RF Compatibility tests of DORIS Simulator with VLBI Broadband Antenna at GGAO

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The Space Geodesy Project

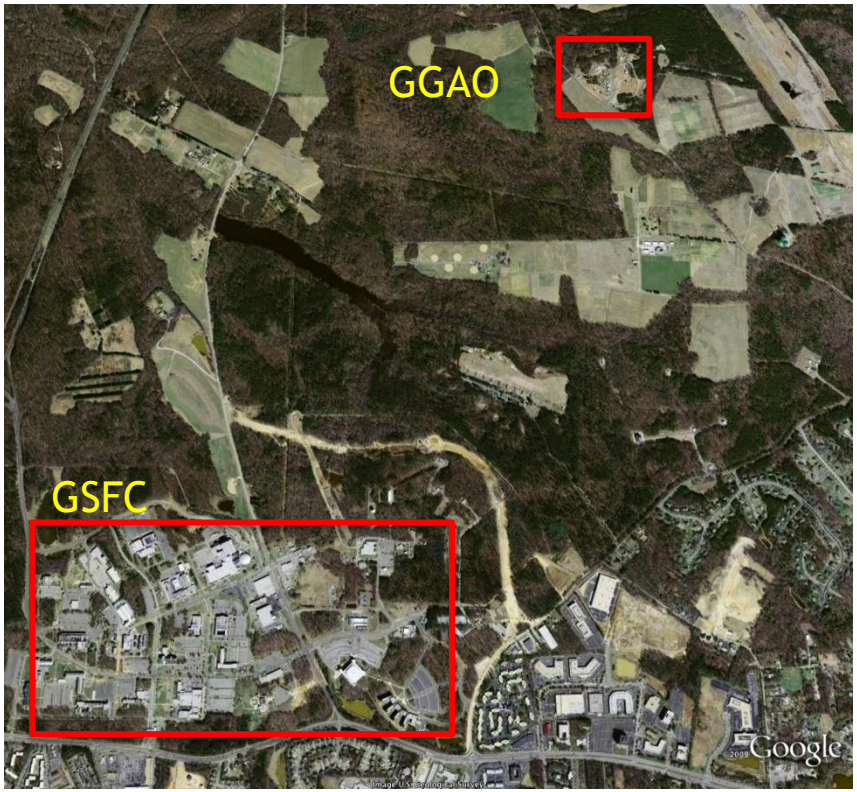
VLBI	NGSLR	GNSS	Vector Tie
			

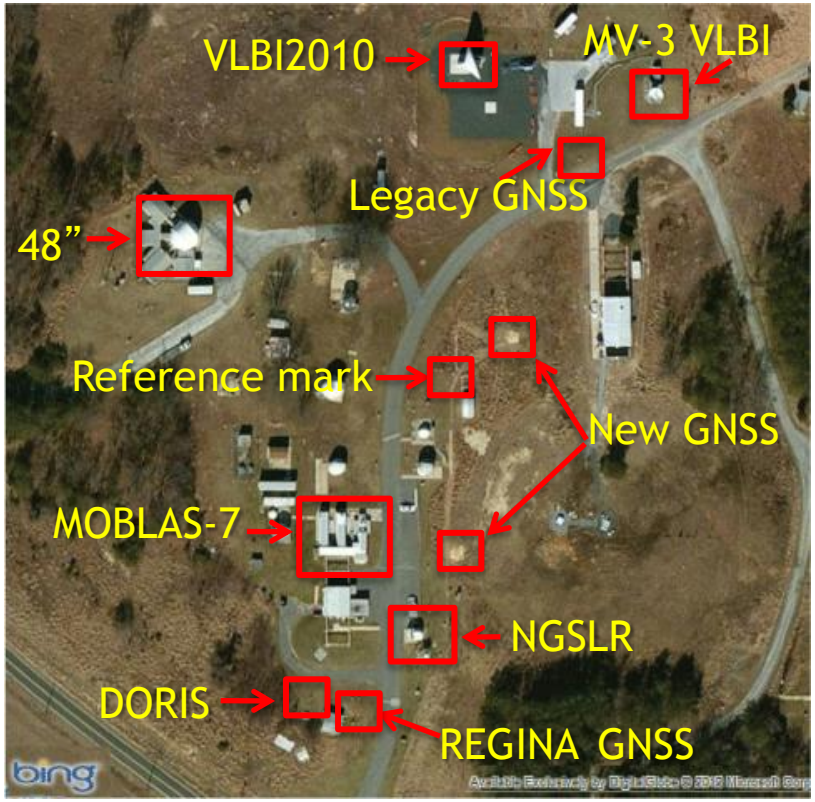
- Establish and operate a prototype next generation space geodetic station with integrated next generation SLR, VLBI, GNSS (and DORIS) systems, along with a system that provides for accurate vector ties between them.
- Develop a Project Implementation Plan for the construction, deployment and operation of a NASA network of similar next generation stations that will become the core of a larger global network of modern space geodetic stations.
- Demonstration by August 2013.

NRC Recommendation: “In the near term, the United States should construct and deploy the next generation of automated high-repetition rate SLR tracking systems at the four current U.S. tracking sites: Haleakala, Hawaii; Monument Peak, California; Fort Davis, Texas; and **Greenbelt, Maryland**. It also should install the next-generation VLBI systems at the four U.S. VLBI sites: **Greenbelt, Maryland**; Fairbanks, Alaska; Kokee Park, Hawaii; and Fort Davis, Texas.”

Prototype Geodetic Station at GGAO

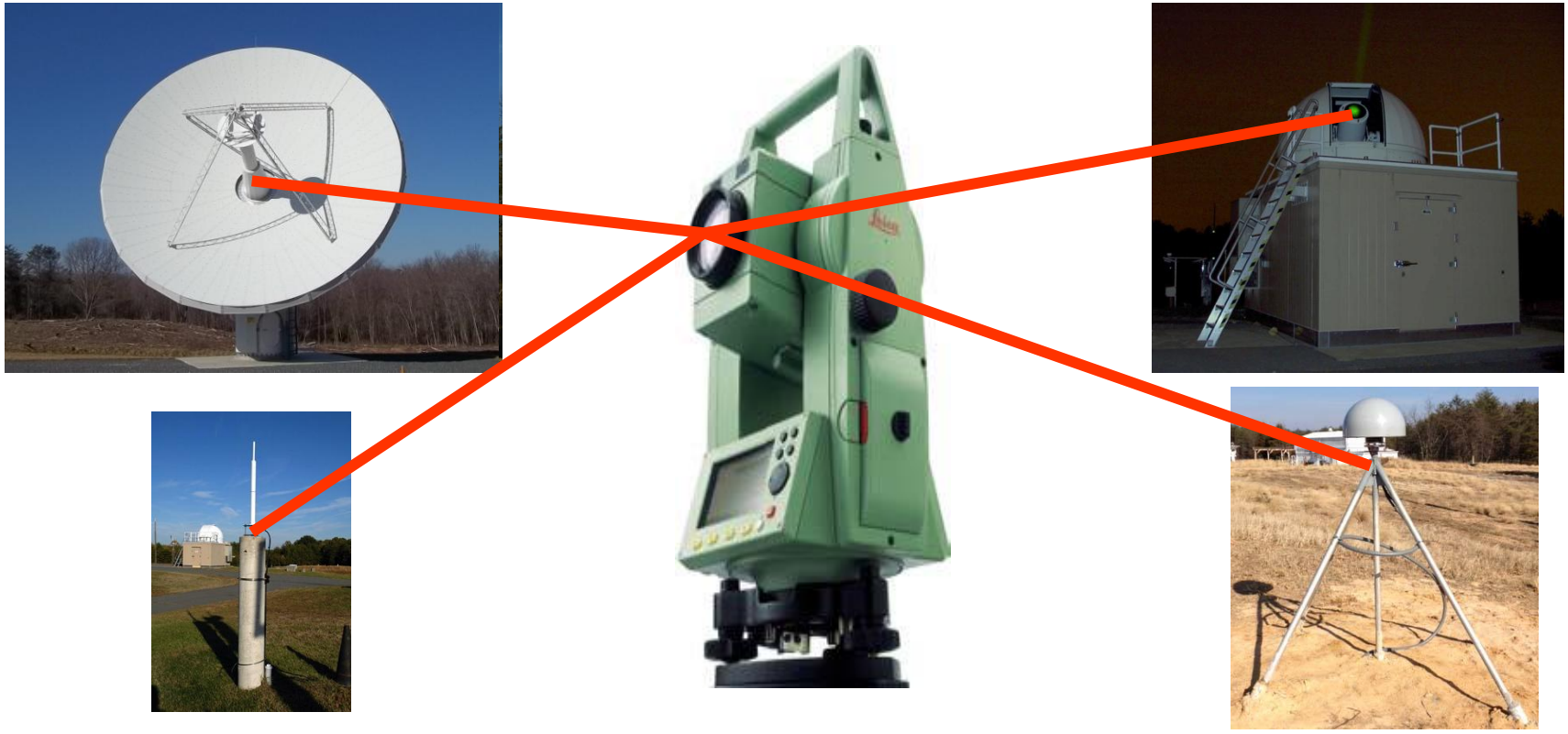
- Goddard Geophysical and Astronomical Observatory (GGAO) is located 5 km from Goddard Space Flight Center in the middle of the Beltsville Agricultural Research Center. GGAO is one of the few sites in the world to have all four geodetic techniques co-located at a single location.





