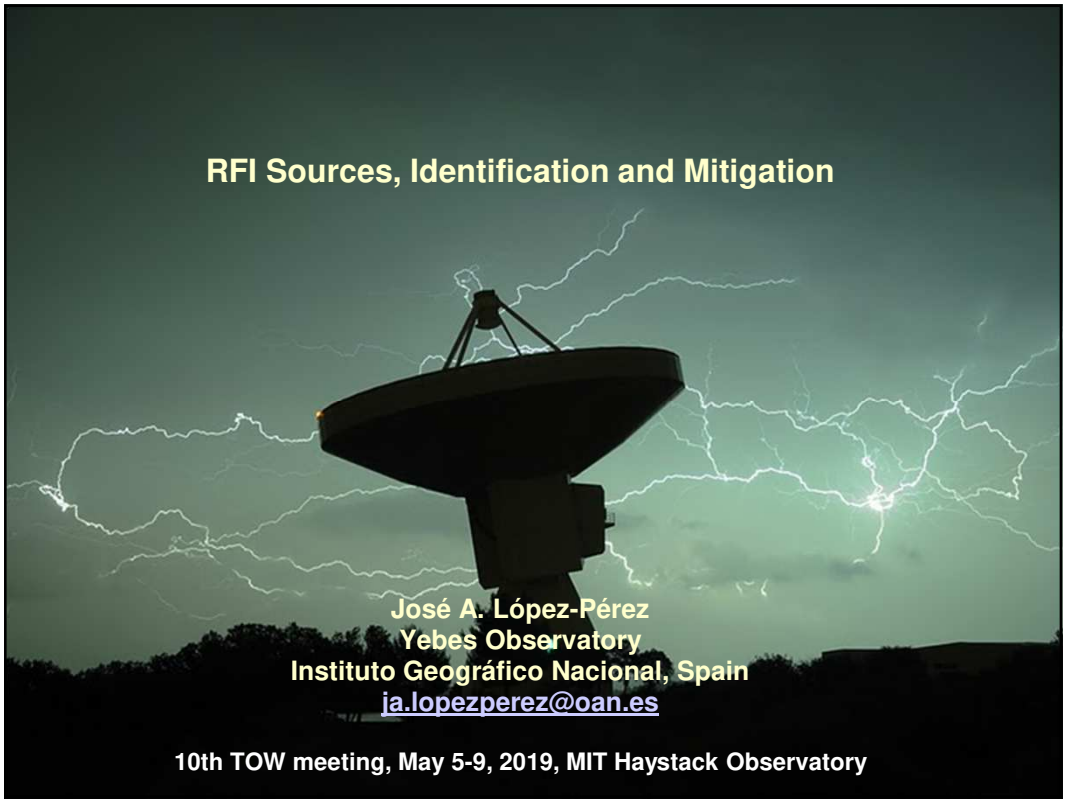


Index

- Some ideas about Frequency Management
- What is RFI. Sources. Detection.
- RFI examples: external and self-generated
- Regulations and protection levels
- Effects of RFI on VLBI and receivers
- RFI mitigation
- RFI surveys. Examples: RAEGE and BRAND
- New RFI measurement system at Yebes
- Conclusions
- References

International Spectrum Management

The International Telecommunication Union (ITU) is an agency of the United Nations, whose responsibility is the **coordination of** the vast and growing range of radiocommunication services and the **harmonization** at international level of the radio-frequency spectrum

The allocation of frequency spectrum resources is the sovereign right of national governments

But radio waves do not respect national borders → International regulations are required!

Asia-Pacific Telecommunity (APT)

Arab Spectrum Management Group (ASMG)

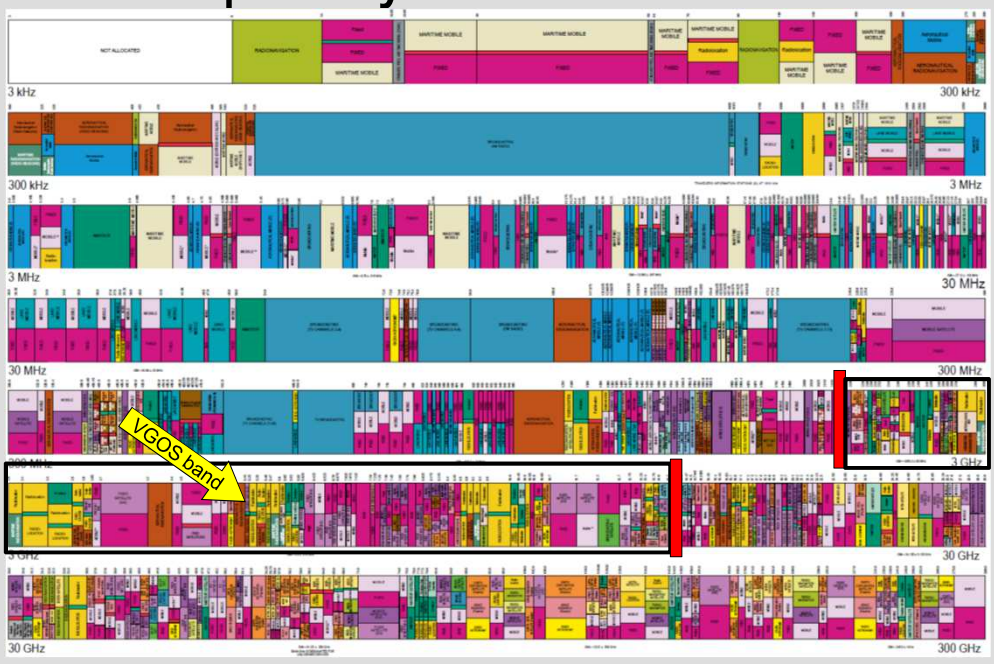
African Telecommunications Union (ATU)

European Conference of Postal and Telecommunications Administrations (CEPT)

Inter-American Telecommunication Commission (CITEL)

Regional Commonwealth in the Field of Communications (RCC)

Frequency Allocation Chart



The value of the spectrum

In Spain, prices of licenses for 20 years:

- Vodafone paid **€198M for 90MHz** in the 3.7GHz band.
- Telefonica paid **€107M for 50MHz** in the 3.6-3.8GHz band
- Orange paid **€132M for 60MHz** in the same range.

In Italy, Vodafone paid **€2.4 billion** for:

- 80MHz of band in 3.7GHz for 19 years
- 2x10MHz of band in 700MHz for 15.5 years
- 200MHz in 26GHz for 19 years

Range of price: 2-6M€ / MHz

1 VGOS antenna ~ 1MHz

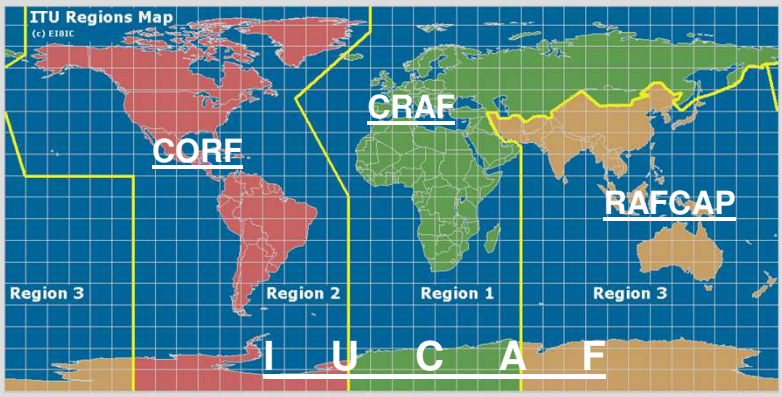
New frequency allocations to come

- 5G mobile networks:
  - USA: 3.1 – 3.55 GHz, 3.7 – 4.2 GHz
  - Europe: 3.4 – 3.8 GHz
  - Japan: 3.6 – 4.2 GHz, 4.4-4.9 GHz
  - China: 3.3-3.6 GHz, 4.4-4.5 GHz, 4.8-4.99GHz
- Starlink (SpaceX): 4,425 LEO sats in 11/14 GHz and 20/30GHz (2 in orbit already)
- OneWeb consortium: 650 LEO sats (6 launched in February'19)
- Project Kuiper (Amazon): 3,236 LEO sats
- High Altitude Platform Stations (HAPS) at 20Km

Radioastronomy Service (RAS)

- In 1959, Radio Astronomy was recognised as a “radiocommunication service” creating a legal basis to seek protection against “harmful” interference.
- A series of frequency bands were allocated to the Radio Astronomy Service. Some bands provide an exclusive allocation (“All emissions are prohibited”) to passive services.
- Geo-VLBI is a radioastronomy service from ITU perspective.

RAS is represented by regional committees



CRAF

- CRAF was established in 1988 and it acts as an ESF Expert Committee
- CRAF: ITU sector member & observer status in CEPT
- 22 Member Countries (incl. Russia, Ukraine, Turkey and South Africa) + International organizations, which have an observer status: ESA, IRAM, IVS and SKA.
- Missions:
  - to keep the frequency bands used for radio astronomical observations free from interference;
  - to argue the scientific needs of the European research community for continued access to and availability of the radio spectrum for radio astronomy;
  - to support related science communities in their needs concerning interference-free radio frequency bands for passive use.
- Funding by MoU: 130 kEuro
- CRAF employes one full-time Frequency Manager

Telescope registration

- To obtain administrative protection
- To avoid direct illumination from strong transmitters
- To be taken into accout by space agencies
- To claim losses due to RFI
- To complain to the responsible of RFI

An ITU Rec. is in preparation which states that RAS station not registered before 2019-nov-22 wouldn't claim protection from certain radio services.

See H. Hase, V. Tornatore, B. Corey: "How to register a VGOS radio telescope at ITU and why it is important". IVS 2016 GM Proc.

