I A R
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Instituto Argentino de Radioastronomía

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Radio Frequency Interference: Equipment and Measurements

IUCAF 4th School on Spectrum Management for Radio Astronomy
Joint ALMA Observatory, Santiago, Chile
7-13 April 2014

2012 - RFI Monitoring Phase I:

Instituto Argentino de Radioastronomía
Guillermo Gancio, Daniel Perilli, Juan José Larrarte, Leandro Garcia, Leonardo Guarrera, Santiago Spagnolo.

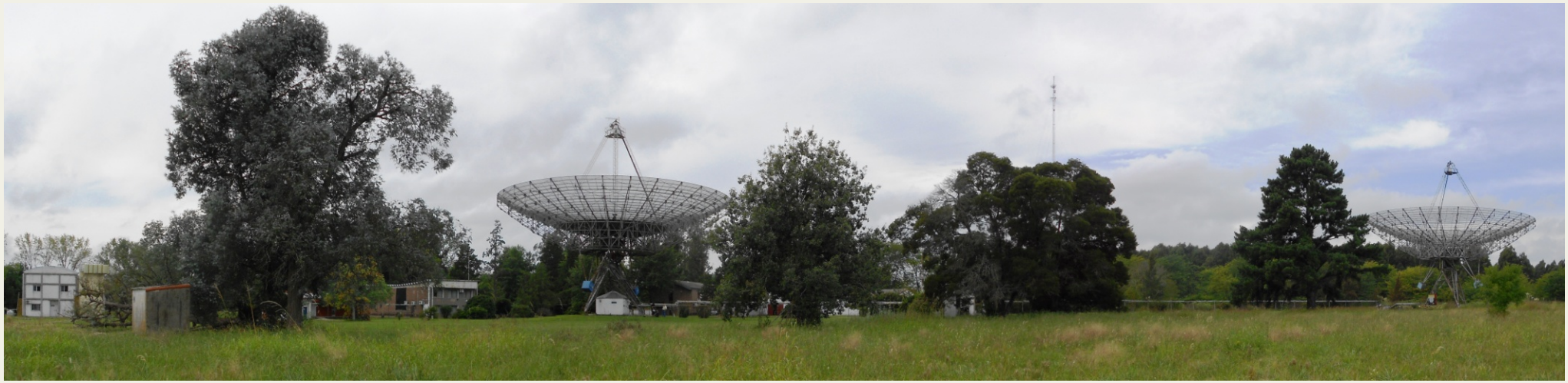
Bundesamt für Kartographie und Geodäsie
Hayo Hase, Gerhard Kronschnabl, Christian Plötz

2013 - RFI Monitoring Phase II:

Instituto Argentino de Radioastronomía
Guillermo Gancio, Juan José Larrarte, Eliseo Diaz, Facundo Aquino, Santiago Spagnolo.

Outline

- ***Why RFI it´s important***
- ***Equipment & measurements for RFI-SKA campaign, 2005***
- ***Equipment & measurements for RFI-TIGO campaign, 2012***
- ***RFI equipment & measurements, IAR NEW development, 2013***
- ***RFI data processing***
- ***Backup Slides***
    - ***Introduction to I.A.R.***



Why RFI it´s important

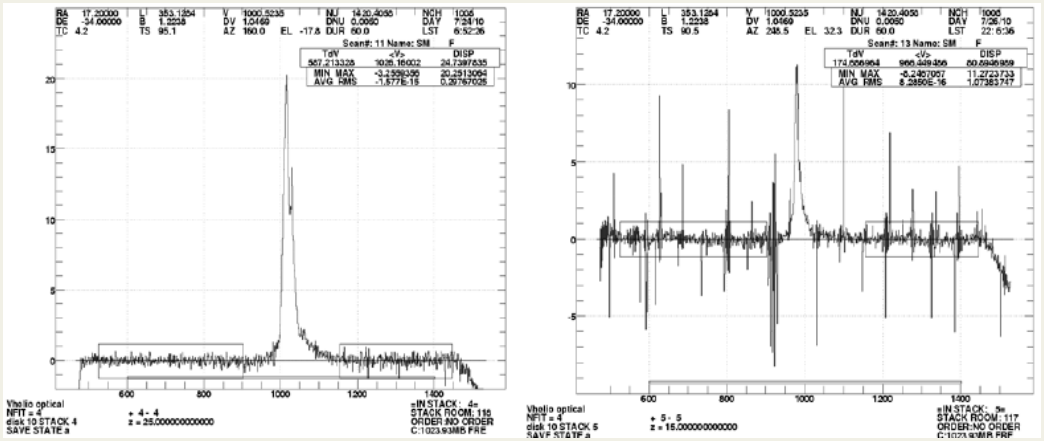
❖ *Radio Astronomy uses frequency spectra to study astronomical phenomena.*
The signals under study are:
- *Very Low Power – Noise Like – Bandwidth dependent.*

According to the phenomena different frequencies and bandwidth are used, e.g.:
IAR 1420MHz@5MHz
TIGO 227MHz@150MHz & 8500MHz@1000MHz
SKA 100MHz-20000MHz@4000MHz

❖*When RF Interference appears….*
- Mask the phenomena under study.
- Saturates low noise amplifiers affecting linearity, possible damage to receiver.

❖As a result:
- Loss of Sensitivity.
- Loss of astronomical data.
- Loss of observation Time (Time is $$$).

A "friend" with the task to remove RFI….



"Mediciones de contraste, Radiometro Antena I, M.Salibe, D.Perilli, J.J.Larrarte."

RFI Identification for working observatories:
- Local Interference
  - Self Generated RFI, Computer, Networks, Power Lines, etc.
- External Interference
  - Radio Links, Cell Phone Masts, TV, FM, Radar, etc.
- Study of Interference
  - Power Spectra – Frequency – Bandwidth – Modulation.
  - Duration over days:
  - Continue – Random.

For Future observatories, site characterization is crucial…

RFI-SKA campaign, 2004

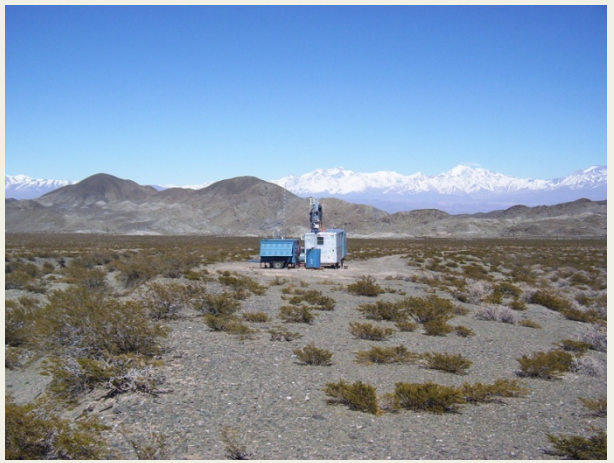
First Experience on Long Period RFI Measurements for the SKA-Site Characterization.
Located on "Pampa del Leoncito" in San Juan,
from February 2005 to March 2006.

RFI Measurements :

- *LNA's from 100Mhz to 22GHz.*
- *Single Pol Antennas with mechanical Pol change.*
- Automated acquisition for 24/7 measurements.

RFI Measurements Results:

- *Poor site for SKA-low and SKA-mid band (.07-3GHz).*
- *Excellent Site for SKA-High bands (3 GHz or higher to 25-50 GHz)*



Still an Excellent Site on High bands for Future Instruments

Transportable Integrated Geodetic Observatory
Concepción - Chile

TIGO, as part of the geodetic VLBI network, owns a 6mts antenna with a cryogenic receiver working in two bands:
S (2.2-2.4 GHz) & X (8.0-9.0 GHz)

For their RFI concern on the new location near the IAR, a two stages of RFI measurements where conducted:

Stage 1: one month survey with IAR-RFI Equipment.
Stage 2: one month survey with BKG-RFI Equipment.

Dr. Hayo Hase Director of TIGO

RFI-TIGO campaign, 2012

Developed for SKA site finding in Argentina
in 2005, quickly reconditioned in 2012 for TIGO

Stage I: RFI Equipment Design & Test ***April 25 @ June 1st***
•Start Campaign By June 11 (one week of delay)

Stage 1

Dual ridge horn antenna

- Frequency range: 1 - 18 GHz.
- polarization change mechanically.
- 359° spatial coverage 5° resolution.

