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Radio frequency compatibility of VLBI, SLR, and DORIS at GGOS stations

Christopher Beaudoin, MIT Haystack Observatory, cbeaudoin@haystack.mit.edu
Brian E. Corey, MIT Haystack Observatory, bcorey@haystack.mit.edu
Bill Petrachenko, Natural Resources Canada, bill.petrachenko@nrc-cnrc.gc.ca

1. Introduction

Electromagnetic compatibility between the instruments in an integrated GGOS ground station presents challenges, particularly for geodetic VLBI. The next-generation VLBI2010 sensor will observe over the frequency range 2-14 GHz. Two GGOS transmitters radiate in this frequency range:

- DORIS beacon at 2 GHz
- X-band (~9 GHz) aircraft surveillance radar in support of SLR

RFI can degrade VLBI sensitivity both at the frequency of the RFI and at all other frequencies, through intermodulation and harmonic products generated by the nonlinear response of electronics at high signal levels.

We present the results of signal simulation studies of the impact on VLBI2010 sensitivity of narrowband signals like DORIS and SLR radar. We also discuss possible strategies to mitigate the effects. Depending on the design of their antenna feeds, current S/X VLBI systems may also be susceptible to degraded sensitivity, particularly from the radar, but we do not investigate those systems here.

2. VLBI Signal Simulation

The VLBI2010 system is modeled conceptually as shown in figure 1. The nonlinearity in this system is modeled as a third-order polynomial in voltage, with parameters derived from the first and second-order intercept points of the LNA. The SLR radar and DORIS RFI induce a station-to-station correlation loss in the geodetic VLBI delay observable. Figure 2 outlines the simulation process used to assess the impact of RFI on the geodetic VLBI correlator output.