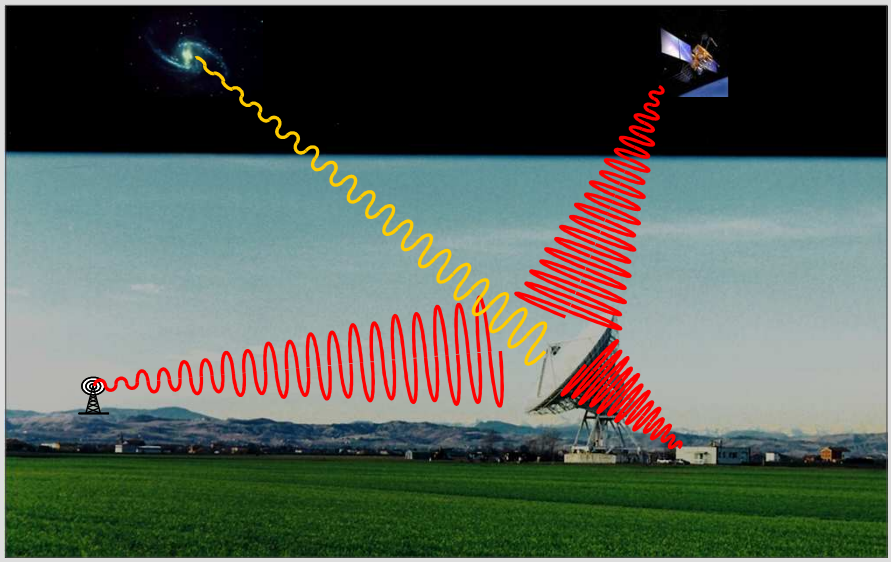
What is RFI?

- According to ITU Radio Regulations Section IV, Radio Stations and Systems – Article 1.166 *interference:*

> The effect of unwanted energy due to one or a combination of **emissions, radiations or inductions** upon reception in a radiocommunication system, **manifested by any performance degradation, misinterpretation or loss of information** which could be extracted in the absence of such unwanted energy.

- Types of interferences:
  - Permissible interference
  - Accepted interference
  - **Harmful interference**

RFI environment



RFI signal properties

- Non-thermal origin
- Variable in time: persistent, intermittent, burst-like
- Variable in space: stationary, mobile
- Variable in spectrum: narrowband, broadband
- Variable in polarization: H, V, RCP, LCP
- Many orders of magnitude stronger than cosmic signals

RFI sources

External

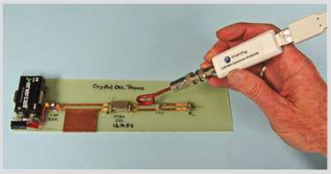
- Satellite downlinks
- Cellular networks
- Radio & TV networks
- Radio-links
- Radars
- Wind-mills
- Spark plugs
- Home appliances
- Electric fences
- Lightnings
- LED light drivers
- Consumer electronics

Self-generated

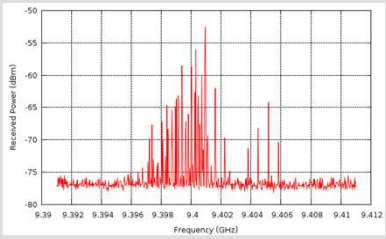
- Servo electronics
- Control buses: Profibus, CANbus
- Leaky connectors
- Leaky cables
- Leaky racks
- Amplifier oscillation - instability
- Signal distributors
- Digital back-ends
- LAN/Ethernet equipment
- Computers
- UPS
- Auxiliary equipment

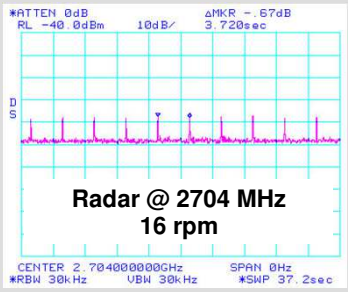
Detecting RFI

- Field probes & sniffers
- Antennas
- Pre-amplifiers
- Spectrum Analyzers
- Receivers
- Preselectors
- Software Defined Radios



RFI example: Radars

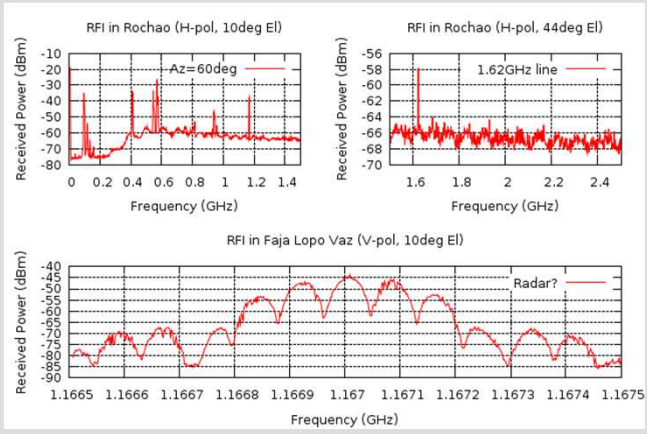




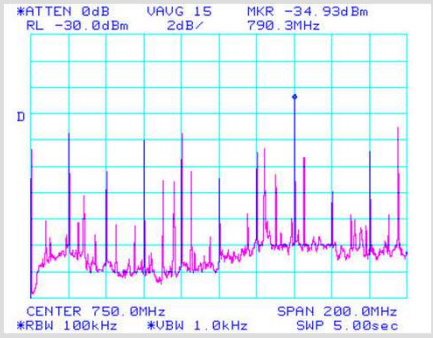
Radar @ 2704 MHz
16 rpm

- **Destruction of 4 units of Yebes X-band cryogenic LNAs in tri-band receiver at Ny-Alesund !!**
- **Similar event in Onsala on one of their broad-band receivers**

RFI example: radio-repeaters and links



RFI example: servo electronics

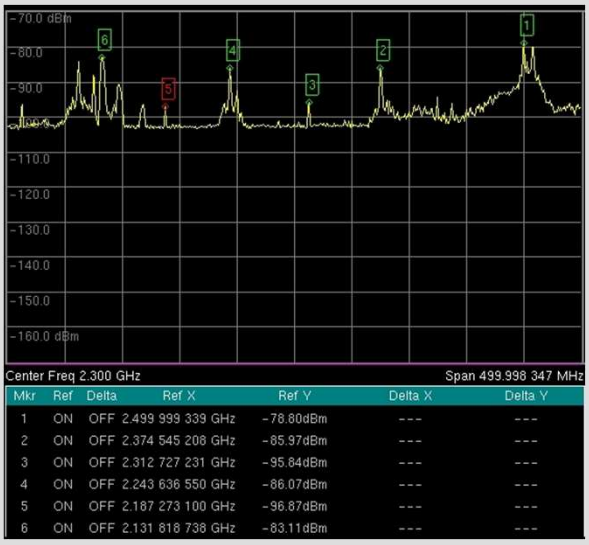


RFI spectrum in S band under normal antenna and Rx's operation

Main sources of interference from antenna servos are:

- **Beckhoff Local Control Panels (train of 20MHz spaced lines).**
- **Hand-Held panel for service operations.**
- **Profibus modules for sensor M&C (train of 16MHz & 48MHz spaced lines).**
- **Power supply from servo racks to servo equipment in Rx room.**

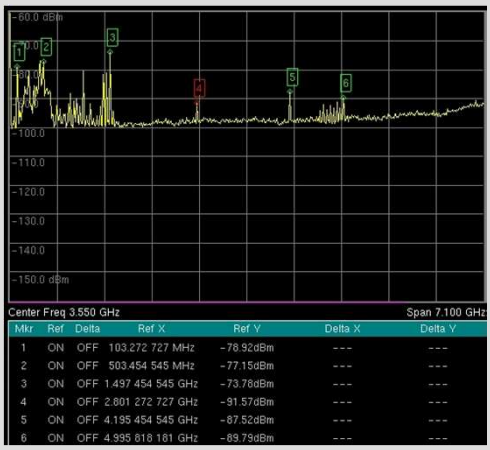
RFI example: LAN/Ethernet switch



Signals radiated by LAN Ethernet Switch in S-band

Reduction of LAN speed to 100MHz or 10MHz doesn't show significant improvement.

RFI example: Station atomic clock



Signals radiated from Hydrogen Maser

ITU regulations to protect RAS

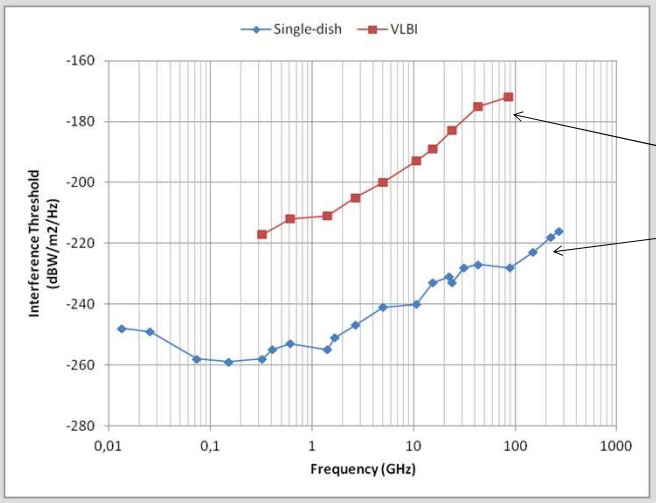
- Thresholds for detrimental interference in RAS bands are given in ITU-R RA.769 .
- Percentage of acceptable data loss ITU-R RA.1513.
- In exclusive RAS primary bands (RR footnote No. 5.340), all emissions are prohibited.
- Other bands: administrations are urged to take all practical steps to protect RAS from interference.

However, ITU regulations only consider RFI received through telescope sidelobes (0 dBi telescope gain).

If RFI were received through the main beam (50 dBi typical telescope main beam gain), the ITU limit for spectral line observations would be exceeded for any RFI with a flux larger than 10 Jy.

Criteria for Harmful Interference

For VLBI, ITU-R criterion is that **RFI should add no more than 1% to the receiver noise** (ITU-R RA.769), which is the typical uncertainty of "well-calibrated" VLBI data.