Antenna box

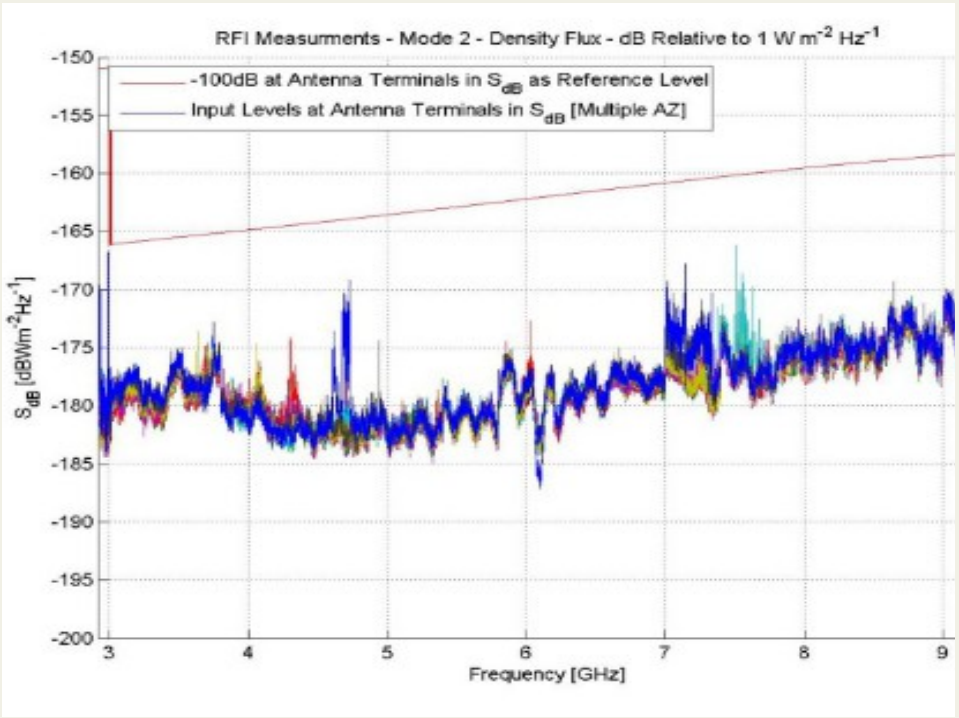
- 3 LNA from Miteq, 2 - 8 GHz (!)
- relays for 50 ohm reference load used for periodic Calibration.

HP9583E Spectrum Analyzer

- Tsys: ~700°K

Data logging:

- Custom software for automated measurements.



overall gain: 75dB at 2 GHz
incl. ~8dbi at 2 GHz antenna directivity

Stage 2-a

Manual pointing

overall gain: 70dB at 2 GHz
incl. ~7dbi antenna

Rohde&Schwarz-Antenna HL024A1

- Frequency range: 1-18 GHz,
- input signal: horizontal + vertical polarization

Antenna box

- 1 LNA for each polarization
- relais for noise cal injection
- noise cal diode NC346B

Receiver Box

- power combiner for both polarizations
- amplifier

Rohde&Schwarz SA FSL18

Tsys: ~300°K

Data logging:

Notebook PC

One week of measurements

Stage 2-b

Combination of RFI-monitoring systems
BKG Wettzell and IAR La Plata

Measurement

- 30kHz resolution bandwidth
- 2-14 GHz range divided in 1GHz bands
- each 1GHz band requires 2.5s sweeptime (12 bands = 30s)
- 8 directions (N, NE, E, SE, S, SW, W, NW) + 1 Cal. = 15min

=> 96 azimuth scans/day

=> 768 images/day

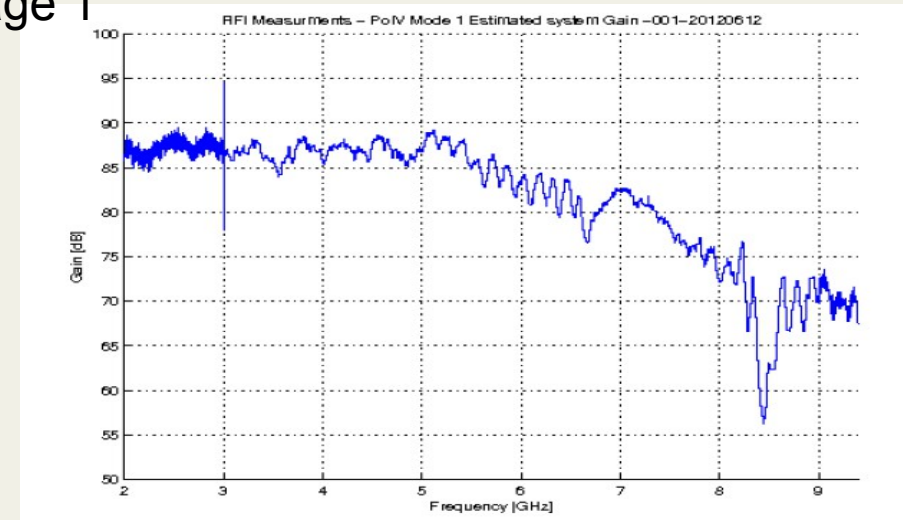
After 30 days of measurement (14.09.-14.10.2012):

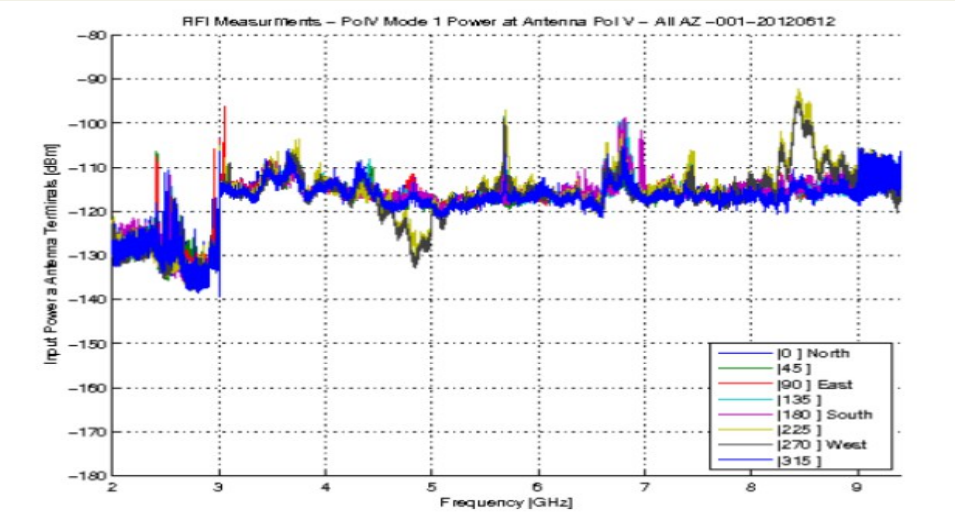
=> 21776 images of the spectrum analyzer recorded

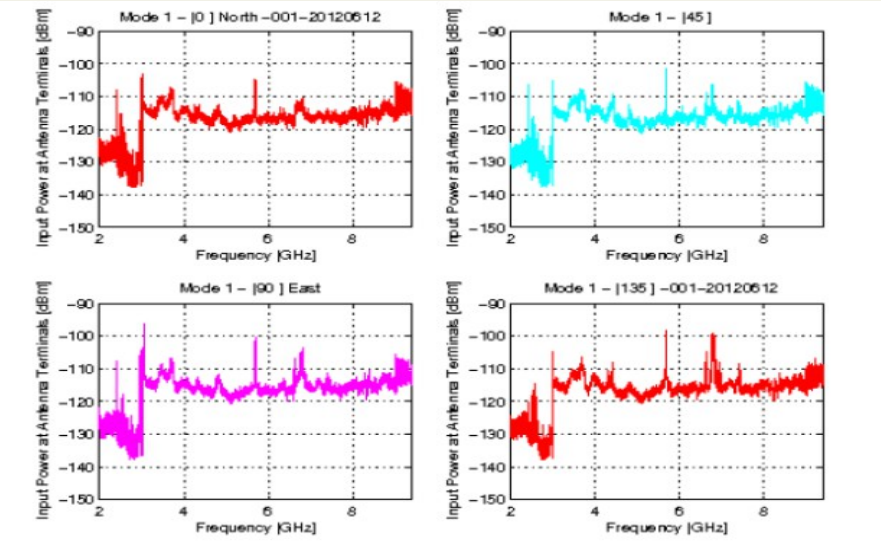
most dense RFI data set known to the IVS

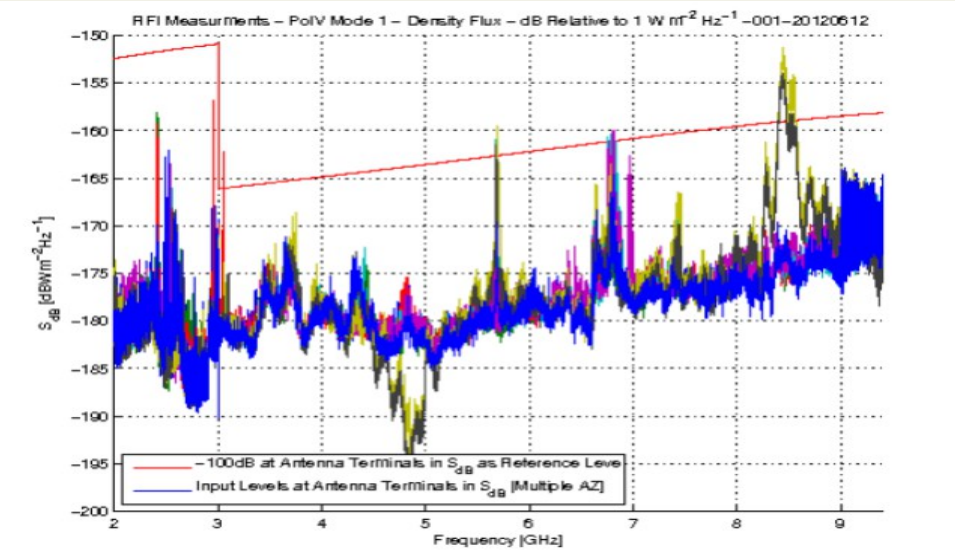
1 image = 9600 amplitude data points spaced by 1.25 MHz.
=> 209 million data points.

