



**International VLBI Service for Geodesy and Astrometry** IVS is an international collaboration of organizations which operate or support

Very Long Baseline Interferometry (VLB I) components.



•Radio Frequency Interference (RFI) Mitigation at Goddard Geophysical and Astronomical Observatory (GGAO) has been addressed in three different ways by NASA's Space Geodesy Project (SGP); masks, blockers, and filters. All of these techniques will be employed at the GGAO, to mitigate the RFI consequences to the Very Long Baseline Interferometer. •The SGP combines the four geodetic techniques of Global Navigation Satellite System (GNSS), DORIS (Doppler Orbitography and Radiopositioning Integrated from Space), Space Geodesy Satellite Laser Ranging (SGSLR), and the VLBI Global Observing System (VGOS).

### **Problem Statement**

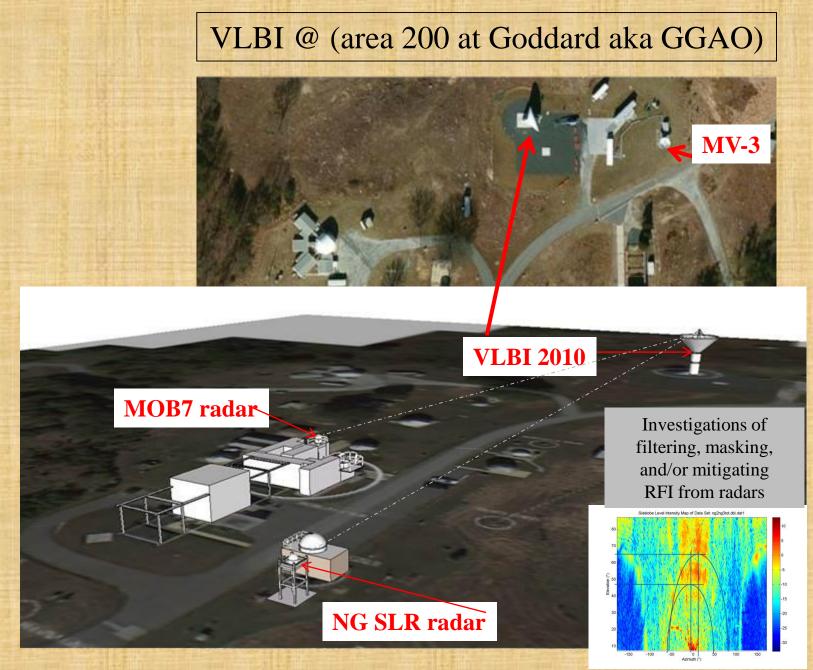
•The problem at GGAO, and at the 4-technique geodetic stations of the future being deployed by SGP, is that both DORIS and SGSLR require emissions that are found in the VGOS broadband. For DORIS, path loss and blockage on the GGAO campus reduce the effect of RFI to that of raising the noise floor to a tolerable level. For SGSLR, we have had to introduce low-elevation restrictions or "masks" to both the Laser Hazard Reduction System (LHRS) radars and the VLBI antenna. The VLBI can be damaged by the 4kW peak power output LHRS radar, so the main lobe (-57.1 dBW at VLBI phase center) must be avoided which will destroy the receiver, and the 1st sidelobe saturates the optical link in the receiver chain in effect blinding VLBI from high band (5-14 GHz). In VLBI, low band (2-5 GHz) does not use the same optical link because the low band RFI (e.g. DORIS, wifi, ..) would saturate as well, but can be carried back via coaxial cable.

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#### Characterizing the 12m Antenna at GGAO

•In October 2012, at GGAO we conducted two different VLBI tests defining the reduced sky coverage impact of using masks to restrict the viewing angle of both the SGSLR and the VLBI on the GGAO campus. We also ran tests earlier in 2012, characterizing the VLBI antenna beam pattern with 9.41 GHz (sidelobe surrogate(ss)) beacons transmitting from locations near the directional antenna locations used by LHRS. With these tests we recognized hot spots associated with the VLBI subreflector looking right at the LHRS ss beacon.