VLBI is more inmune to uncorrelated RFI that single-dish

Calculation example

Speed of light	3,00E+08	m/s
Signal frequency	0,9	GHz
Signal wavelength	333,3	mm

Tx power	27	dBm
Tx antenna gain	0	dBi
TX EIRP	-3	dBW
Tx channel bandwidth	30	KHz

Distance	385000	Km

Power flux density at Rx site	-186	dB(W/m2)
Spectral power flux density at Rx site	-230	dB(W/m2·Hz)
	897	**Jy**

Rx antenna diameter	13,2	m
Rx antenna aperture efficiency	0,70	70%
Rx antenna gain	40,3	dBi
Rx antenna effective area	95,8	m2

RFI power at LNA input	-166	dBW
	-136	**dBm**

Mobile Phone on the Moon (assume 0.5W/30 kHz channel @ 900 MHz)

Power at Earth is ~900 Jy, which is almost that of Cassiopeia A

RFI effects on single-dish

- In total power mode, the presence of RFI will distort/bias the total power measurements, unless it is very narrowband.
- In spectral line observations, RFI can obscure, distort or degrade the profile of the molecular lines under observation.
- These effects are even worse if RFI changes with time/frequency/position, because “substraction” techniques for calibration are invalidated (position or frequency switching) .

The Guardian

Microwave oven to blame for mystery signal that left astronomers stumped

Australian scientists first detected interference in 1998, which they assumed was from lightning strikes, but earlier this year they finally found the real culprit

▲ The source of 'suspicious perytons' that caused headaches for astronomers at the Parkes radio telescope for years has finally been identified. Photograph: Julian Chang/Guardian Australia

The mystery behind radio signals that have baffled scientists at Australia's most famous radio telescope for 17 years has finally been solved.

The signals' source? A microwave oven in the kitchen at the Parkes observatory used by staff members to heat up their lunch.

RFI effects on VLBI

- Unless it overloads the receiver, arrays are less sensitive to RFI, because it is not present in all sites and, therefore, is not correlated between telescopes.
- RFI will not have the characteristic fringe frequency and delay of a cosmic source, so “fringe stopping” will decorrelate RFI signal
- Raw cross-correlation coefficient:

$$\frac{P_i * P_j}{\sqrt{P_i^2 \cdot P_j^2}}$$

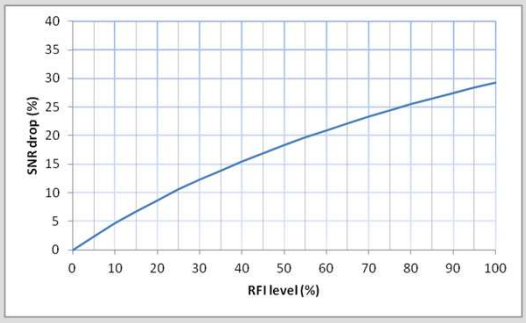
RFI added to signal “Pi” will reduce the coefficient and can drive to fringe amplitude errors

RFI effects on VLBI

- RFI increases Tsys, which implies:
  - less sensitivity, i.e., SNR reduction
  - Higher System Equivalent Flux Density $SEFD[Jy] = \frac{2kT_{sys}}{A_e} \cdot 10^{26}$
- Artifacts in source mapping
- Failure of geodetic bandwidth synthesis if several channels are affected by RFI
- SNR is given by:

$$SNR = \frac{S_{source} \cdot \sqrt{N_{bits}}}{\sqrt{SEFD_i \cdot SEFD_j}}$$

If RFI is 50% of system noise power , SNR drops by 18%



RFI effects on group delay

According to Shaffer simulations (2000 IVS GM paper):

- RFI effects looks like a variable clock offset
- RFI bias group delay estimates, rather than delay noise
- RFI from one particular direction tends to "pull/bias" site position estimation in that direction
- **RFI levels (>10% of Tsys) will cause delay errors > 1ps with implies a geometric error > 1mm**
- **Less accuracy in geodetic/astrometric measurements**

RFI effects on receivers

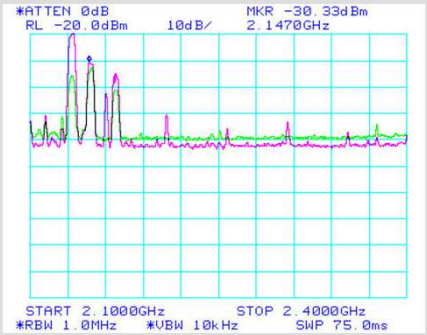
- LNA damage !!
  - It is the first and most sensitive amplifier in the chain.
  - Typical Po1dB = -30dBm => set máx. input power to -40dBm to guarantee linearity
  - Typical damage level is 10mW (10dBm)=> PFD threshold of -40 dB(W/m2) for a VGOS antenna.
- Gain compression at some point of the receiver's chain:
  - Intermodulation + harmonics => spurious signals
  - Tsys increase => less sensitivity.
  - Lack of linearity in the receiver

RFI mitigation

Options to avoid LNA damage:

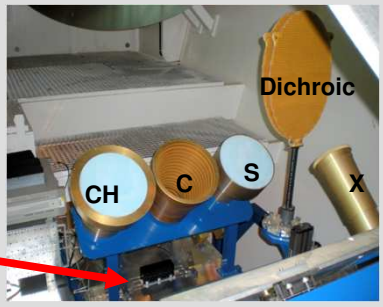
- Blanking of transmitters
- Dynamic schedule to avoid direct pointing to transmitter
- Diode power limiters at LNA input (degrades sensitivity)
- HTS filters at LNA input (less degradation than limiters)

RFI mitigation: radio-link filtering

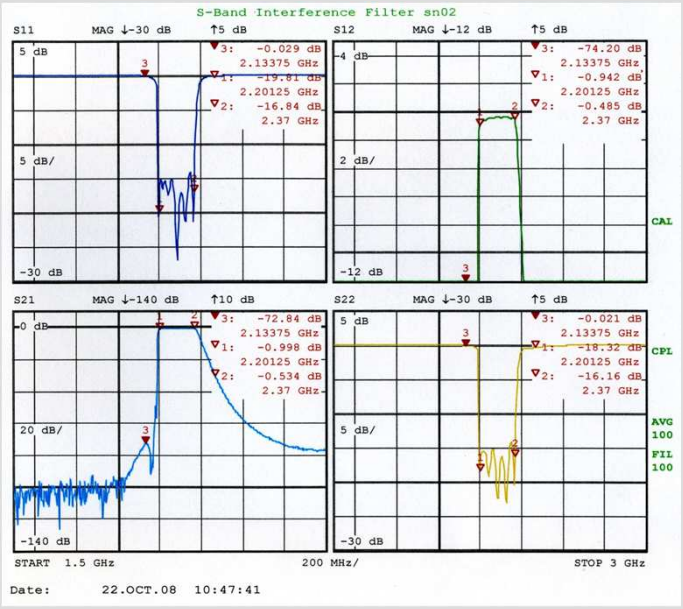


Three 4MHz BW lines coming from outside Yebes.

They were filtered out using customized 8-sections band-pass filters (see pictures below)



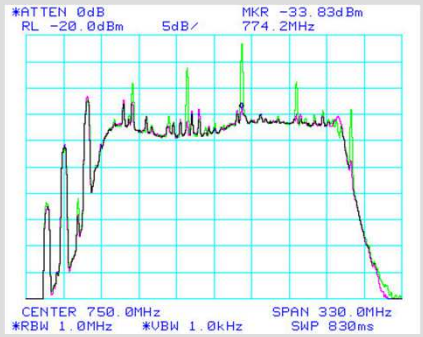
RFI example: radio-link filtering



S Band RFI High Selectivity Filter Response

RFI mitigation: Servo electronics shielding

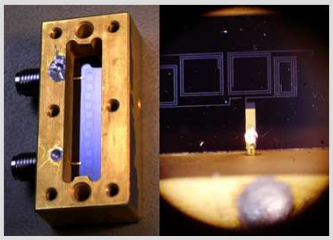
M3 Mirror Profibus Module inside shielded box

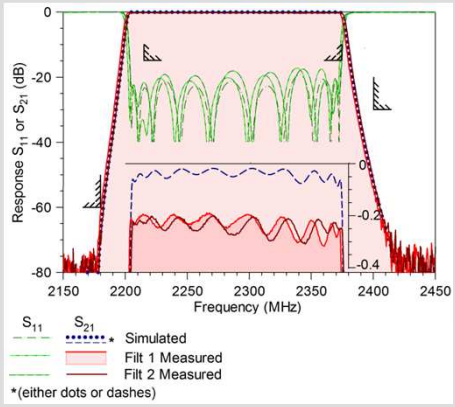


Some improvement …

but not enough !

HTS filters





S-Band: 2.2-2.37 GHz
9 poles band-pass filter

Fo = 2295 MHz
BW= 2215 - 2375 MHz
Max insertion loss: **0.1dB @ 20 Kelvin**
Rejection **> 60 dB at 2115 <= f <= 2180**
Rejection **> 30 dB at f > 2400 MHz**
Max VSWR in/out: 1.4:1

Frederick Huang, Pietro Bolli, Luca Cresci, Sergio Mariotti, Dario Panella, Jose A. Lopez-Perez, Pablo Garcia: **Superconducting spiral bandpass filter designed by a pseudo-Fourier technique**. *IET Microw. Antennas Propag., 2018, Vol. 12 Iss. 8, pp. 1293-1301*

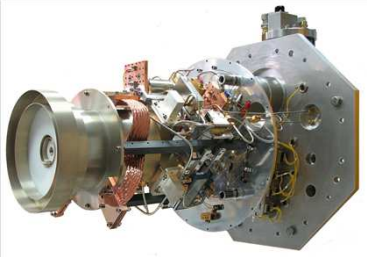
The Spanish VGOS experience: RAEGE

Baselines:

- Yebes – Gran Canaria : 1800 km
- Yebes – Santa María : 2000 km
- Yebes – Flores : 2400 km
- Gran Canaria – Flores : 2000 km
- Santa María – Flores : 540 km

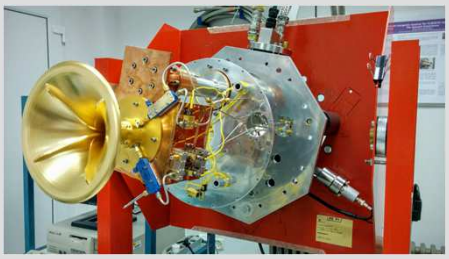
Geodetic receiver developments

Tri-Band Rx S/X/Ka



- Technology: HEMT LNA
- Band: S: 2.2 – 2.7 GHz
  X: 7.5 – 9 GHz
  Ka: 28 – 33 GHz
- Trx S < 30 Kelvin
- Trx X < 35 Kelvin
- Trx Ka < 35 Kelvin