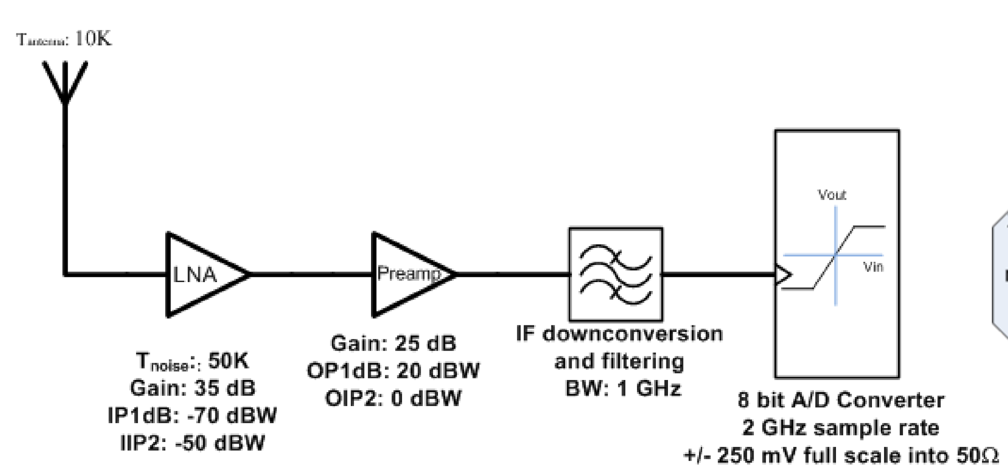

Figure 1. VLBI receiver chain model

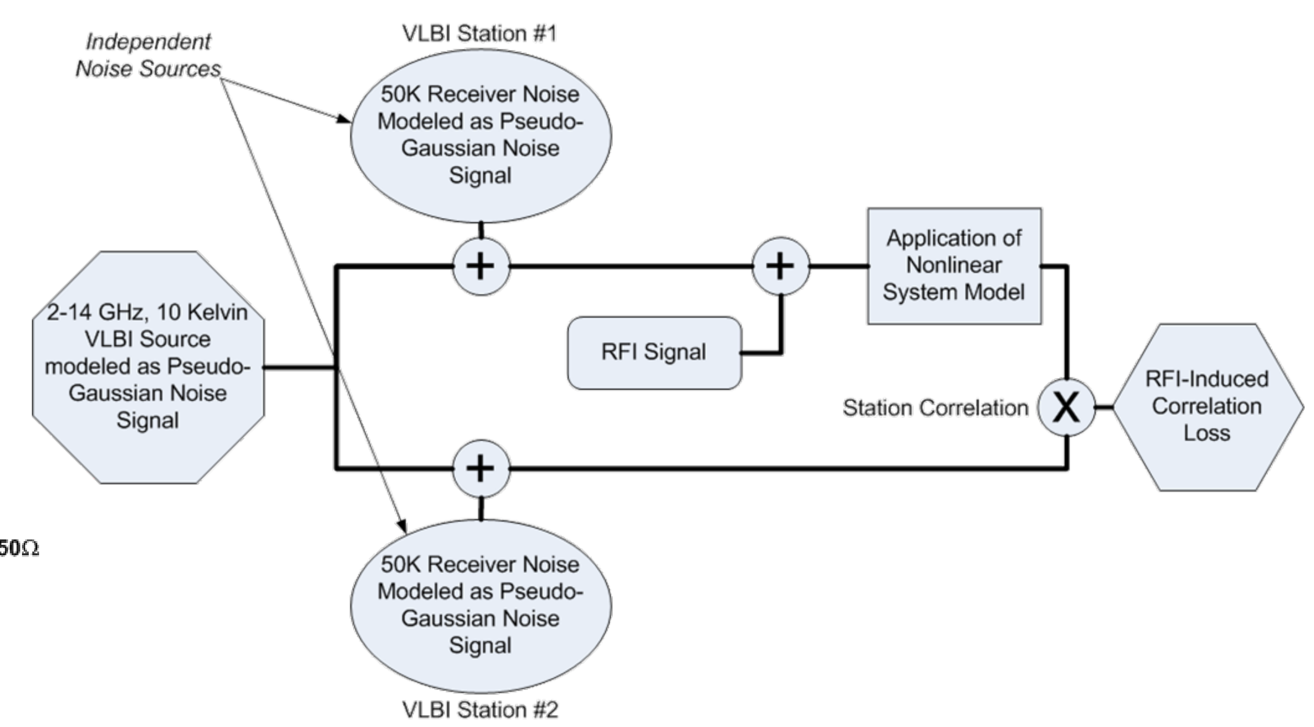

Figure 2. Block diagram outlining VLBI signal simulation used to assess station correlation loss

3. DORIS, SLR radar, and VLBI antenna characteristics

Table 1 lists the primary characteristics of the DORIS and SLR radar transmitters assumed here. The radar parameters are those of the Raytheon R20XX radar system at GGAO. The areal power density of the signal from the DORIS beacon at GGAO has been measured and agrees well with the value calculated from the table. For the antenna gain of the VLBI and radar antennas, we use the ITU-R SA.509 model for the upper envelope of the antenna sidelobes as depicted in figure 3.

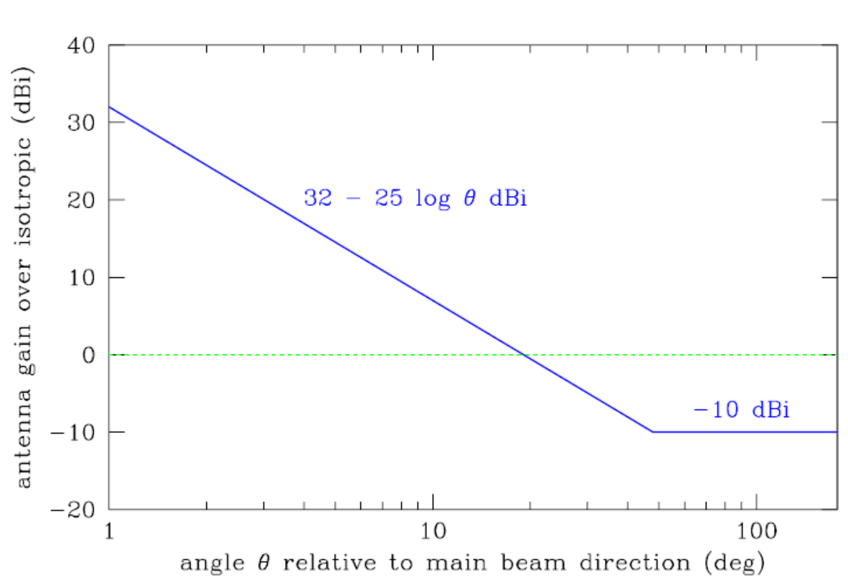

Figure 3. ITU-R SA.509 model of peak sidelobe levels for the VLBI and SLR radar antennas.

	DORIS	SLR radar
Frequency	2.036 GHz	9.4 GHz
Peak power level	9.5 W	4 kW
Duty cycle	100%	0.05%
Antenna gain	0 dBi	see figure 3

Table 1. Assumed properties of DORIS and SLR radar

4. Limits on RFI level from simulation results

Simulations were conducted as described in section 2 for a range of RFI signal strengths in two different scenarios. In the first scenario, we studied the LNA-induced correlation loss dependence on the input RFI level. In the second scenario, we studied the correlation loss dependence induced in the entire receiver chain, up to, but not including, the sampler. The results are summarized in figure 4.