# Comparison to ANSI sidelobe envelope ng2ng3tot.dbi.dat1: 9 GHz, V/V, NGSLR site S0th percentile S0th percentile IFU-R SA 509 20 40 60 60 100 angle between 12-m boresight and transmitter (deg) Figure 1: ITU-5009 antenna sidelobe envelope model incorporated in merical RFI-compatibility studies.

envelope presented in Figure 1, is assumed to provide a worst-case 2m antenna gain vs. pointing-to-RFI-source. This assumption should be alidated experimentally to provide assurance of the 12m antennas gain (combined with other information) will provide confidence in the received DORIS/radar power levels will not exceed the worstcase expectation

#### Planned Experimentation

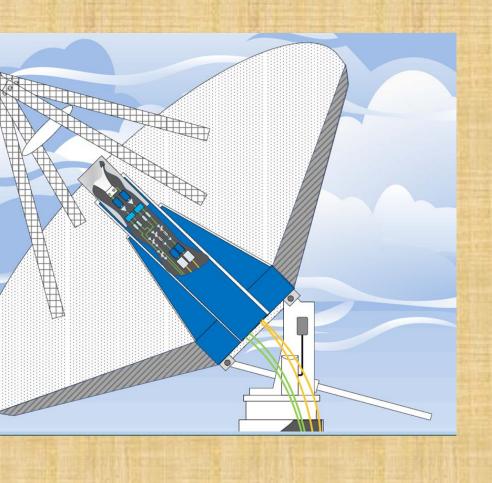
To validate the sidelobe model, a separate field test of the 12m sidelobe envelope is planned. The field test will be carried out with a mobile beacon that is capable of transmitting at the DORIS and aircraft tracking radar frequencies, 2.036 and 9.4 GHz respectively.

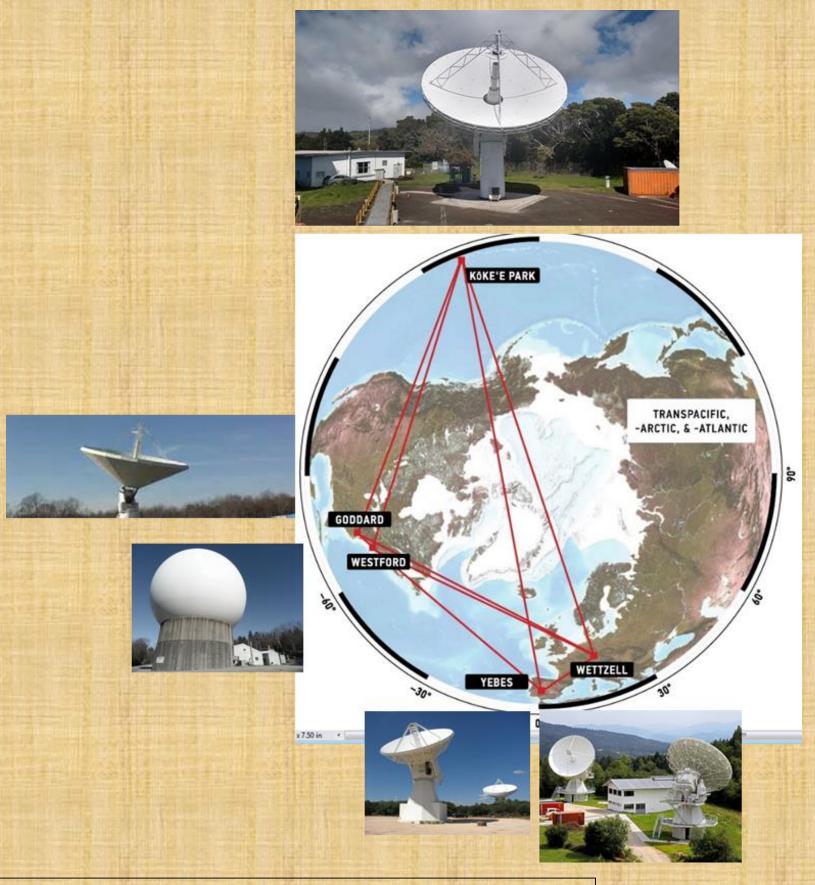
# RFI Mitigation and Testing Employed at GGAO for NASA's Space Geodesy Project (SGP)'