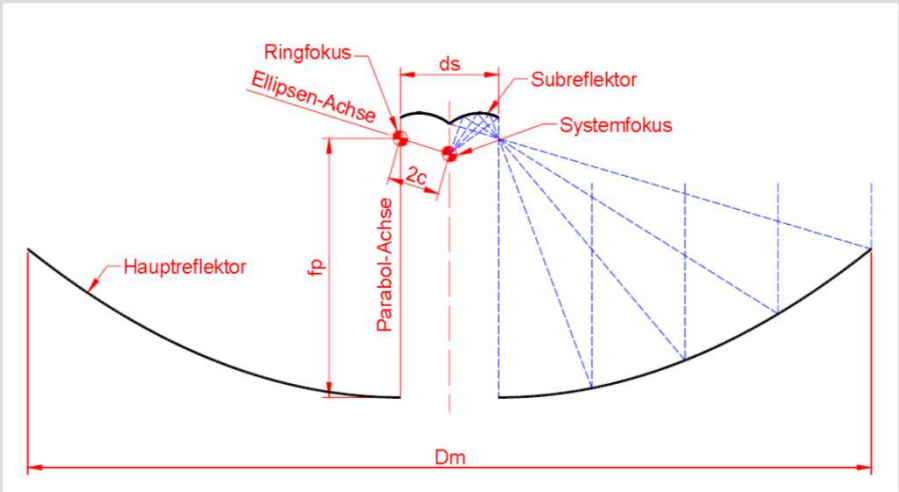
VGOS Broadband Rx (2-14GHz)



- Tecnology: HEMT LNA
- Band: 2 – 14 GHz
- Trx < 25 Kelvin

Currently 3 VGOS Rxs under construction: NMA, FGI and IGN (Santa María, Azores)

The ring-focus antenna optics

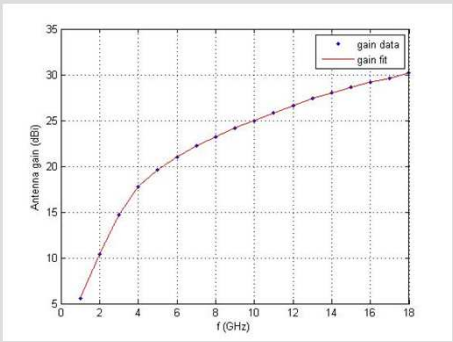


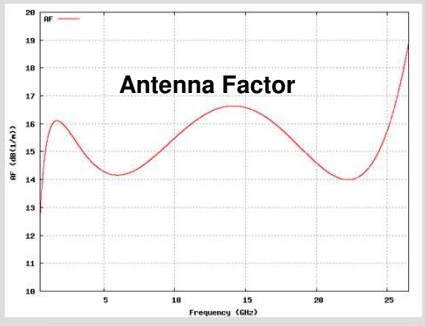
Advantages:
- No blockage
- High aperture efficiency

Yebes RFI measurement system

- Wideband 0.9m parabolic antenna AC008 from RS on a tripod
- Wideband 1 - 18 GHz crossed log-periodic antenna HL024S5 from RS, as the feed of the parabola, with internal pre-amplifiers
- GB016S5 feed control unit for polarization (H or V) and pre-amplifiers control.
- DC - 20 GHz Keysight N9344C spectrum analyzer with internal pre-amplifier
- Low loss coaxial cables
- Lap-top for data acquisition
- Auxiliary equipment
- It has been used for the evaluation of candidate RAEGE-VGOS sites in Azores and Canary islands
- It has been used for the measurement of RFI environment in Yebes (Spain), Westerbork (Netherlands), Effelsberg (Germany) and Onsala (Sweden)

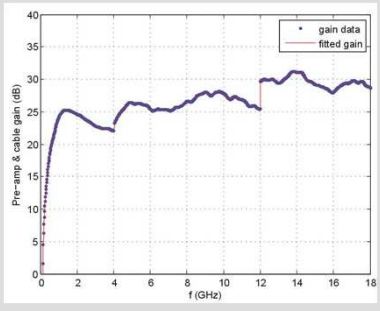
Yebes RFI measurement system





Parameter	2-4 GHz	4-8 GHz	8-12 GHz	12-18GHz
Gain (dB)	26	30	33	38
Gain response (± dB)	2	2	2	2
Noise Figure (dB, max.)	2.5	3.5	4	4.5
Po1dB (dBm, min.)	+15	+15	+15	+15
Max. input power (dBm)	30	27	27	27
VSWR (max)	2	2	2	2
DC supply at +15Vdc (mA)	200	300	300	300

Table 1: Active feed preamplifiers.



Sensitivity < -180 dB(W/m2·Hz) @ 1MHz RBW

Measurement procedure

1. **Install and set-up RFI measurement system in desired location**
2. **Set parabolic antenna elevation angle (0º worst case)**
3. **Set feed polarization and select feed pre-amplifier**
4. **Set spectrum analyzer parameters and MAX-HOLD mode**
5. **Turn the parabolic antenna by 360º in azimuth while analyzer accumulates data**
6. **Read/save accumulated spectrum with lap-top**
7. **Repeat from step 3 for each polarization and desired band**

Typical spectrum analyzer parameters:
- RBW = 1MHz
- VBW = 100 KHz
- Number of points = 461 (fixed)
- Sweep time = 150 ms (depends on span and RBW)
- Pre-amplifier: ON/OFF depending on RFI level

Conversion formulas

$$E\left[dB\left(\frac{\mu V}{m}\right)\right] = AF\left[dB\left(\frac{1}{m}\right)\right] + V[dB(\mu V)]$$

$$AF\left[dB\left(\frac{1}{m}\right)\right] = 20 \cdot \log(f[MHz]) - G_a[dBi] - 29.77$$

$$V[dB(\mu V)] = 107 + P_{meas}\,[dBm] - G_{rx}[dB]$$

$$\Psi\left[dB\left(\frac{W}{m^2 \cdot Hz}\right)\right] = -128.55 + P_{meas}\,[dBm] - G_{rx}[dB] - 10 \cdot \log(RBW[MHz]) + \cdots 20 \cdot \log(f[MHz]) - G_a[dBi]$$

$$\Psi_{total}\left[\frac{W}{m^2 \cdot Hz}\right] = \sqrt{\Psi_H\left[\frac{W}{m^2 \cdot Hz}\right] + \Psi_V\left[\frac{W}{m^2 \cdot Hz}\right]}$$

https://github.com/bwinkel/pycraf/blob/master/notebooks/01_conversions.ipynb

Yebes RFI protection table

ORDEN CTE/1444/2003, de 22 de mayo, por la que se establecen limitaciones a la propiedad y servidumbres para la protección radioeléctrica del Centro Astronómico de Yebes.

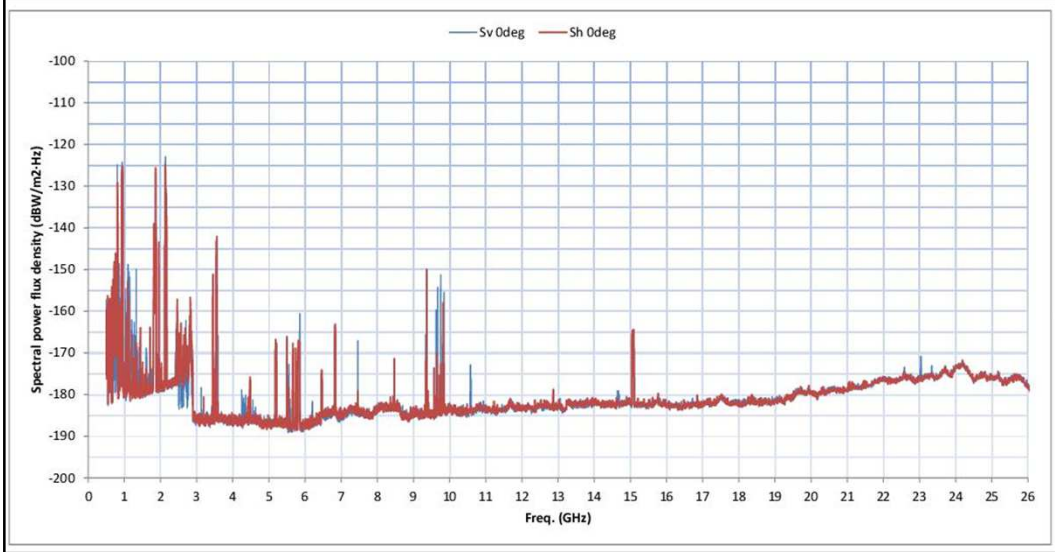
Banda de frecuencias	Densidad de flujo de potencia ($db(w/m^2)$)	Intensidad de campo eléctrico equivalente ($dB(\mu V/m)$)
1400-1427 MHz	-180	-34,2
1610,6-1613,8 MHz	-181	-35,2
1660-1670 MHz	-181	-35,2
2690-2700 MHz	-177	-31,2
4990-5000 MHz	-171	-25,2
10,6-10,7 GHz	-160	-14,2
15,35-15,4 GHz	-156	-10,2
22,21-22,5 GHz	-148	- 2,2
23,6-24 GHz	-147	- 1,2
31,3-31,8 GHz	-141	4,8
42,5-43,5 GHz	-137	8,8
86-92 GHz	-125	20,8

Para todas las demás frecuencias, se establece una limitación de la intensidad del campo eléctrico de +88.8dB (μV/m), medida en la ubicación de la Estación de Radioastronomía.