Vector Tie System (VTS)

- Accurate measurement of inter-station vectors is an essential aspect of an integrated space geodesy site.
- Measurements provide closure between terrestrial reference frames derived from different space geodesy techniques.
- Tests of technologies and currently available systems underway at GGAO.

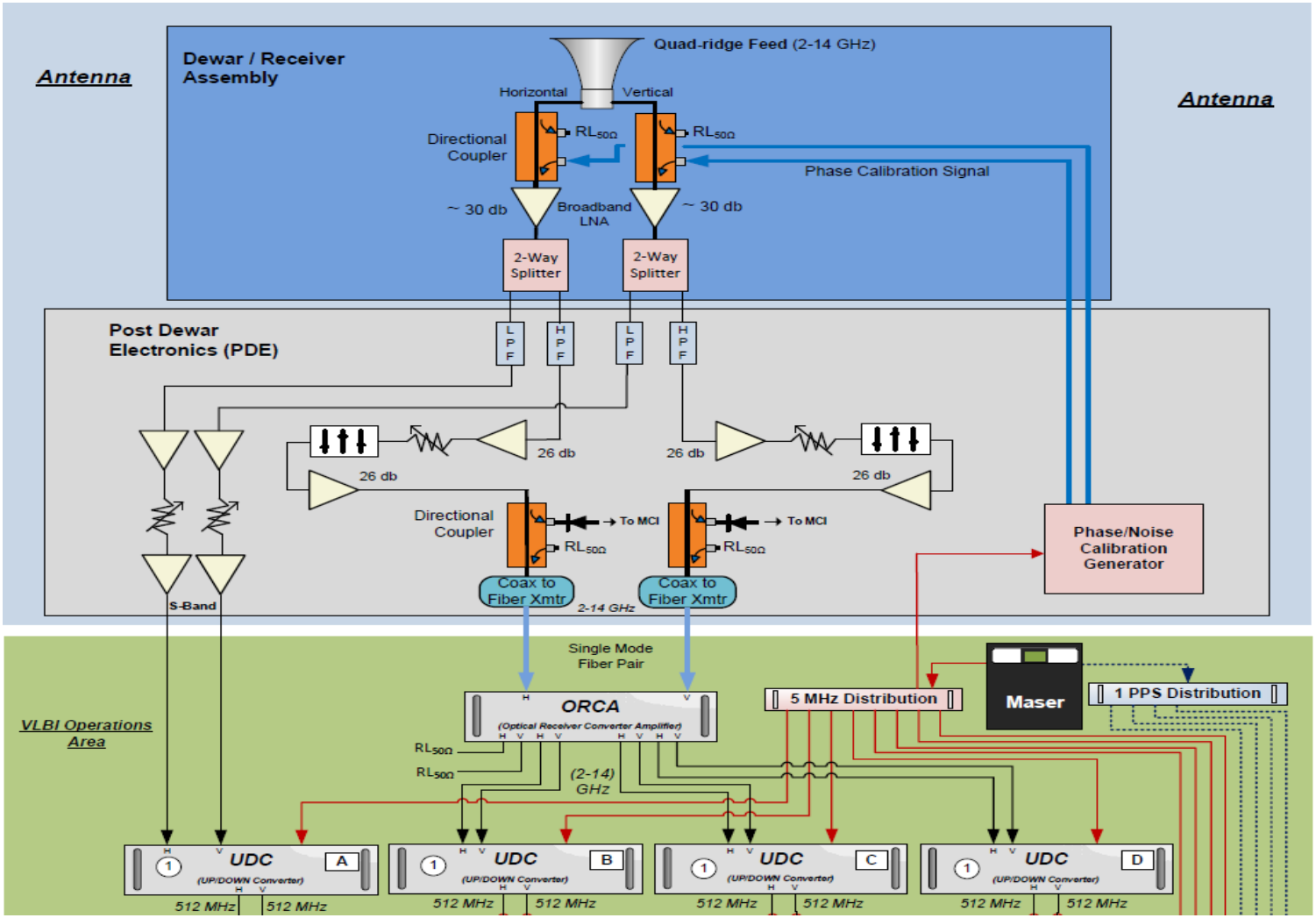


Space Geodesy Project (SGP) and RFI

- Modeling the GGAO environment and VLBI2010 susceptibility before & after the trees came down
- Measuring the DORIS Beacon, and the NGSLR radars in South , radar masks & DORIS path loss provide mitigation
- Measuring 12m side lobes with a standard gain horn simulator ≥100m away
- Mitigate RFI with masks, filtering, and shielding
- Measure the effectiveness of an all-weather blocker to reduce the RFI of a DORIS Test Transmitter placed 136 meters away
- Measure the multi-path effects of the blocker on DORIS
  - Different distances and heights of blocker
  - Different angles of blocker

S-Band Filtering

- S- Band (2-5 GHz) is transferred separately to avoid saturation from RFI in the fiber optic link



RF Compatibility Methodology

Measurement of Transmitter Radiation Properties in 2010-2011

MOBLAS 7 Summary

Location	Expected Power (+/- 2 dB)	Measured Power			
		No Obstruction	Radome	Railings	Radome-Railings
Loc #2	-4.1 dBm	-4.9 dBm	-7.0		-0.7
GODEW	-1.0 dBm	-0.8 dBm	-5.9	8.1	2.4

NGSLR Summary

Location	Expected Power (+/- 2 dB)	Measured Power	
		No Obstruction	Radome
Loc #2	-3.0 dBm	-3.6 dBm	-0.7

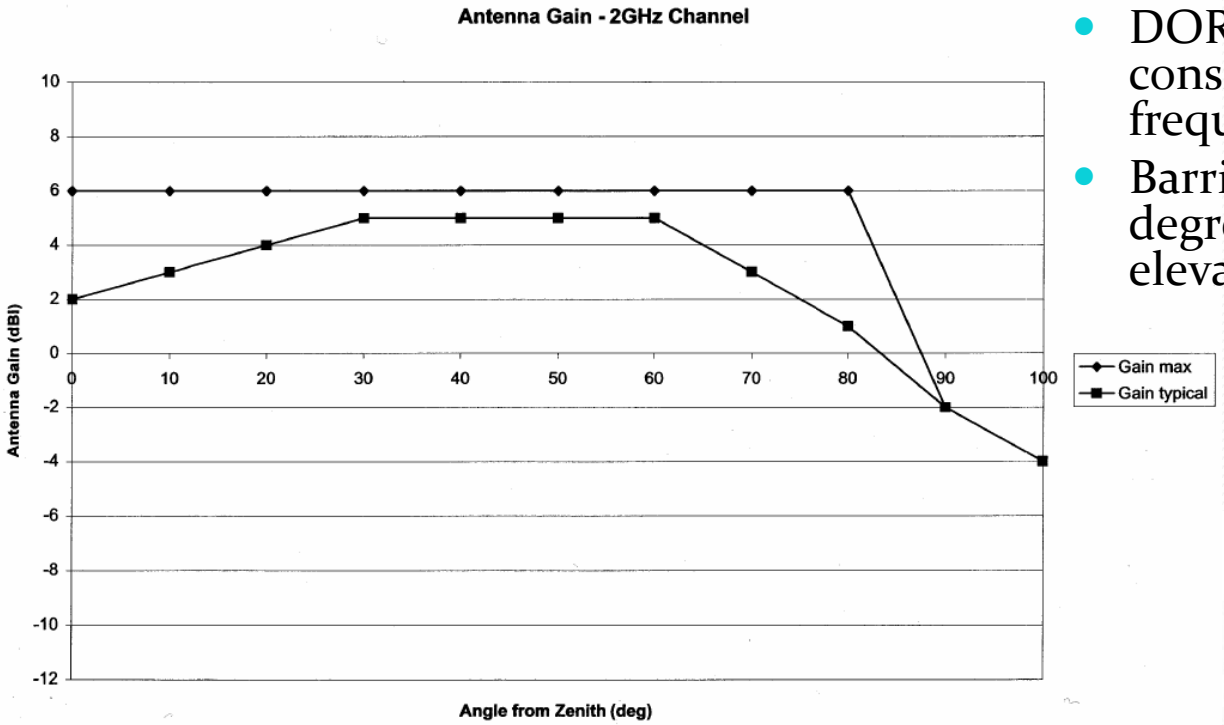
DORIS Summary

Location	Expected Power	Measured Power
DORIS Pad	-1.3 dBm	-1 dBm
Observatory Pad	-29.5 dBm	-27.6 dBm

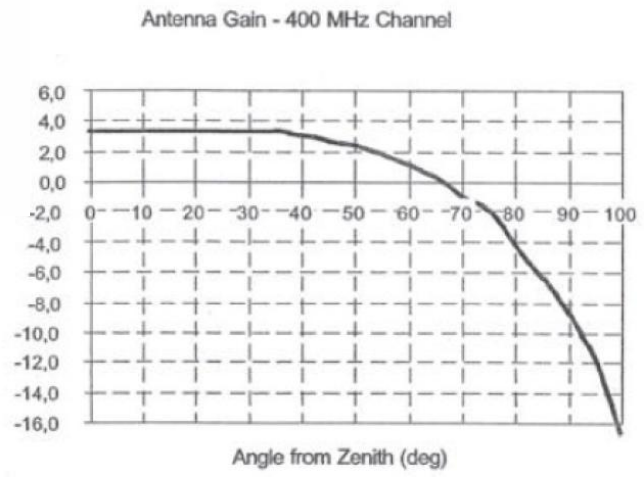
- DORIS and SLR radar power levels were measured using S and X-band standard gain horn antennas
- SLR Radar Power Level Measurement Memo:

http://www.haystack.mit.edu/geo/vlbi_td/BBDev/037.pdf

DORIS beacon characteristics



- DORIS barrier must be considered for two frequencies
- Barriers modeled for 6 degrees in azimuth and elevation



