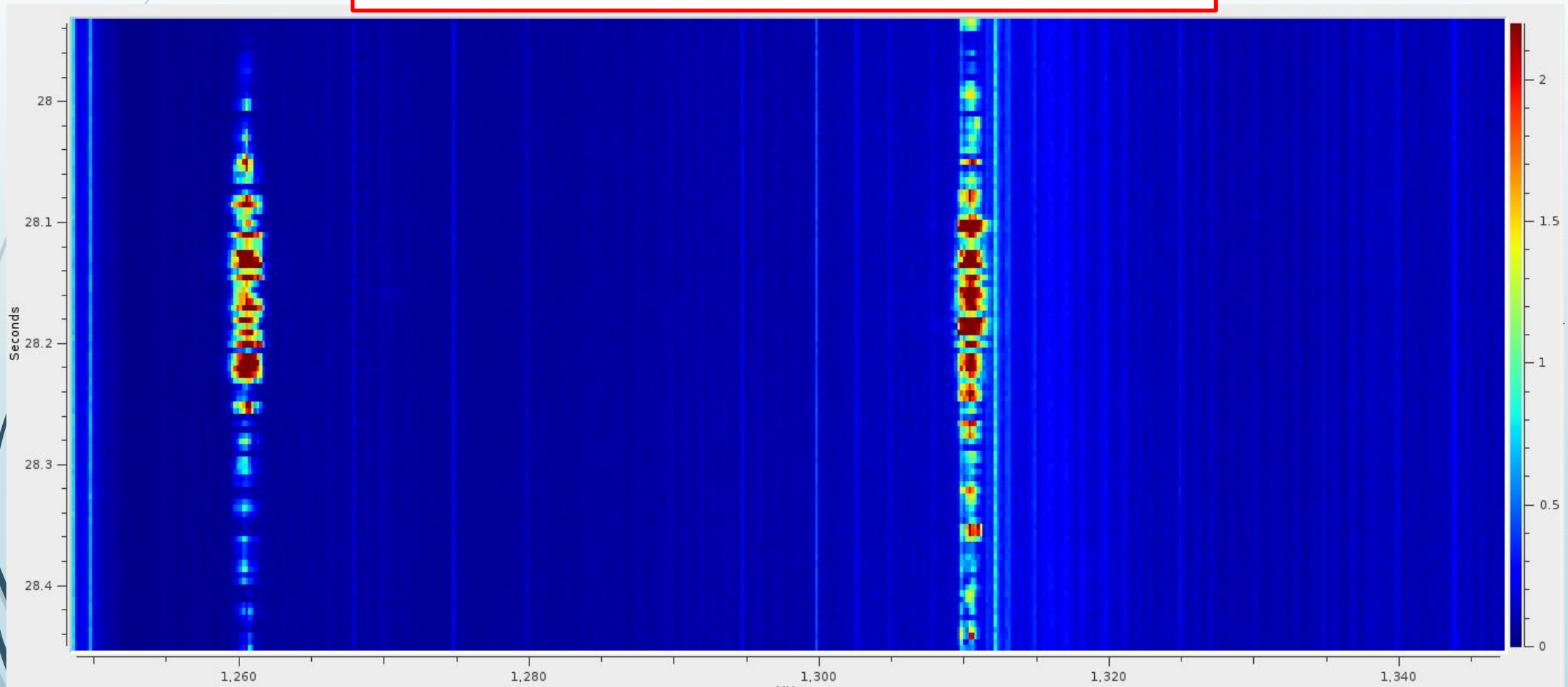
Int time = 5 ms, temporal span =10 s freq span = 1250-1370 MHz



Mitigation tools: preliminary tests @ SRT

Strong known RFI (radar) in the L-receiver band (1.3-1.8 GHz) :

Int time = 5 ms, temporal span =0.5 s freq span = 1260-1340 MHz



Mitigation tools: preliminary tests @ SRT

W3OH (astronomical calibrator) and strong RFI in the C-receiver band

Project Summary

- In two years (2014-2016) the project has allowed to:
  - create a network of people from different observatories/facilities of the INAF and external partners to face together the RFI issue affecting the RA observations
  - support the local RFI groups in increasing the RFI monitoring at the national telescopes (RFI environment is constantly evolving)
  - develope HW/SW tools in common at IRT for a national RFI mitigation
    - WBLGB spectrometer by using the local know/How in using ROACH-FPGA tecnologies and Casper development environment
    - Dish Washer based on a python free software providing:
      - an user-friendly GUI
      - Manual RFI flagging
      - Automatic RFI flagging (at moment a basic sigma-clipping has implemented)
      - In general, a software platform where sophisticated automatic methods for RFI mitigation can be implemented