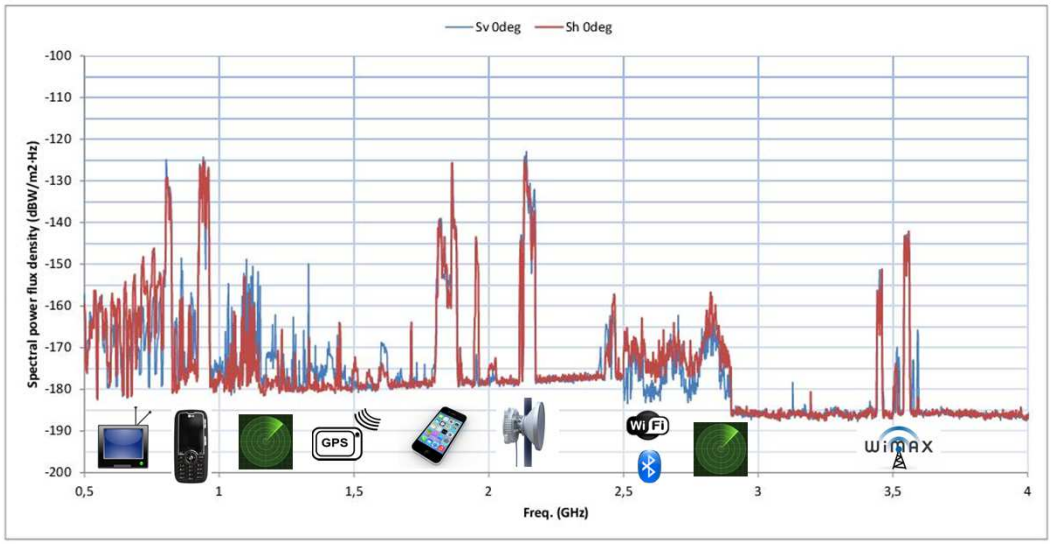
+88.8 dB(uV/m) => -117 dB(W/m2·Hz) in 1MHz BW

1 Jy = -260 dB(W/m2·Hz)

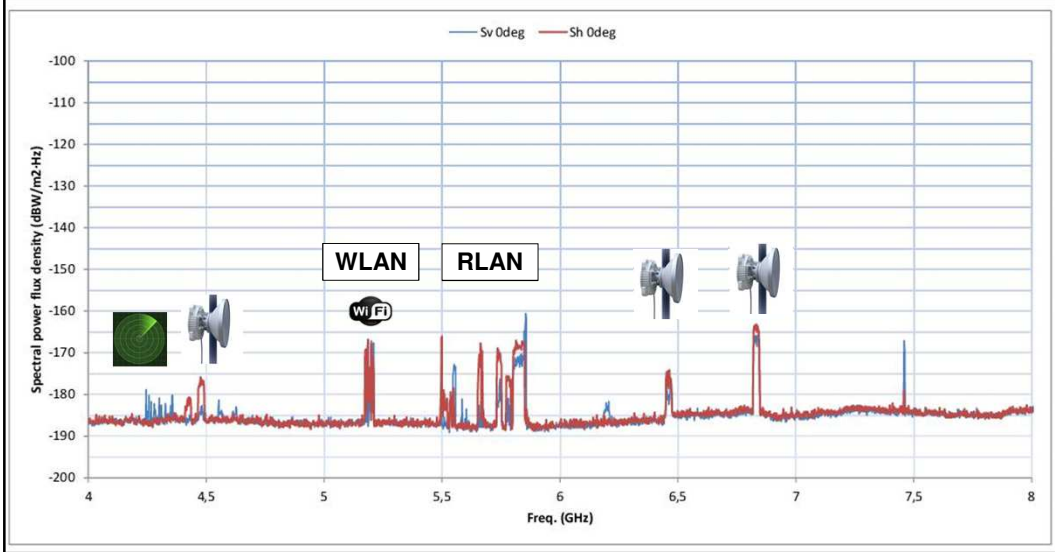
Yebes RFI panorama @ 0º El.