**VGOS** Future: Five different stations participated in the recent VGOS test performed in May 2017

INTERNATIONAL GNSS SERVICE

•Background: The VGOS version of VLBI has recently been modernized to collect a 2-14 GHz broadband spectrum in accordance with VLBI2010: Current and Future Requirements for Geodetic VLBI Systems . One of the objectives of that 2005 report was to "Reduce Susceptibility to External Interfaces" and "continuous frequency coverage ... to 14 GHz, but the channels and frequencies actually used would be selected as those that are most free from RFI at all sites".



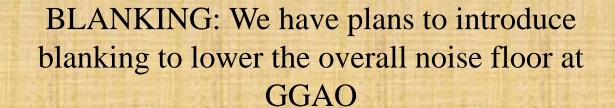


### BLOCKING: Effective for DORIS, but hard to use in wind

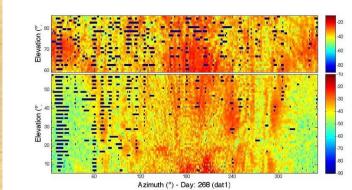
•Reflective Blockers were investigated as well using solid cloth, and stainless steel mesh materials in 2012 and had the effect of 20 dB attenuation when located in the far field between SGSLR and VLBI. In 2014, a test DORIS was loaned to SGP by CNES to conduct similar tests on the blocking effectiveness realized from an unobstructed DORIS (direct line of sight) with less path loss and tuned to a slightly different frequency discernable by DORIS receivers in orbit above GGAO.

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



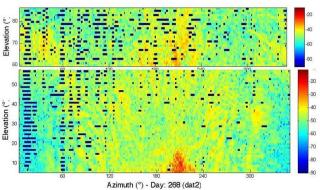


# VLBI Sidelobe Tests on 9/25 and 10/8



Data Dropouts are due to the spectrum analyze re-calibrating October 8<sup>th</sup> tests were conducted with the mask up and the SLR radars likely raise the noise floor

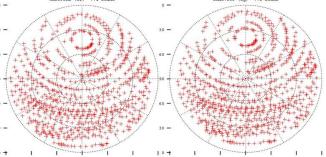
- Tests above 60 degrees elevation were conducted on October 8th ests on September 25<sup>th</sup> (day 268) were
- conducted without radars operating ncludes Azimuth angles that are usually
- masked out below 40 degrees including DORIS test beacon line of sight