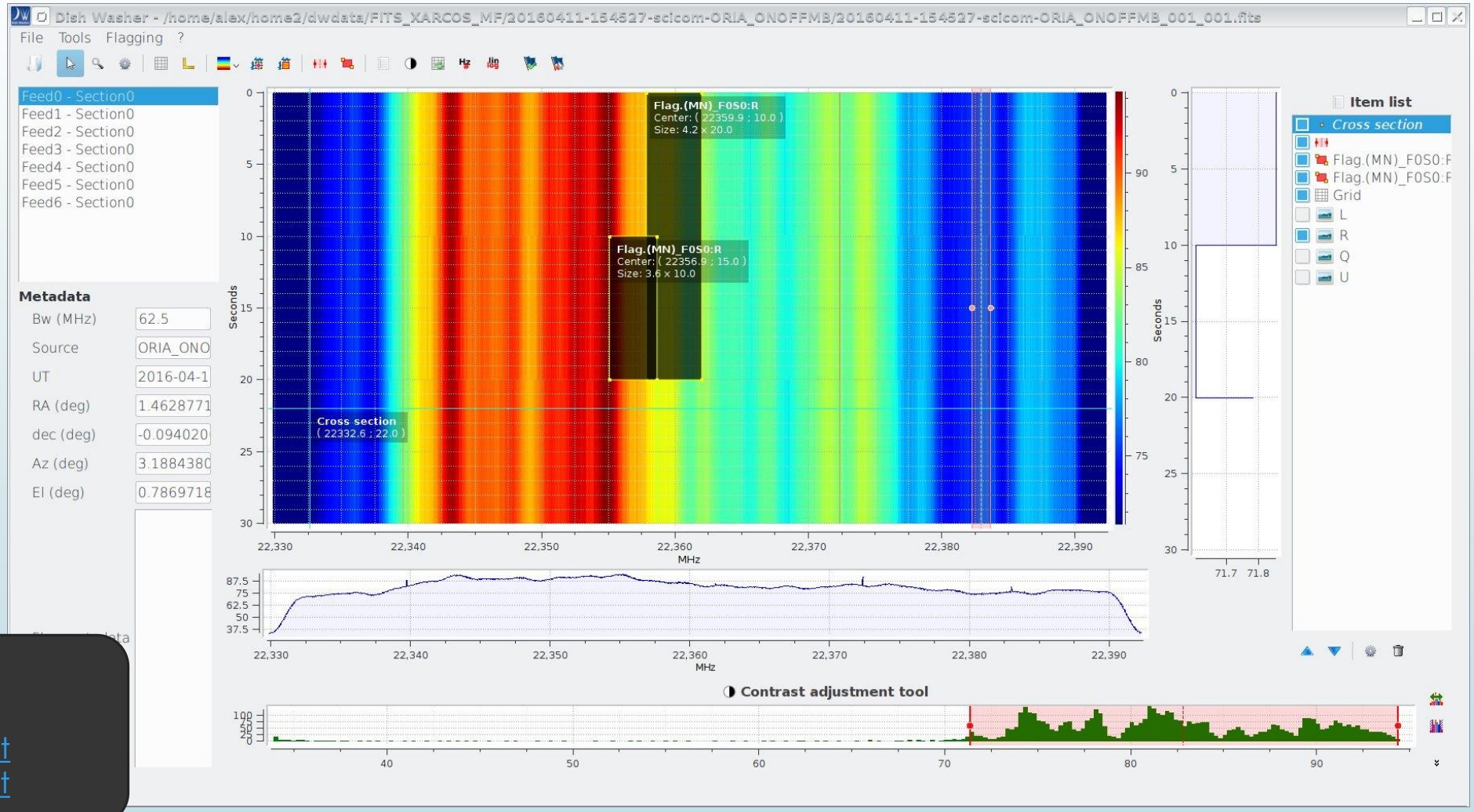
Ongoing developments

Since the end of project (July 2016) the same network of people have been still working on:

- Finish DW debugging and test with various types of data (spectropolarimeters, telescopes, also involving the international collaborators) → almost completed
- Public release: it requires improving/testing some graphical functionalities and updating the documentation → almost completed
- Implement more sophisticated RFI detection algorithms → to be done (collaboration with other people involved in RA community would be very welcome)
- Implement support for different input data formats → Start/continue collaboration with other facilities (GBT tests encouraging!)

Thanks for your attention. Questions?

Dish Washer



Contacts :
a.zanichelli@ira.inaf.it
mbartolini@med.ira.inaf.it
g.serra@oa-cagliari.inaf.it