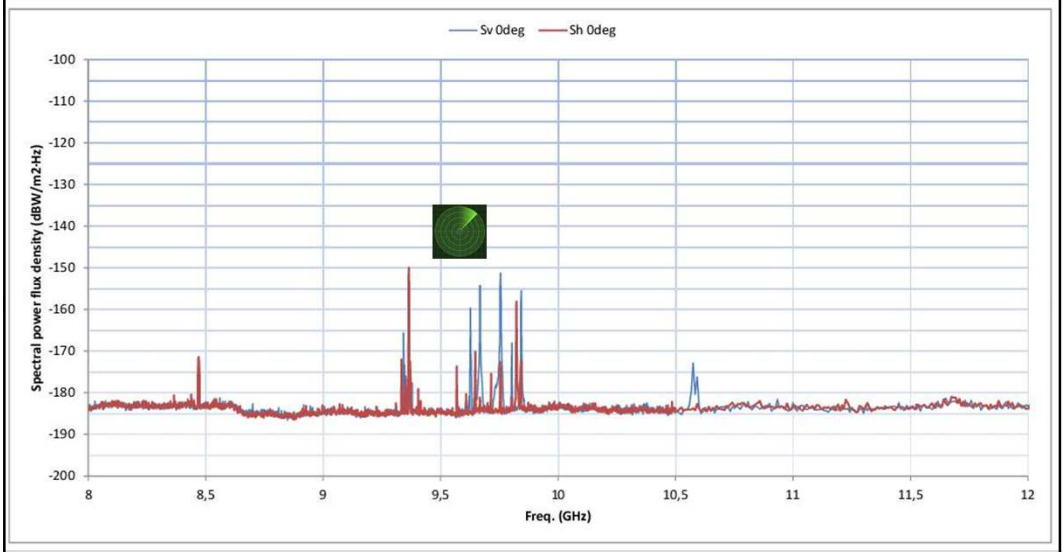
0.5 – 4 GHz zoom



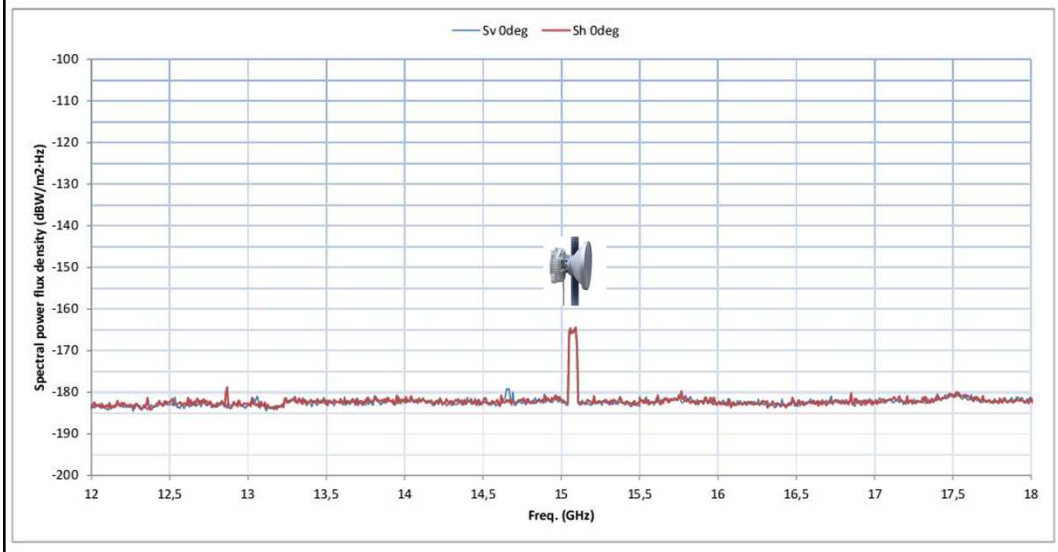
4 – 8 GHz zoom



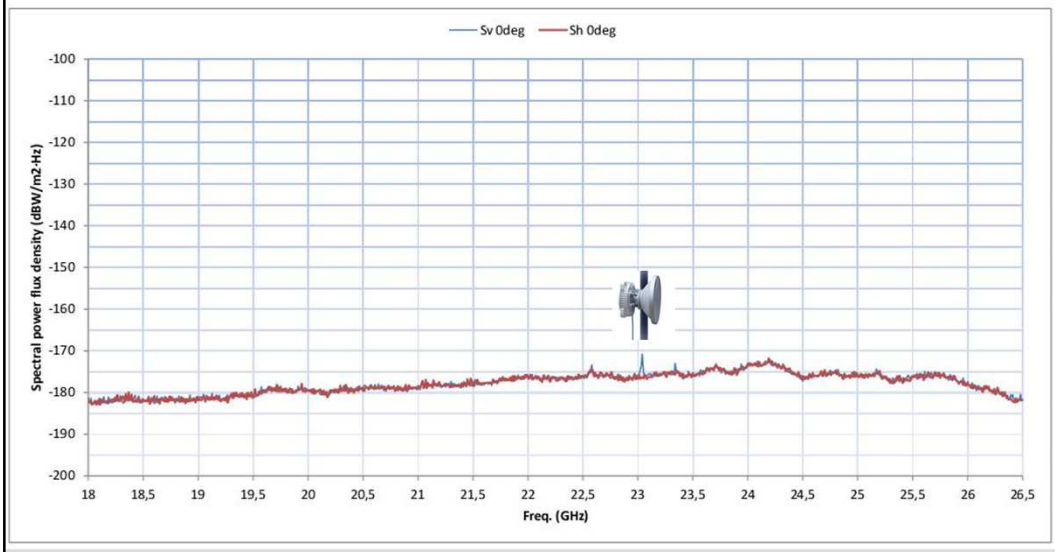
8 – 12 GHz zoom



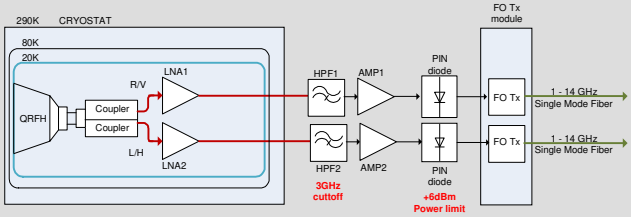
12 – 18 GHz zoom



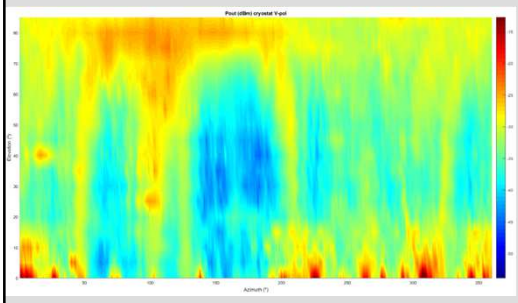
18 – 26.5 GHz zoom



RFI in VGOS band at Yebes

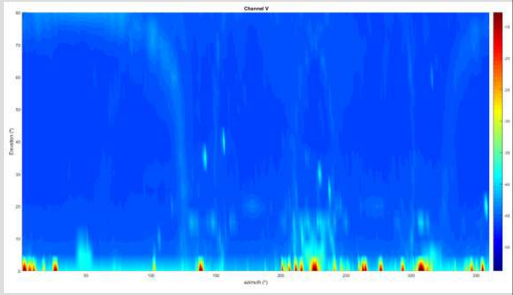


Elevation over Azimuth RFI power maps



a) Original situation without RFI filters

Tsys ≈ 70K

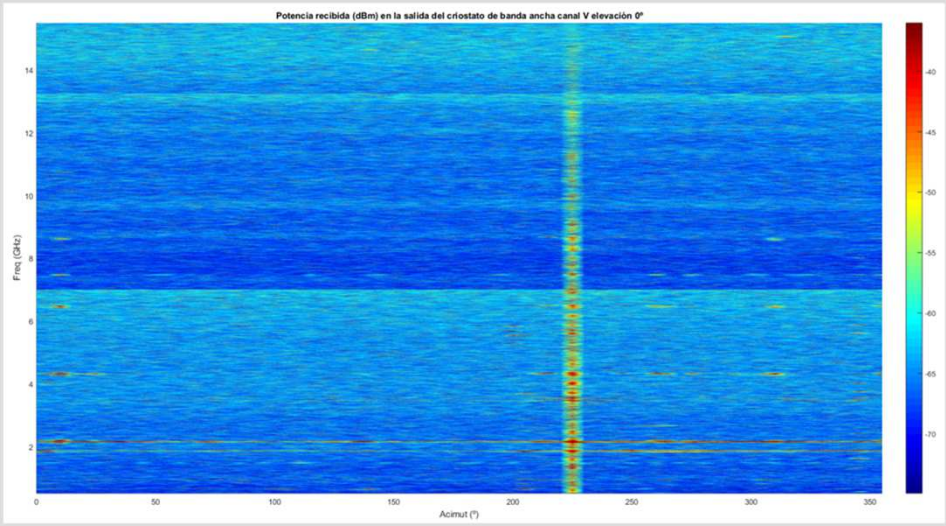


b) New situation with filters and pre-amplifier

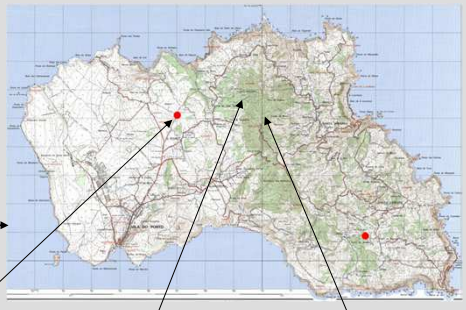
Tsys ≤ 50K

RFI in VGOS band at Yebes

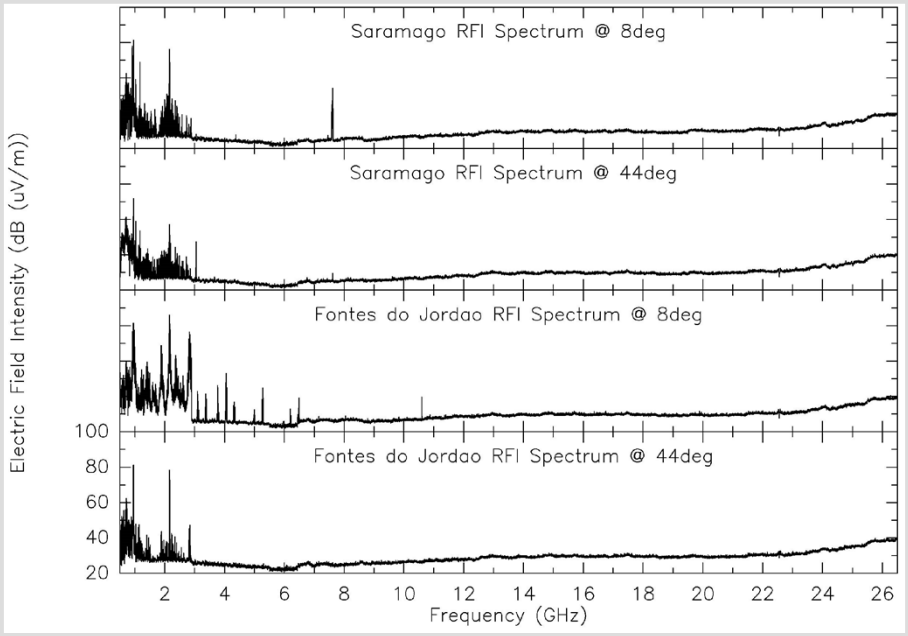
RFI frequency vs. Azimuth map



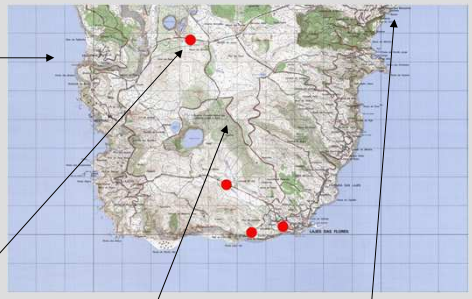
Santa María RFI measurements



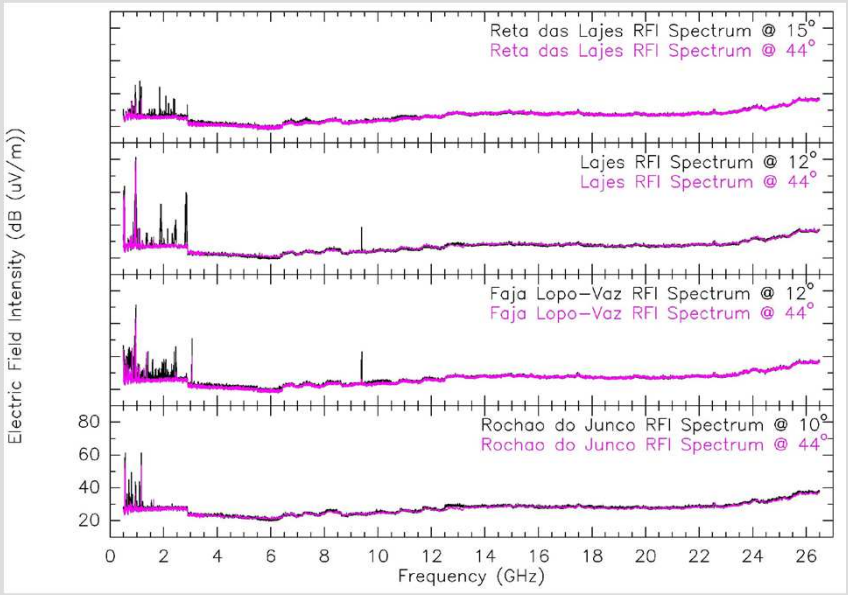
Santa María RFI panorama



Flores RFI measurements

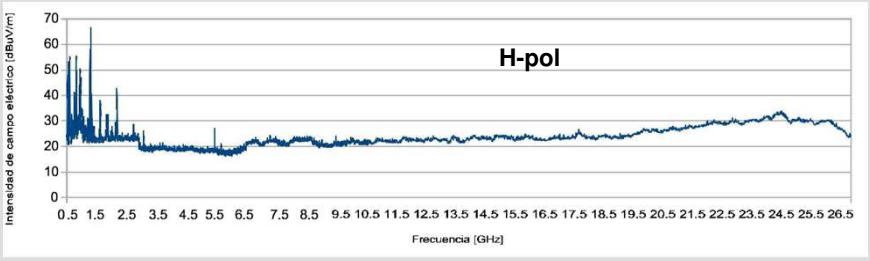


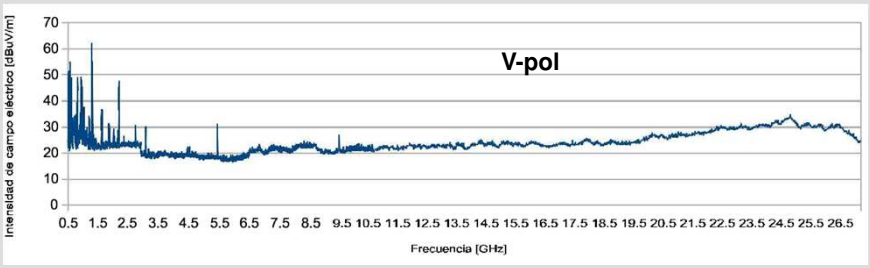
Flores RFI panorama



Gran Canaria RFI measurements

Artenara RFI panorama





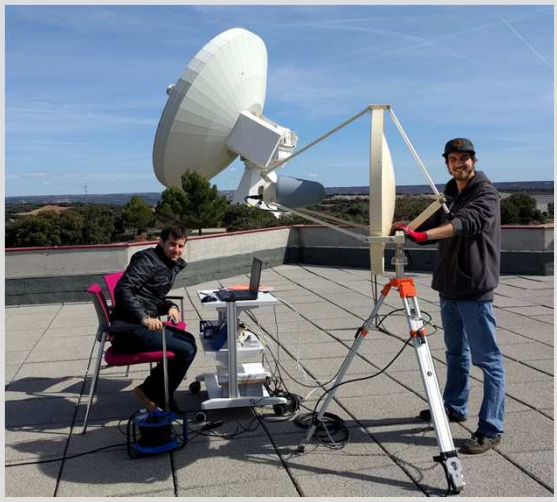
BRAND-EVN goals

- Build a prototype broad-band digital prime-focus receiver for Effelsberg 100-m radio telescope
- Freq. Range: 1.5 – 15.5 GHz
- Adaptation to other EVN antennas (secondary focus)
- Back-end (8-bit sampler) will operate in 0-16 GHz range => no analogue frequency conversion required
- Multi-band simultaneous observations => increase EVN observing time
- Single cooled receiver will replace multiple VLBI receivers => lower maintenance costs
- **VGOS compatibility**

BRAND-EVN issue: RFI

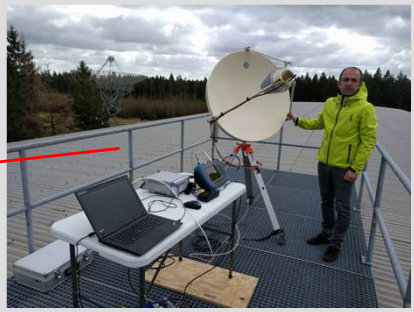
- Freq. Range: 1.5 – 15.5 GHz is shared with several telecommunication services:
  - Different type of radiolinks
  - Different type of radars
  - Mobile communications (UMTS / LTE / 4G / 5G)
  - Satellite communications
  - ISM band signals: WiFi, Bluetooth
  - UWB
  - …
- One of the very first BRAND WP is to evaluate the RFI environment

Yebes measurement location



On the roof of the laboratory building

Westerbork measurement location

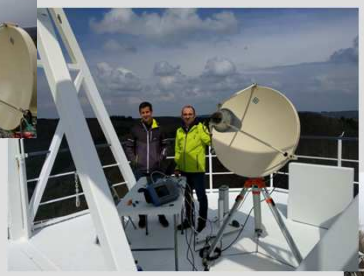


On the roof of the construction building, 16m above ground level

Thanks to Hans van der Marel, Jan-Pieter de Reijer and their team for their support.