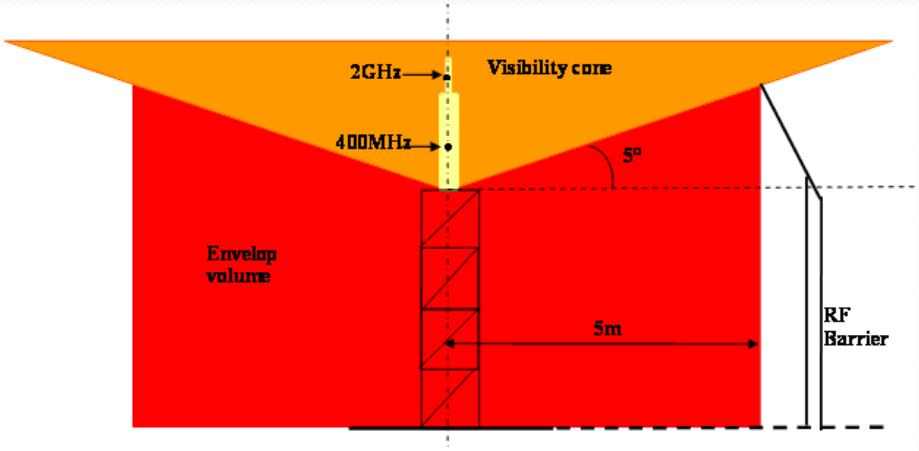
Tradeoffs to RFI Mitigation Techniques

Technique	Current Implementation	Current results/limitations	Next steps
Masking	MOBLAS 7/ 20^0 NGSLR / 30^0 VLBI/ 40^0 and 30^0	May 16th , 2012 geodetic test lost targets due to mask	Masks will be removed when absorber/reflector go up
Filtering	2-5 GHz lowband filter separating high band 4-14 Ghz on optical fiber from lowband on coaxial wire	No limitations due to high band / low band separation. Additional complication in design. DORIS at GGAO will not saturate VLBI.	Combination of high pass filter and isolation w/ tailored dynamic range . Notch at DORIS frequencies a possibility
Shielding	Radars are blocked by GGAO buildings	Radar platform guard rail occupies space. Metal guardrails re-resonate	Deliberate shielding must control back reflection
Absorbing	No absorber currently deployed		Cover guard rails
Shielding/ Absorbing		Further experiments necessary. 35 degree above horizontal experiment – must be all - weather	

Next Steps – RFI Mitigation at GGAO

- When radar and VLBI are past SGP Prototype validation milestones conduct another coordinated blocker test
  - From both positions on two lines of sight
  - With all weather, moderate wind materials used in construction of blocker
- Conduct Blocker effectiveness tests with DORIS
- Full Characterization of on and off-campus RFI at GGAO

DORIS Environment Definition



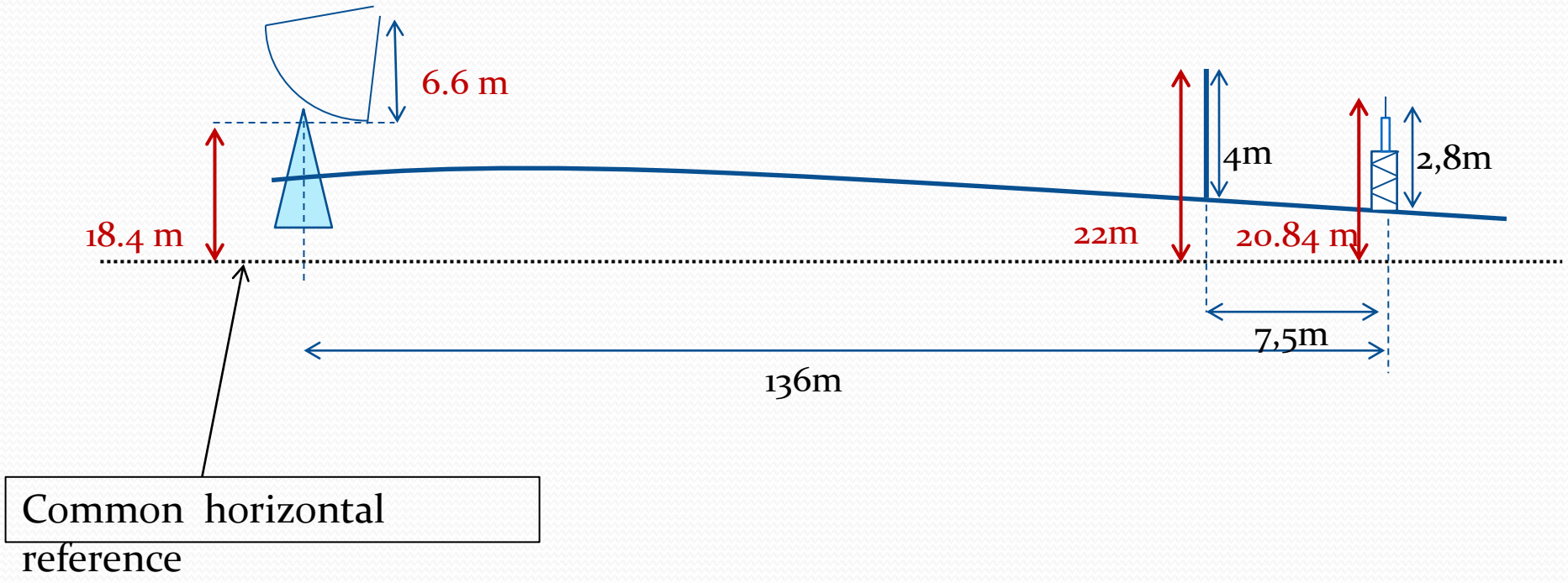
- The requirements are :
  - No metallic object must be located within the envelope volume (except for the DORIS antenna nominal support).
  - Nothing must stand within the visibility cone, apart from the antenna itself.
- This implies :
  - the barrier should be placed at 5m from the antenna and
  - the barrier should raise a height that does not exceed the limit of the visibility cone
  - rem. : a derogation could be made to take a value slightly higher for the visibility cone (between 5 and 8°)

DORIS Test transmitter at GGAO

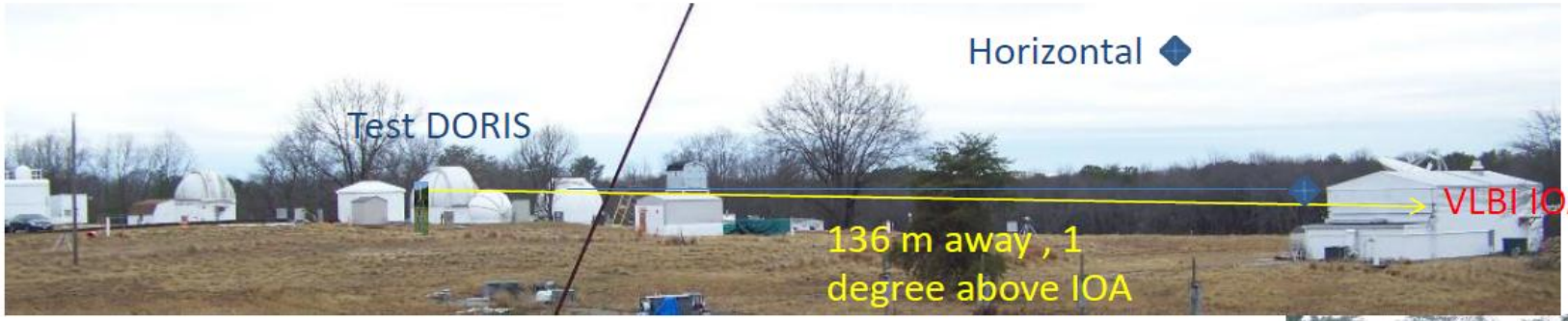
Figure 1: DORIS Beacon setup in GNSS Equipment Building, A temperature controlled room

Figure 2: DORIS Antenna view, The DORIS Beacon Coaxial cables leave the GNSS building on the lower left. The VLBI Line of Sight is on the right.

