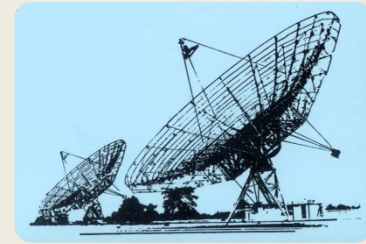


Radio Frequency Interference TIGO - IAR Measurement Campaign



Dec-2012

Why RFI it's important



Radio Astronomy uses frequency spectra to study astronomical phenomena.

Signal characteristics:

- Very Low Power.
- Noise Like.
- Bandwidth Dependent.

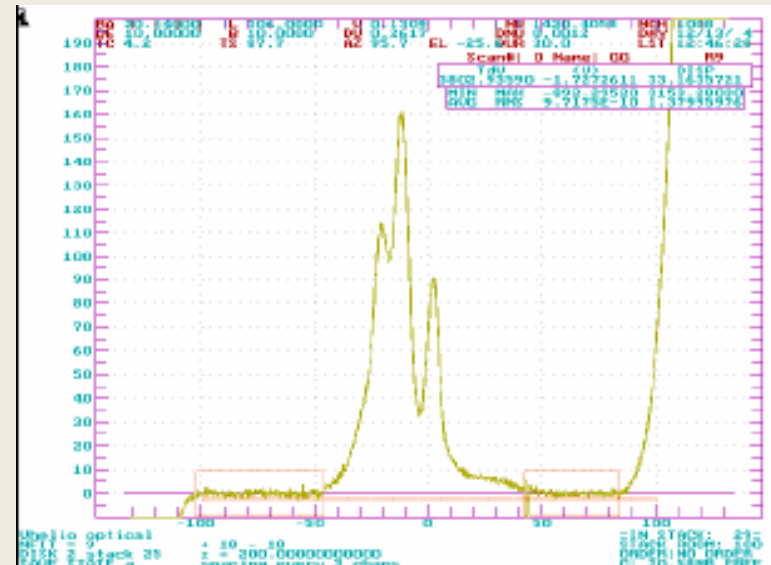
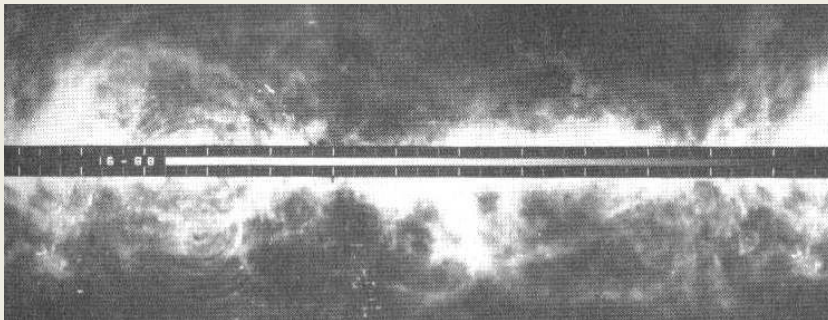
According to the phenomena different frequencies and bandwidths are used.

IAR @ 1.42GHz -> BW 10MHz

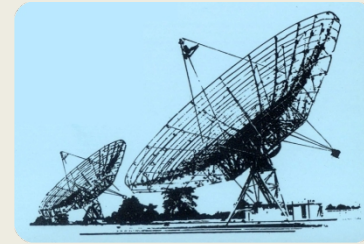
TIGO @ 2.27GHz -> BW 150MHz

@ 8.5 GHz -> BW 1000MHz

SKA 100MHz -20GHz -> BW 4000MHz



Why RFI it's important

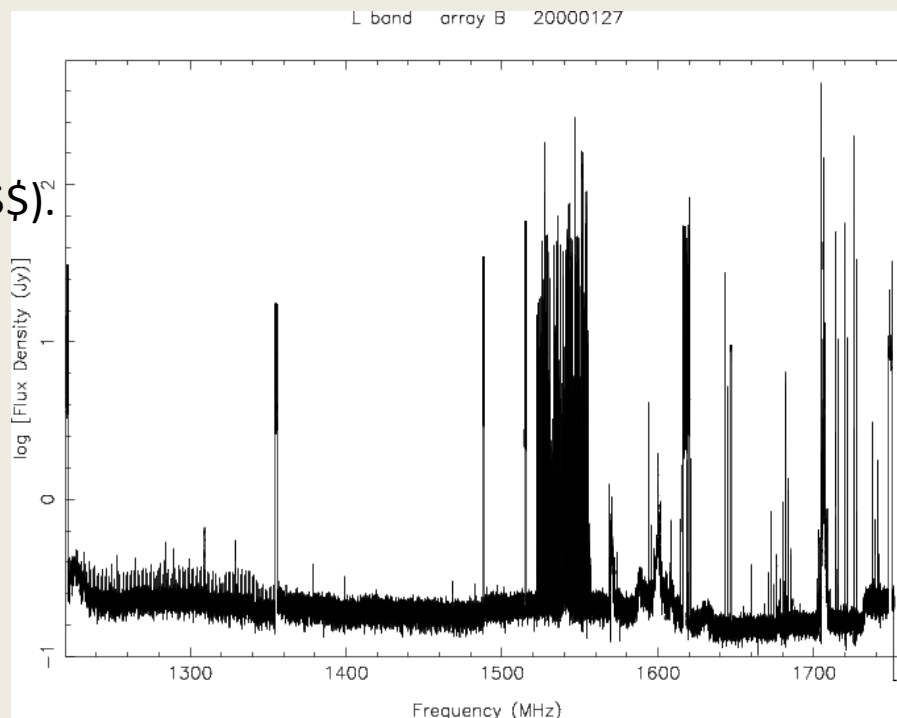


When RF Interference appears....

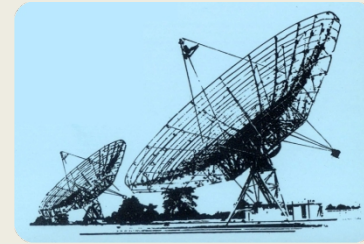
- Mask the phenomena under study with same F_o .
- Saturates low noise amplifiers affecting linearity close to the F_o .

As a result:

- Loss of astronomical data.
- Loss of observation Time (Time is \$\$\$).
- Loss of Bandwidth.
- Loss of Sensitivity.



Why RFI it's important



Committees, Regulations, Meetings...

- The Committee on Radio Astronomy Frequencies (CRAF) ESF. <http://www.craf.eu/>
- ITU-R RA .769 <http://www.itu.int>
- NRAO RFI/SPECTRUM MANAGEMENT <http://www.cv.nrao.edu/~hlszt/RFI/>
- ASTRON RFI Mitigation Workshop <http://www.astron.nl/rfi/presentations.php>

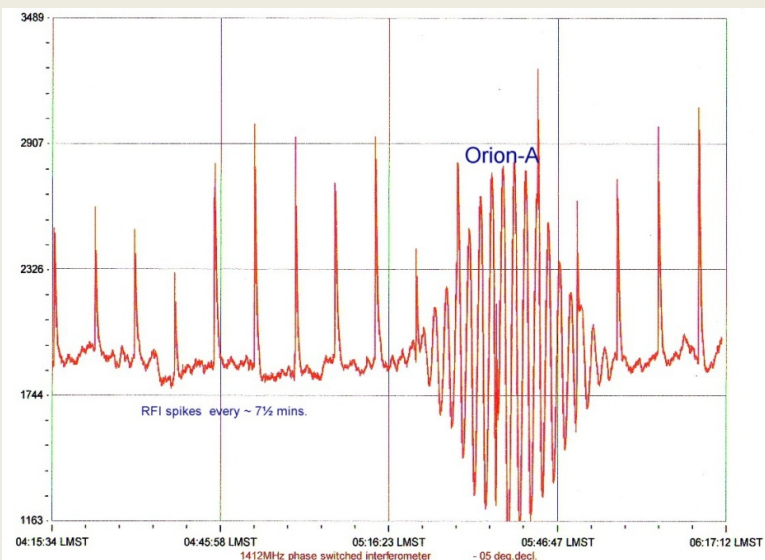
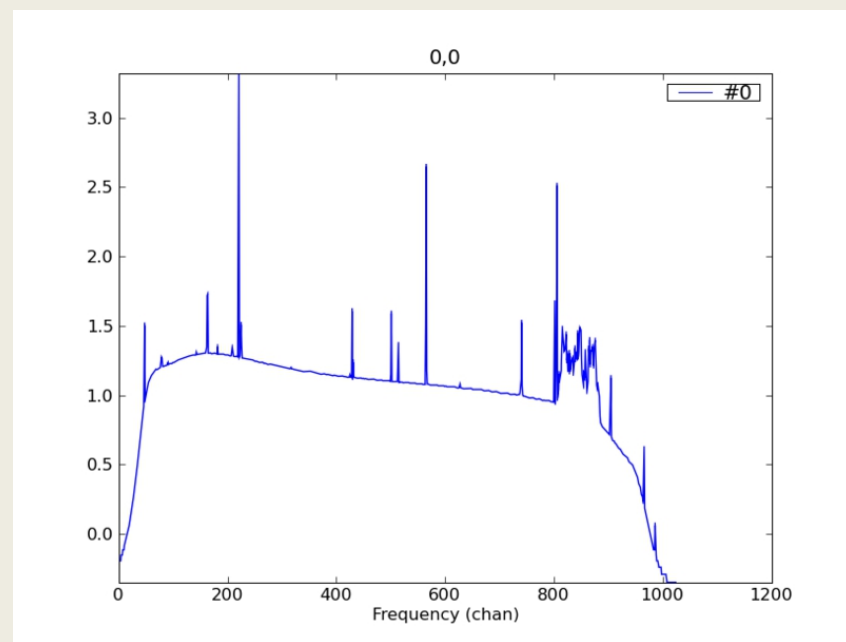
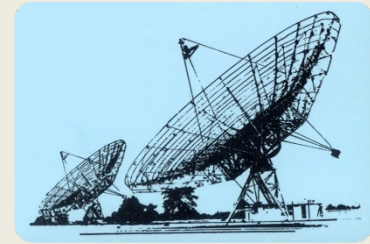


Chart Started 9/12/2010 by Wavelab in Guilderton, W.Australia



Why RFI it's important



Study the Radio Frequency Spectra in order to identify the *kind* of Interference.
Then prepare a plan of action or contingency according to instrumentation.
Single Dish – VLA – VLBI – Spectral Line – Continuum.

- 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 and Bandwidth.
 - Modulation.
- Duration over days; % of time during observation.
 - Continue.
 - Random.

And Only Then-> RFI MITIGATION TECHNIQUES.....(For other talk)

RFI Measurement Campaign



Phase I RFI Measurement Requirements (**April 25/2012**):

- Frequency coverage from 2GHz up to 9Ghz.
- Noise Floor $> -100\text{dBm}$.
- Vertical and Horizontal Antenna Polarization.
- Spatial coverage of 360° .
- Automatically controlled.
- At least one month of measurements.
- RF components on Hand.
- *Start campaign by **June 1st /2012!***



SKA Campaign
San Juan Argentina 2006

RFI Measurement Campaign



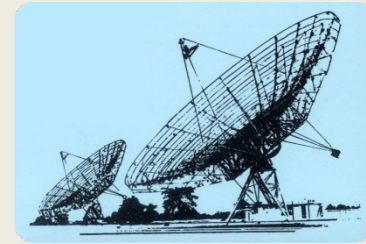
The SKA Measurement protocol sets:

- The instrumentation requirements.
- RFI measurements requirements to be met.
- The protocol seeks to identify RFI originating from terrestrial or airborne sources.
- Satellites and astrophysical sources of RFI are considered to be more or less the same for all candidate sites and, thus not interest in the evaluation.

The protocol divides the measurements into two parts, Mode 1 and Mode 2

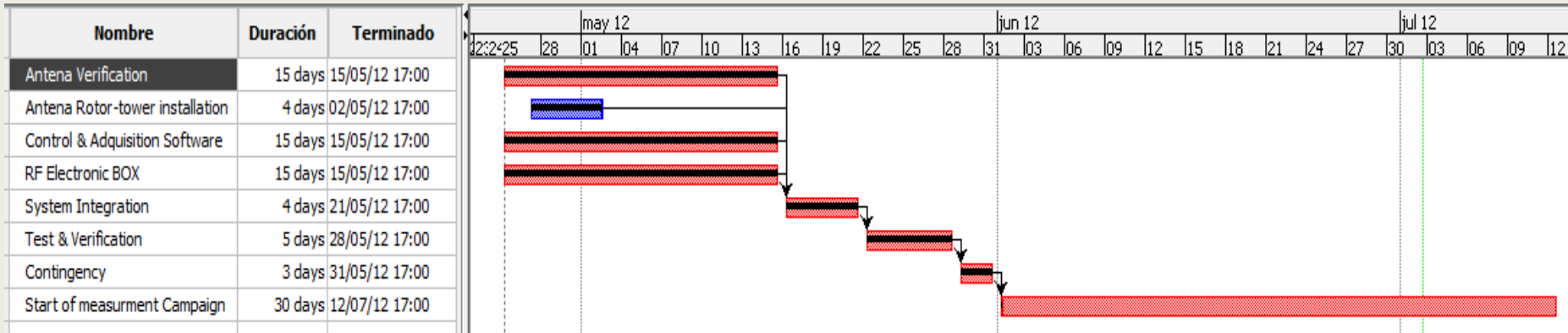
- The first one, with low sensitivity requirements, is defined for the observation of strong RFI.
- Mode 2, with high sensitivity requirements, is defined for the observation of weak interferences, which potentially will obscure weak signals of interest.