Effelsberg measurement location

On the roof of the main building

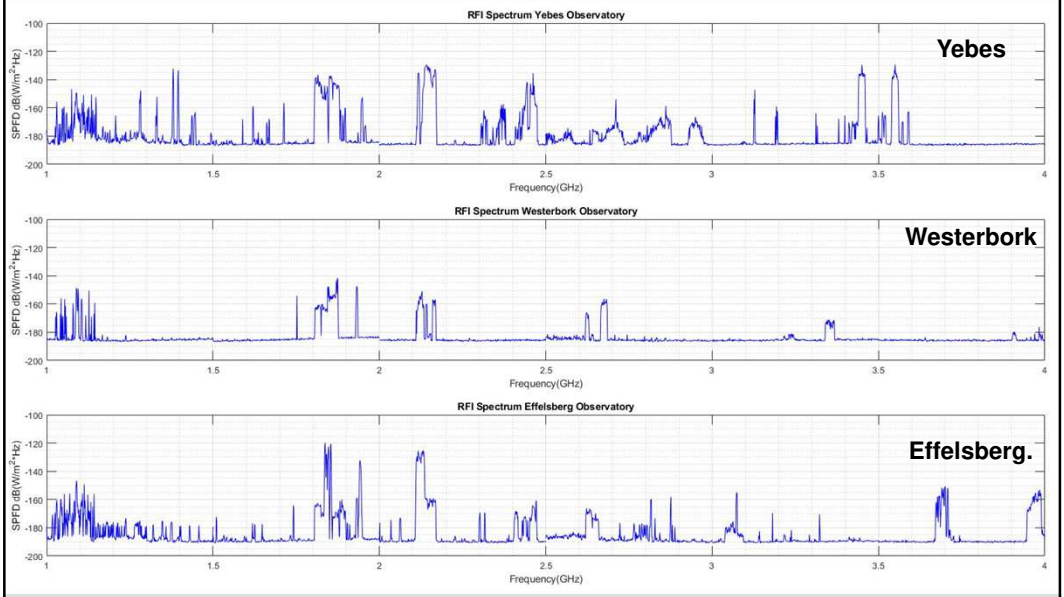


On top of the 100-m radiotelescope subreflector room

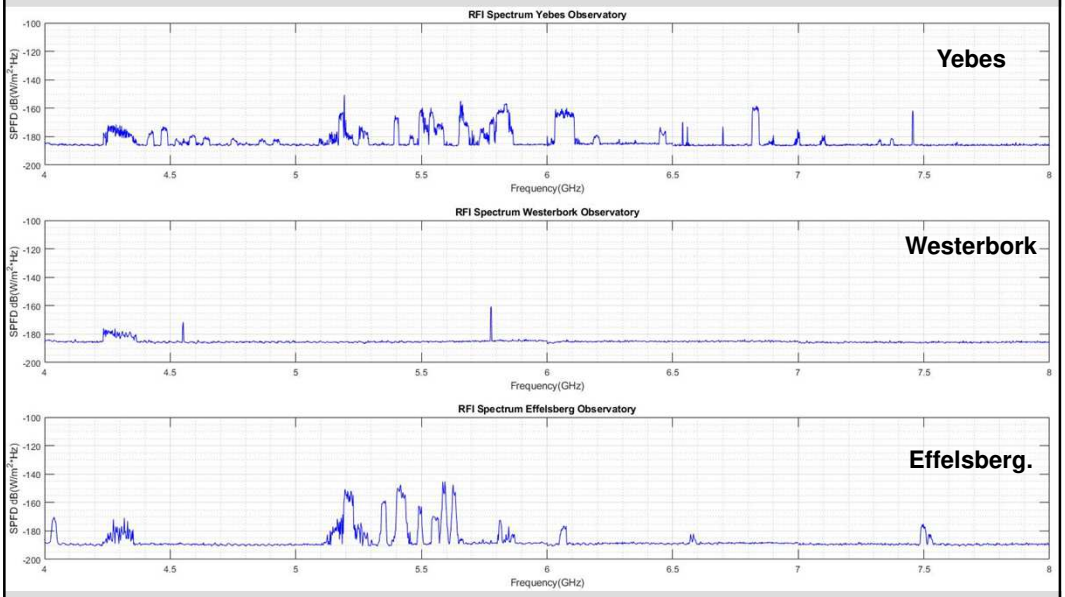
At the entrance of the visitor center

Thanks to Reinhard Keller and his team for their support.