Profile Geometry of the DORIS-VLBI Test Range



DORIS Test antenna ~ 136 m from Standard Gain Horn at IOA



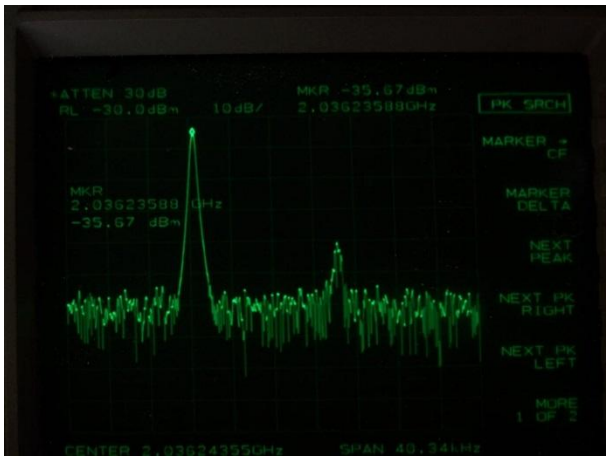
-29.4 dBm
received

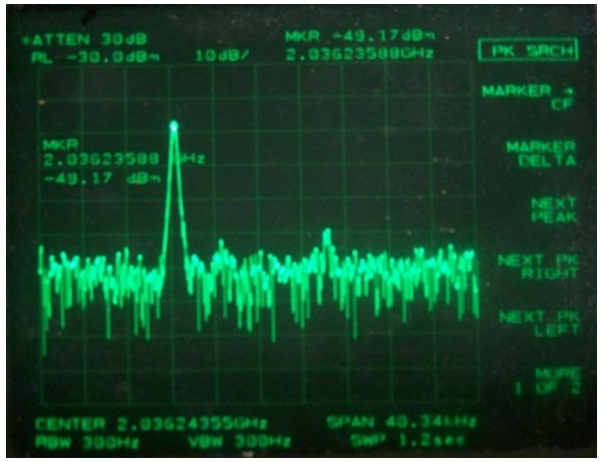
15.1 dB
cable loss

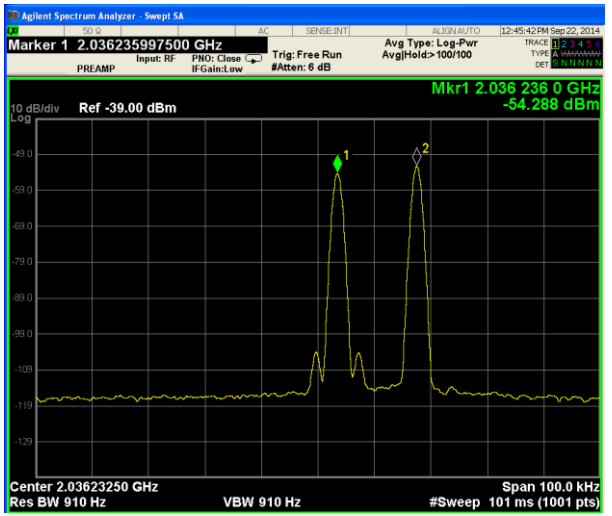
-44.5 dBm
on SA

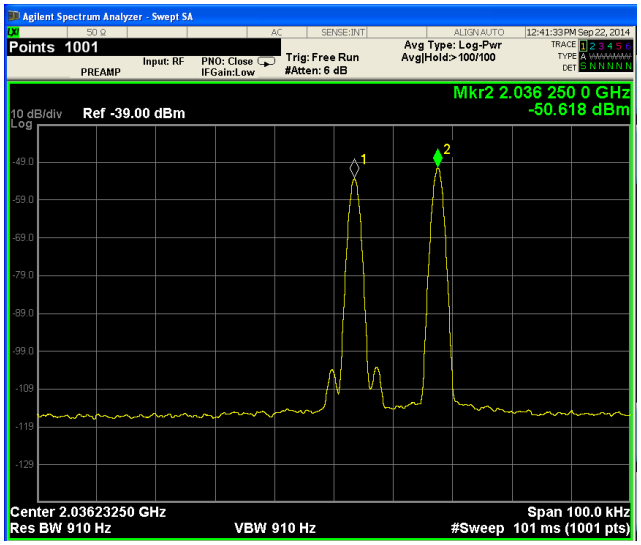
DORIS test as measured at VLBI antenna.

September 5th: With blocker (-49.2 dBm) and without (-35.7 dBm), blocker measured at IOA with Standard Gain Horn . At – 40 dBm is where the VLBI LNAs would saturate.





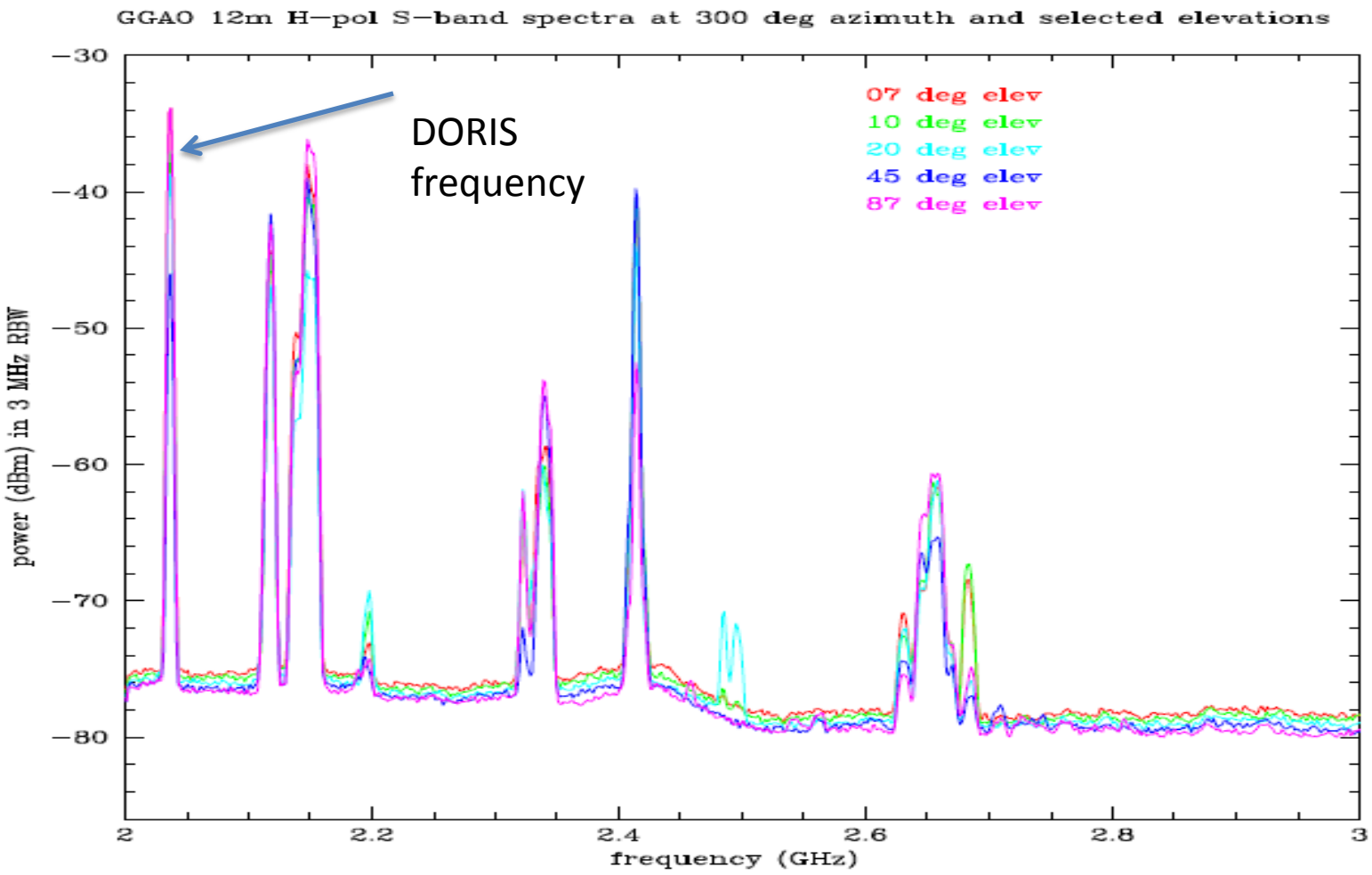




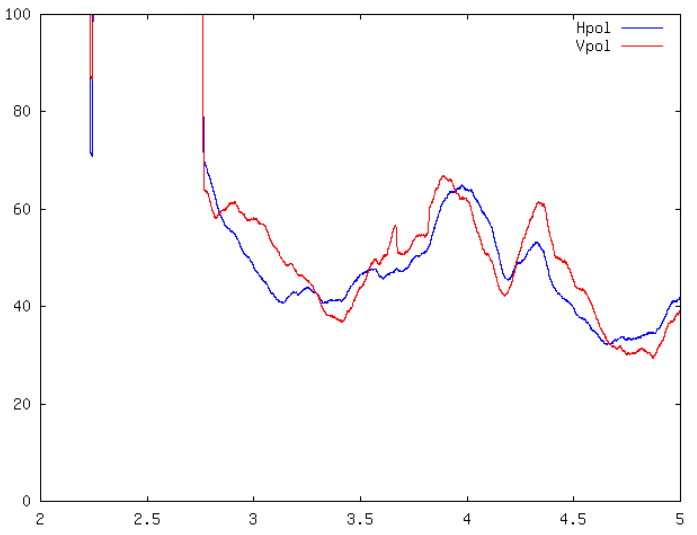
September 22nd : With blocker measured by the 12 meter(Marker 1:Test DORIS=-54.3 dBm, Marker 2: Operational DORIS=-50.6 dBm)