Stage 1


RFI Measurments – PolV Mode 1 Estimated system Gain –001–20120612
Gain [dB]
Frequency [GHz]

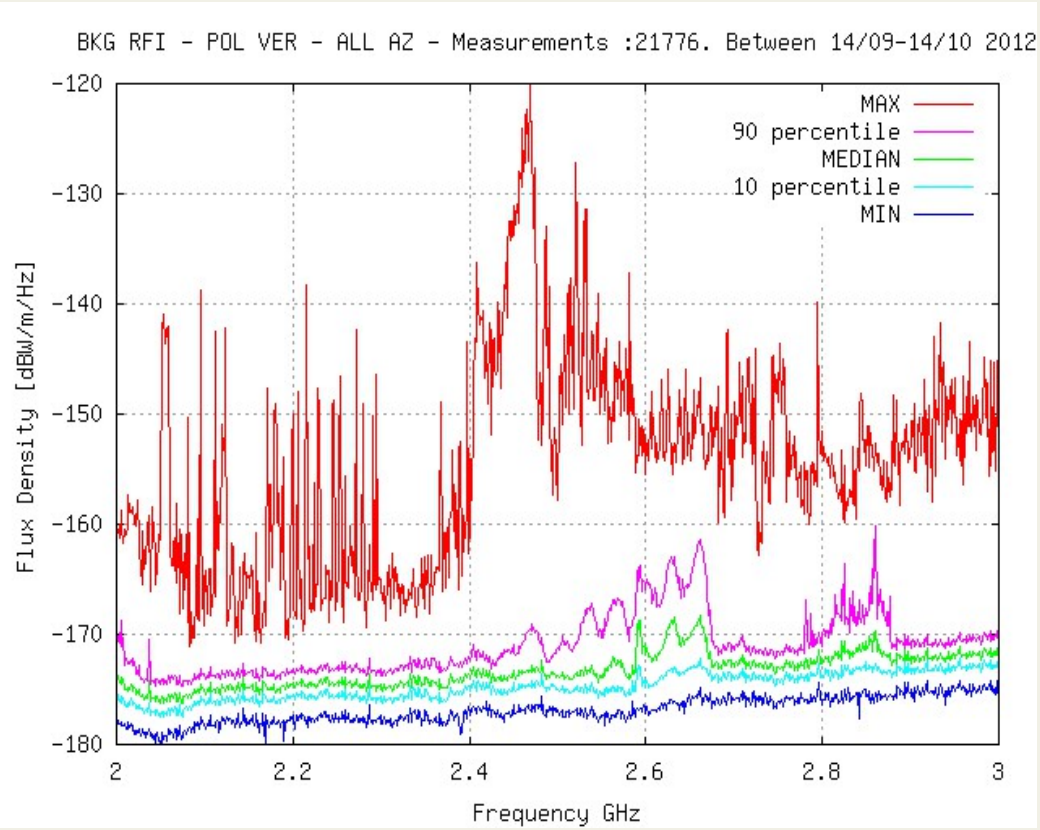

RFI Measurments – PolV Mode 1 Power at Antenna Pol V – All AZ –001–20120612
Input Power a Antenna Terminals [dBm]
Frequency [GHz]
|0] North
|45]
|90] East
|135]
|180] South
|225]
|270] West
|315]

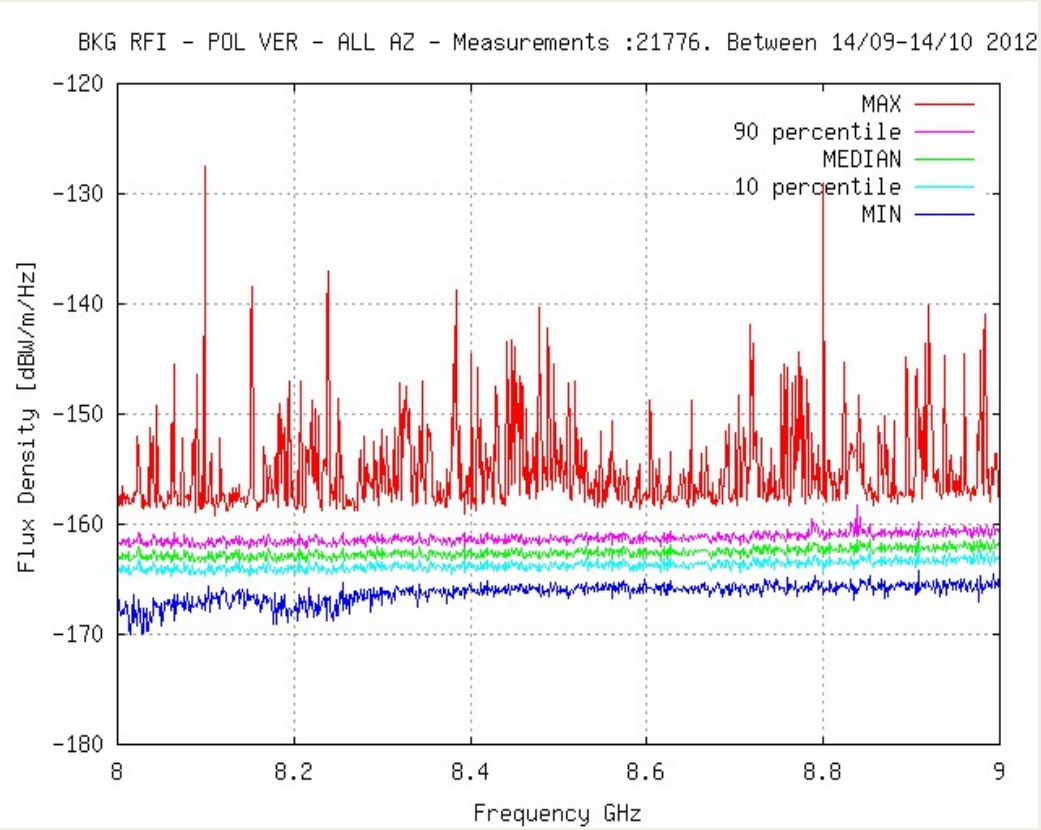

Mode 1 – |0] North –001–20120612
Mode 1 – |45]
Mode 1 – |90] East
Mode 1 – |135] –001–20120612
Input Power at Antenna Terminals [dBm]
Frequency [GHz]


RFI Measurments – PolV Mode 1 – Density Flux – dB Relative to 1 W m-2 Hz-1 –001–20120612
Sdb [dBWm-2Hz-1]
Frequency [GHz]
–100dB at Antenna Terminals in Sdb as Reference Leve
Input Levels at Antenna Terminals in Sdb [Multiple AZ]