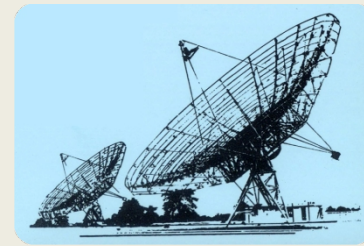
RFI Measurement Equipment



Phase I Schedule

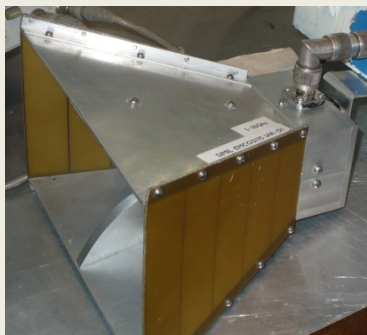
- RFI Equipment Design & Test **April 25 to June 1st**
 1. Antenna Verification.
 2. RF Electronics.
 3. Antenna Rotor & Acquisition Software.
 4. System Integration.
 5. Test & Verification.
 - 6. Start Campaign.**



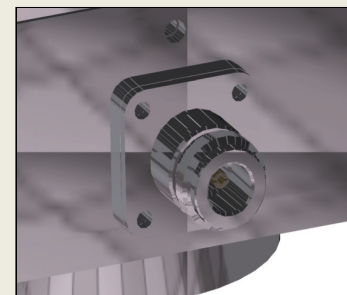
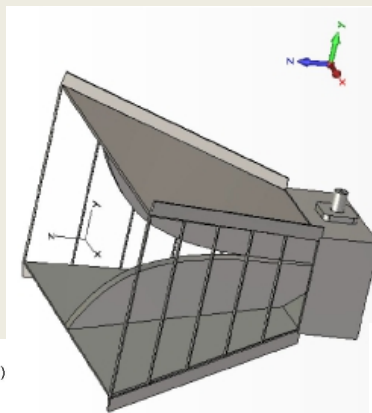


Phase I RFI Equipment Design & Test *April 25 @ June 1st*

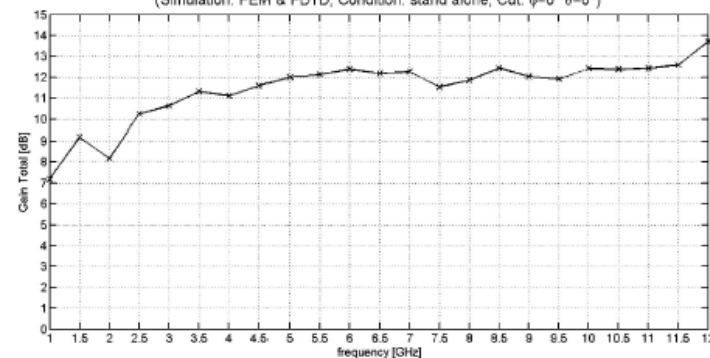
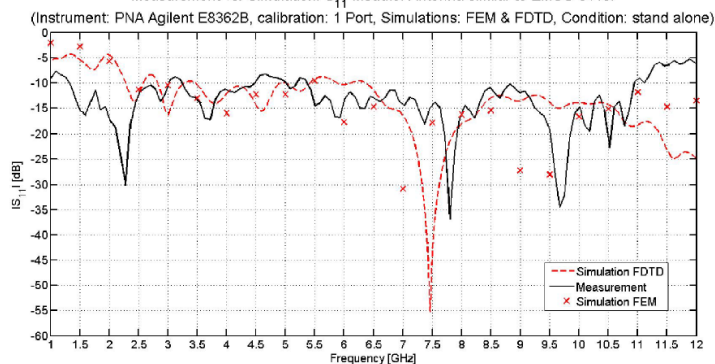
- **Antenna Verification**
Measurement & Simulation.



Measurement vs. Simulation. S_{11} Module. Antenna similar to EMCO 3115.



Simulation. Gain Total. Antenna simil to EMCO 3115.
(Simulation: FEM & FDTD, Condition: stand alone, Cut: $\phi=0^\circ$ $\theta=0^\circ$)



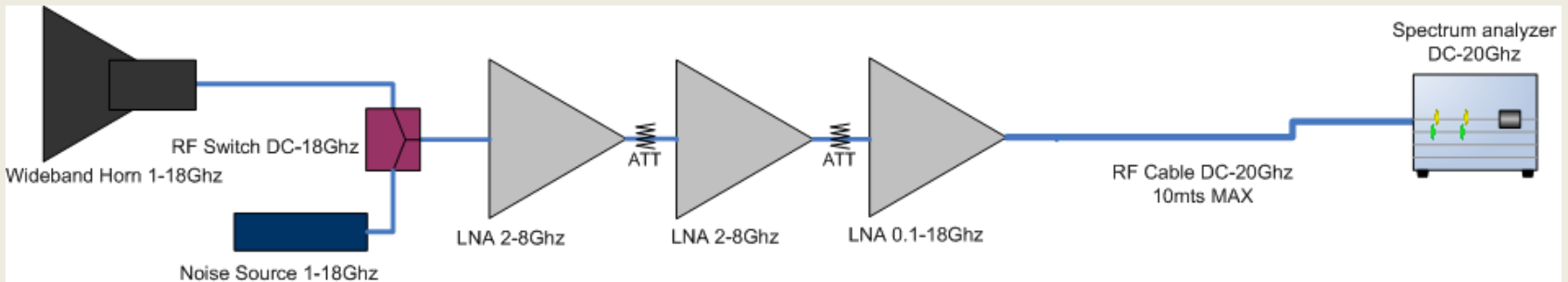


Phase I RFI Equipment Design & Test *April 25 @ June 1st*

- **RF Electronics.**

Receiver Design , Construction & Measurement.

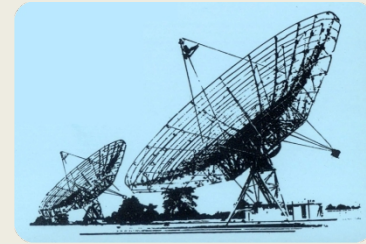
Based on: R.P Millenaar, “SSSM System Design Considerations,” Doc. No.ASTRON-RP-013.



Two Observation Modes according SKA Protocol for the 2GHz – 9GHz Band.

- Mode 1 for identify strong RFI.
- Mode 2 for weak RFI and define sensitivity levels.

RFI Measurement Equipment



Phase I RFI Equipment Design & Test *April 25 @ June 1st*

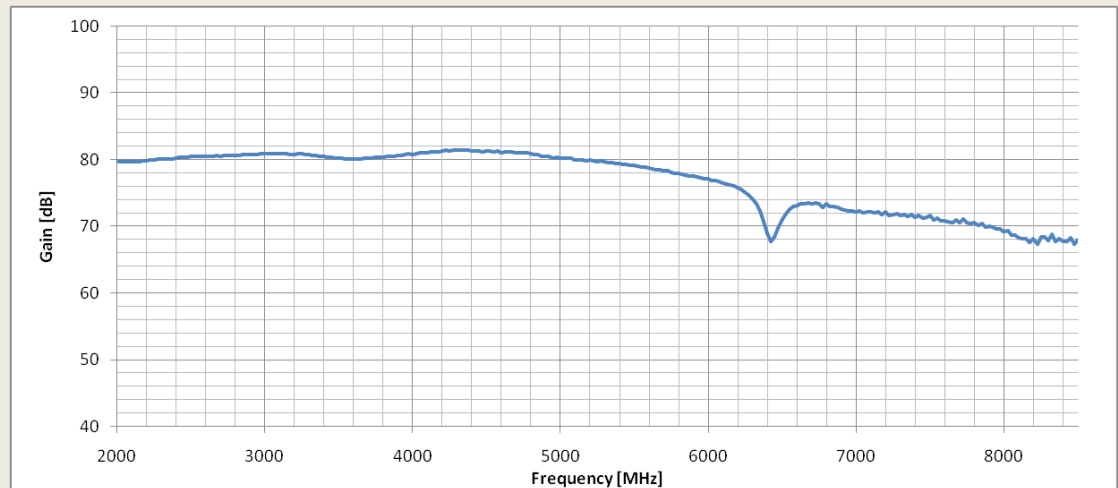
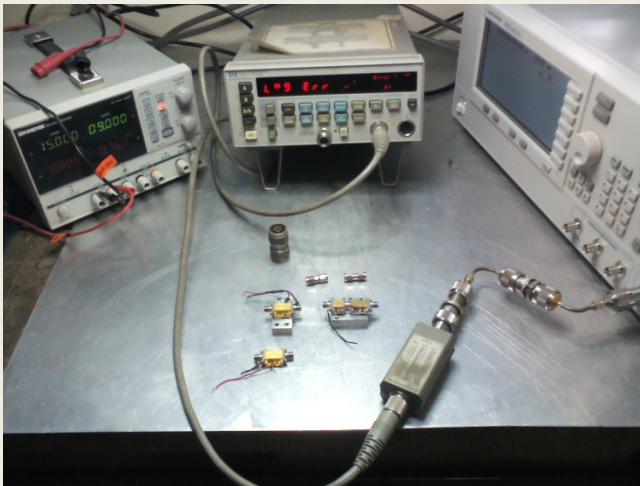
- **RF Electronics.**

Each RF component measured independently.

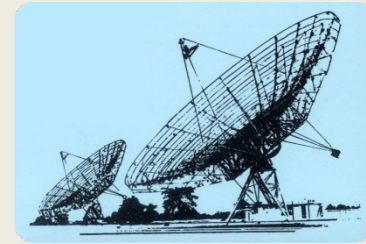
Low Noise Amplifiers from MITEQ.

Extremely Low RF Input Insertion Loss, critical for system Noise -> System Sensitivity.

Measure of complete system Gain.



RFI Measurement Equipment



Phase I RFI Equipment Design & Test *April 25 @ June 1st*

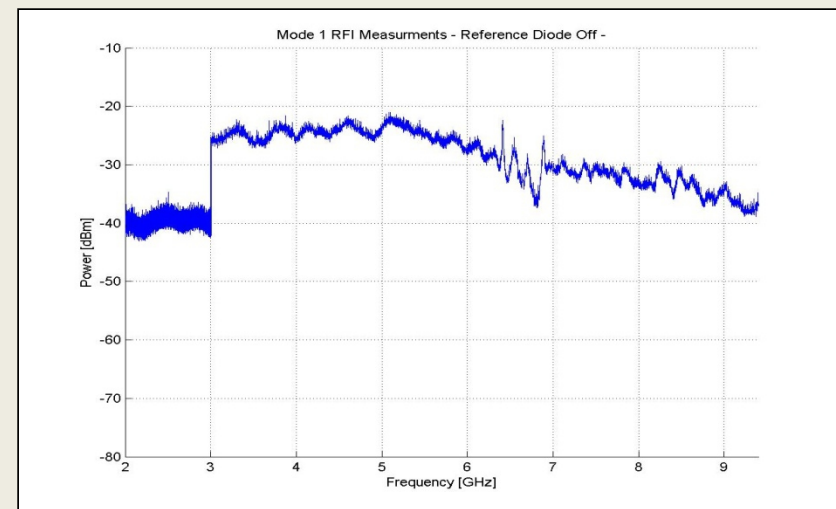
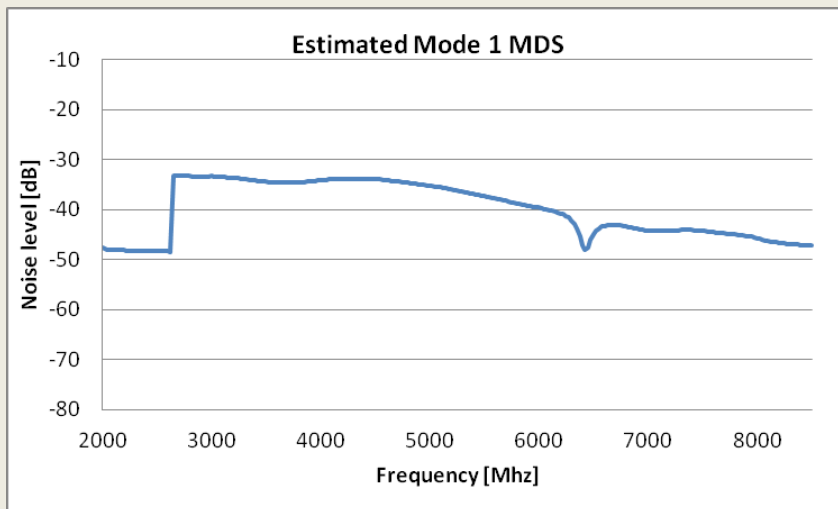
- RF Electronics.**

Average System Gain 70dB.

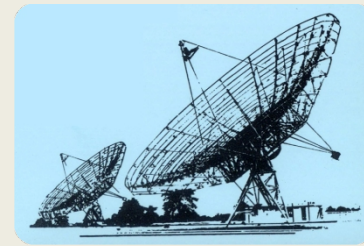
Average Theoretical System Noise ~ 3.5 dB.

Theoretical System Temperature $\sim 350^\circ - 700^\circ$ K (Worst Case due to Spectrum Analyzer DANL).

~~Noise Source for Calibration~~ (Component Not Available).



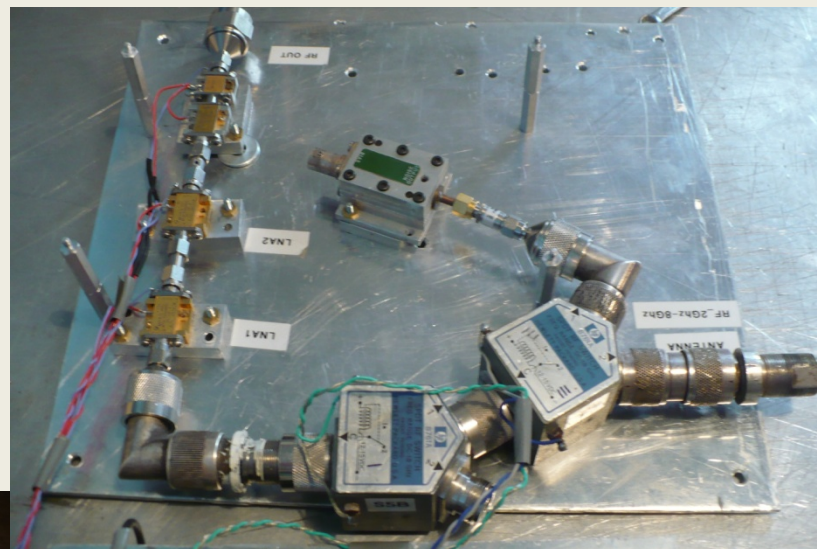
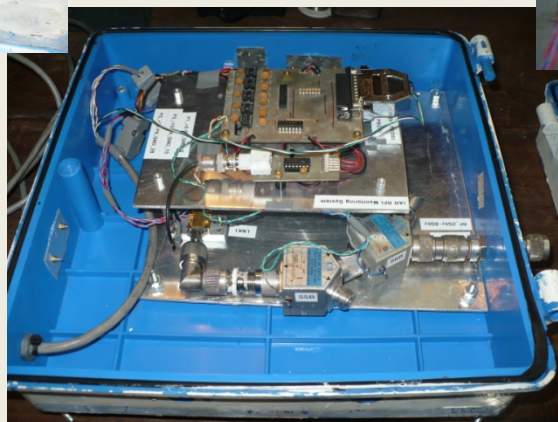
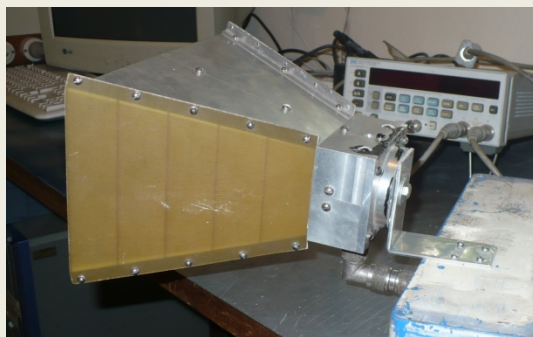
RFI Measurement Equipment



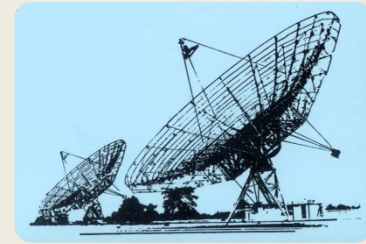
Phase I RFI Equipment Design & Test *April 25 @ June 1st*

- **RF Electronics.**

Antenna assembled directly to RF, Lower In Loss.