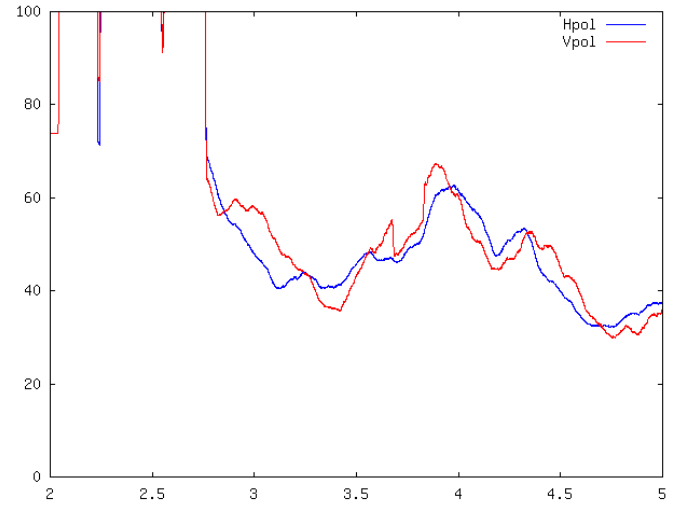
S-Band RFI spectra

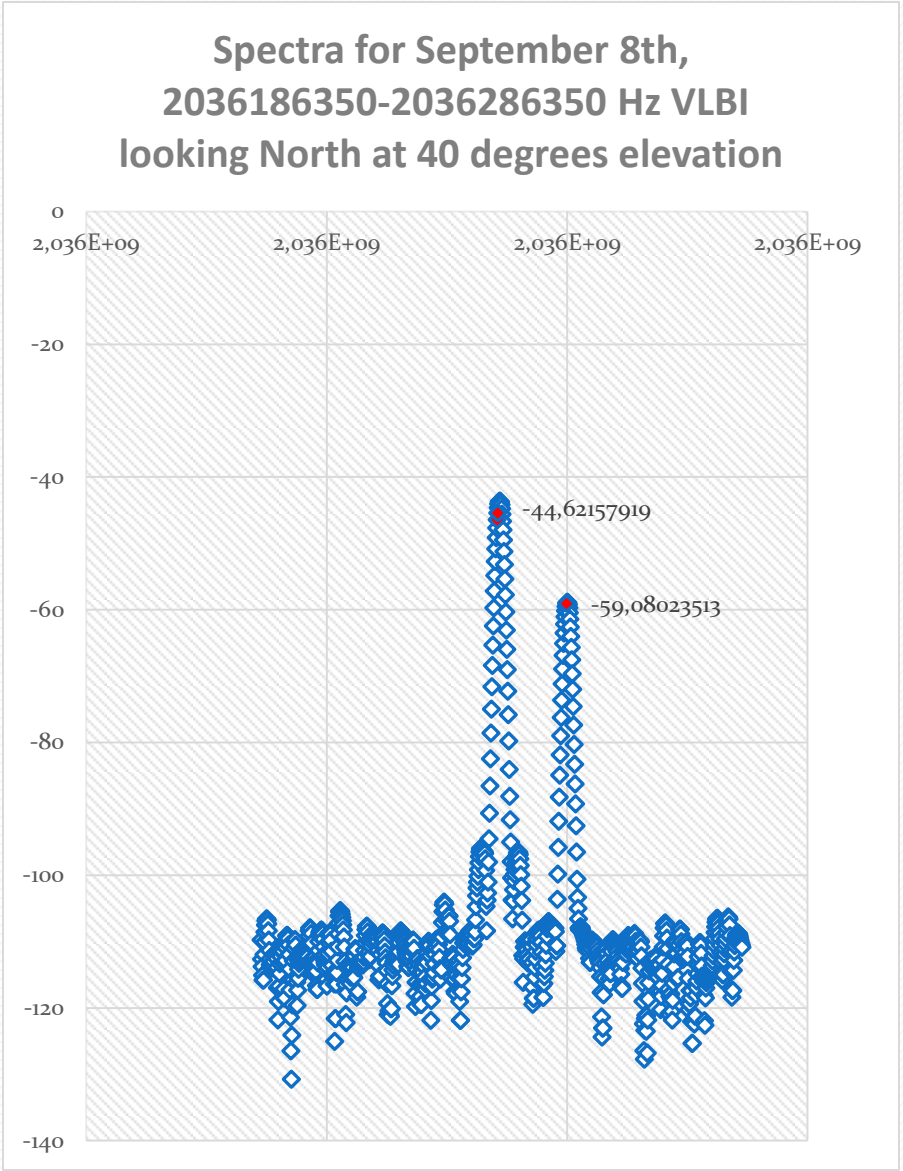
- S- Band RFI as measured at various elevation sweeps and 300 degrees azimuth - Northwest



Comparison of VLBI Tsys with and without DORIS Test transmitting

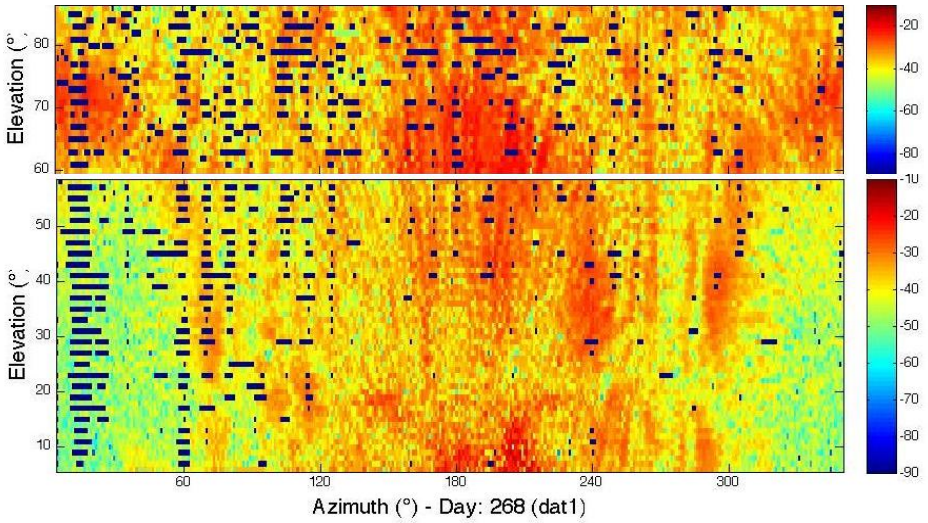






Raising the blocker to 4 meters blocks lines of sight to all positions of the VLBI subreflector

VLBI Sidelobe Tests on 9/25 and 10/8

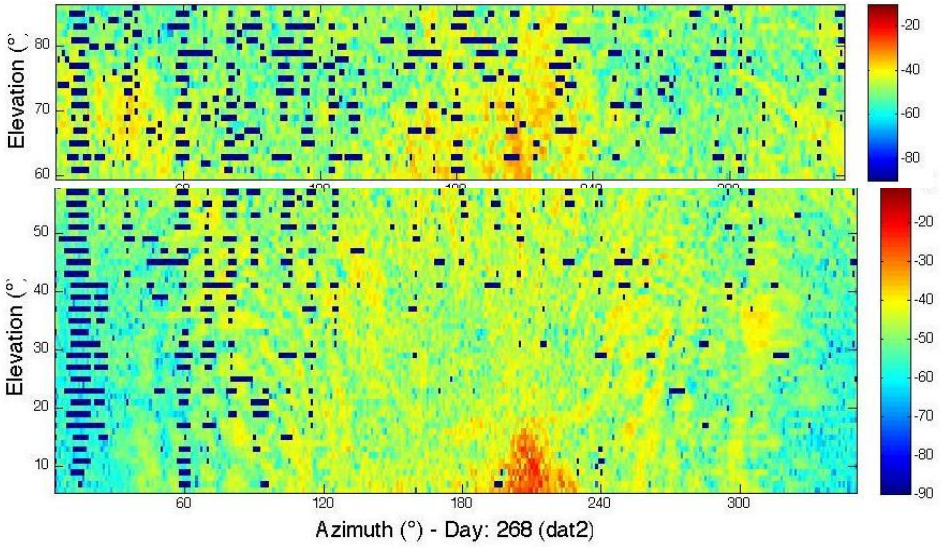


- Tests above 60 degrees elevation were conducted on October 8th
- Tests on September 25th (day 268) were conducted without radars operating

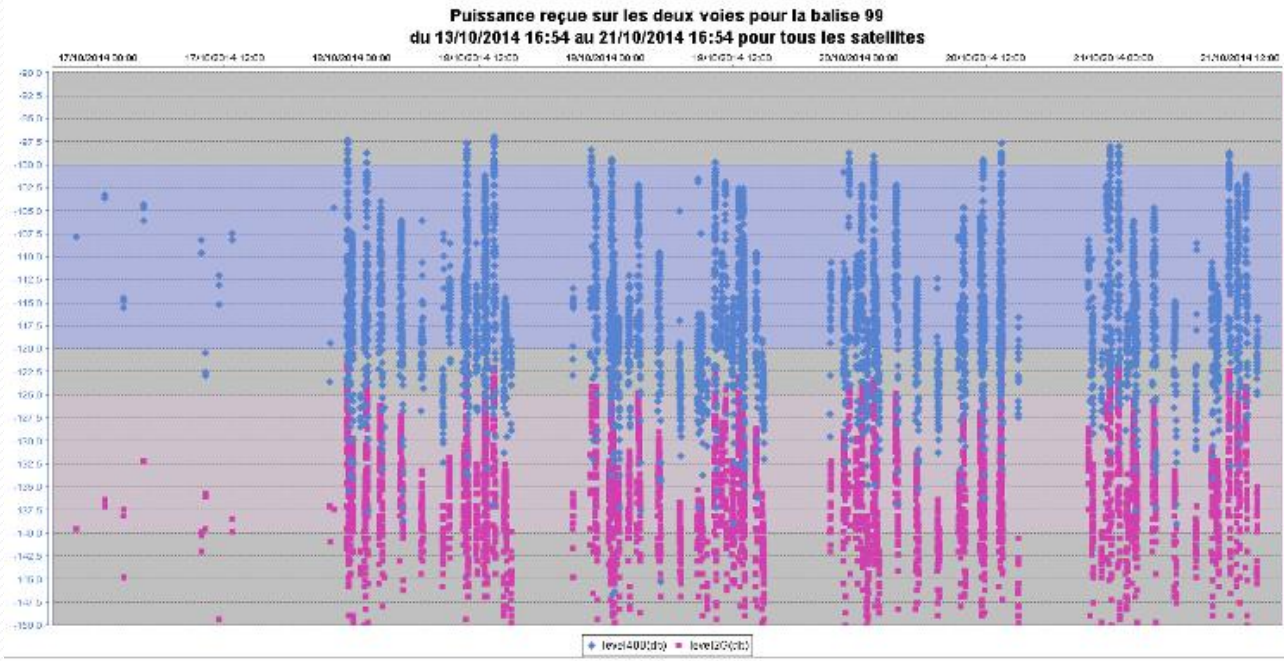
  Includes Azimuth angles that are usually masked out below 40 degrees including DORIS test beacon line of sight