RFI-TIGO campaign, 2012

Stage 2

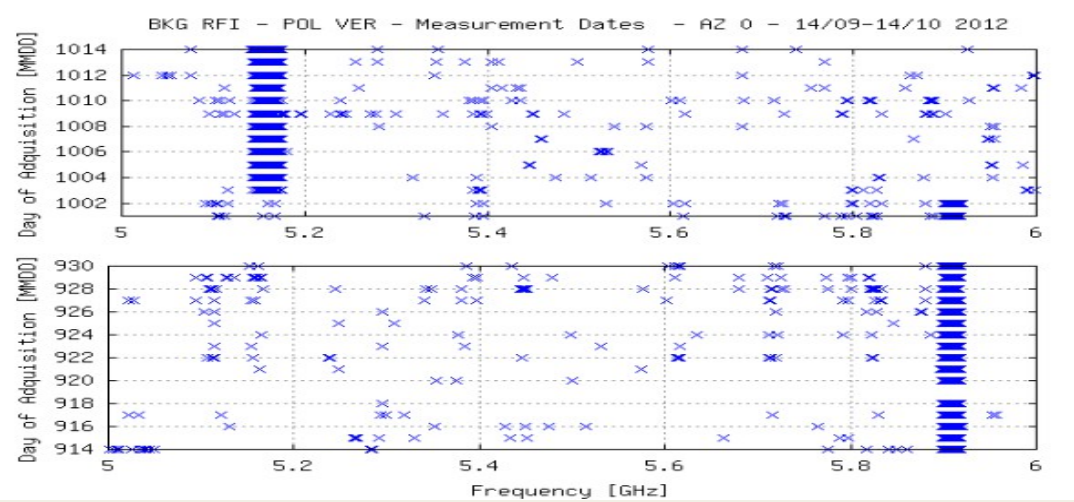


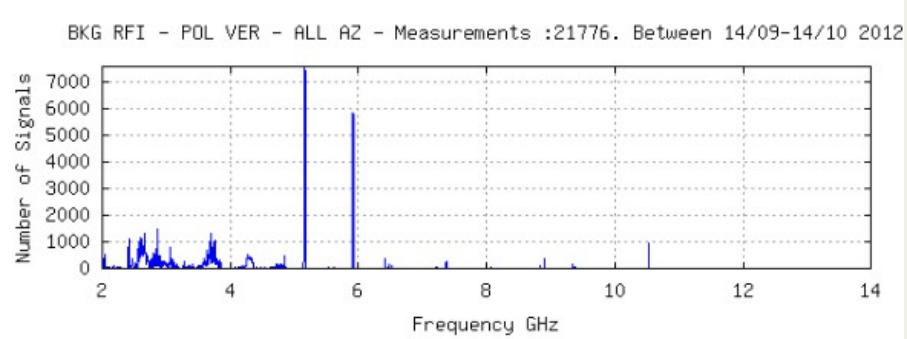


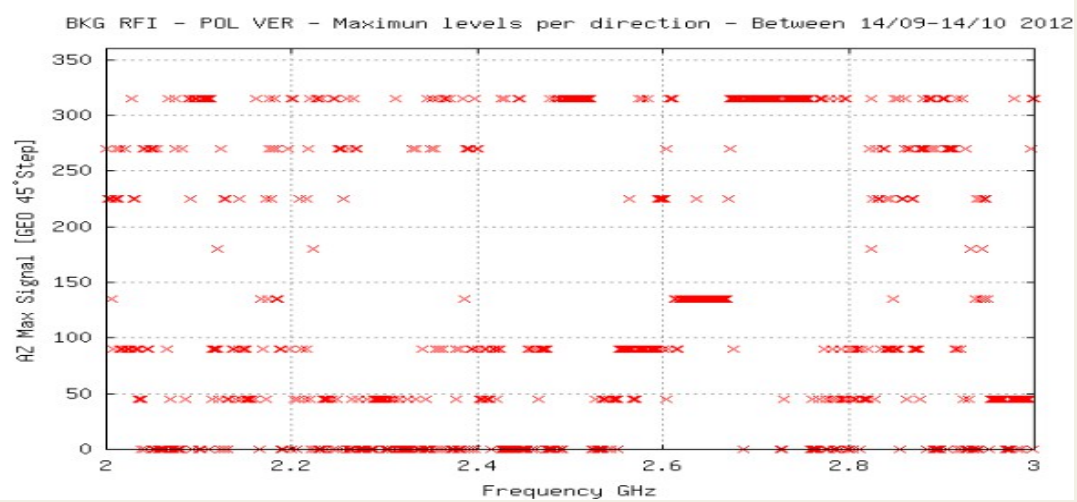
TIGO VLBI FREQUENCY BANDS

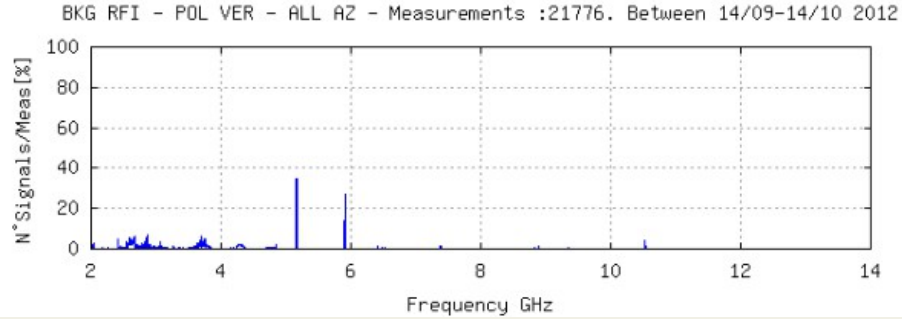
RFI-TIGO campaign, 2012

Stage 2

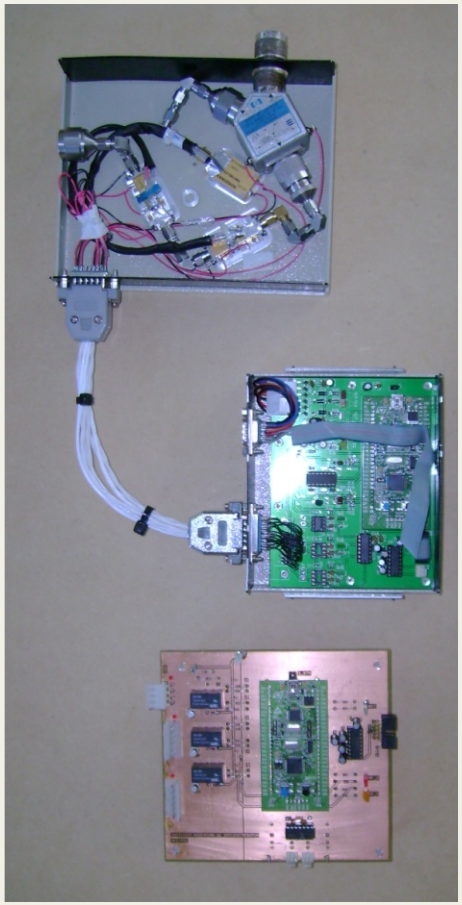








With the need to expand frequency and obtain a better S/N ratio.



RF-BOX

RF-TLMY

PDU

System Gain: 70dB~60 dB.
~3-10dBi from Antenna.

NEW Dual ridge horn antenna EST-Lindgren 3117

- frequency range: 1 - 18 GHz.
- HPW 85°@2GHz – 40°@18GHz (E-Plane)

Antenna box

- New 2 LNA from Miteq, 1 - 18 GHz!
- relais for 50 ohm reference load used for periodic Cal.

NEW Spectrum Analyzer

- Agilent N9344C better DANL (display average noise level) of spectrum analyzer.

NEW Antenna Rotor

- Improved mechanics.
- polarization change mechanically.
- 359° spatial coverage 5° resolution.

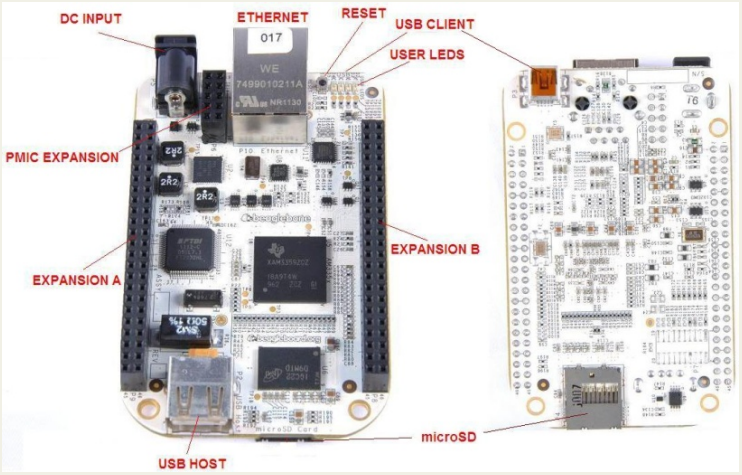
Data logging: PC (or SBC) with custom software for automated measurements.