RFI Measurement Equipment



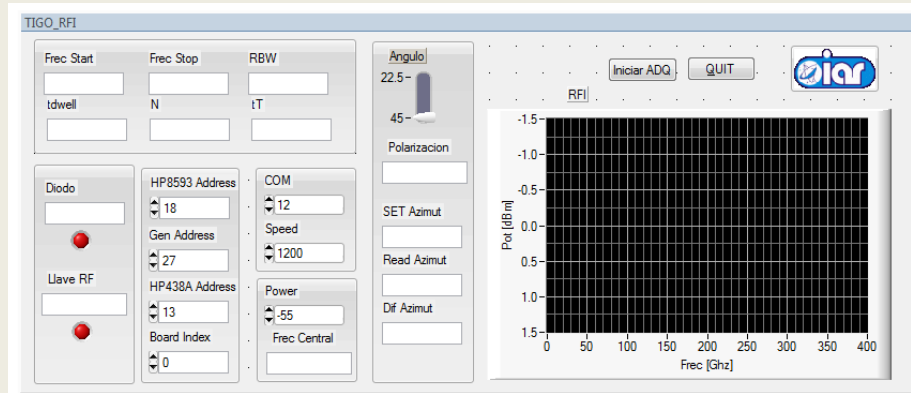
Phase I RFI Equipment Design & Test *April 25 @ June 1st*

- Antenna Rotor & Acquisition Software.**

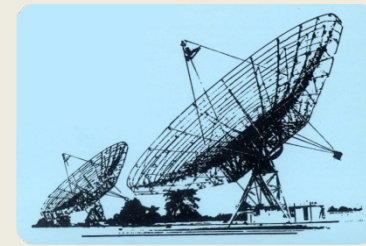
Same Hardware as SKA Campaign 2005.

New Software (CVI/LabWindows) according to new requirements.

Mounted on top of the Antennas control room @ ~14mts above ground.

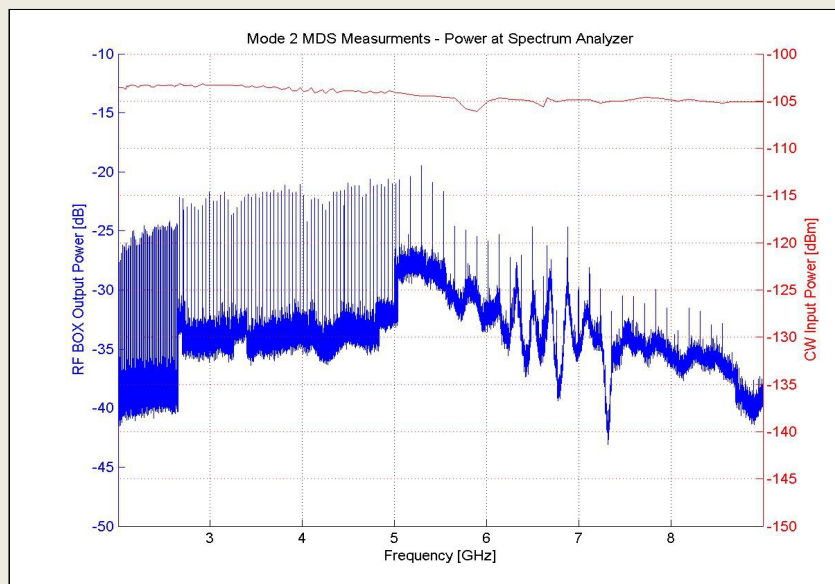
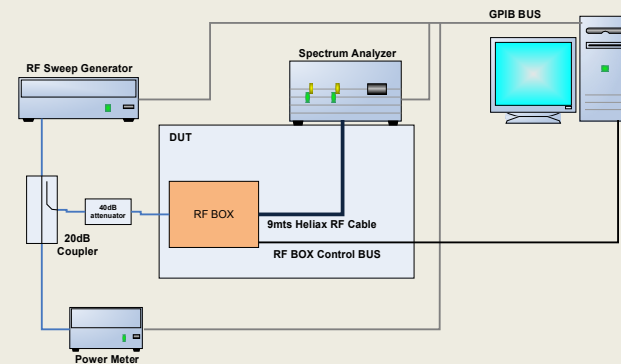


RFI Measurement Equipment

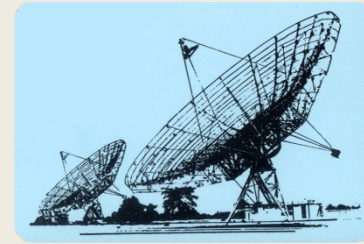


Phase I RFI Equipment Design & Test *April 25 @ June 1st*

- **System Integration / Test & Verification.**
Complete Assembly.
System Evaluation & Measurement.



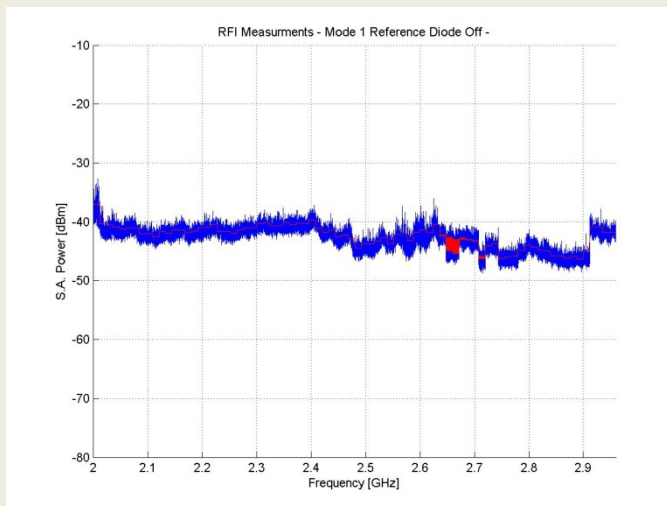
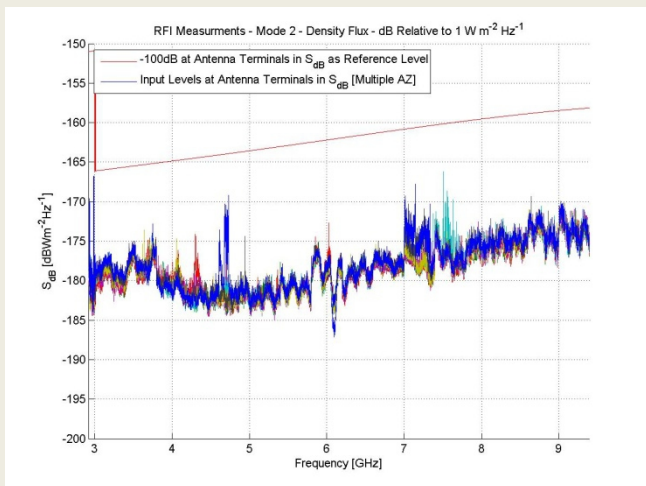
RFI Measurement Equipment



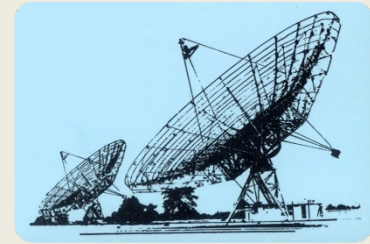
Phase I RFI Equipment Design & Test *April 25 @ June 1st*

- **Start Campaign By *June 11* (one week of delay).**

*First week problem.....RF Downlink cable.....
Loss of sensitivity for upper frequency band.*



RFI Measurement Equipment



Phase I RFI Equipment Design & Test *April 25 @ June 1st*

- **Start Campaign By *June 11* (one week of delay).**
Each Mode Measurement Time

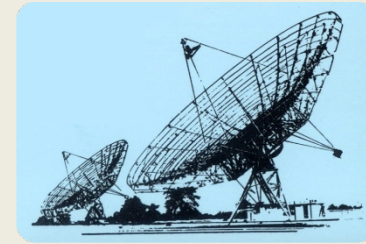
MODE 1				MODE 2			
ANTENNA		REFERENCE		ANTENNA		REFERENCE	
POL-V	"POL-H"	N.D.-ON	N.D.-OFF	POL-V	"POL-H"	N.D.-ON	N.D.-OFF
C1	C1	C1	C1	C1	C1	C1	C1
....
Cn	Cn	Cn	Cn	Cn	Cn	Cn	Cn

For a 360° coverage with an antenna pattern of 45°@-3dB lobe 8 single azimuth points are observed

Mode 1 All AZ~ 6Hs

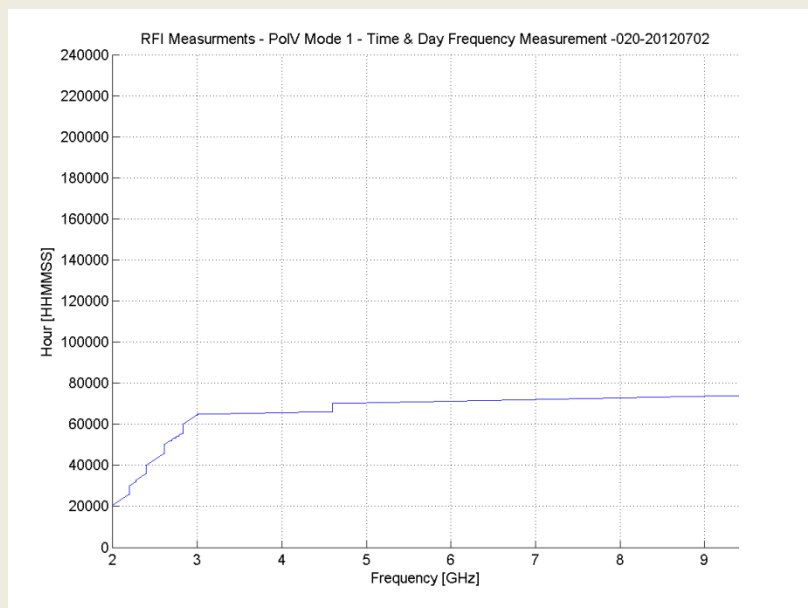
Mode 2 All AZ ~ 16Hs

RFI Measurement Equipment

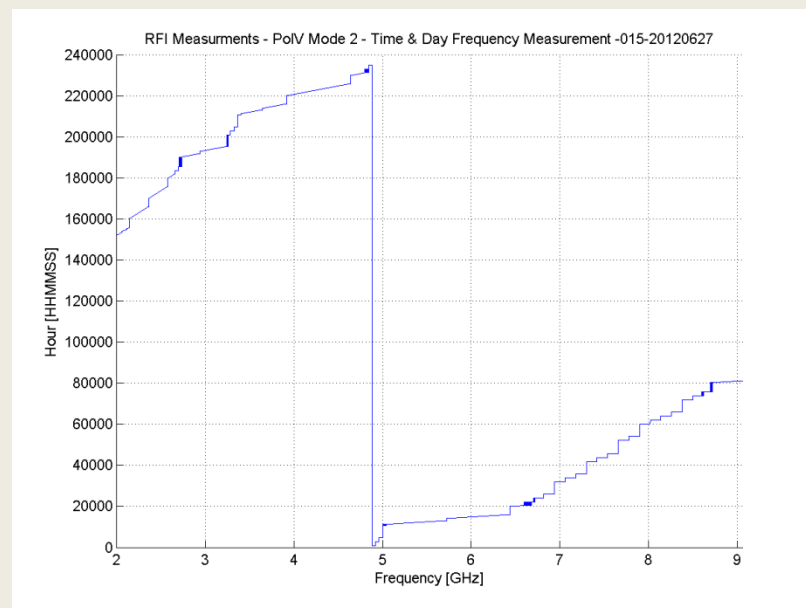


Phase I RFI Equipment Design & Test **April 25 @ June 1st**

- **Start Campaign By June 11 (one week of delay).**
Each Mode Measurement Time

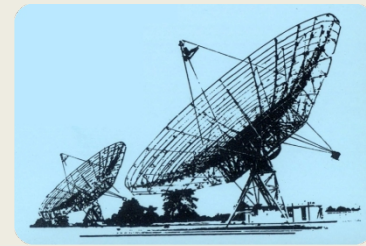


Mode 1 All AZ ~ 6Hs

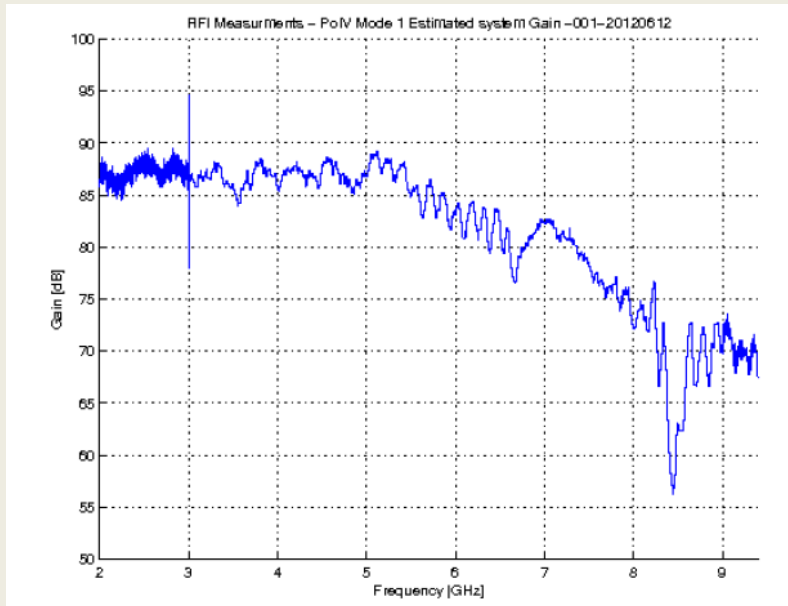


Mode 2 All AZ ~ 16Hs

RFI Data Results.