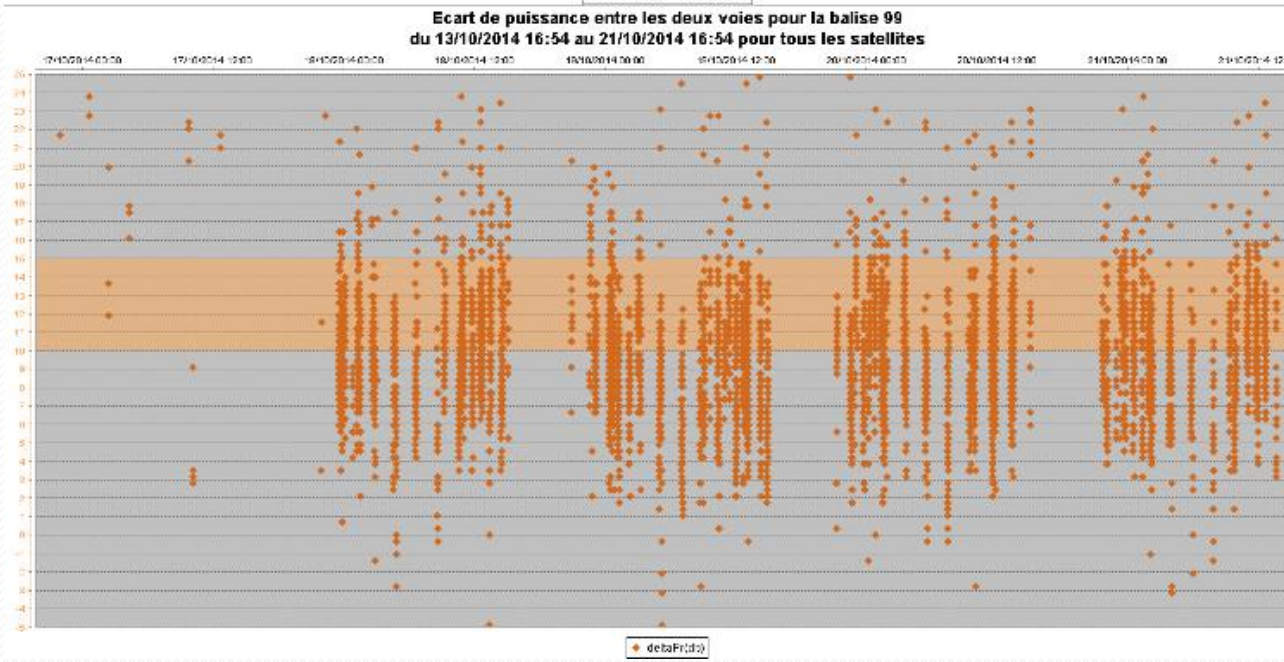
Data Dropouts are due to the spectrum analyzer re-calibrating

October 8th tests were conducted with the mask up and the SLR radars likely raise the noise floor



DORIS test beacon – 10/13- 10/21



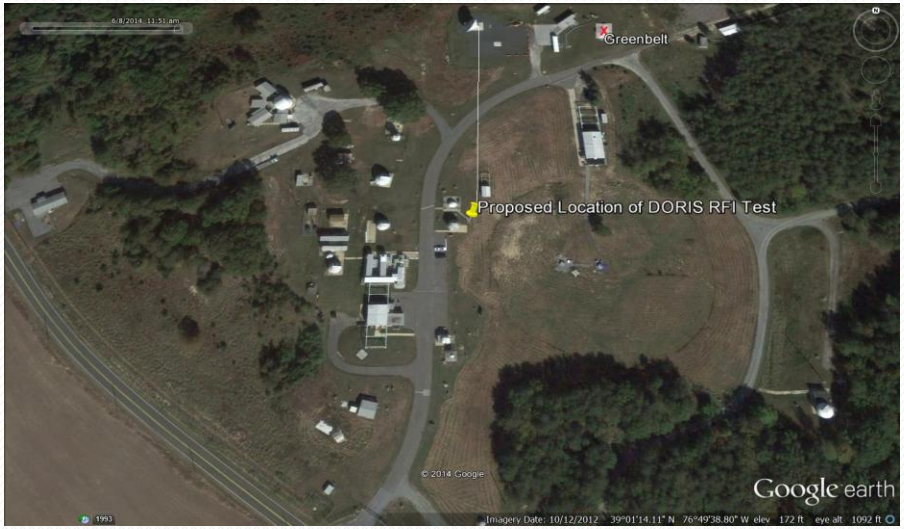


Summary of 2014 DORIS-VLBI Tests

- At 136 meters a DORIS test beacon was placed at GGAO and required RFI mitigation not to saturate the VLBI
- A stainless steel blocker that was 3m wide and 4m high and placed 7 meters away introduced 10-15 dB attenuation. This allowed linear operation of VLBI over the entire hemisphere
- Multipath effects of the stainless steel blocker are still being investigated by the DORIS team
- Thank you to CNES, Haystack Observatory, and NASA GSFC for your efforts on these tests

Backup Charts – 2012-2013 Tests at X-band

DORIS Test antenna location

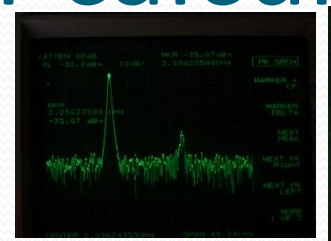


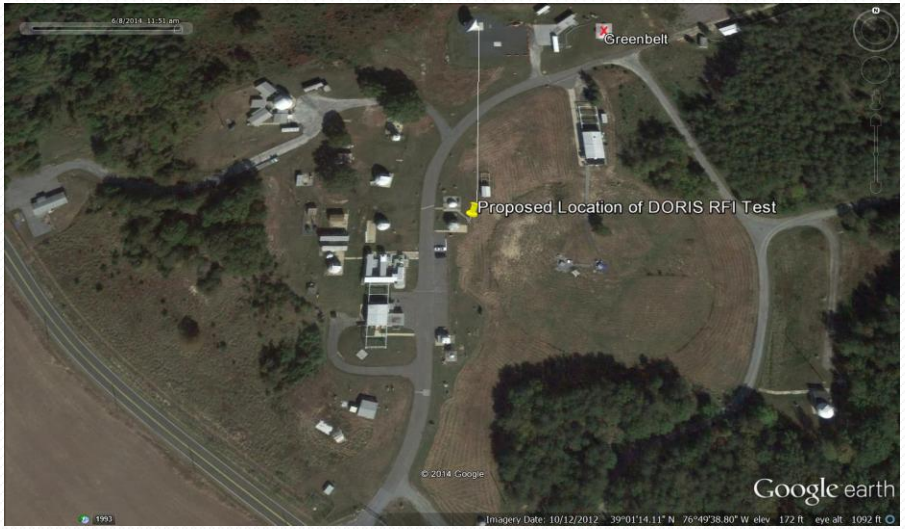
Desc	Latitude	Longitude	Ellip. Ht. (M)
Temp. DORIS Antenna	39° 01' 14.86116"	076° 49' 38.50753"	20.84
Feed Horn (@ VLBI 2010 antenna)	39° 01' 19.28129"	076° 49' 38.29029"	18.37

Point to Point Inverse Using Ellipsoidal Heights. Added Azmiuth & Elevation Angles

From	To	AZ	EL	Ellipsoidal Distance (M)
Feed Horn (@ VLBI 2010 antenna)	Temp. DORIS Antenna	182° 11' 44.1506"	1° 2' 12.32"	136.41
Feed Horn (@ VLBI 2010 antenna)	NGSLR Radar	183° 36' 19.8639"	1°28'36.12"	202.77
Feed Horn (@ VLBI 2010 antenna)	MOB 7 Radar	194° 57' 31.6373"	2°07'25.64"	160.53

DORIS Test Standard Gain Horn-calculations





					Rcv antenna			Rcv at Spectrum Anal
freq	T/R pol	Tx power	range	Tx gain	gain	path loss	cable loss IOA to SA	
GHz		dBm	m	dBi	dBi	dB	dB	
2.036	C/C	39.8	136.40	3.0	15.5	81.31	15.10	-41.1
2036236.0 KHz assign marker 1	C/H	36.8	136.40	3.0	15.5	81.31	15.10	-44.1
DORIS-op at 2036250 KHz, from azimuth 193° 21' 05.2064" assign Marker 2		36.8	222.80	3.0	12.5	85.58	15.10	-51.4
2.036	C/H	36.8	136.40				15.10	-44.5
2.036	C/H	36.8	136.40					-56.7
2.036		36.8	222.80					-77
2.036	C/H	36.8	136.40					-44.56
2.036		36.8	222.80					-57.6
2.036		36.8	222.80					-77