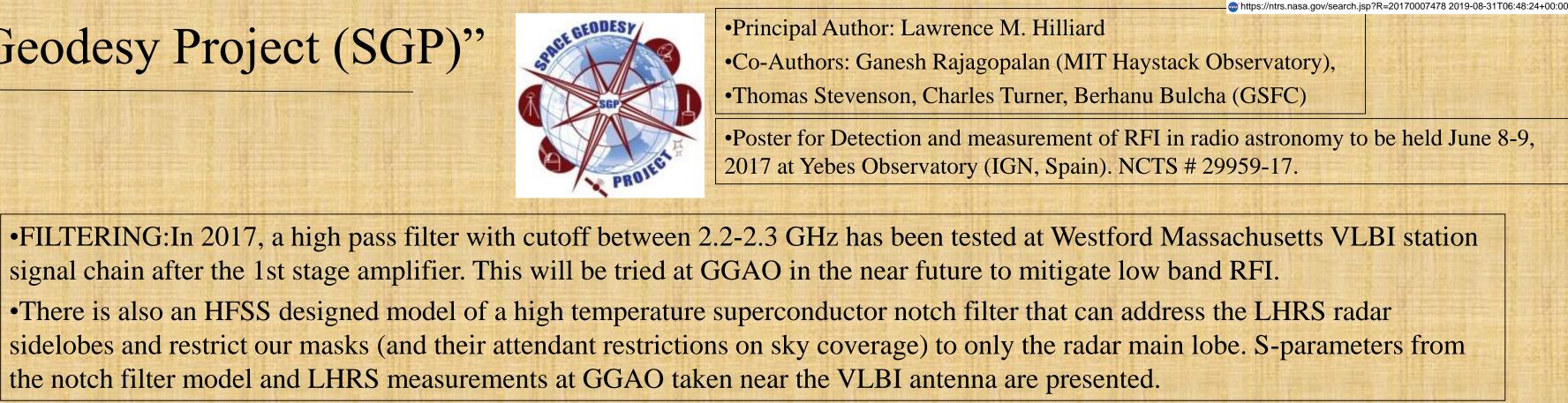
# MASKING: Impact on VLBI and SLR

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

- Oct  $4^{\text{th}} \rightarrow$
- These observing plans were specially prepared with knowledge of VLBI mask avoidance

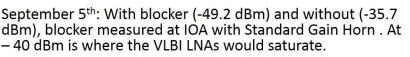


For more information on geodetic VLBI please go to: http://space-geodesy.nasa.gov http://ivscc.gsfc.nasa.gov/

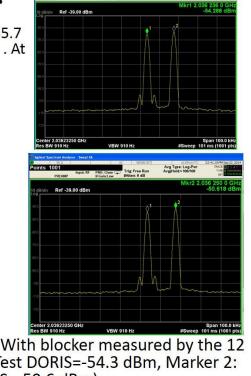


## DORIS test as measured at VLBI

antenna.