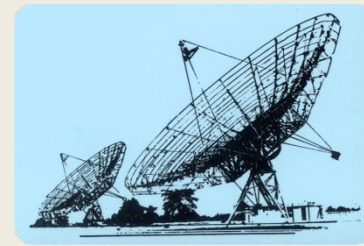


RFI Data, what and how to show....

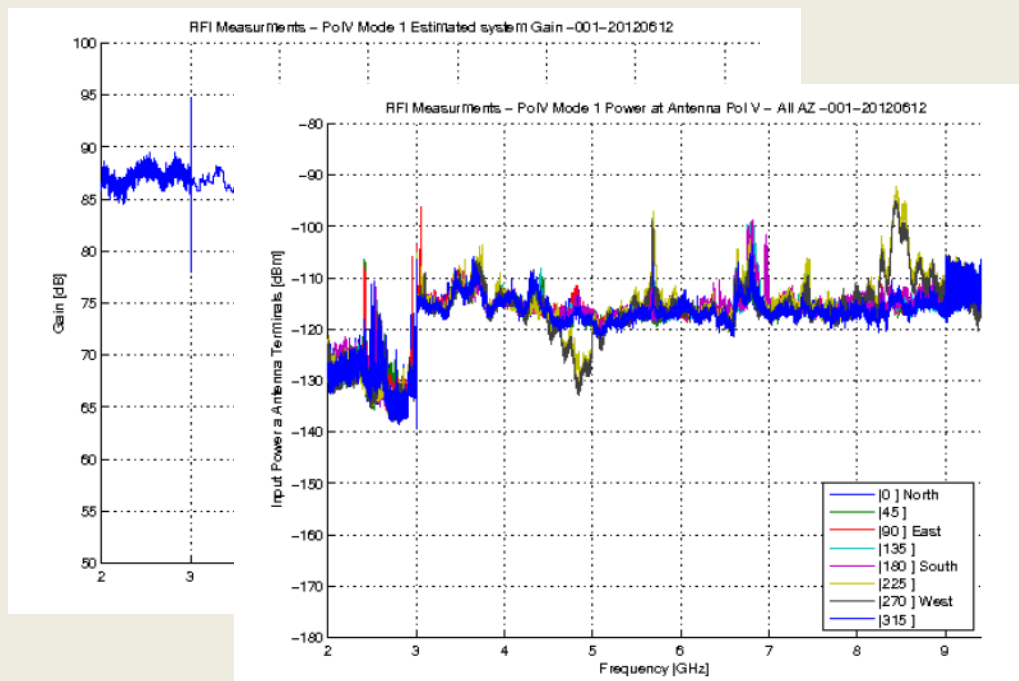


Estimated System Gain.

RFI Data Results.

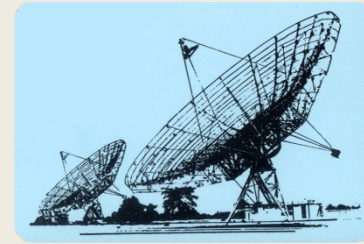


RFI Data, what and how to show....

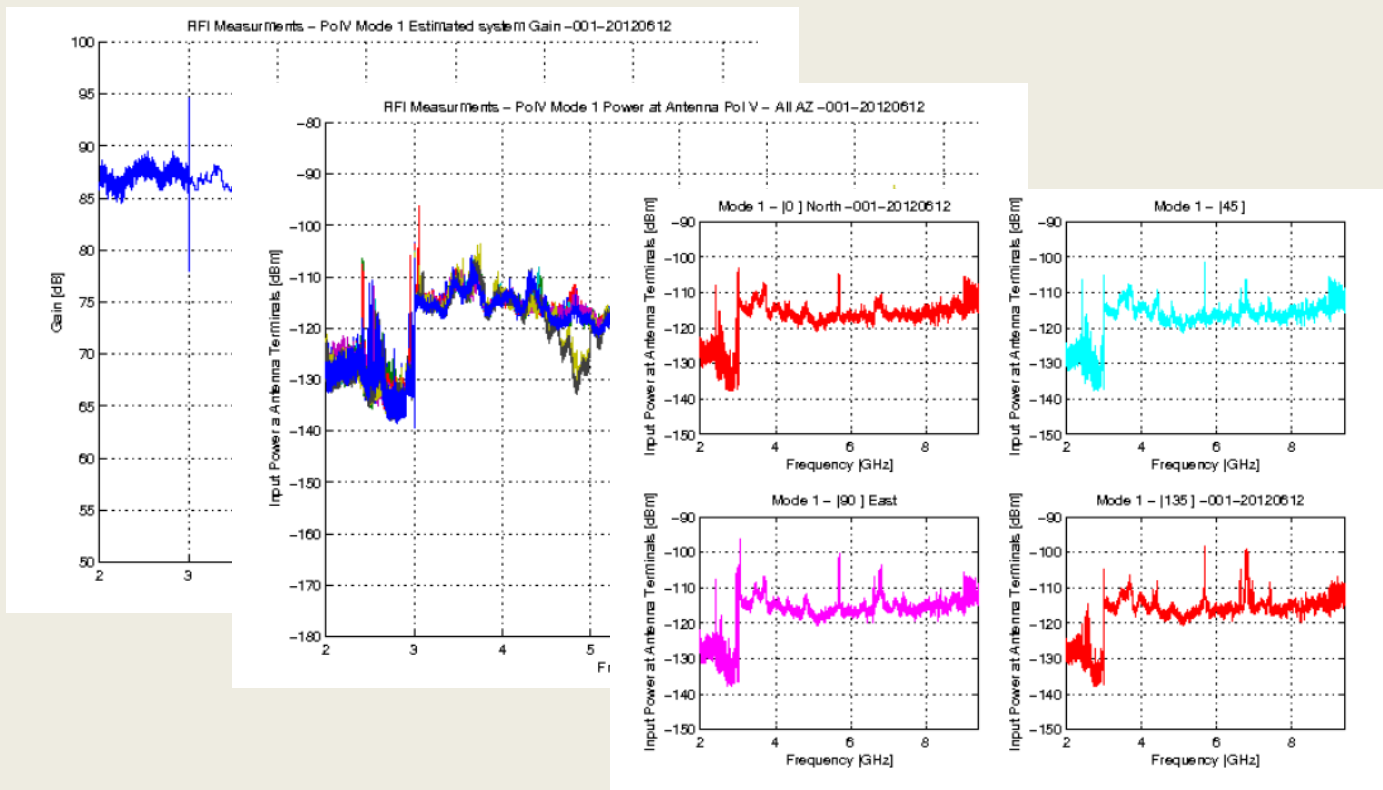


Plot with all Directions.

RFI Data Results.

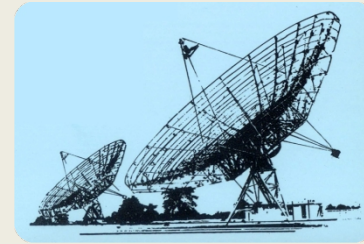


RFI Data, what and how to show....

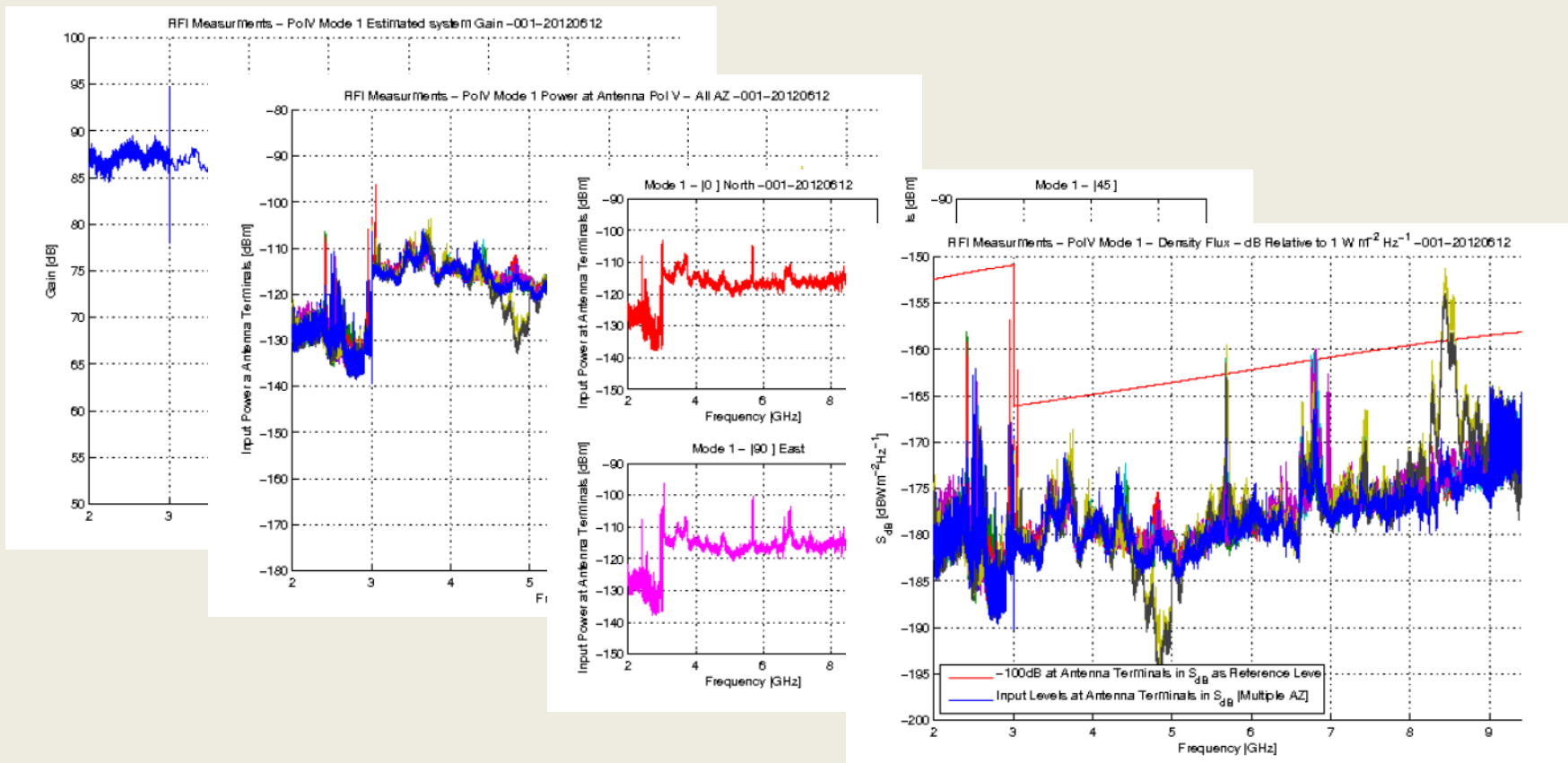


RFI Direction Identification

RFI Data Results.

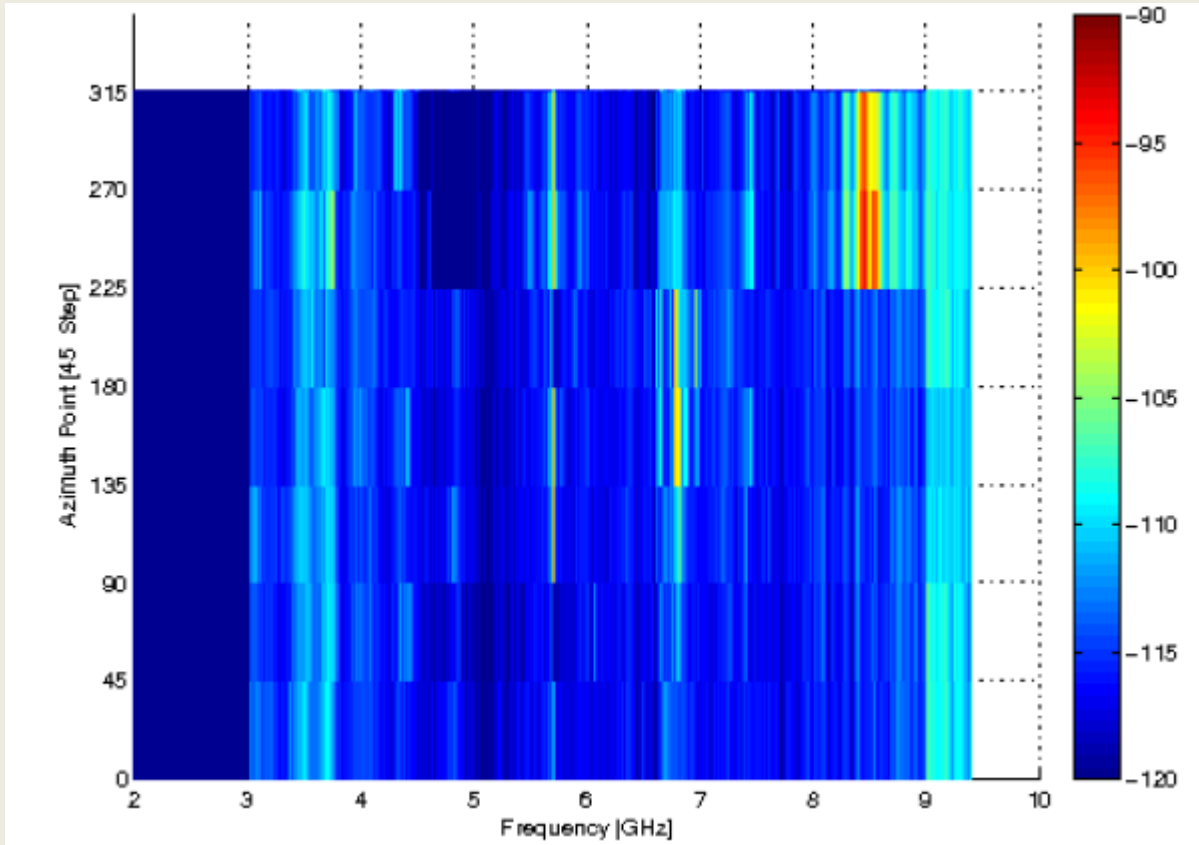
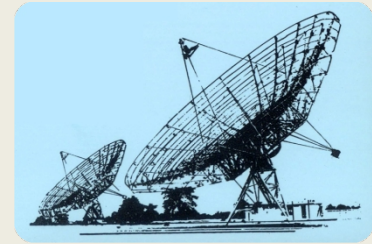


RFI Data, what and how to show....