12 Meter X-band and C-Band side lobe characterization at GGAO

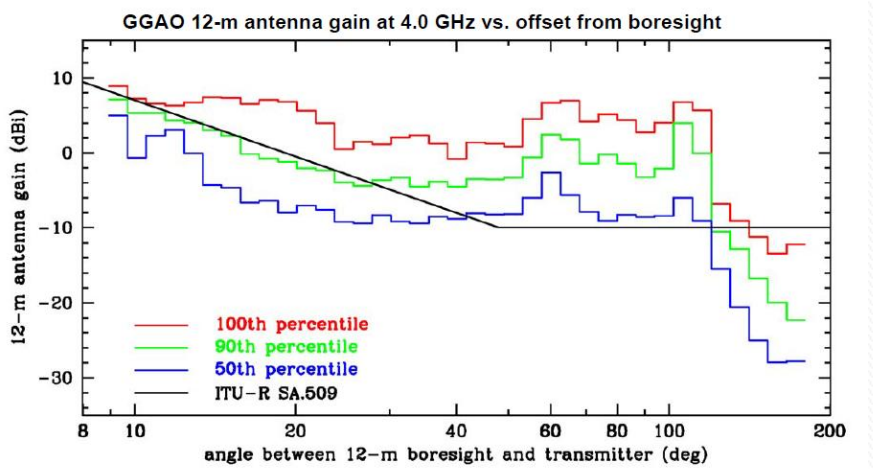
antenna gain vs. angle between 12-m boresight and transmitter. The data have been binned by angle into 40 bins equispaced in log(angle). The 4 "curves" are

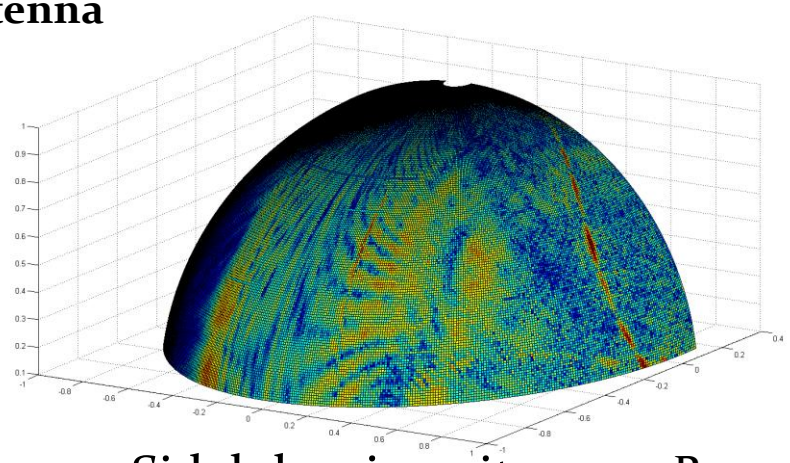
red 100th percentile in each bin (i.e., max gain)

green 90th percentile

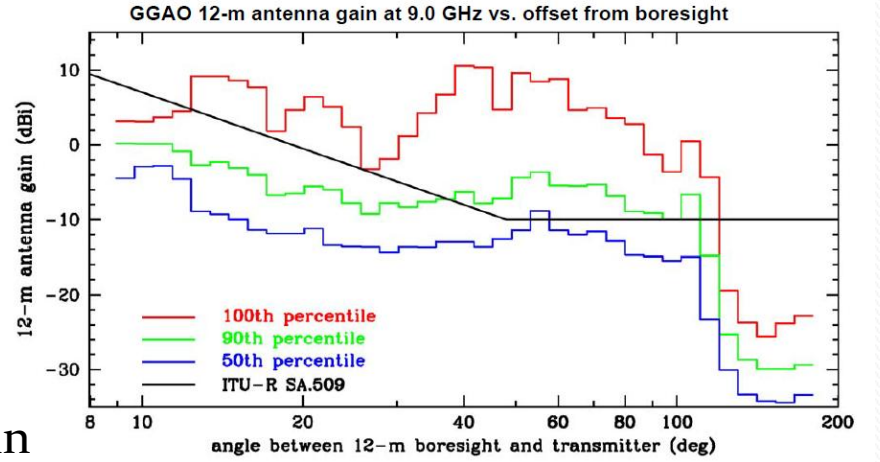
blue 50th percentile (i.e., median gain)

black ITU-R SA.509 standard for the 90th percentile of the far-field gain of a large antenna



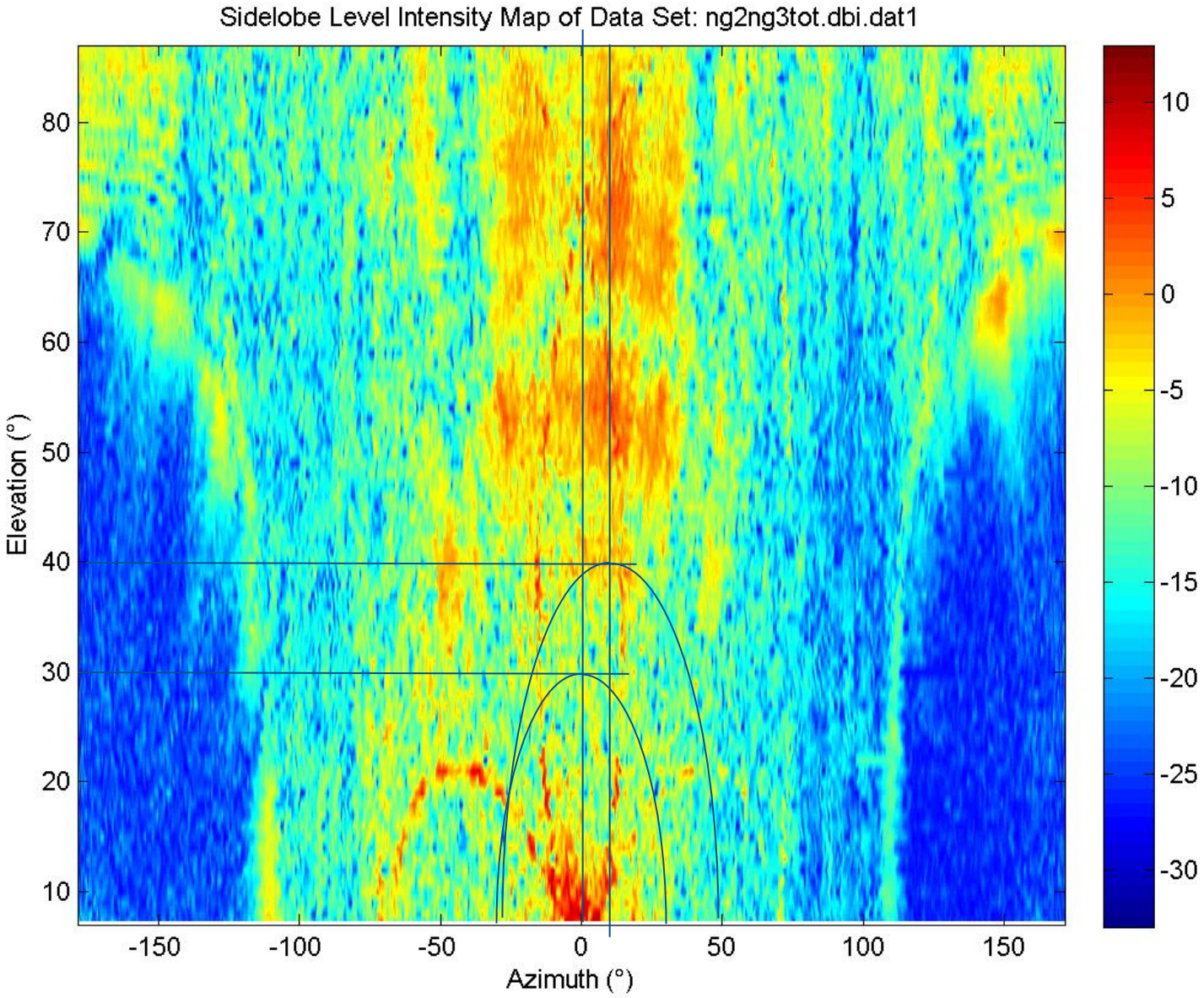


12 m Sidelobe views it peripherally in the North



Beacon in the East

Sidelobe Measurement of 12 meter antenna - with beacon deployed near NGSLR LHRS phase center