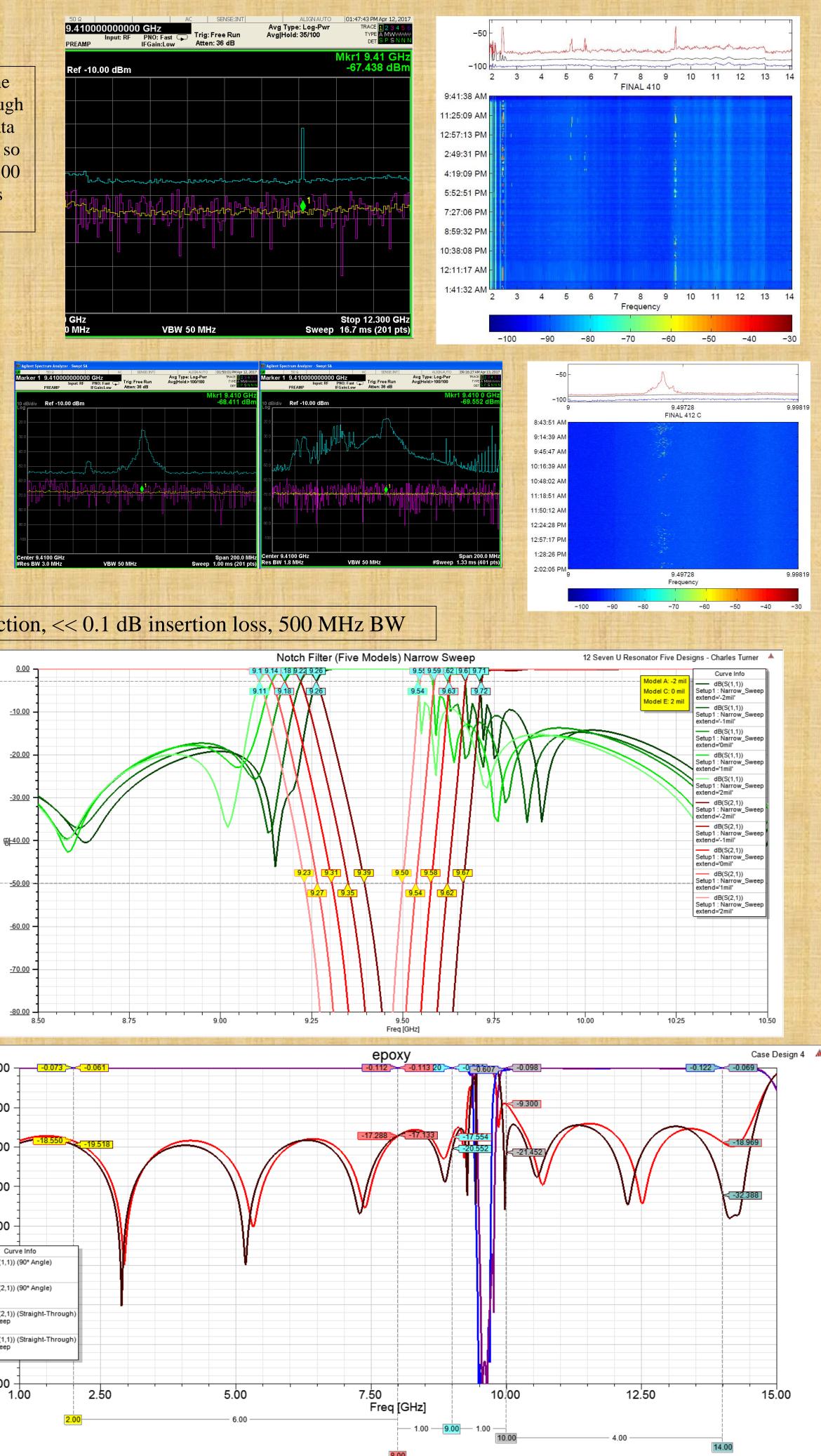


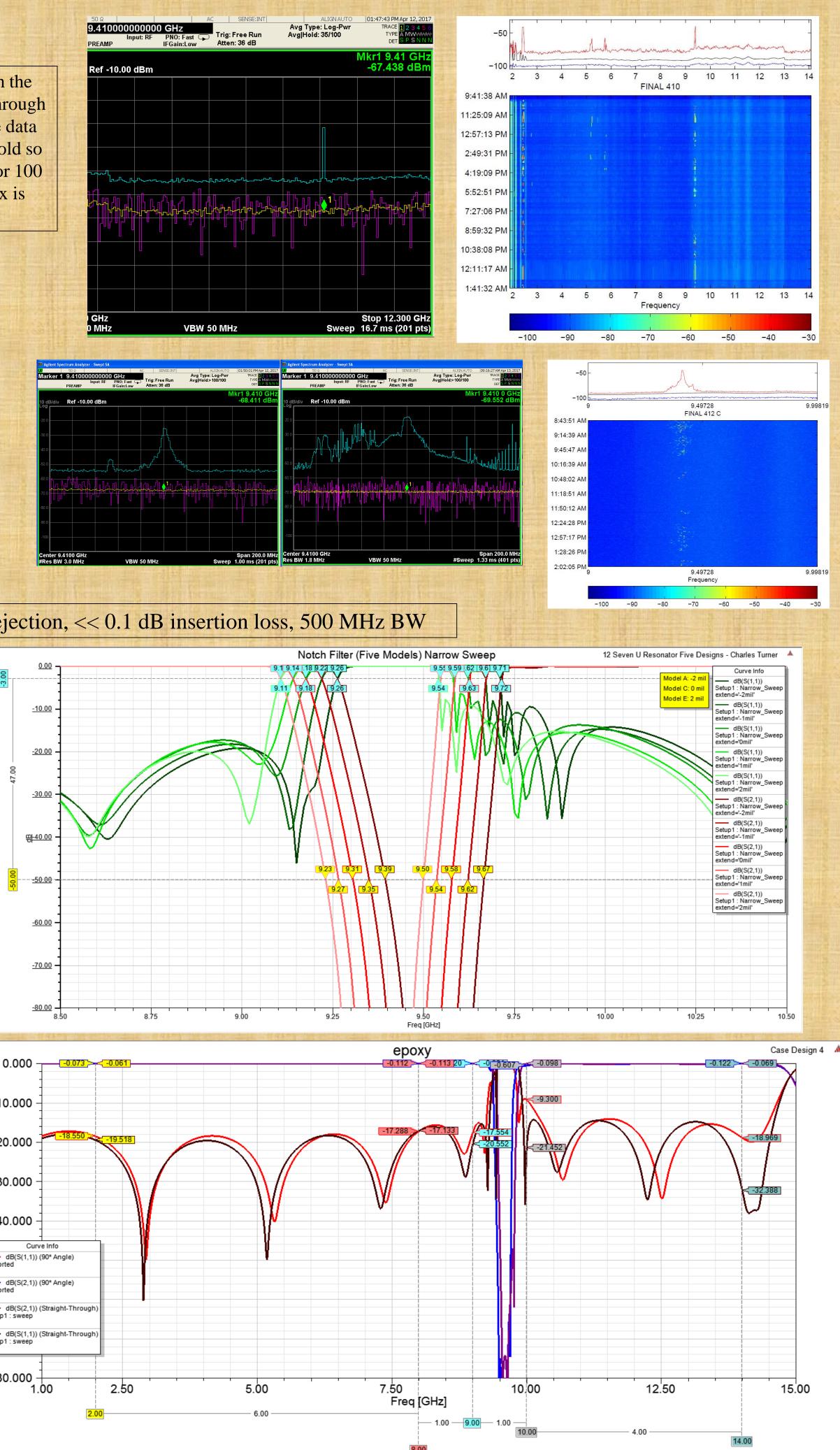


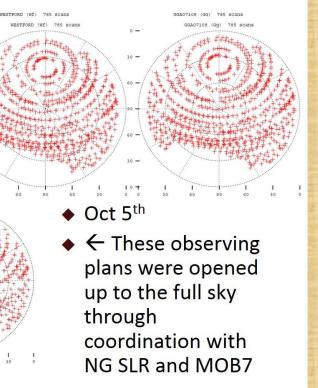


September 22<sup>nd</sup> : With blocker measured by the 1 meter(Marker 1:Test DORIS=-54.3 dBm, Marker 2 Operational DORIS=-50.6 dBm)

•These are measurements of the radar through the 12m antenna at GGAO(black screens), and through the RFI monitor system that takes cumulative data (blue plots). These plots were taken in max hold so a large radar pulse detection would register for 100 sweeps and then the file closes and a new max is found.