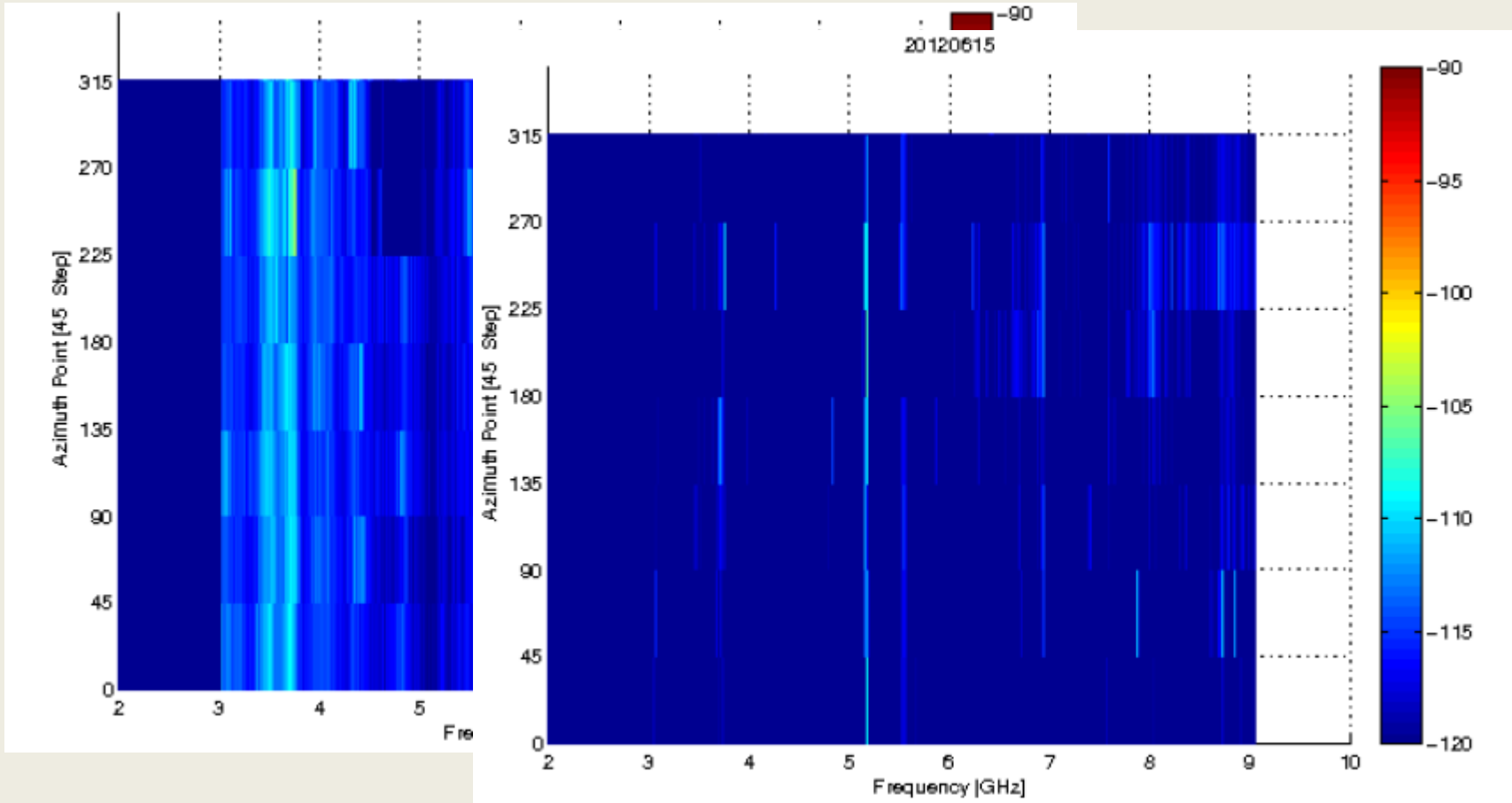
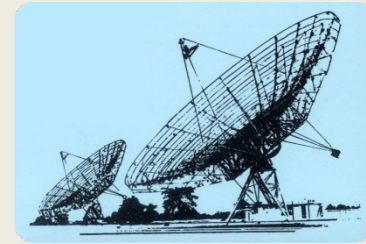
Data as Flux Density

RFI Data Results.



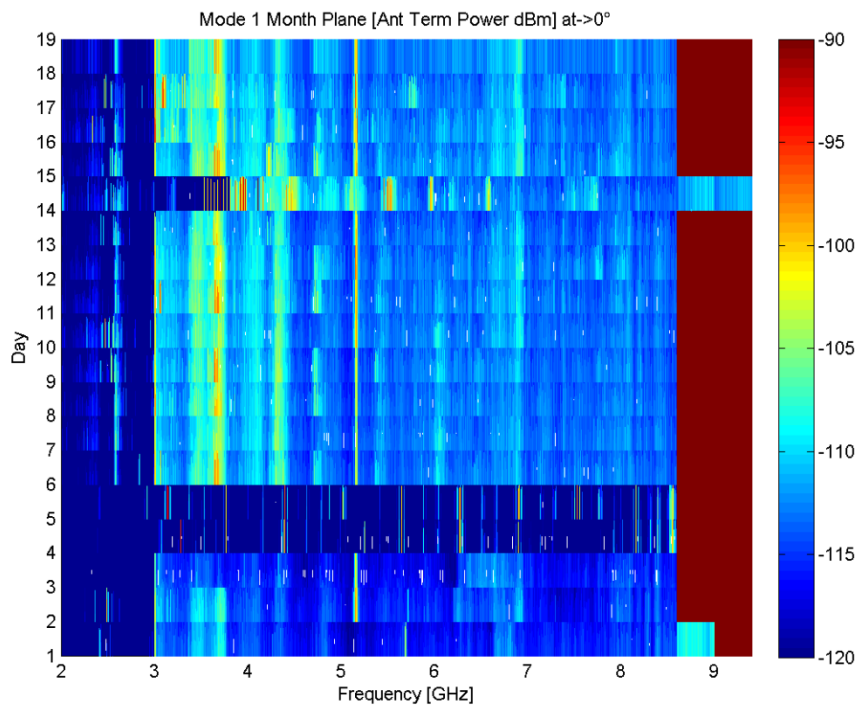
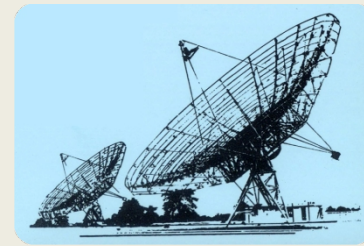
Daily Report: Direction – Frequency Diagram.

RFI Data Results.



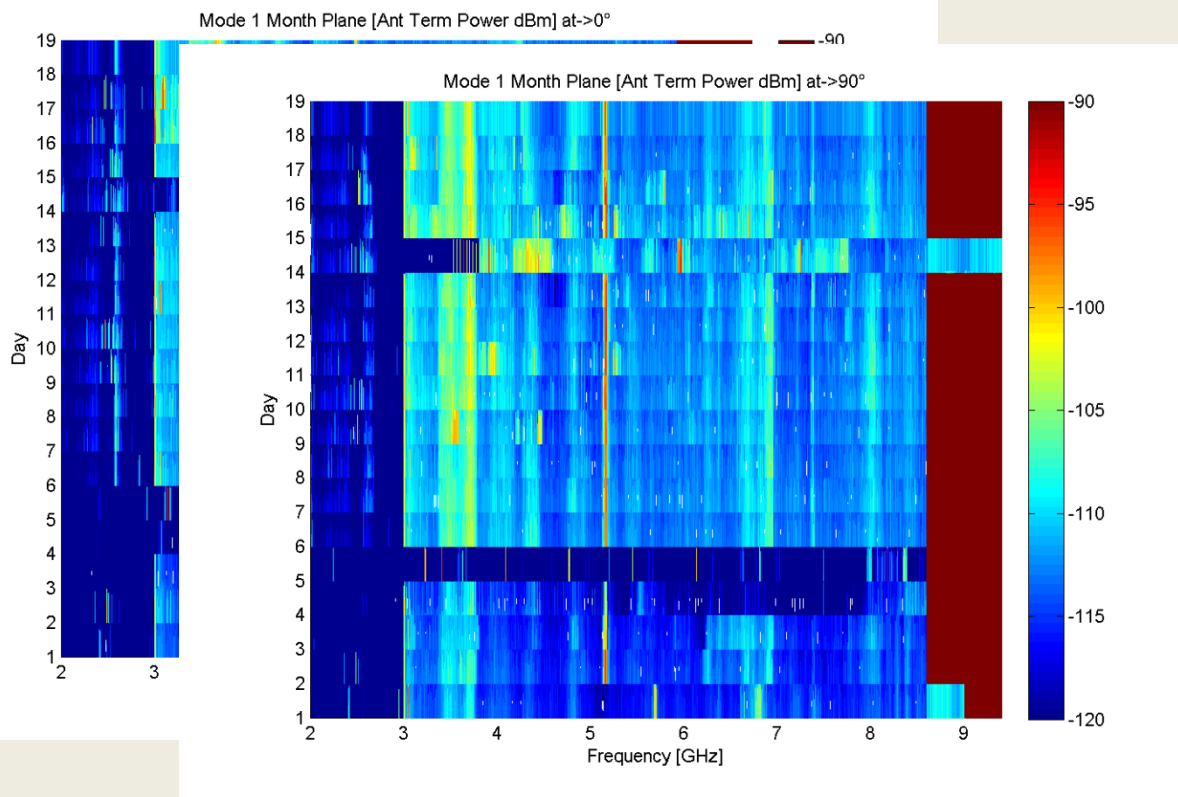
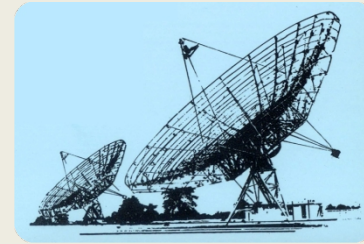
Daily Report: Direction – Frequency Diagram.

RFI Data Results.



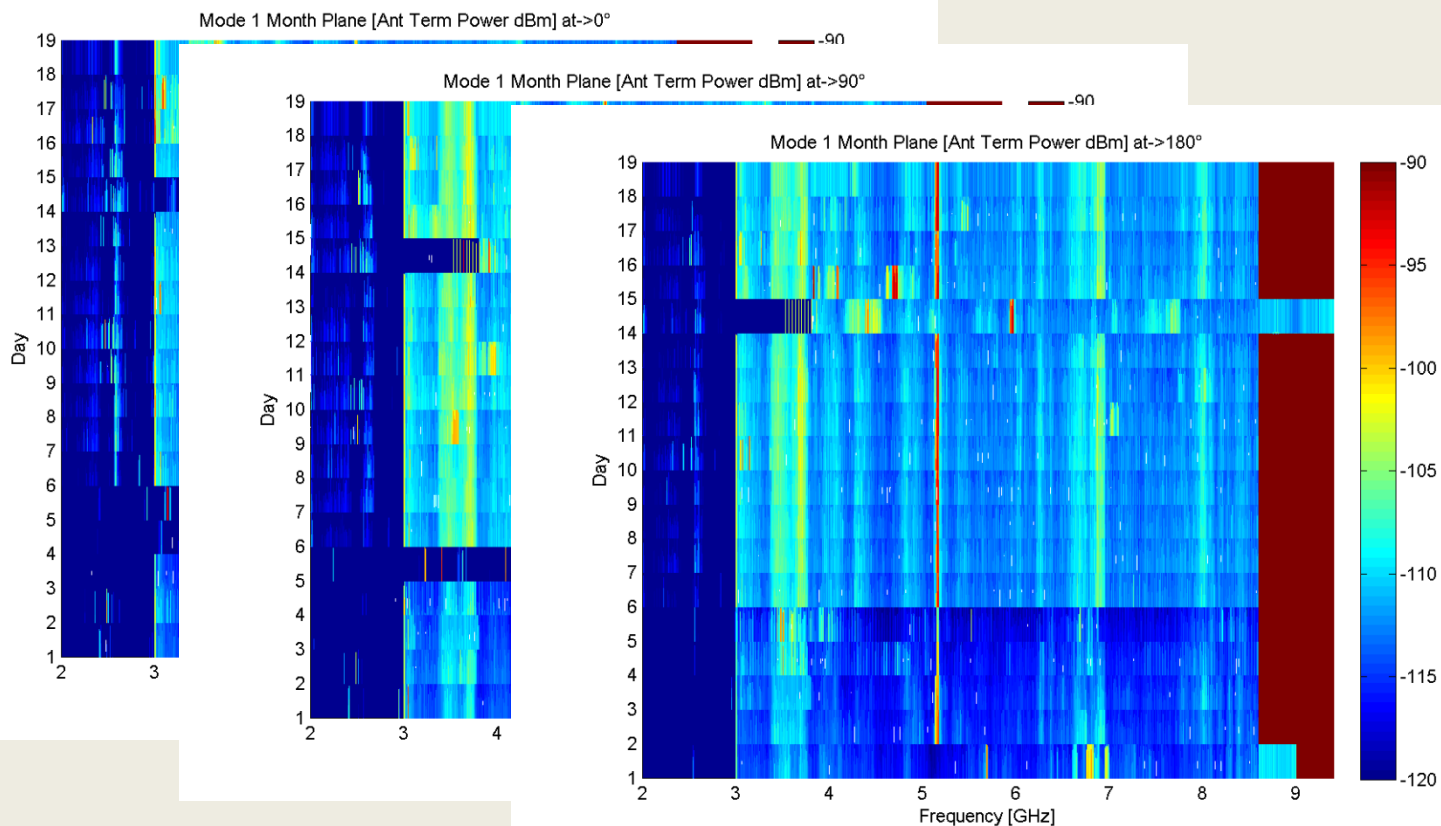
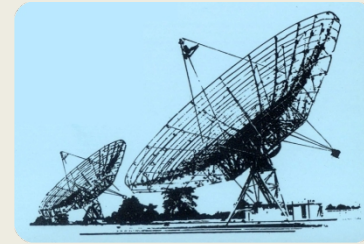
Monthly Report: Direction – Frequency Diagram.

RFI Data Results.