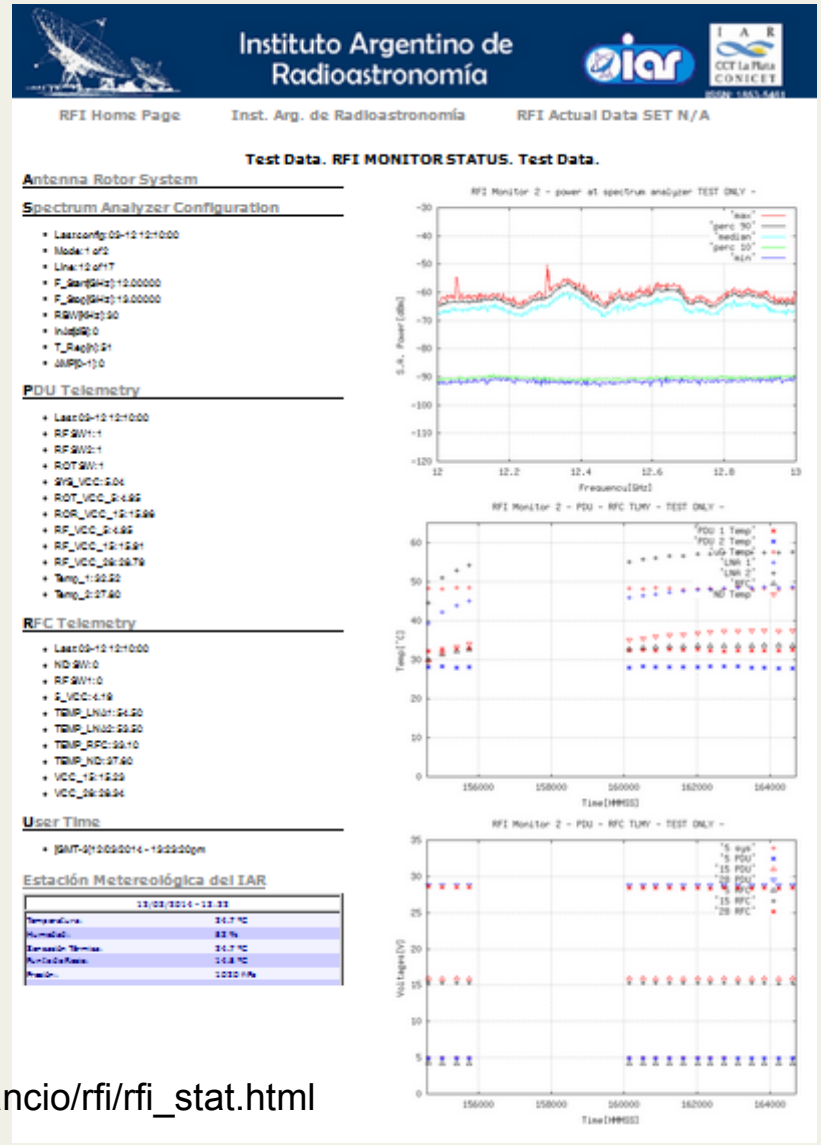
Software Description

- Controls the PDU unit, RF-Ctrl Unit and Rotor Unit
- Configure and reads the Spectrum Analyzer
- Web page for monitoring system status
- Measurements configuration from external file

Run's on Linux PC or Linux SBC (like BeagleBone)

- BeagleBone SBC present a Smaller size then PC (CreditCard Format).
- More sensitive to loss of power (OS stored in uSD).



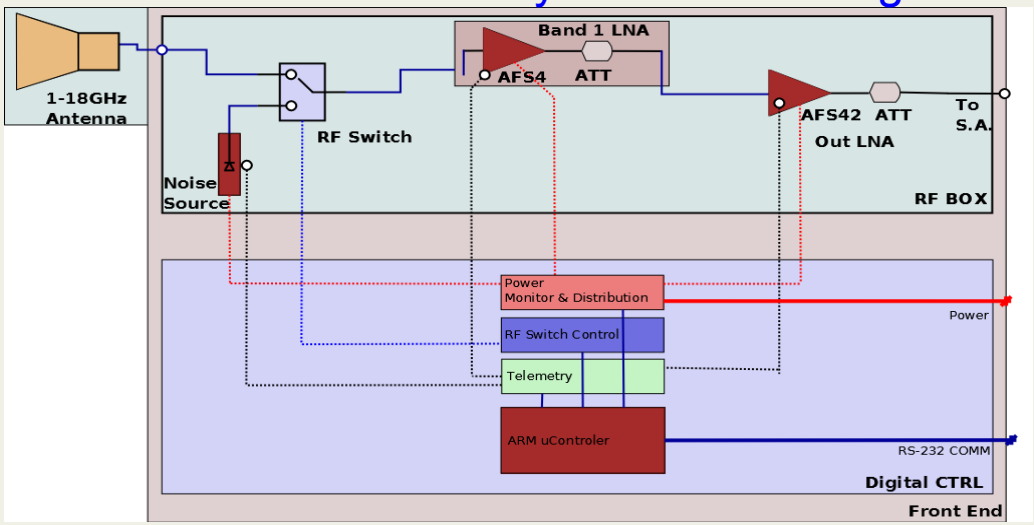


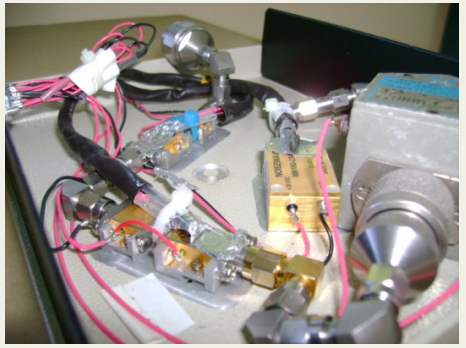

```
#Configuration Sample File
2.0 3.0 30 0 0 0 52 2 8
3.0 4.0 30 0 0 0 52 2 8
……..……
17.0 18.0 30 0 0 0 52 2 8

# End of File
```

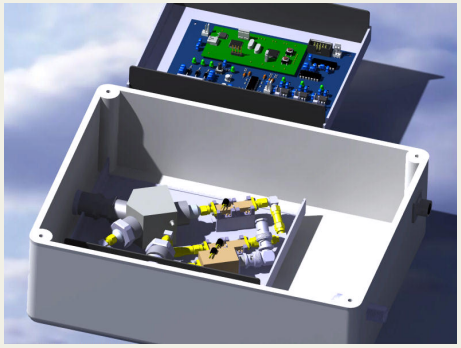
http://www.iar-conicet.gov.ar/~ggancio/rfi/rfi_stat.html

Work in Progress

System Block Diagram







- x2 LNA ~38dB Gain NF~2.5dB
- RF Switch
- Noise Source NoiseWave ENR23dB + 20dBAT

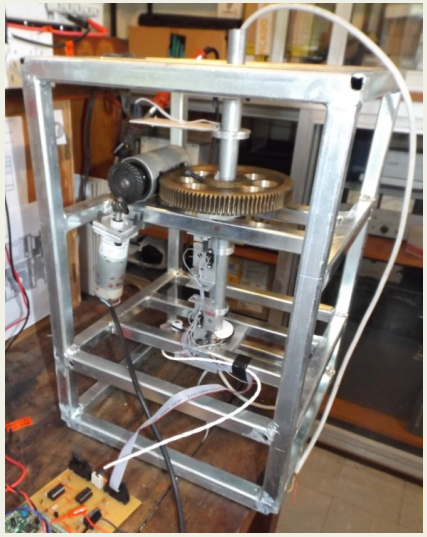
Band 1	Tr line + RF Switch x1	1 LNA	AT	RF Switch	2 LNA	AT	CABLE x 10mts	Spectrum A.
Gain [dB]	-1,50	38,00	-6,00	-0,50	38,00	0,00	-12,00	0,00
Gain Ratio	0,71	6309,57	0,25	0,89	6309,57	1,00	0,06	1,00
NF [dB]	1,50	2,50	6,00	0,50	2,50	0,00	12,00	39,50
DANL 13,2-20Ghz [dBm]								-137,00
Tn [°K]	119,64	225,70	864,51	35,39	225,70	0,00	4306,19	2584337,72
Gtot		0,71	4466,84	1122,02	1000,00	6309573,44	6309573,44	398107,17
		-1,5	36,5	30,5	30	68	68	56
OIP3 [dB]	100	10	100	100	10	100	100	
IIP3 [dB]	-60,13							
OIP3 [dB]	-4,13							
RBW [Khz]	*30*							
MDS [dBm] → Noise Figure [dB]	*-125,19*							
S/N [dB] → Sensitivity [dBm]	*3,00*							
T rcv [°K]	*445,39*							
Tint [mS]	*10,00*							
So	*1,00E-20*							
SH	*-200,00*							
Dt [m°K]	*1,92*							

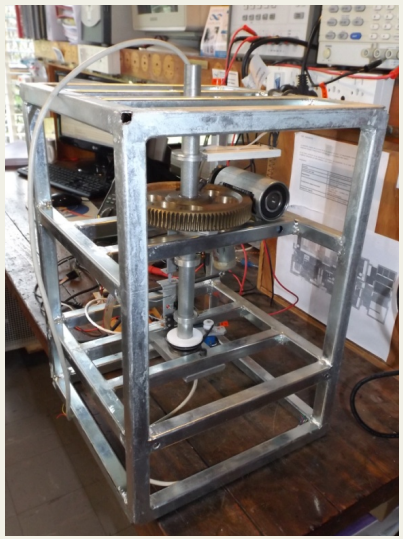
Estimated Values @2GHz

- Voltage & LNA Temperature measurements.
- RF-Switch & Noise Source Control.
- RS-232 Communication.