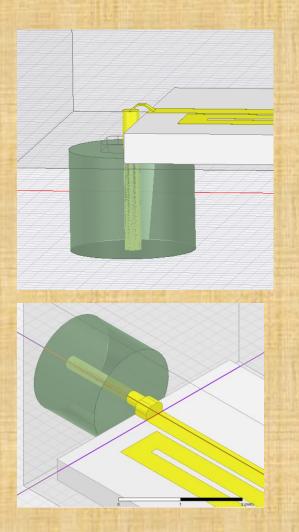


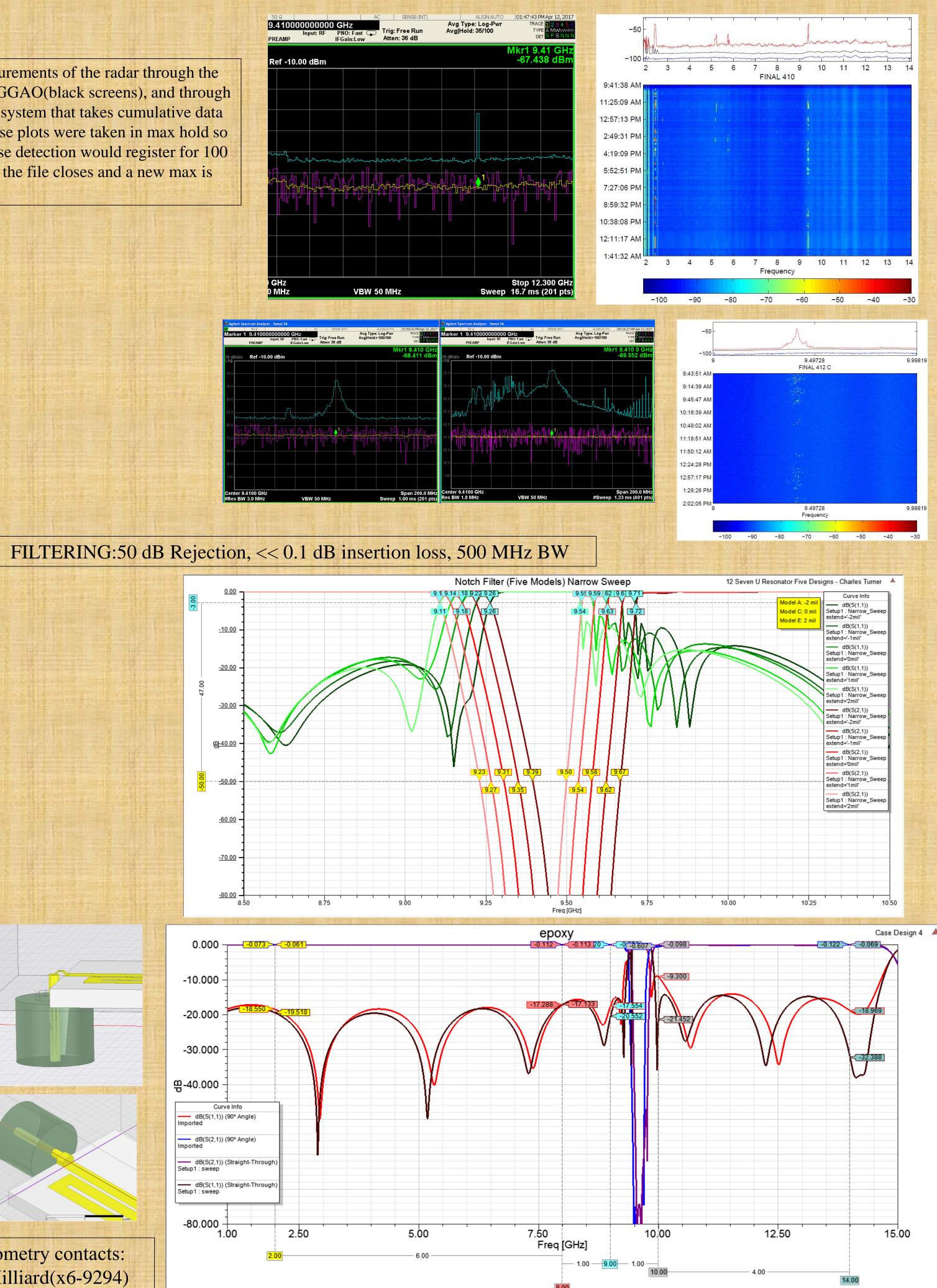
•5 different designs were requested of the foundry.

•We hedged this because of uncertainty in the material properties and tolerances could cause us to miss the notch we wanted.

•The model was given further detail after the foundry run was started to see the effect of connectors

•The simulation shows that reflection is less if we use a straight connector versus a 90 degree bend





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