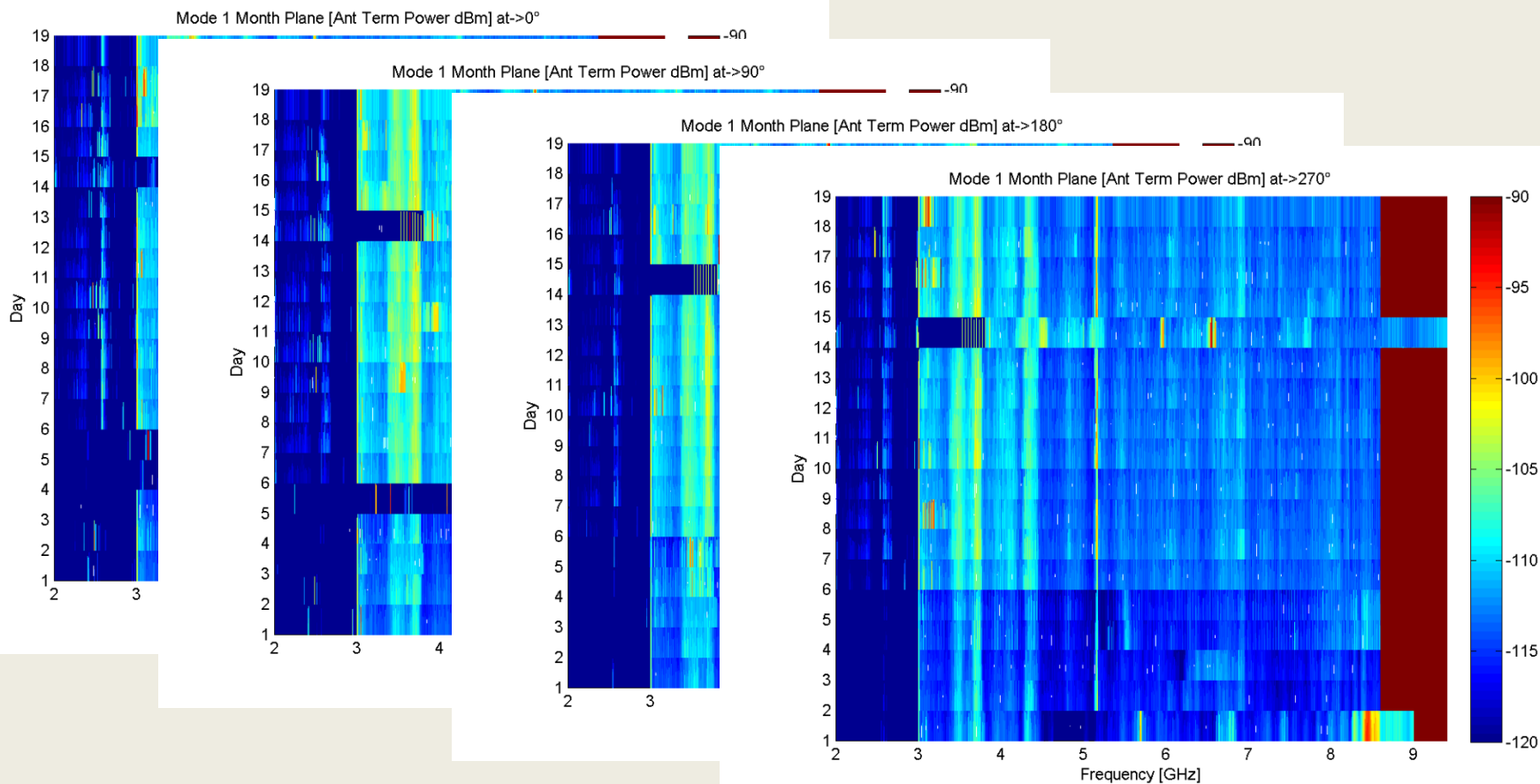
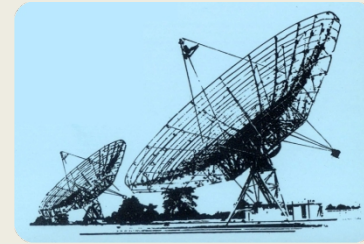
Monthly Report: Direction – Frequency Diagram.

RFI Data Results.



Monthly Report: Direction – Frequency Diagram.

RFI Data Results.

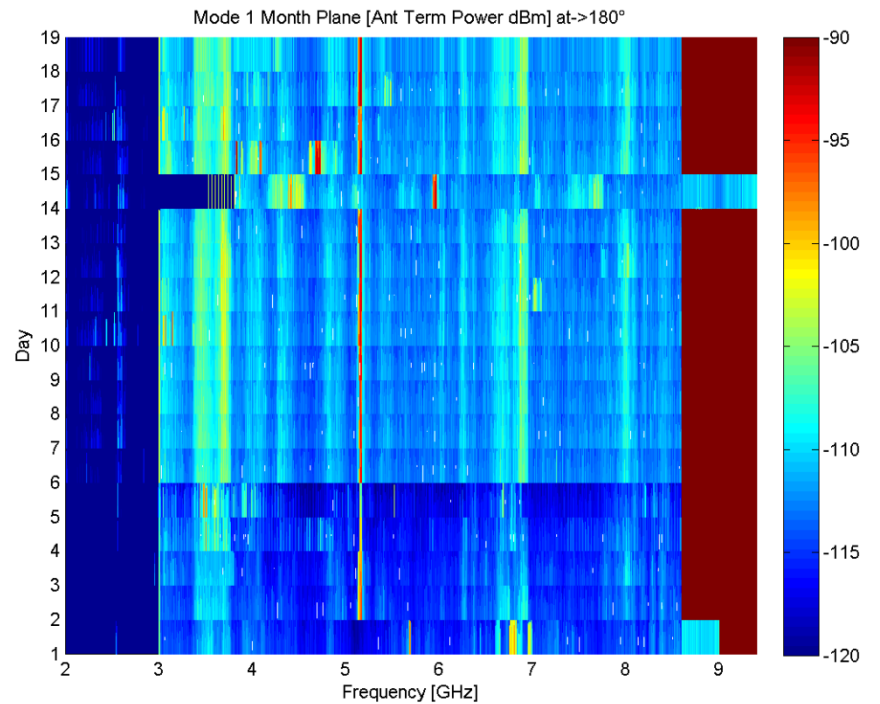
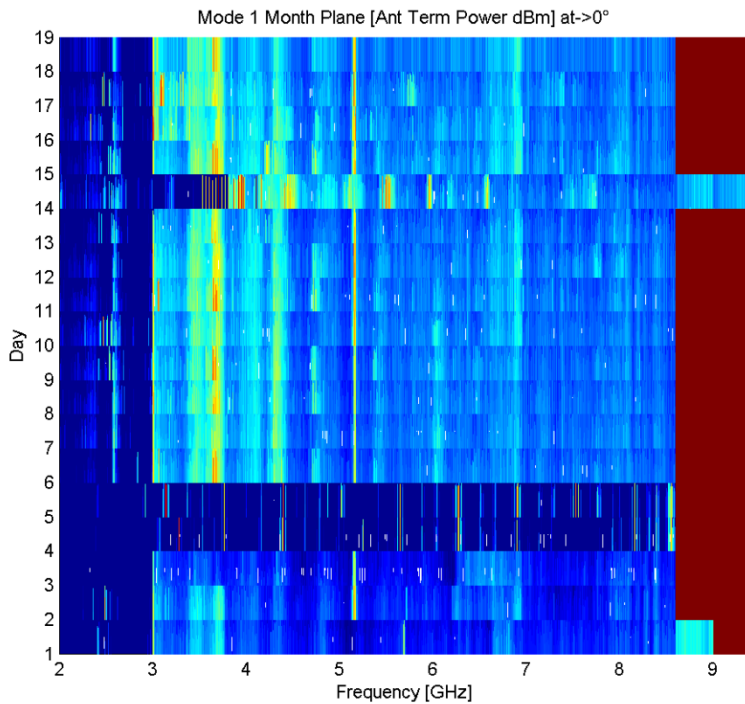


Monthly Report: Direction – Frequency Diagram.

RFI Data Results.

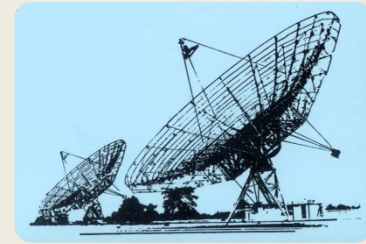


RFI Data, Sample / Simple analysis.



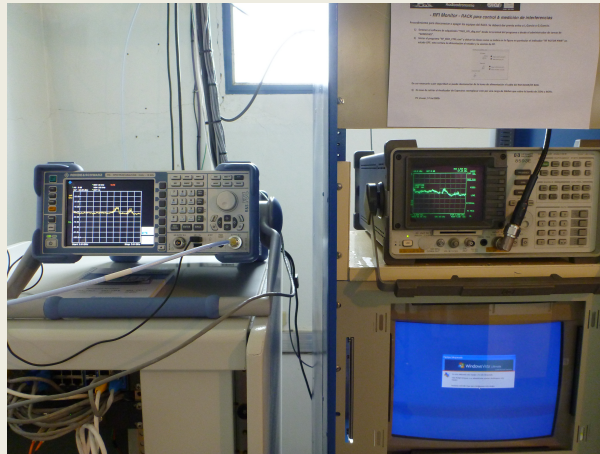
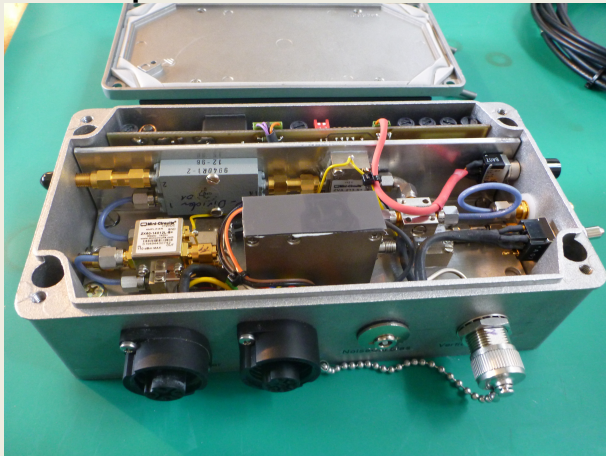
Monthly Report: Direction – Frequency Diagram.

BKG Campaign & Results



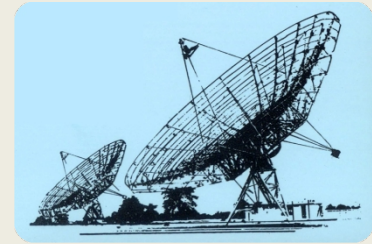
Due to IAR RFI system low sensitivity and no calibration, BKG sends their new RFI Receiver for a period of two months in order to complete the RFI campaign.

- Antenna
- RF Electronics
- R&S Spectrum Analyzer
- RF Low Loss Cable
- Tripod



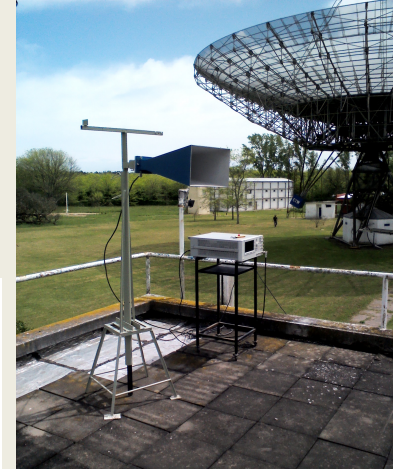
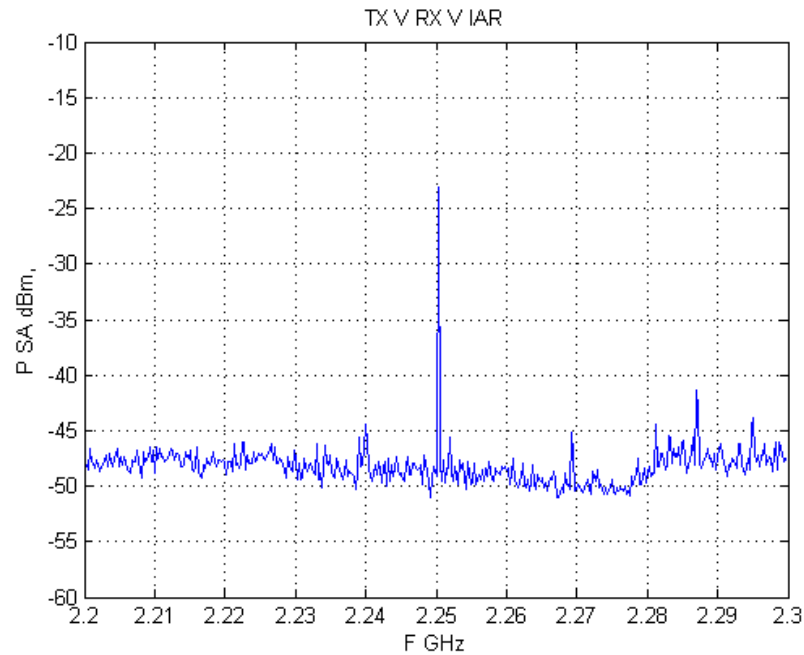
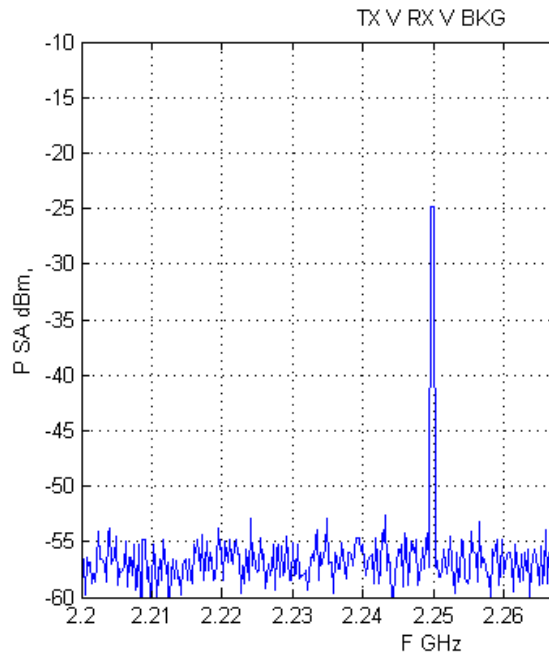
Dr Hayo Hase was present for a full week to realize custom RFI Measurements

BKG Campaign & Results



BKG & IAR Instruments Comparison With a reference antenna transmitting on 2.25GHz

- Same Polarization.