Custom Antenna Rotor

Work in Progress





Custom Design

- Robust.
- Small Size – (..Almost Lightweight..).
- Simple Installation.
- Easy to disassemble for repair / verification.

Spatial Coverage

- 355° in Azimuth with ~5° resolution.
- 0° to 90° for Mechanical Polarization change.

Remote Control

- Serial Interface
- Position measurement with magnetometer & Potentiometer.

RF signal thru RF rotary Joint

RFI data processing

Off-Line Process Math's with Octave Scripts

$$ENR = 10^{\frac{ENR_{dB}}{10}}$$

$$T_0 = T_{amb}$$

$$T_{hot} = T_0 * (ENR + 1)$$

$$Y = \frac{P_{on}[W]}{P_{off}[W]}$$

$$T_{rcv} = T_0 * (\frac{ENR}{(Y-1)} - 1)$$

$$G_{e\_rcv} = \frac{P_{on}[W]}{k * RBW[Hz] * (T_{hot} + T_{rcv})}$$

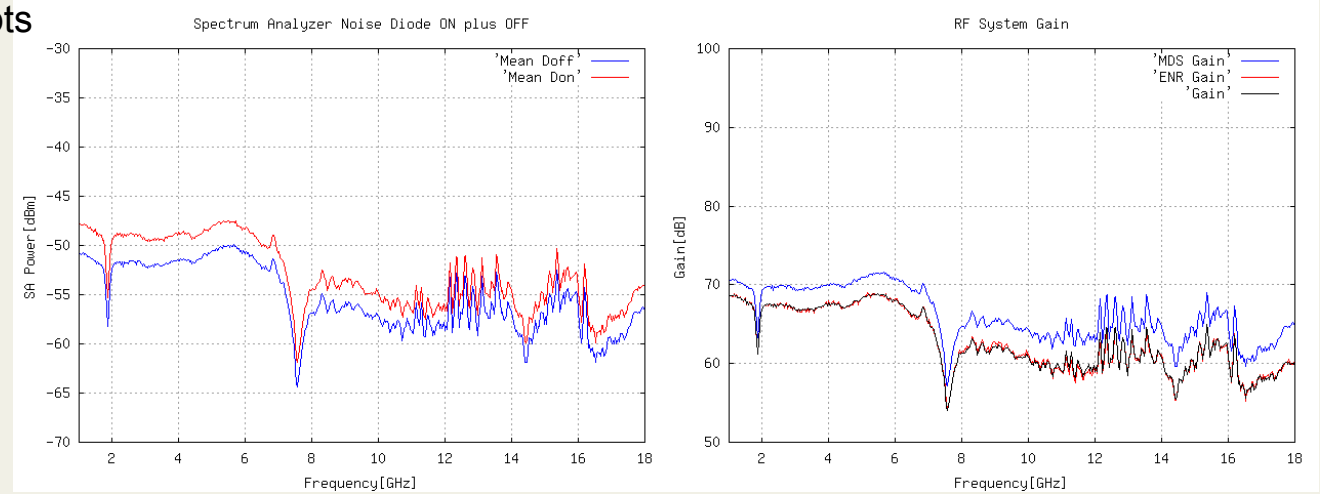
$$S_{dB} = P_{SA_{dBm}} - 10\log_{10}(RBW) - G_{rcv\_dB} + K_{A_{dB}} - 35.77[dB\,Wm^{-2}Hz^{-1}]$$

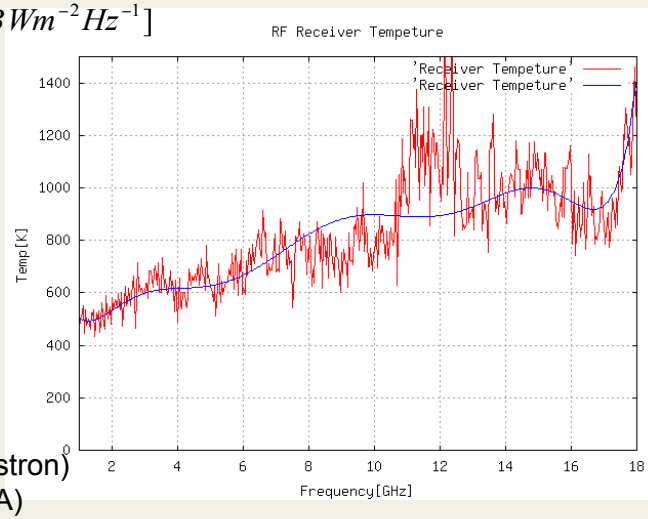
Where:

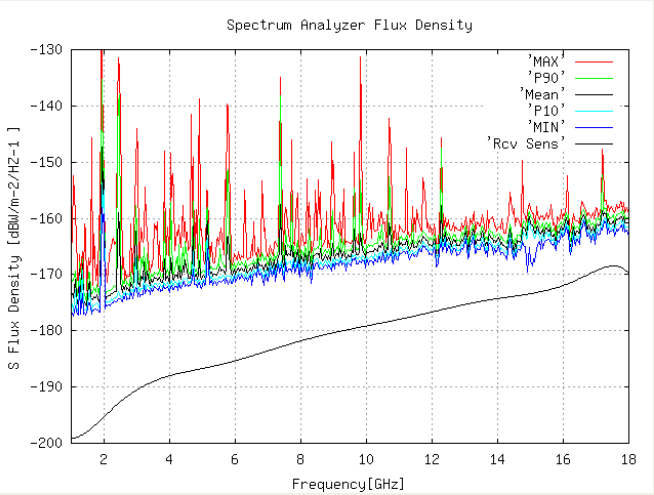
$$K_{A_{dB}} = 20\log_{10}(f_{MHz}) - G_{dBi} - 29.79$$

$$S_o \cong 0.265 * \frac{k * T_{rcv} * K_A^{\,2}}{\sqrt{B\tau}} - 30[dB\,Wm^{-2}Hz^{-1}]$$

- Analysis thru direction of measurement.
- Peaks above noise floor.
- Percentage thru time of measurement.







References:
SSSM System Design Considerations (R.P. Millenaar – Astron)
SKA site Spectrum Monitoring (Boonstra / Millenaar – SKA)
1-14GHz TIGO RFI Monitoring System (Gancio / Larrarte – IAR)

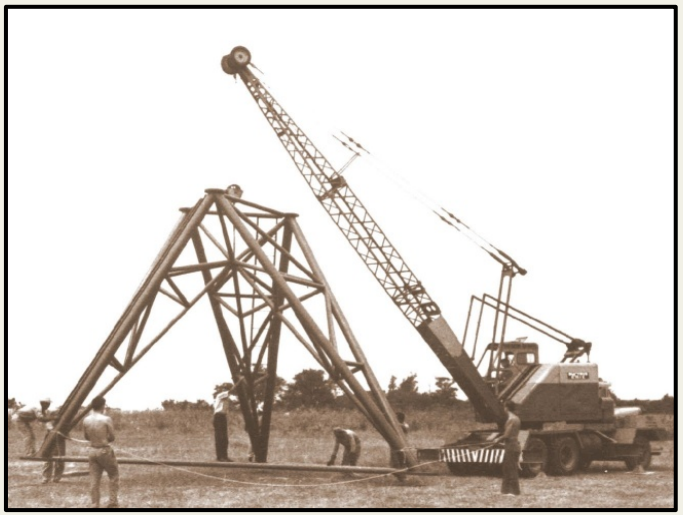
Thanks for your attention!