Comparison to ANSI sidelobe envelope

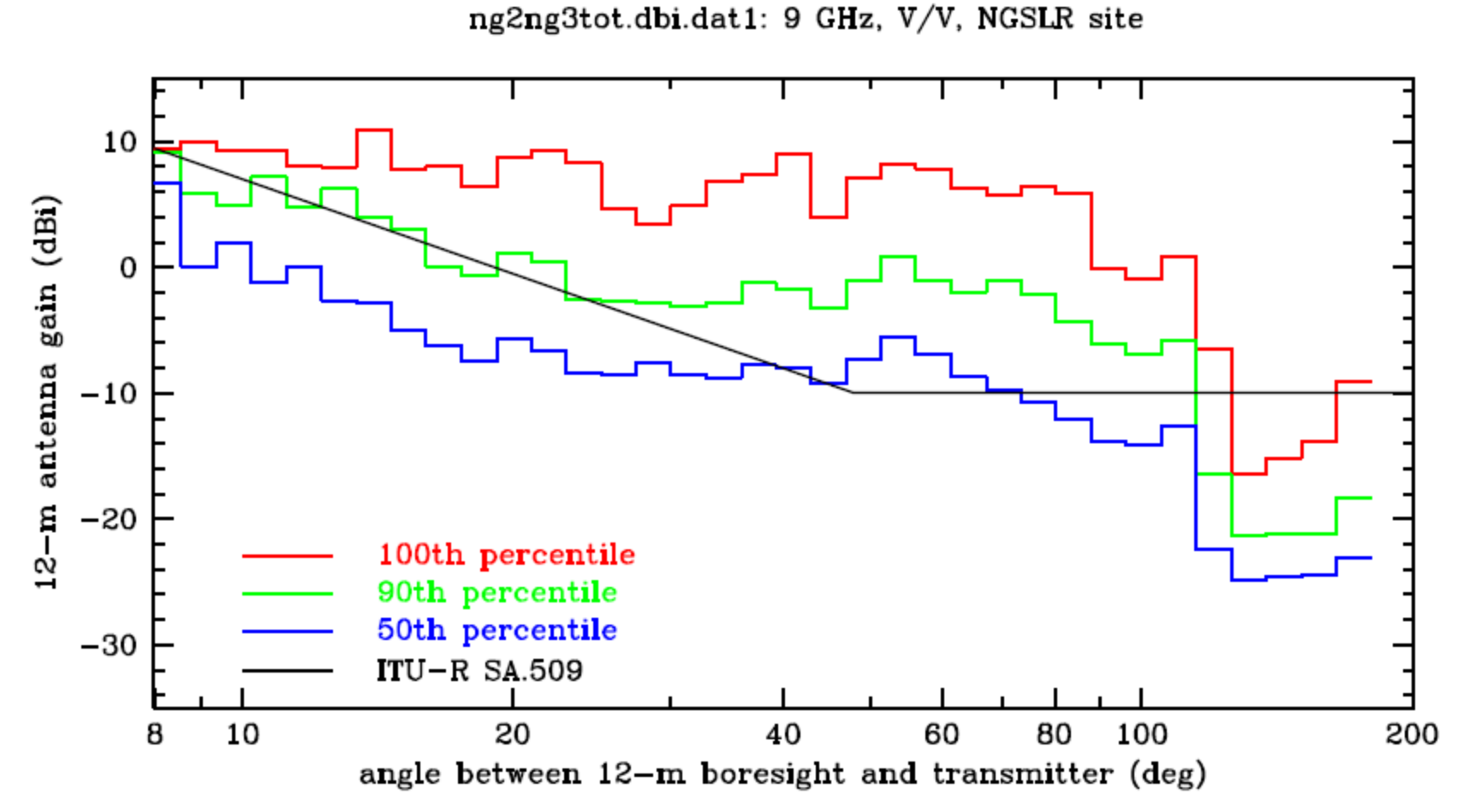
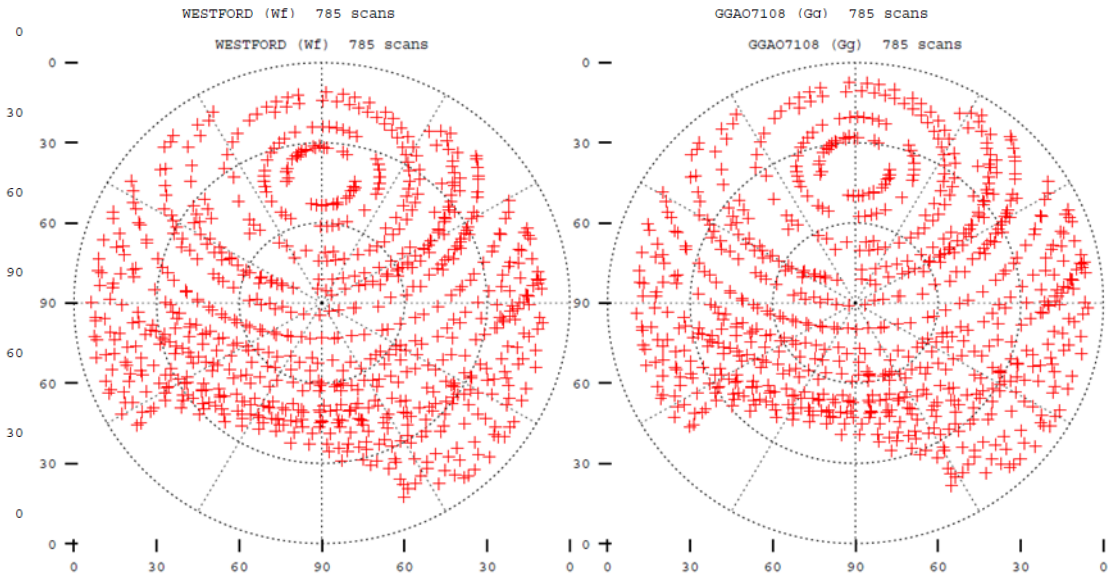
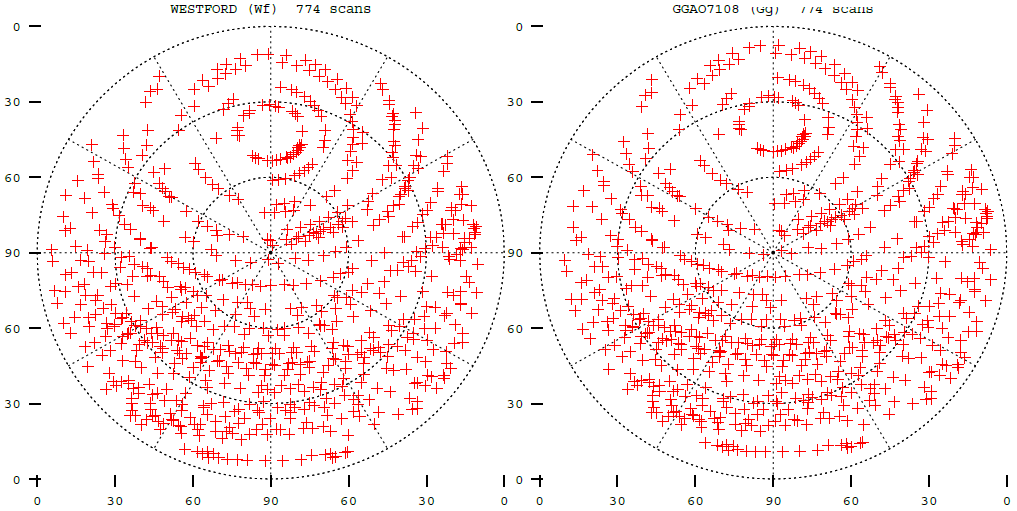


Figure 1: ITU-5009 antenna sidelobe envelope model incorporated in numerical RFI-compatibility studies.

Loss of the Southern sky must be planned around due to radar masks at GGAO

- Oct 4th →
- These observing plans were specially prepared with knowledge of VLBI mask avoidance



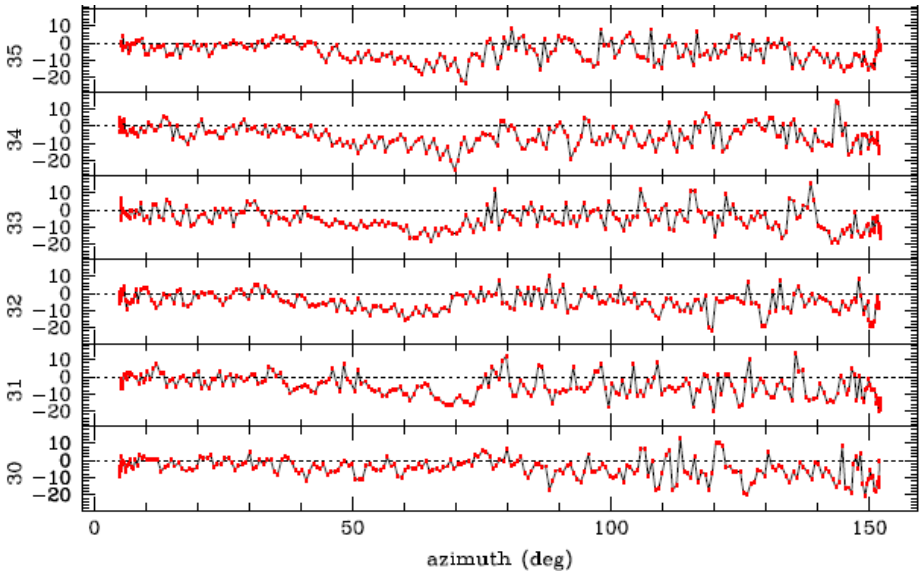


- Oct 5th
- ← These observing plans were opened up to the full sky through coordination with NG SLR and MOB7

Profile and Link Budget for Far Field RFI Mitigation between NG SLR LHRS radar and VLBI

dataset	nail	freq GHz	T/R pol	Tx power dBm	range ft	range m	Tx gain dBi	electronic SGH Rcv ant gain dB	path loss dB	dBi-dBm adjust. dB	250 m Fiber loss dB	20 ft coax loss dB	Recvd power dBm	VNA Noise floor
NG SLR range		9.410	ZX60-14012L-S+	10.0		200.00	35.0	22.0	97.93	30.93	35.00	10.00	-75.9	-80.00

Results of subreflector blocker on NG SLR and MOB7 line of sight to VLBI



- April 17th , 2013 Test
  - 10’ x 15’ Blocker in NG SLR line of sight
  - Standard Gain Horn from ground was surrogate for radar

- April 26th, 2013 Test
  - 10’ x 15’ Blocker in MOB7 line of sight
  - Standard Gain Horn from ground was surrogate for radar