Instrumentation Developments for VGOS at IGN-Yebes Observatory

J. A. López-Pérez, F. Tercero-Martínez, J.M. Serna-Puente, B. Vaquero-Jiménez, M. Patino-Esteban, P. García-Carreño, J.D. Gallego-Puyol, I. Malo-Gómez, I. López-Fernández, M. Díez-González, J. González-García, A. García-Castellano, C. Albo-Castaño, J. López-Ramasco, L. Barbas-Calvo, M. Bautista-Durán, O. García-Pérez, F. J. Beltrán-Martínez, A. Baldominos-Delgado, G. Gómez-Molina, P. de Vicente-Abad, J. A. López-Fernández

10th TOW meeting, May 5-9, 2019, MIT Haystack Observatory

Index

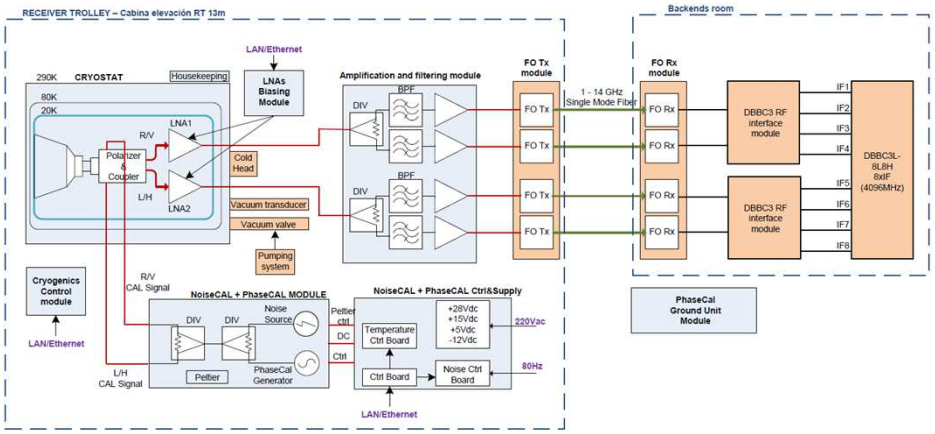
- VGOS receivers
- QRFH design
- Linear to circular polarization using hardware
- LNA's developments
- PhaseCal developments
- Cryogeny and Vacuum control module
- RFI in VGOS band
- Local tie measurements

VGOS receivers (1)

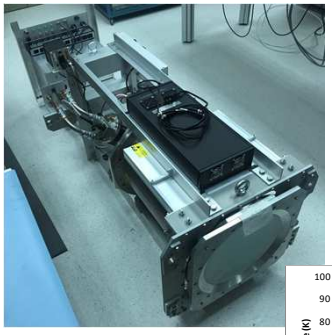
- Construction of two receivers for Norwegian Mapping Authority (NMA)
- Construction of one receiver for Finnish Geospatial Research Institute (FGI)

- Future receiver for RAEGE Santa María station has been outsourced.

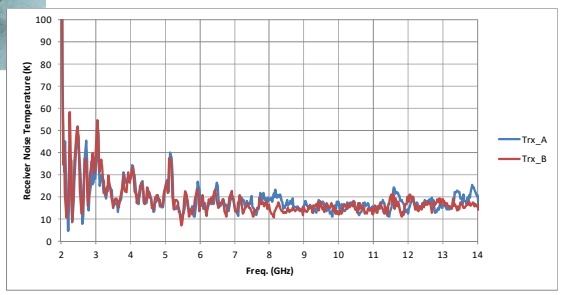
VGOS receivers (2) block diagram



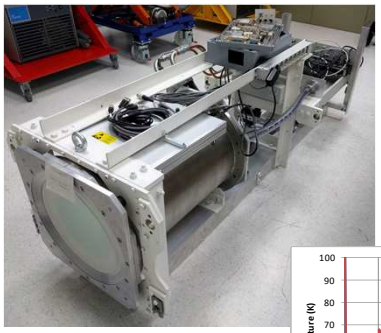
VGOS receivers (3): NMA



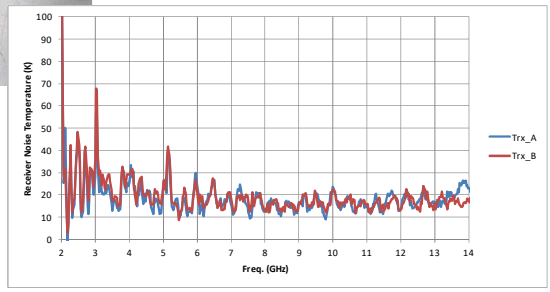
- Delivery scheduled for August'2019
- Trx < 25 Kelvin