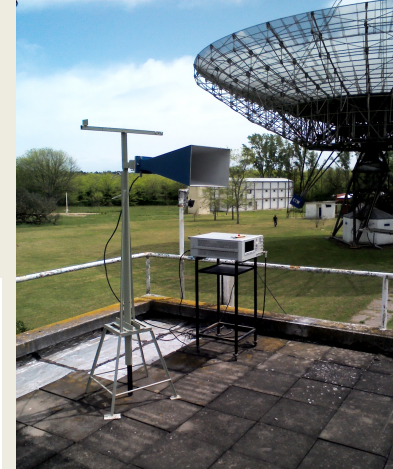
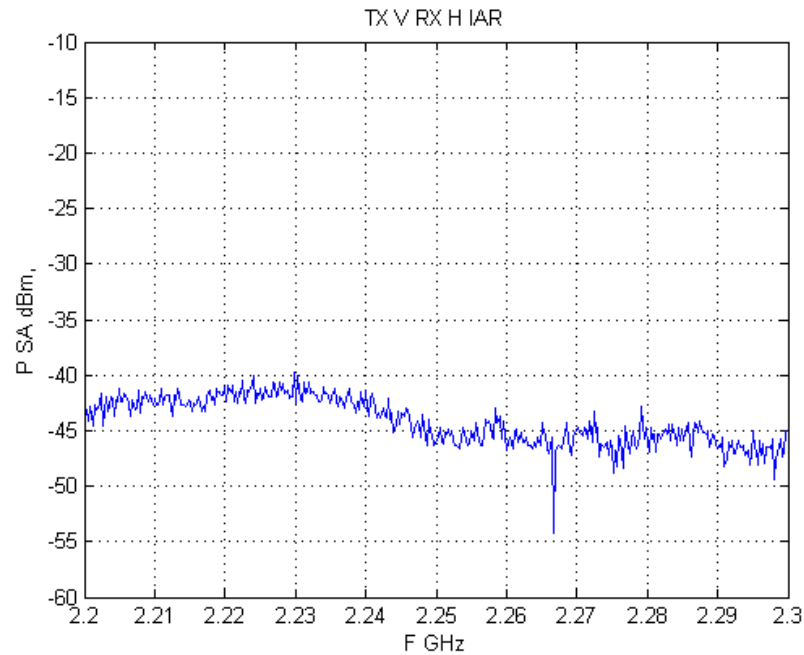
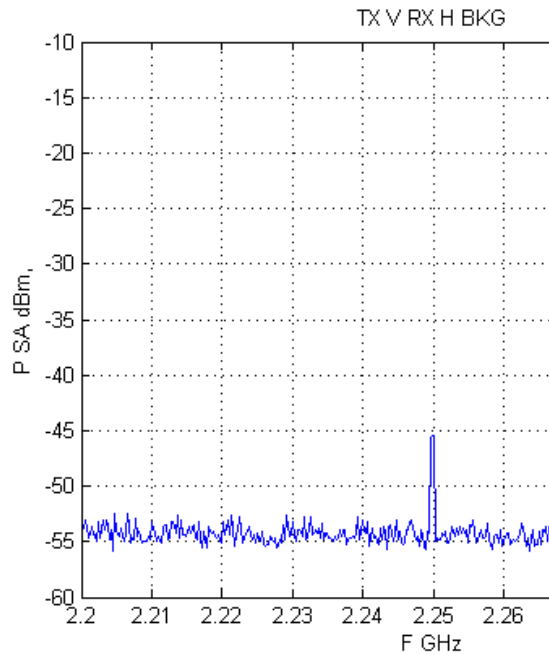


BKG Campaign & Results

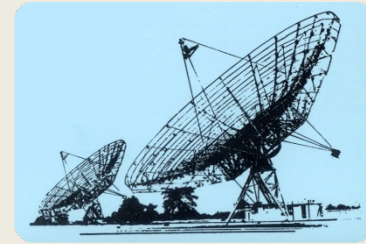


BKG & IAR Instruments Comparison With a reference antenna transmitting on 2.25GHz

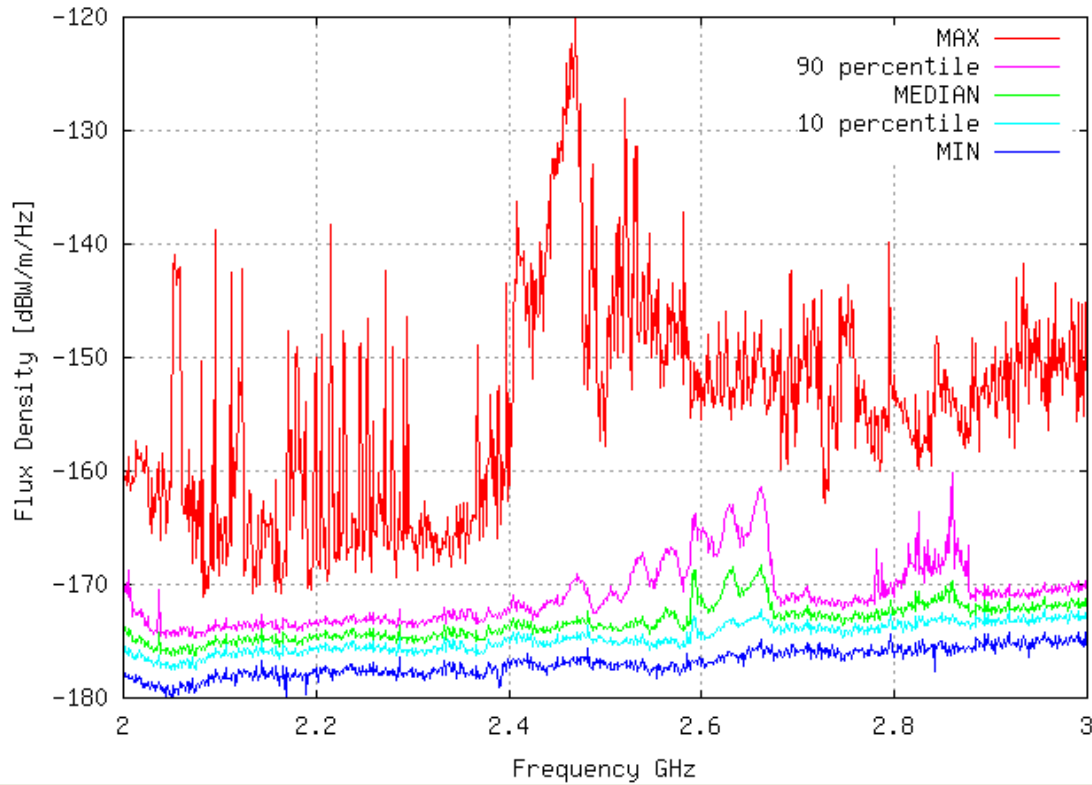
- Cross Polarization.



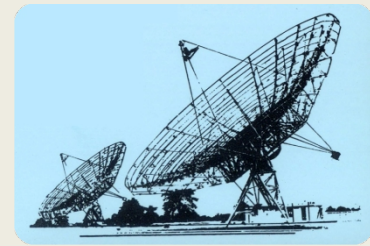
BKG Campaign & Results



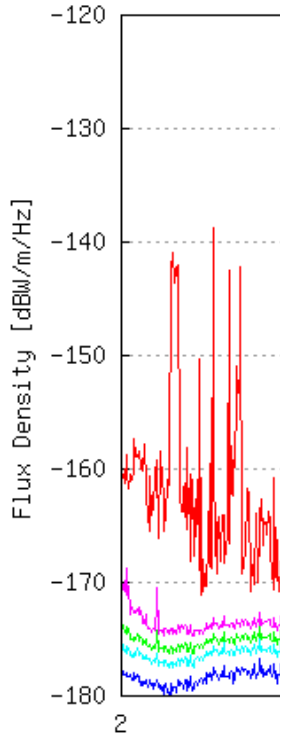
BKG RFI - POL VER - ALL AZ - Measurements :21776. Between 14/09-14/10 2012



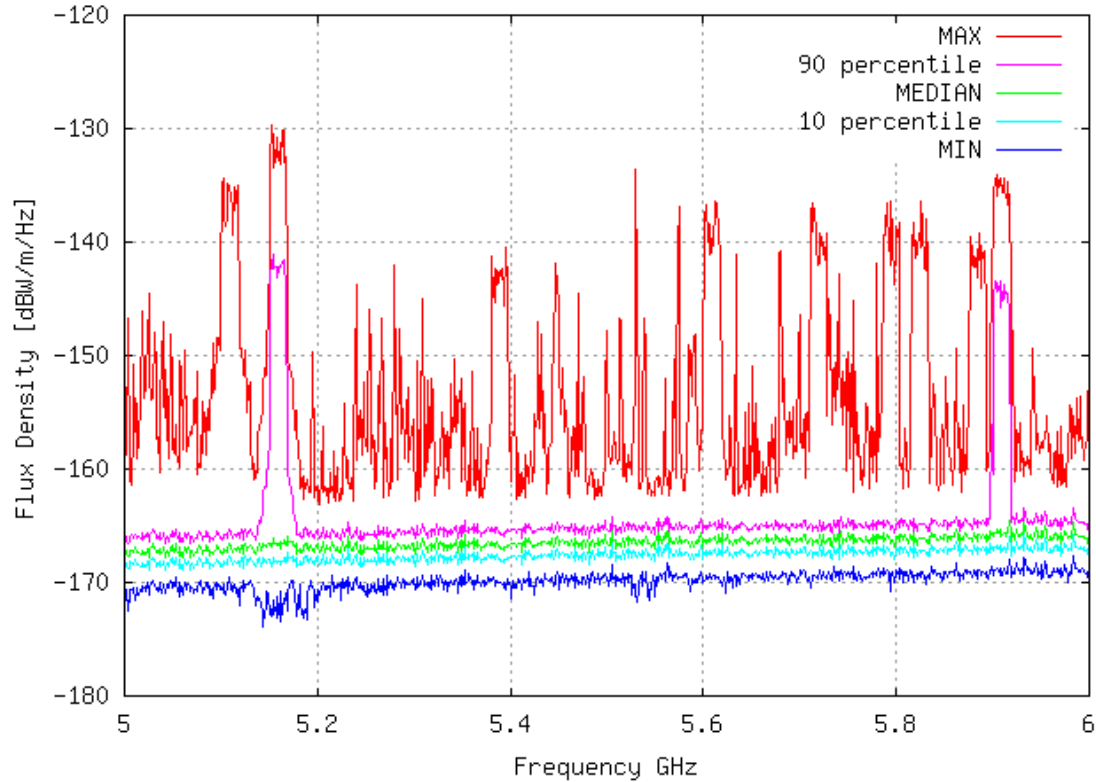
BKG Campaign & Results



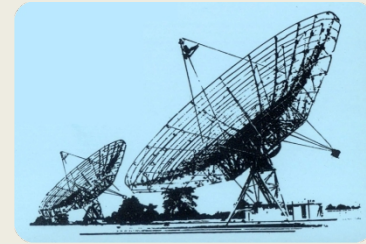
BKG RFI - POL VER - ALL AZ - Measurements :21776 - Between 14/09-14/10 2012



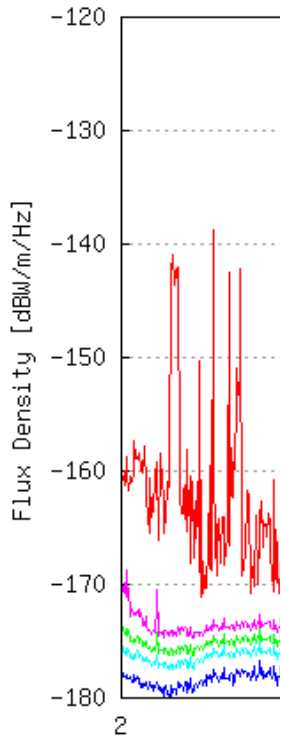
BKG RFI - POL VER - ALL AZ - Measurements :21776 - Between 14/09-14/10 2012



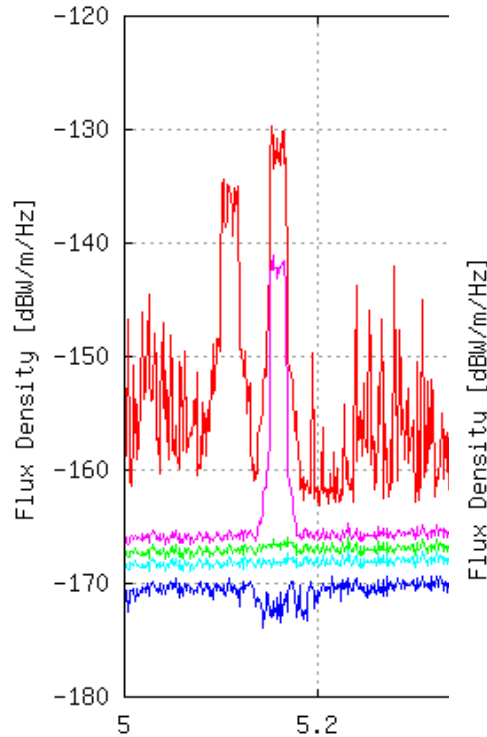
BKG Campaign & Results



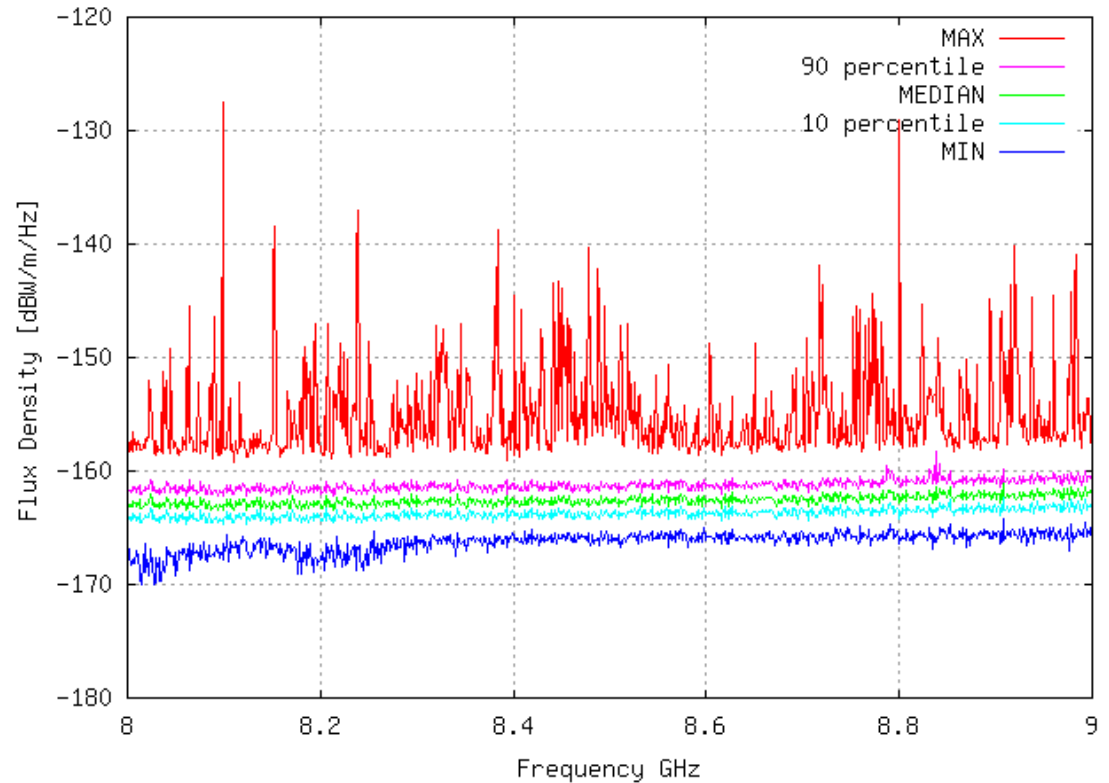
BKG RFI - POL VER - ALL AZ - Measurements :21776. Between 14/09-14/10 2012