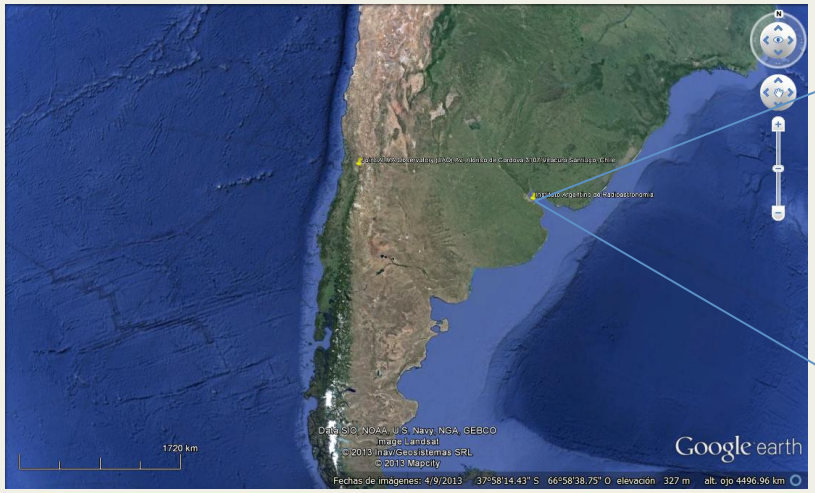
Some Links of interest…
Instituto Argentino de Radioastronomía
http://www.iar.unlp.edu.ar/proyectos.htm – ggancio@iar-conicet.gov.ar

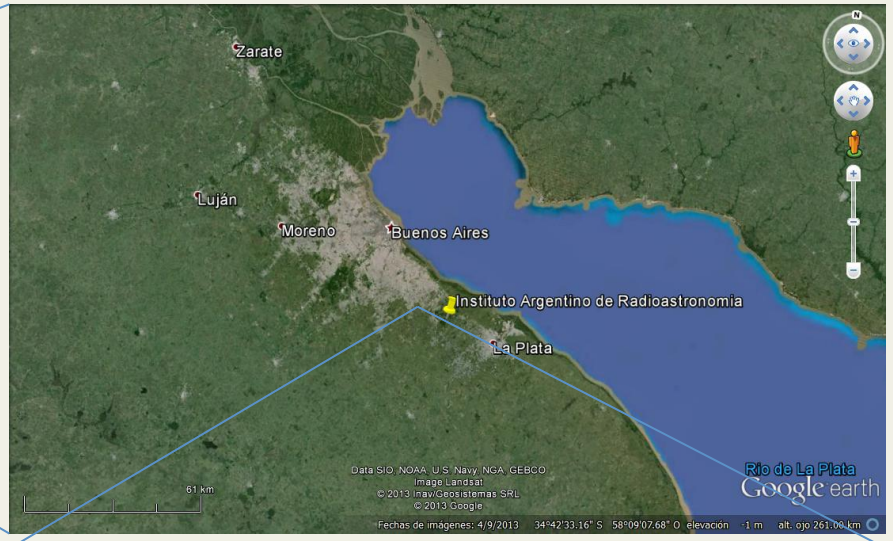
RFI Monitor System web page (English)
http://www.iar.unlp.edu.ar/rfi-eng.htm

Online Data
http://www.iar.unlp.edu.ar/~ggancio/rfi/rfi_stat.html

Backup Slides







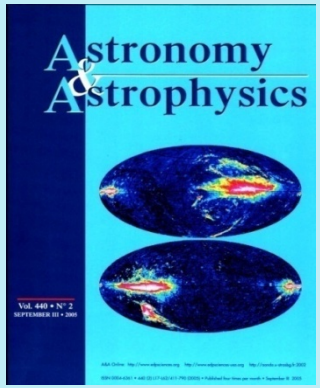
Instituto Argentino de Radioastronomía (IAR)

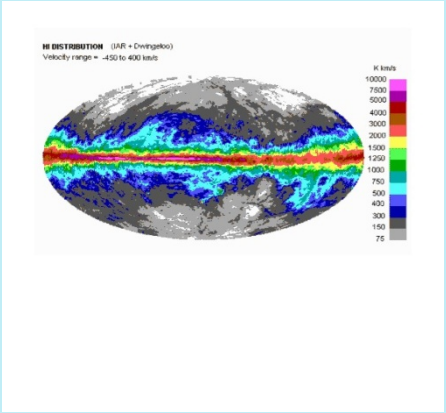
Consejo Nacional de Investigaciones Científicas y Técnicas (CCT La Plata - CONICET)

- Director: Dr. E. Marcelo ARNAL
- Vice director: Dra. Paula BENAGLIA

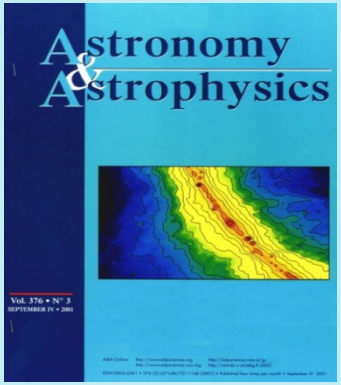
-Commitment for creation agreement: 30/10/1962
Primary Objective
Scientific research on frequency bands corresponding to hydrogen.
-First Observation: 24/3/1966
-Creation agreement : 10/12/1969 (CICPBA, CONICET, UBA, UNLP)
-12/11/85 -> Depends only on CONICET.

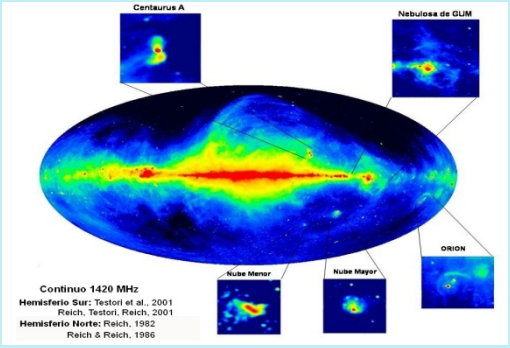
Latitude : -34° 51′ 57″.35 Longitude : 58° 08′ 25″.04



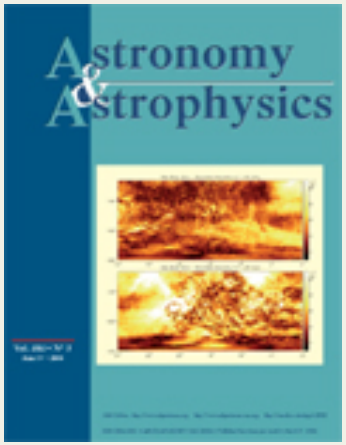


Hydrogen Distribution

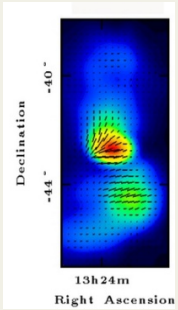


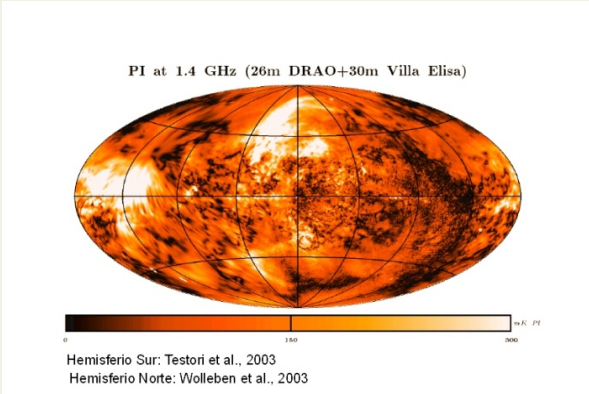


Radio Continuum on 21cm



High energy astrophysics, compact objects
Clusters of galaxies and active galactic nuclei
Circumstellar disks
Early interstellar medium and stars
Getting radio astronomical data bases
planetary Systems
Mathematical Models and Algorithms for Signal Processing