FGI VGOS receivers (4): FGI

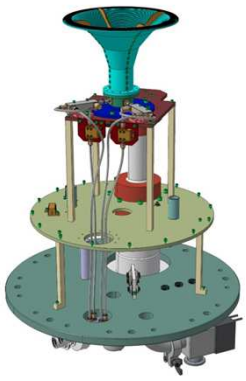


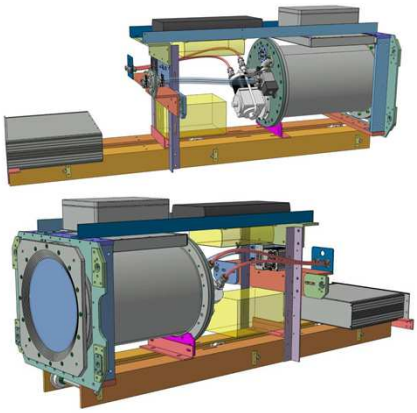
- Delivery scheduled for September'2019
- Installation support during October'2019
- Trx < 25 Kelvin



VGOS receivers (5): Santa María

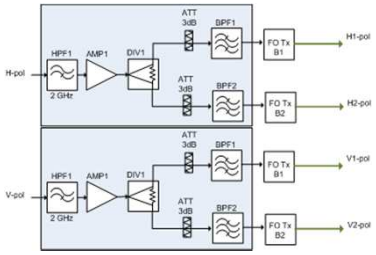
- Contracted with Spanish company: TTI-Norte



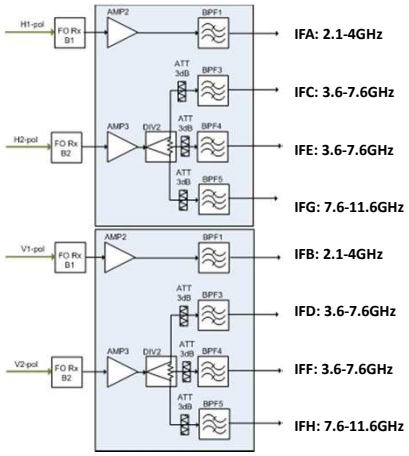


VGOS receivers (5)
Filtering and pre-amplification units

•Signal conditioning for dBBC3
•Under construction for NMA and FGI



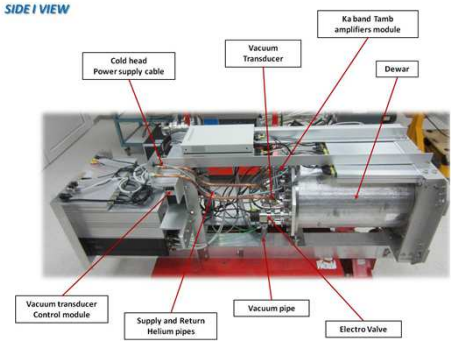
Low band: 2.1 – 5.6 GHz
High band: 3.6 – 11.6 GHz



Tri-band receiver support to NMA (1)

- NMA borrowed Yebes tri-band receiver for the commissioning of twin telescope at Ny-Alesund.
- Yebes supported NMA with Rx installation, operation and telescope control.

Tri-band receiver support to NMA (2)

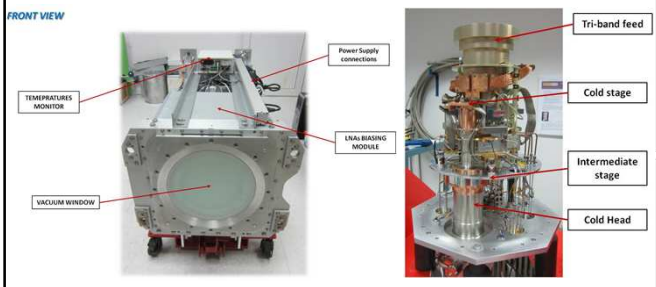


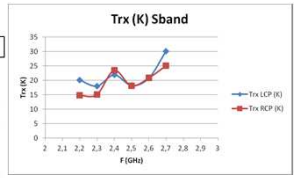
Installation in VLBI2 antenna: april 2017
Installation in VLBI1 antenna: march 2018

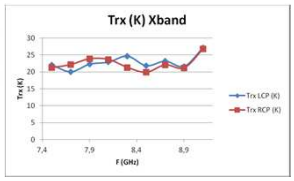
VGOS receiver installation in VLBI2 antenna around june/july 2019.