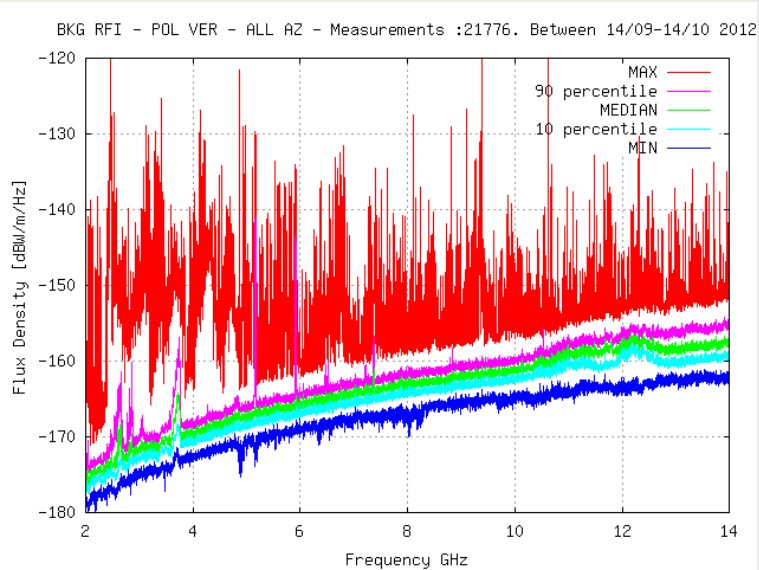
BKG RFI - POL VER - ALL AZ - Measurements :21776. Between 14/09-14/10 2012



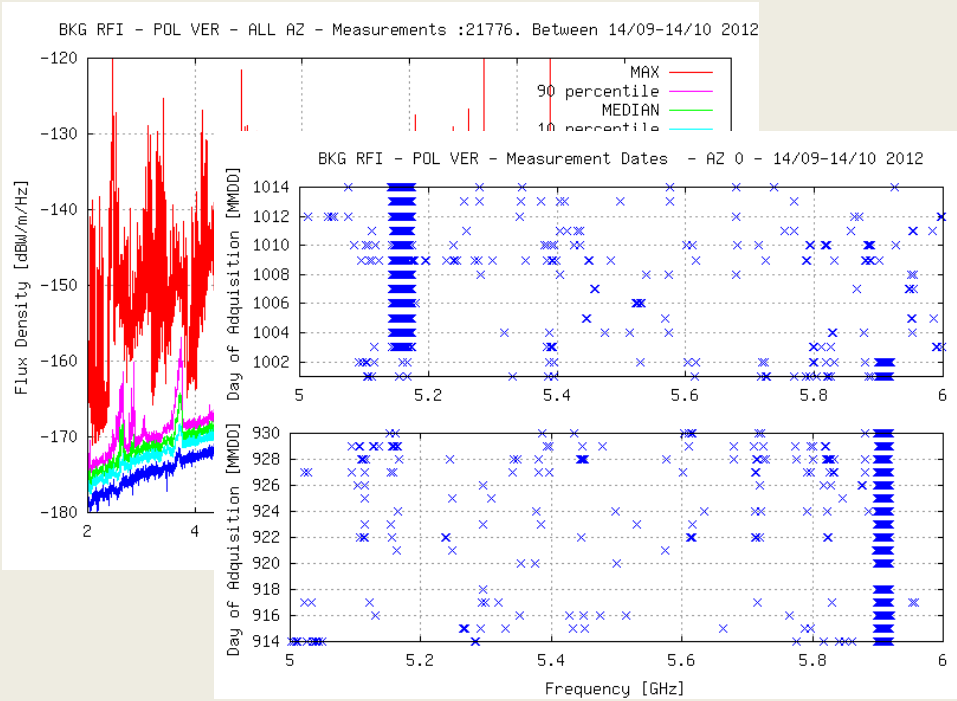
BKG RFI - POL VER - ALL AZ - Measurements :21776. Between 14/09-14/10 2012



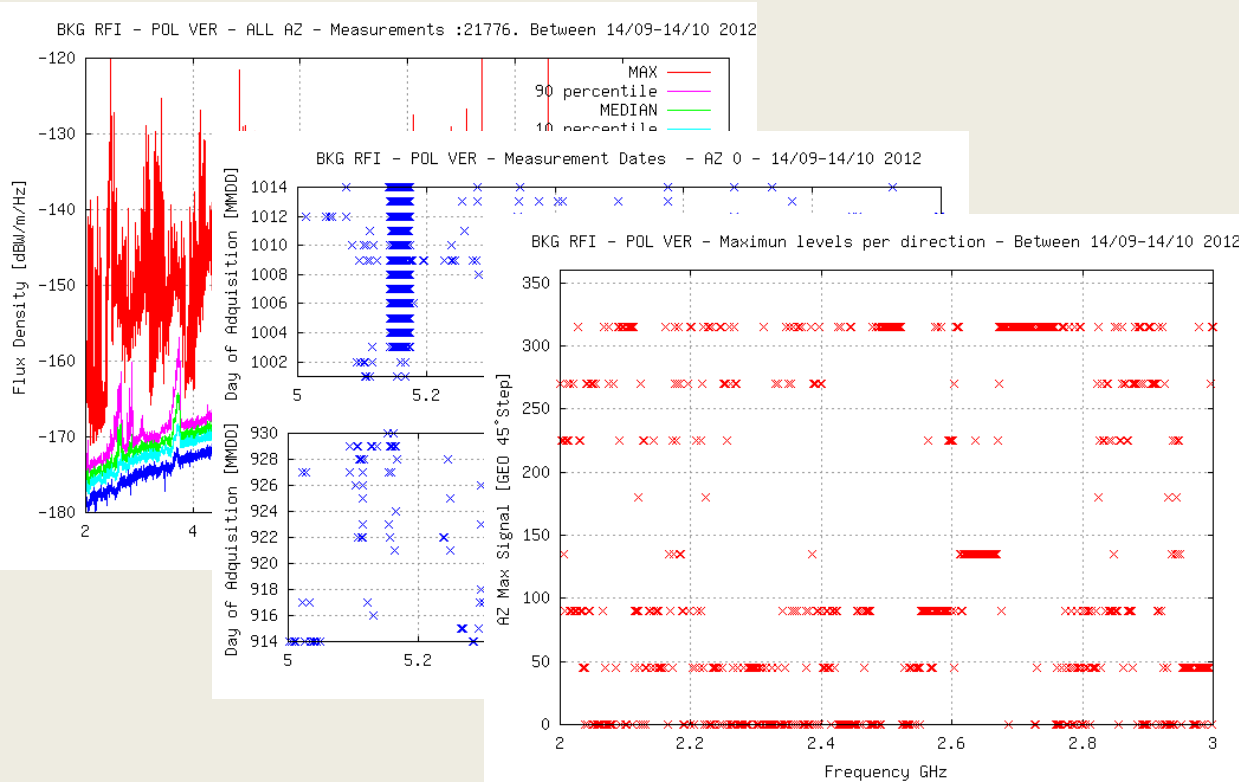
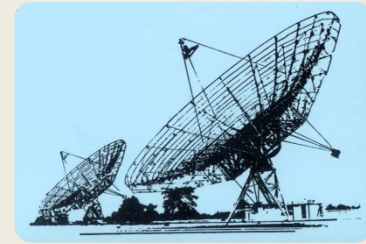
BKG Campaign & Results



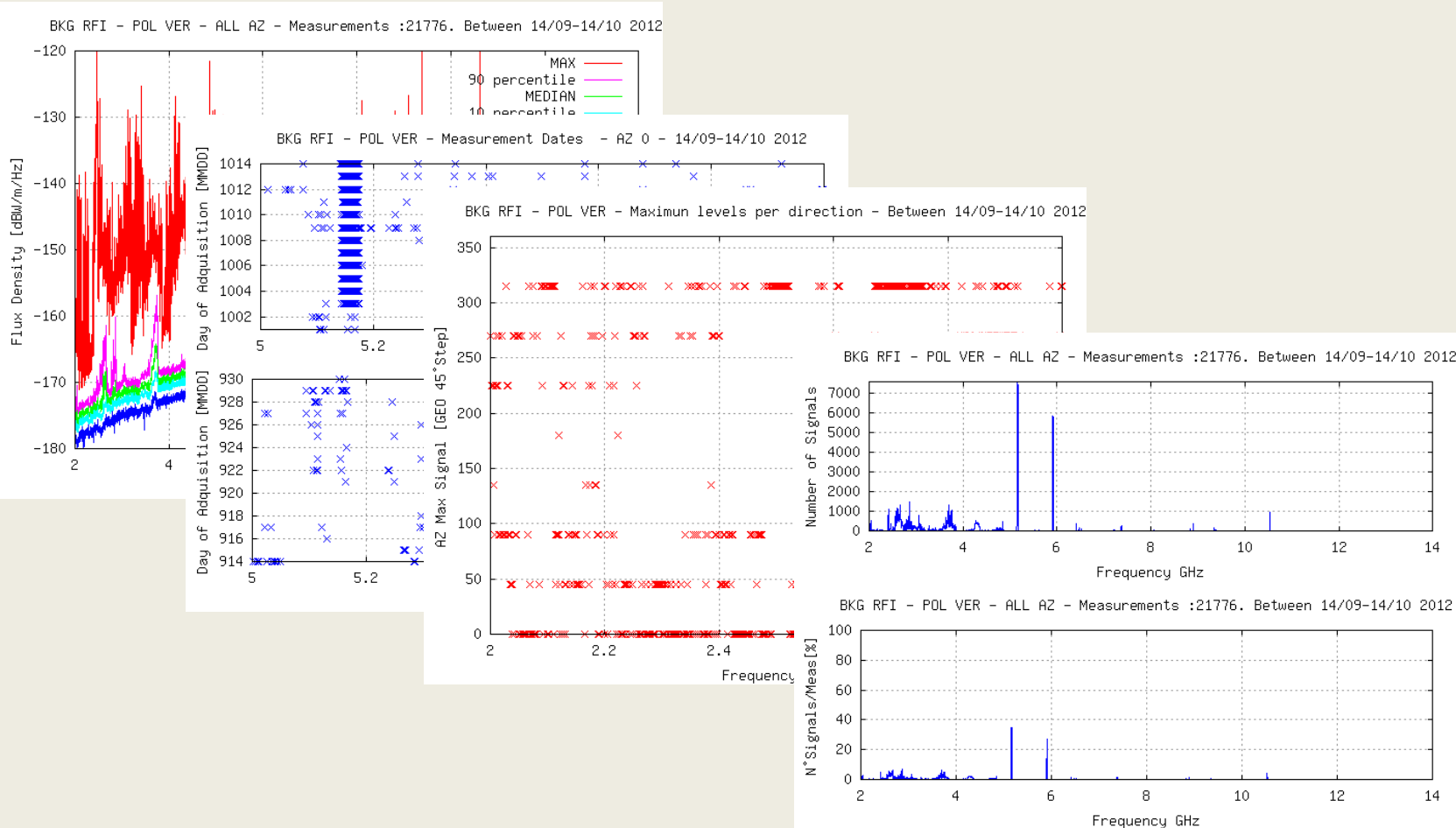
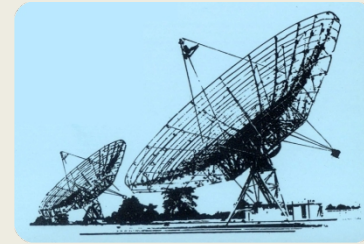
BKG Campaign & Results



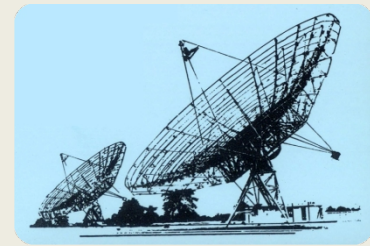
BKG Campaign & Results



BKG Campaign & Results



RFI Up next

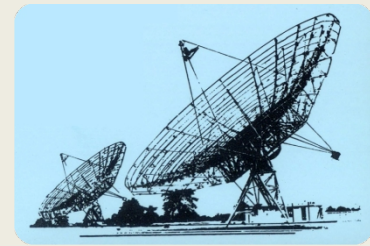


Phase II - Permanent RFI Measurement System:

Same as previous with some upgrades.....

- *Newest LNA's with Frequency extension from 1GHz up to 18Ghz.*
 - *Improve of system parameters, Tsys, Gain,*
- *New Noise Source for permanent system calibration.*
- *New Antenna with calibration certificate for antenna validation.*
- *New Antenna Rotor Designed and build at IAR.*
- *New Spectrum Analyzer with improved DANL.*
- *Backup RF components.*
- *New House Keeping electronics to monitor the inside RF BOX parameters*
 - *Voltages, Current's, Temperature, etc....*
- ***Project Design begins on August 2012.***

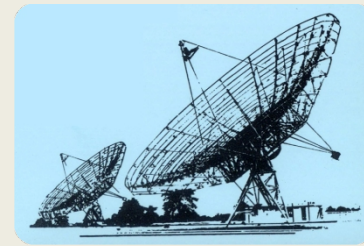
Conclusion



To remark... ***The important collaboration of all the personnel at the IAR.***

- *With a propose to install a new observatory in the location of the IAR a requirement to know the local frequency spectrum was requested.*
 - *In a short period of time (less then one month) a RFI Monitor system was designed, assembled and tested in order to start the measurement campaign.*
 - *The System was build with electronic components in house, (No time for new components acquisitions) and all the data generated was shared with our colleagues from TIGO.*
 - *Quick answer due to experience in similar campaigns, SKA Argentine Site Survey.*
-
-

Thanks for your attention



Some Links of interest...

RFI Monitor System web page

<http://www.iar.unlp.edu.ar/rfi-esp.htm>

Data Reports

<ftp://tux.iar.unlp.edu.ar/pub/tigo/>

Online Data

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