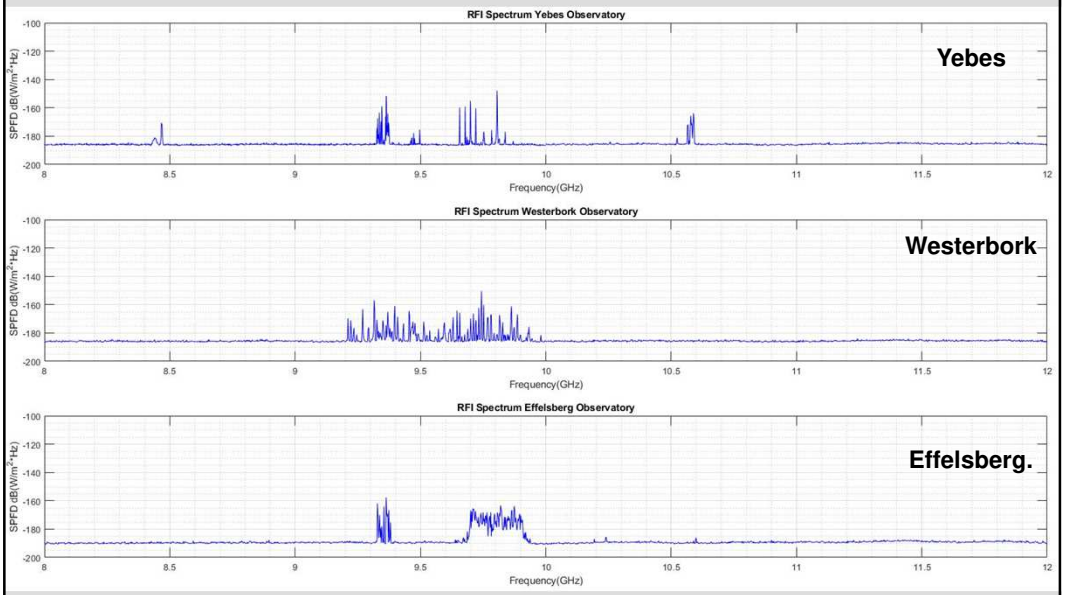
1 – 4 GHz band



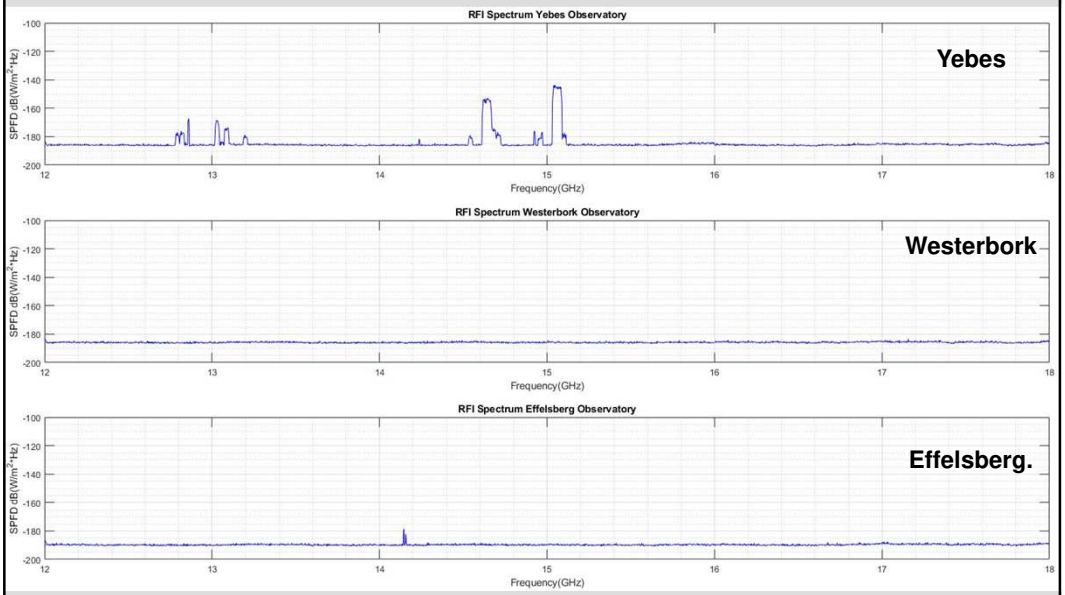
4 – 8 GHz band



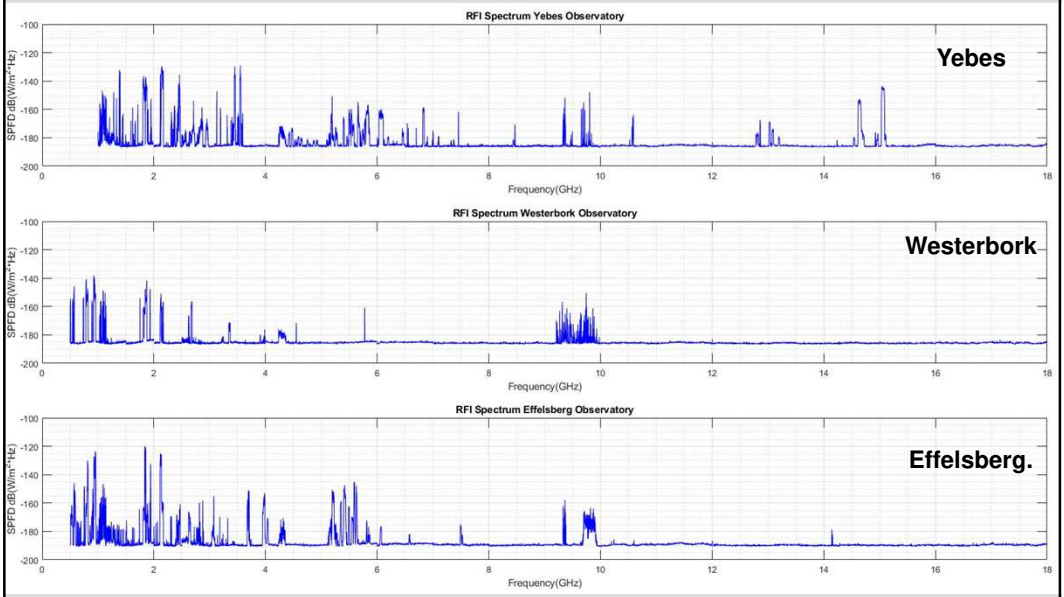
8 – 12 GHz band



12 – 18 GHz band



1 – 18 GHz full span



BRAND RFI mitigation: HTS filtering

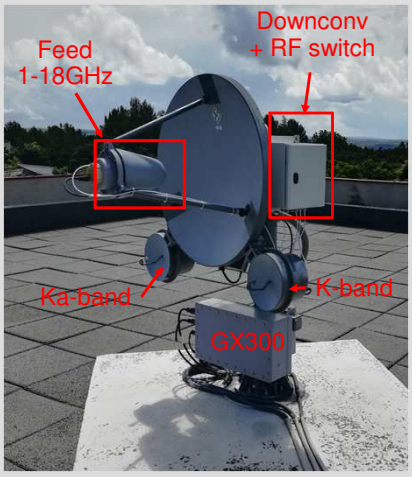
RFI band	Integrated RFI Power		% of total RFI power
f (GHz)	Power (dBm)	Power (mW)	
14,14-14,17	-46,7178	2,13E-05	0,000%
12-12,1	-53,66	4,30E-06	0,000%
10,59-10,61	-54,7	3,38E-06	0,000%
9,7-9,95	-22,78	5,30E-03	0,017%
9,32-9,38	-27,65	1,70E-03	0,006%
7,485-7,535	-37,88	1,63E-04	0,001%
6,55-6,6	-46,6859	2,14E-05	0,000%
6,05-6,08	-34,242	1,19E-04	0,000%
5,8-5,82	-36,9735	2,01E-04	0,001%
5,62-5,64	-14,9428	0,032	0,104%
5,58-5,6	-12,3593	5,81E-02	0,189%
5,39-5,45	-10,6967	8,52E-01	2,765%
5,34-5,36	-21,7115	6,70E-03	0,022%
5,19-5,23	-13,2865	4,64E-02	0,151%
4,22-4,36	-35,6418	2,73E-04	0,001%
4,02-4,06	-34,0516	3,93E-04	0,001%
3,94-3,99	-17,0805	1,96E-02	0,064%
3,67-3,72	-15,8983	2,57E-02	0,083%
3,07-3,076	-24,9679	3,20E-03	0,010%
2,874-2,878	-31,5385	7,02E-04	0,002%
2,811-2,82	-30,4705	8,97E-04	0,003%
2,61-2,665	-29,0092	1,30E-03	0,004%
2,4-2,48	-26,7882	2,10E-03	0,007%
2,11-2,17	11,248	1,33E+01	43,264%
2,06-2,066	-42,3913	5,77E-05	0,000%
2,03-2,04	-50,1462	9,67E-06	0,000%
2-2,005	-52,011	6,29E-06	0,000%
1,92-1,95	-1,9401	6,40E-01	2,076%
1,86-1,90	-26,5581	2,20E-03	0,007%
1,83-1,86	11,98	1,58E+01	51,212%
1,8-1,825	-25,5551	2,80E-03	0,009%
1,74-1,745	-37,2933	1,86E-04	0,001%
1,645-1,652	-52,1283	6,13E-06	0,000%
1,615-1,63	-48,0162	1,58E-05	0,000%
1,509-1,512	-45,2495	2,99E-05	0,000%
Total Power	14,9	30,8	100,0

- the out-of-band RFI signals (0.5 – 1.5 GHz) using a 1.5 GHz high-pass filter
- the band 1.83 – 1.86 GHz using a notch
- the band 2.11 – 2.17 GHz using a notch

The final solution adopted is:

- One HTS high-pass filter
- Onet HTS band-pass filter with 2 notches

Yebes new permanent RFI monitoring system



AC308R2 0.25m dish
Freq: 18 – 26.5 GHz
Gain: 29 – 33 dBi
HPBW: 4.5º - 3º

AC308R3 0.25m dish
Freq: 26.5 – 40 GHz
Gain: 33 – 36 dBi
HPBW: 3º - 2º

AC090 SHF 0.9m dish
Log-periodic feed HL024S7
Freq: 1 - 18 GHz
Gain: 15 – 40 dBi
HPBW: 19º - 1.1º
Surface < 430 um
Az: 0º - 360º
El: -5º - 95º
Accuracy: +/-0.2º

Wideband parabolic antenna AC090 from R&S on Az over El rotor

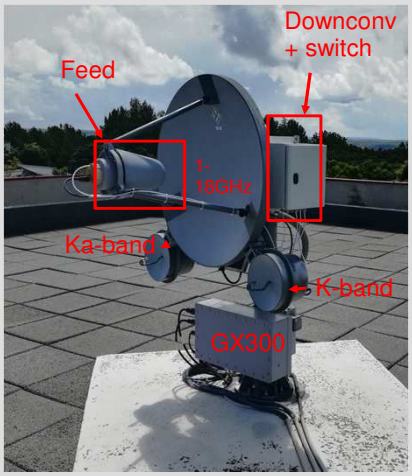
Yebes new permanent RFI monitoring system

RFI antenna:

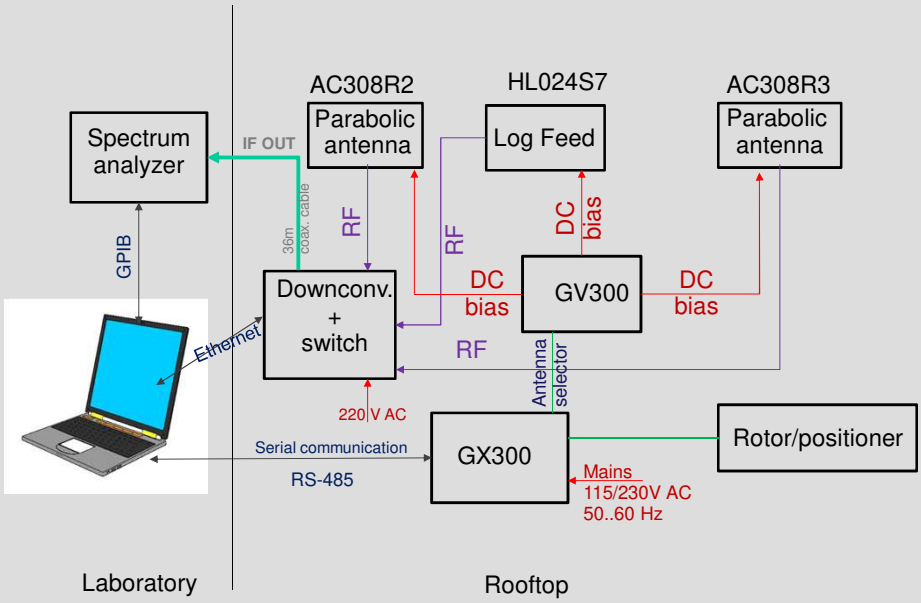
- Rhode-Schwarz AC090 SHF (90 cm diameter antenna).
- Rhode-Schwarz HL024S7 log-periodic antenna (band from 1-18 GHz).
- AC308R2 SHF (25 cm diameter antenna): from 18-26.5 GHz.
- AC308R3 SHF (25 cm diameter antenna): from 26,5-40 GHz.

Downconverter + IF switch:

- Controlled via Ethernet
- 1 IF output selected by the switch



Block diagram



Conclusions

It is clear that:

- RFI degrades VLBI observations
- RFI levels are going to increase

So:

- Register your telescope in ITU database (contact national authority to do it)
- Support your commitee (CORF, CRAF or RAFCAP)
- Set an RFI measurement system to detect RFI and claim for protection in RAS bands if needed.

References

- ITU-R RA.2188: Power flux-density and EIRP levels potentially damaging to radio astronomy receivers.
- ITU-R RA.2428-0: Parameters for the registration of distributed radio astronomy systems
- ITU-R RA.RA-769: Protection criteria used for radioastronomical measurements
- ITU-R RA-314: Preferred frequency bands for radioastronomical measurements
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- J. A. López-Pérez, F. Tercero: "Report on recommendations for individual EVN antennas". BRAND-EVN work package deliverable 6.1. H2020-INFRAIA-2016-2017/H2020-INFRAIA-2016-1. 2017-06-22.
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- **H. Hase, V. Tornatore, B. Corey: "How to register a VGOS radio telescope at ITU and why it is important". IVS 2016 GM Proc.**
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Thanks!!