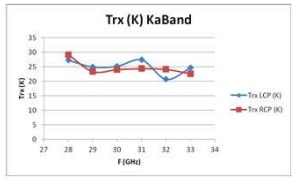
Special care with RFI from ship radars from the fyord !!! Two X-band LNAs were destroyed.

Tri-band receiver performance







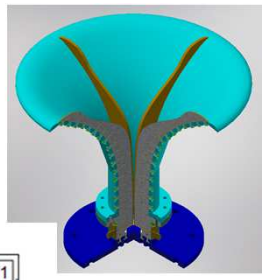


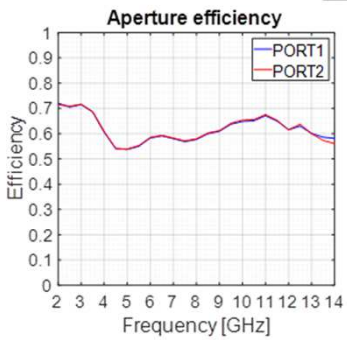
Three tri-band receivers built at Yebes:

- First light receiver for Yebes VGOS antenna
- Tri-band receiver for Ishioka station
- Tri-band receiver for Santa Maria VGOS station

QRFH design

- Wideband antenna 2.3-14 GHz.
- Dual linear polarization
- Manufacturing easiness
- 2 output coaxial conectors



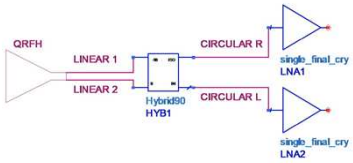


12

Linear to circular polarization conversion using hardware (1)

- Adding a 3dB/90º microwave hybrids as potential (hardware) solution to convert dual linear polarization from the QRFH antenna into dual circular polarization.

- **Degradation of LNA noise by 1-3 Kelvin along the 2-14GHz band**



O. García-Pérez, F. Tercero, I. Malo, J. A. López-Pérez: **"Linear to circular polarization conversion using microwave hybrids for VGOS (2-14 GHz)** ", CDT Technical Report 2018-13.

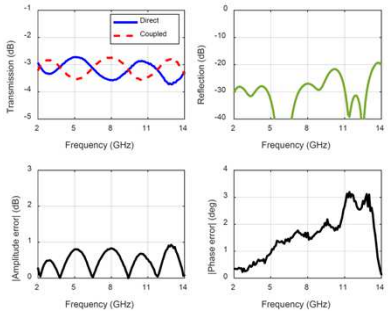
I. Malo-Gómez, J. D. Gallego-Puyol, C. Díez-González, et al., "**Cryogenic hybrid coupler for ultra-low-noise radio astronomy balanced amplifiers**," *IEEE Trans. Microw. Theory Tech.*, vol. 57, pp. 3239-3245, Nov. 2009.

Linear to circular polarization conversion using hardware (2)

Multi-octave stripline hybrids developed at Yebes:

• Bandwidth: 2-14 GHz (1.5 – 15.5 GHz also available)
• amplitude unbalance < 0.9 dB
• phase unbalance < 3 deg
•Optimized for cryogenic operation

Hybrid performance



Linear to circular polarization conversion using hardware (3)

Estimated cross-polar discrimination for circular polarization:

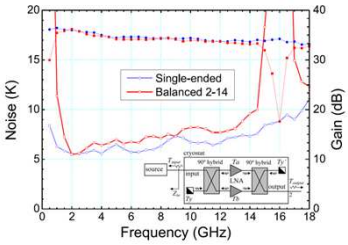
• XP < -25 dB → Axial Ratio < 1 dB

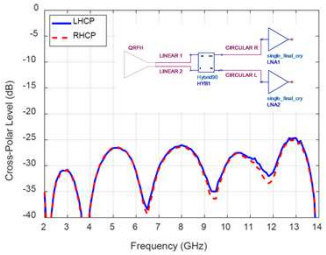
Additional degradation can be expected if the cables between antenna and hybrid have not identical length , e.g.:

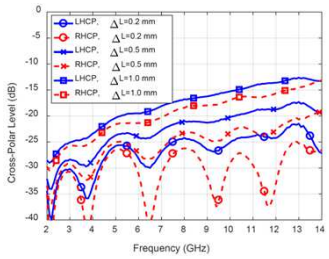
• XP(max)= -17 dB for ΔLength = 0.5 mm

Measured noise increase due to losses:

• ↑NT < 3K (@15K)







Yebes ultra-wide band LNAs (1) Single-ended version

- Hybrid
- Small/compact size
- Usable in 0.5-18 GHz

Band	2-14 GHz
Tn	6.1 K (ETH)
Gain	33.9 dB
IRL	-1.5 dB
ORL	-16.9 dB
Power	36 mW

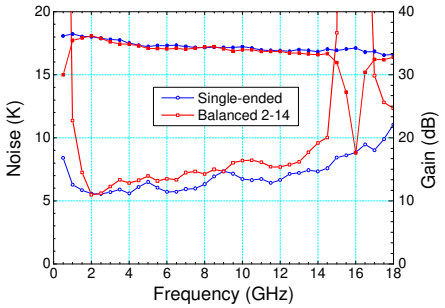
20 x 22 x 9 mm (excl. conn.)

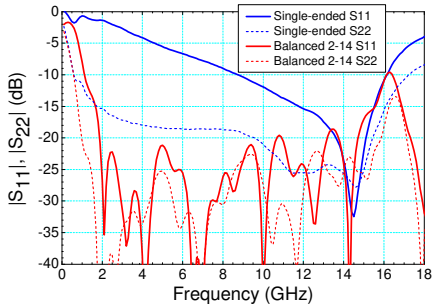
Yebes ultra-wide band LNAs (2) Balanced version

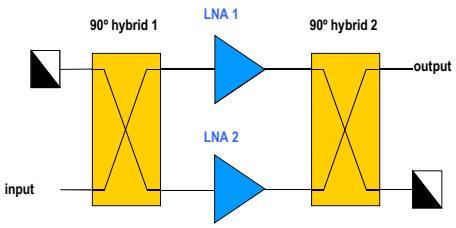
- Using 3dB/90º hybrids
- Very low noise penalty
- Drastic improvement of input reflection
- Balanced versions for 2-14 GHz and 1.5-15.5 GHz available

Band	2-14 GHz
Tn	7.6 K (ETH)
Gain	33.8 dB
IRL	-21 dB
ORL	-23 dB

Yebes ultra-wide band LNAs (3) Balanced vs. Single-ended performance

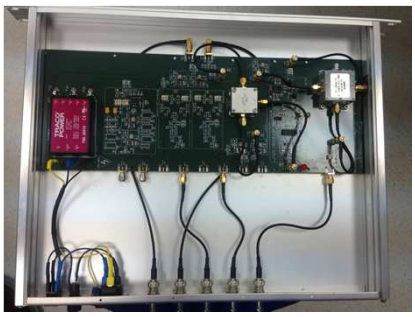






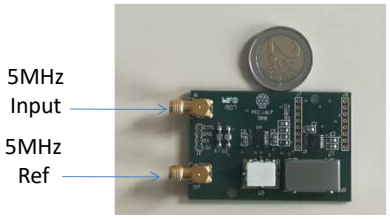
PhaseCal Developments (1)
Integrated Ground Unit (CDMS)

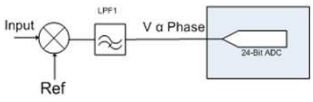
- In the back-end room
- Reference: 5MHz
- Cable delay measurement
- Follows Haystack legacy approach integrated in a single board inside a 19”/1U rack

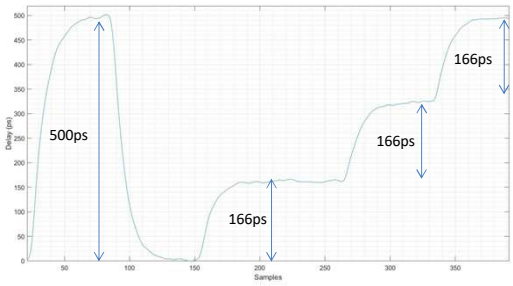


- Subsystems:
  - Phase Detector / Modulating Generator
  - 5MHz – 25Hz Generator
  - Start / Stop Generator
  - Cable Multiplexer
  - **REQUIRES A FREQUENCY COUNTER !!!**
  - Units for BKG, AGGO, NMA and FGI have been developed at Yebes labs.