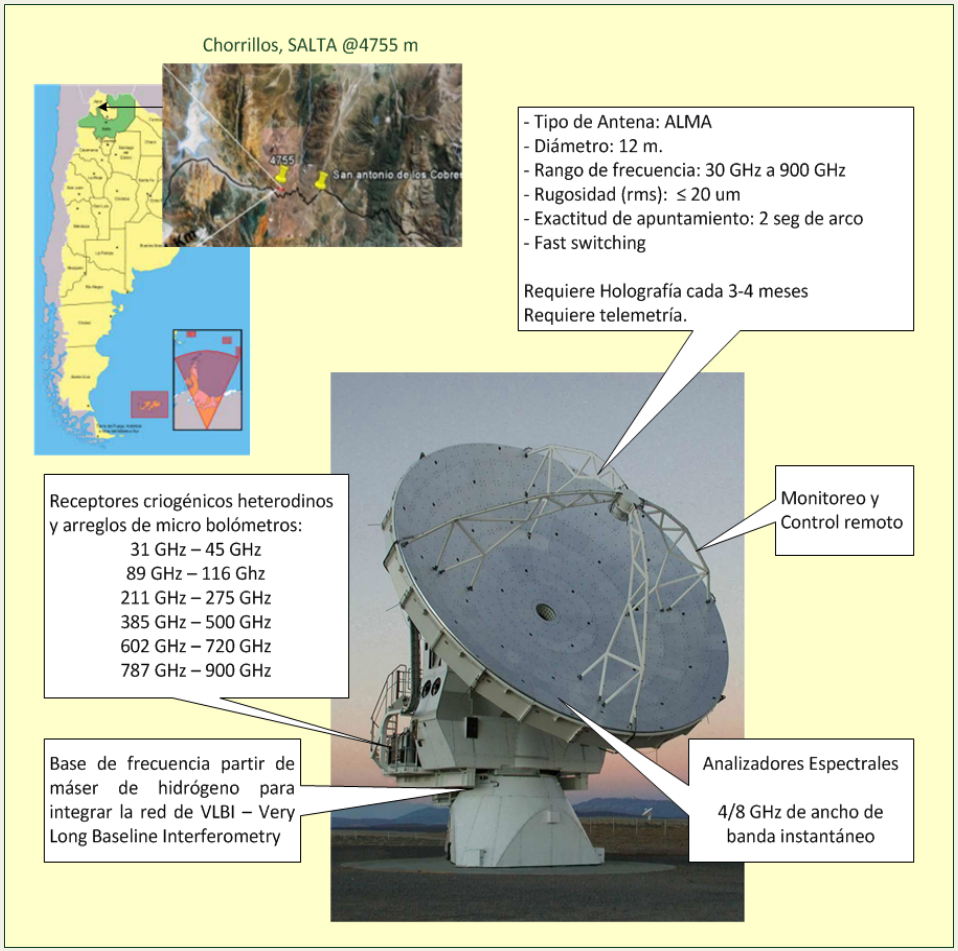


Galaxy Radio Polarization

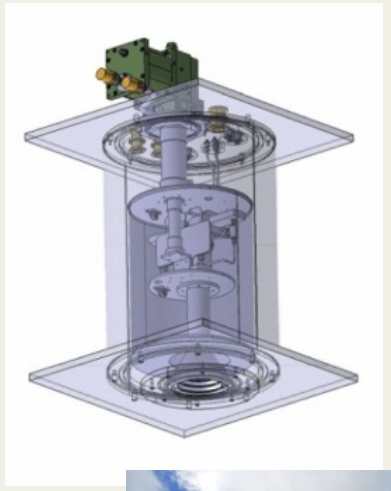
Current Instrumentation

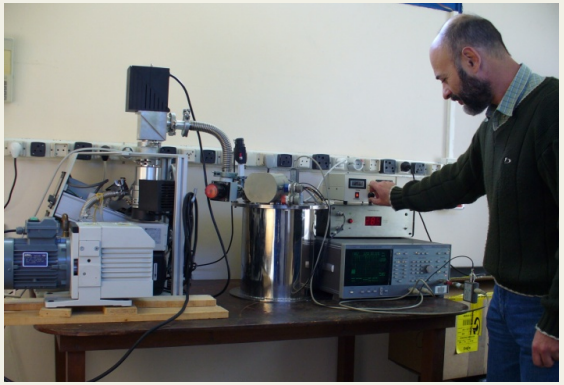
Antenna:	Two Parabolic dish: 30mtr in diameter
Sky coverage:	- 90° < d < - 9.1°
Sky Following:	- 30° < t < + 30°
Observation frequencies:	1420 MHz (HI) Spectral Lines 1410MHz Continuum 1612, 1665, 1667, 1720MHz (OH)
Amplifiers Temperature:	15°K (-258°C)
Angular resolution:	30' (1420 MHz)

New Astronomical Projects



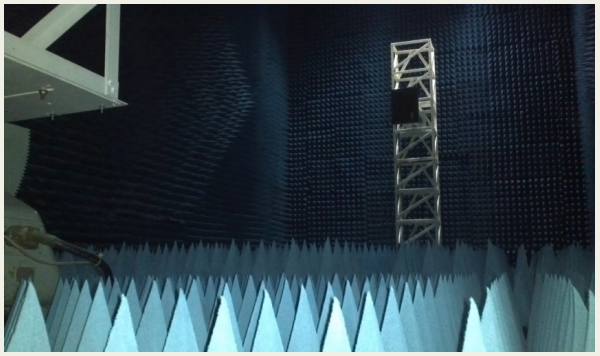
"LLAMA (Long Latin American Millimeter Array)"





5.5GHz 500MHz BW Continuum receiver

Technological Facilities



Anechoic Chamber

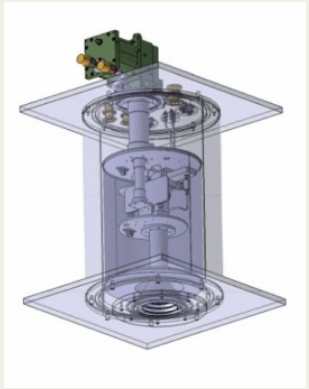
Electronics Laboratory

Infrared Characterization Laboratory

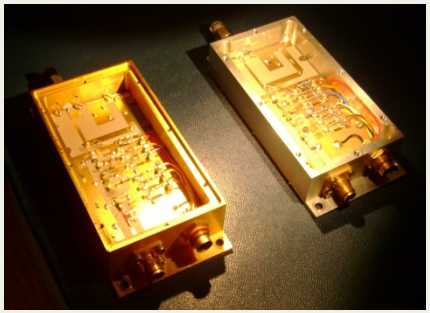
Electronics Assembly Laboratory

Open Field Antenna Measurement

Technological Developments

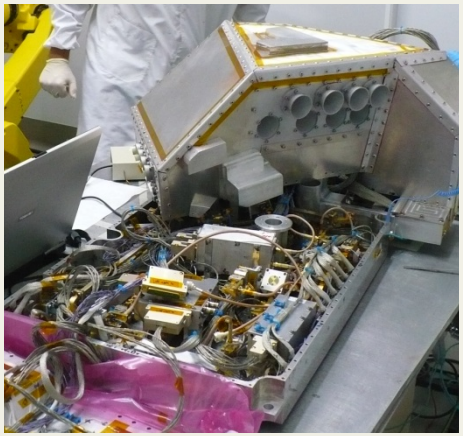


Radiometers

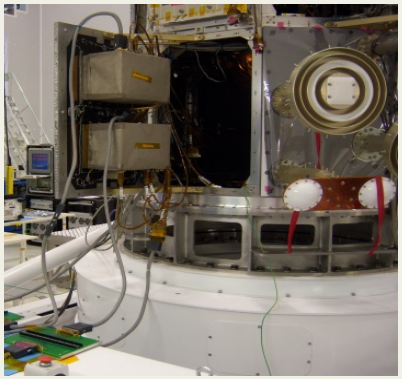


RF Design

Satellite Instruments



MWR, Microwave Radiometer 23&36GHz



Pad, Data Acquisition computers

Digital Design

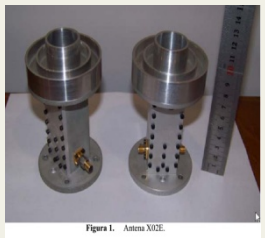


Figura 1. Antena X02E.

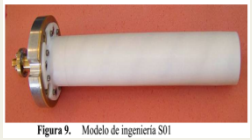
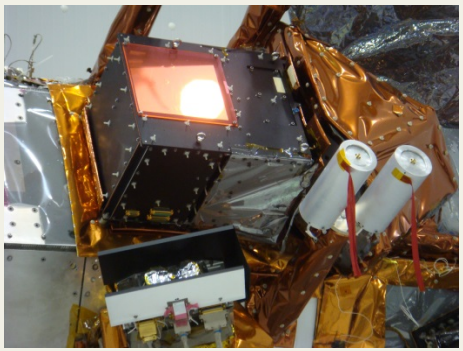
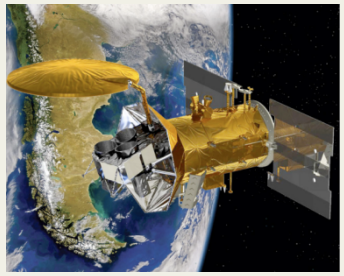


Figura 9. Modelo de ingeniería S01

Antenna Design



NIRST, New Infra Red Sensor Technology



IAR and the "SAC-D / Aquarius" Satellite

Microwave Radiometer (MWR) 23GHz-Single Pol & 36GHz-Two Pol

- Functional prototype design.
- Development and construction of the flight model.
- Environmental Campaign tool: measures vibration, thermal vacuum testing and EMI / EMC. Test antennas and feeders.
- Integration and Test the Service Platform, satellite environmental campaign in Brazil, campaign launch and commissioning (Commissioning).

New Infrared Sensor Technology (NIRST)

- Design, development, construction, verification and validation of electronic acquisition and control of the instrument and environmental campaign (vibration, thermal vacuum and EMI / EMC).
- Integration and Test the Service Platform, satellite environmental campaign in Brazil, campaign launch and commissioning (Commissioning).

Antennas TT & C (Tracking, Telemetry and Command) S-band satellite)

- Design and Development.
- Flight model and acceptance testing: electromagnetic parameters with the antenna mounted on the satellite platform model (laboratory LaMa - Córdoba CONAE), thermal vacuum tests (FIE-CONAE Córdoba) and vibration tests (GEMA-UNLP).

Processing and Data Acquisition (PAD)

- Design, development, implementation, verification and validation of flight software and environmental campaign (vibration, thermal vacuum and EMI / EMC).
- Design, development, implementation, verification and validation of the script is for the four instruments (DCS, MWR, and NIRST ROSA) and PAD.
- Integration and Test the Service Platform, satellite environmental campaign in Brazil, campaign launch and commissioning (Commissioning).