PhaseCal Developments (2)
New CDMS under tests

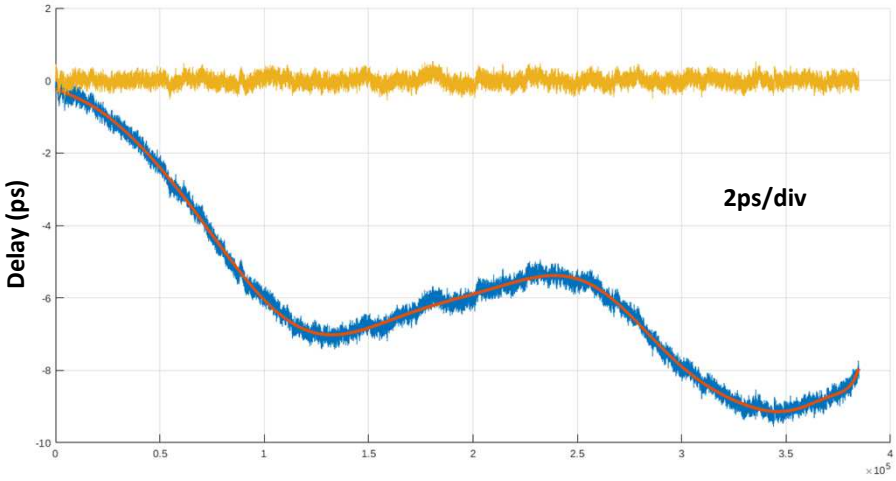






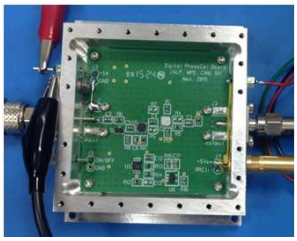
- Phase detector at 5MHz
- 24-bit ADC
- **Frequency counter is not required, only a cheap Raspberry Pi**

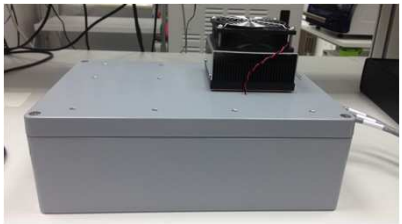
PhaseCal Developments (3)
New CDMS under tests



PhaseCal Developments (4)
NoiseCal&PhaseCal Antenna Unit

- In the receiver trolley (Front-end)
- 2-14GHz
- Pulse spacing: 10MHz
- Pulse Generator: based on Hitite Ultrafast logic gates (Haystack approach)
- NoiseCal can be switched at 80Hz rate
- Temperature stabilization: Peltier cooler and passive insulation.
- Units for BKG, AGGO, NMA and FGI have been developed at Yebes labs

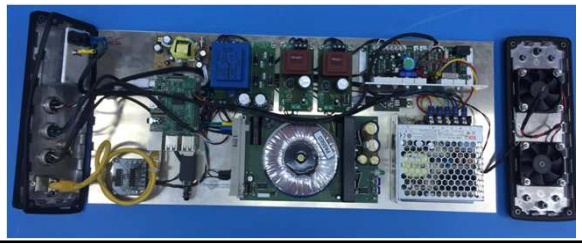




PhaseCal Developments (5)
PhaseCal Control and Power Supply

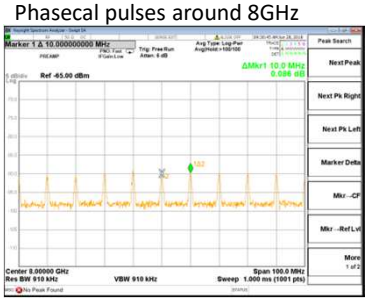
- Control HW
  - Raspberry Pi
  - Peltier control module: PR59 Laird Technologies
  - NoiseCal control PCB
- Control SW
  - Python – 2 programs
    - Peltier (set/get temperature, on/off)
    - Pulses and noise diode (pulses on/off, noise diode on/off/80Hz, status)



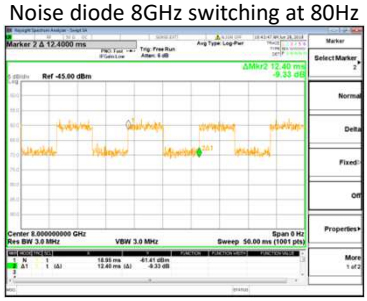



PhaseCal Developments (6)
performance

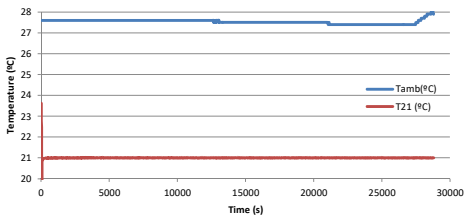
Phasecal pulses around 8GHz



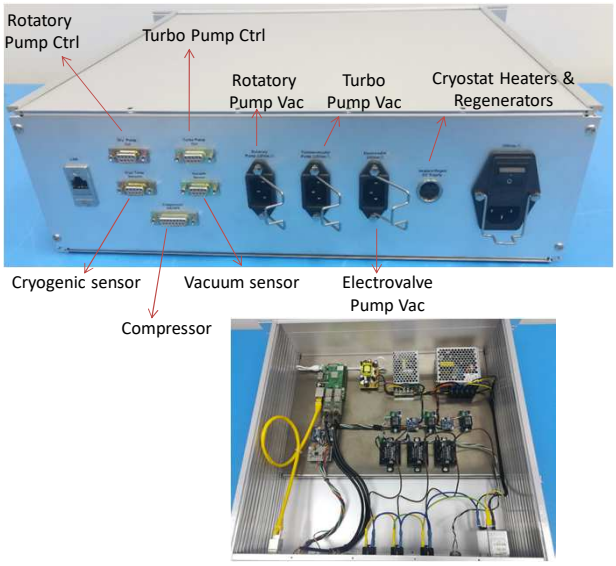
Noise diode 8GHz switching at 80Hz



Temperature stability



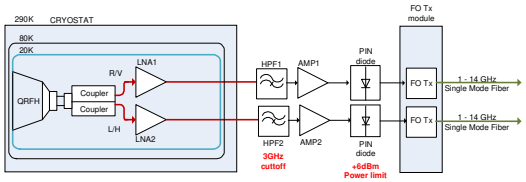
Cryogeny & Pumping Control System



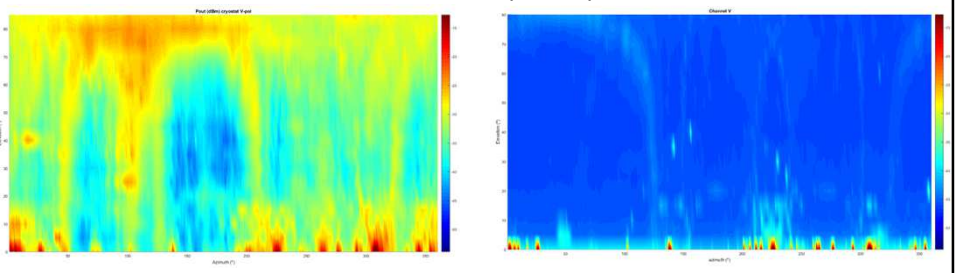
LAN remote monitor and control of:

- Rotatory Pump
- Turbo Pump
- Cryogenic temperature sensors
- Vacuum sensor
- Compressor
- Electrovalve
- Heat Resistors
- Regenerators

RFI in VGOS band at Yebes



Elevation over Azimuth RFI power maps



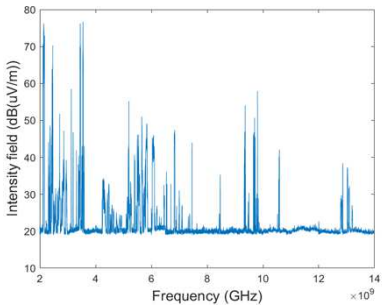
a) Original situation without RFI filters

Tsys ≈ 70K

b) New situation with filters and pre-amplifier

Tsys ≤ 50K

RFI spectrum 2-14 GHz



More RFI to come from upcoming allocations for:

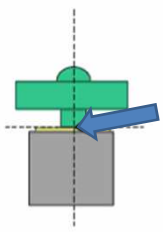
5G mobile phones:
- 3.3-4.2 GHz
- 4.4-4.9 GHz
- 5.9-7.1 GHz

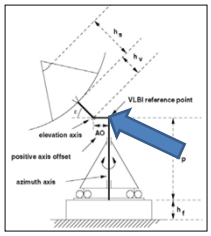
satellite-based internet:
- 10.7 – 12.7GHz

Local Tie (1)

- ITRS = Combining reference frames (ITRF) of each technique by the IERS
- ***Local or link-local tie is a three-dimensional vector connecting reference points of different geodetic techniques.***
- Measured local tie between GNSS and VLBI antennas at Yebes

G.N.S.S.

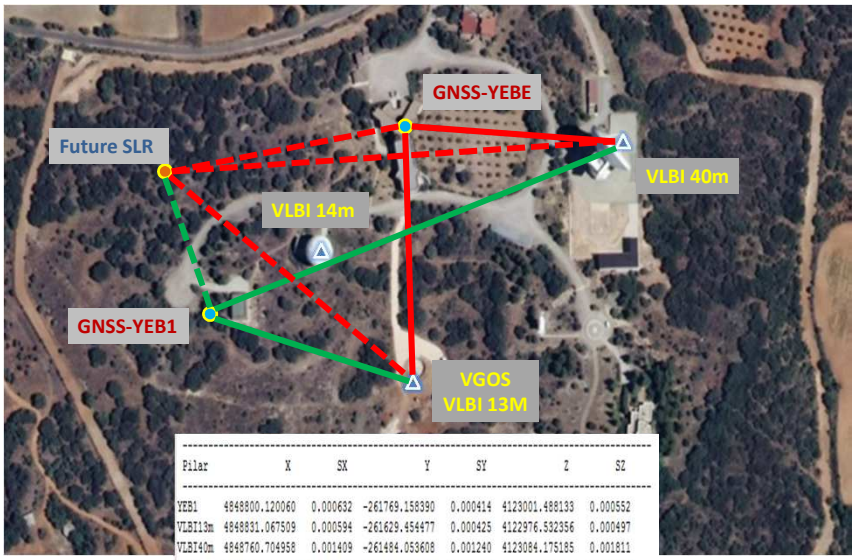




V.L.B.I

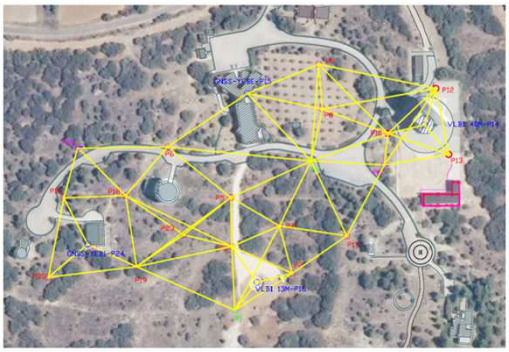
28

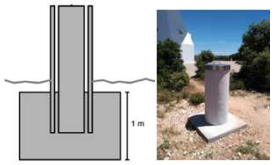
Local Tie (2)



Pilar	X	SX	Y	SY	Z	SZ
YEB1	4848800.120060	0.000632	-261769.158390	0.000414	4123001.488133	0.000552
VLBI13m	4848831.067509	0.000594	-261629.454477	0.000425	4122976.532356	0.000497
VLBI40m	4848760.704958	0.001409	-261484.053608	0.001240	4123084.175185	0.001811
YEBE	4848724.595679	0.000565	-261631.978731	0.000434	4123094.304297	0.000488

Local tie (3): Network of pillars





- Simulated design to evaluate the feasibility to get 1 mm of accuracy of local tie.
- 20 Reinforced concrete pillars of 30 cm in diameter and 1.30 m high.
- Isolated 5 cm of a protective tube which provides thermal and climatic stability.
- Forced centering screw with standard 5/8 '' over stainless steel plate.
- Depth of excavation to bedrock 1-1.5 meters.
- Stainless steel lid.
- Drain hole for rain.

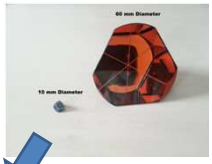
Measuring the invariant reference point (IRP) of VGOS radiotelescope

From Inside the Cabin.



From Outside the Cabin.






Thanks for your attention!!