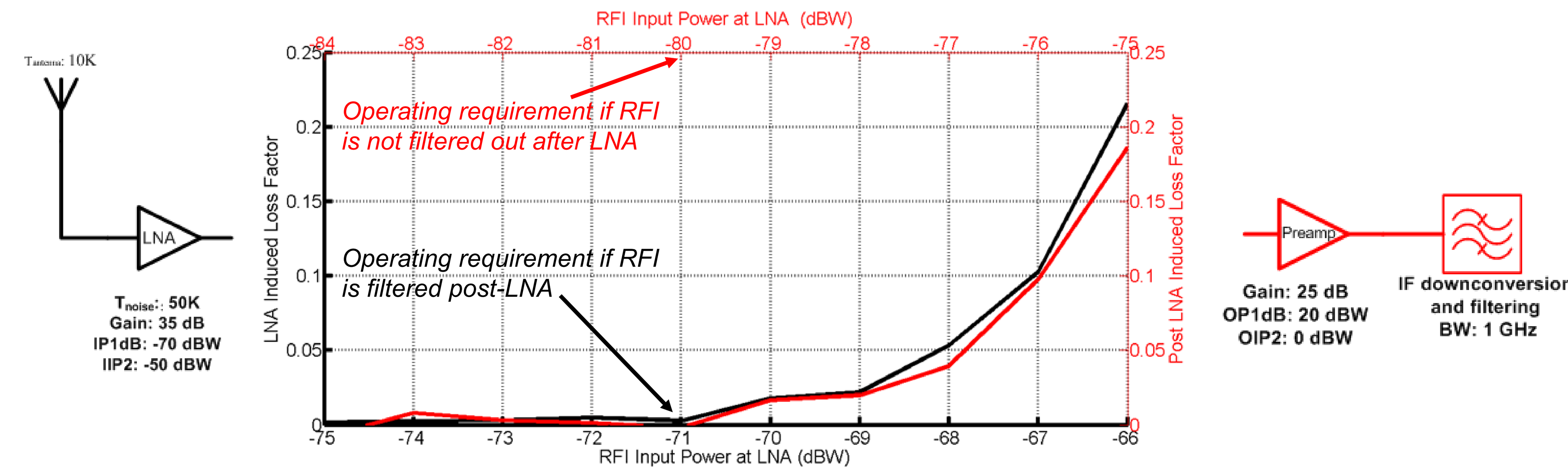

Figure 4. Dependence of correlation losses on the input RFI level when the LNA is overdriven and when the post-LNA hardware is overdriven

5. Implications for RF compatibility

Assuming the presence of a post-LNA notch filter in the VLBI receiver, we used the results shown in figure 4 to set the following limits on the acceptable LNA input signal levels:

* DORIS < -80 dBW

* peak radar < -70 dBW

The power level received from DORIS and radar were calculated from the parameters in section 3 for different pointing directions of the VLBI and radar antennas. Some results are shown in figures 5 and 6, along with the power level limits found in this study.

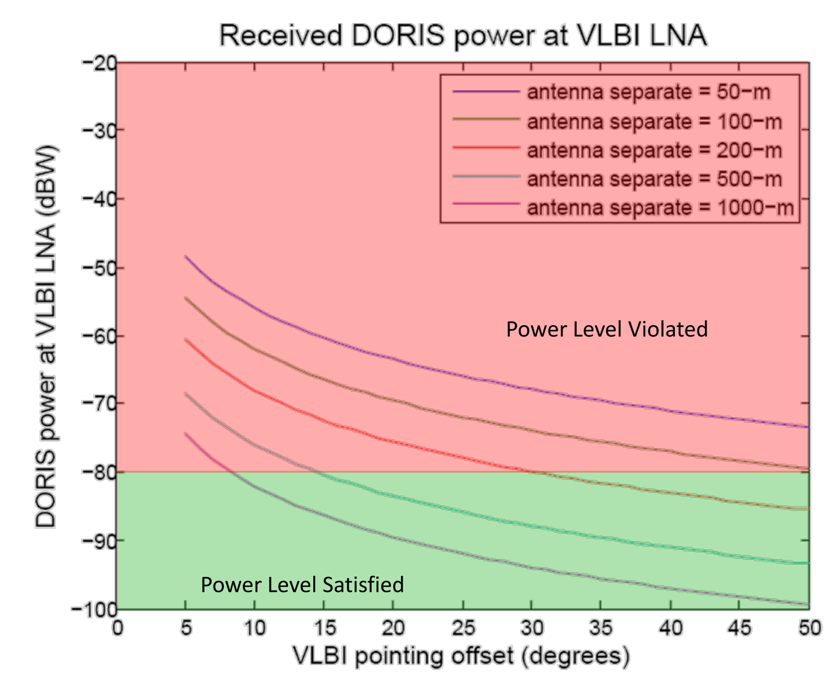

Figure 5. DORIS Pointing Offset Requirements

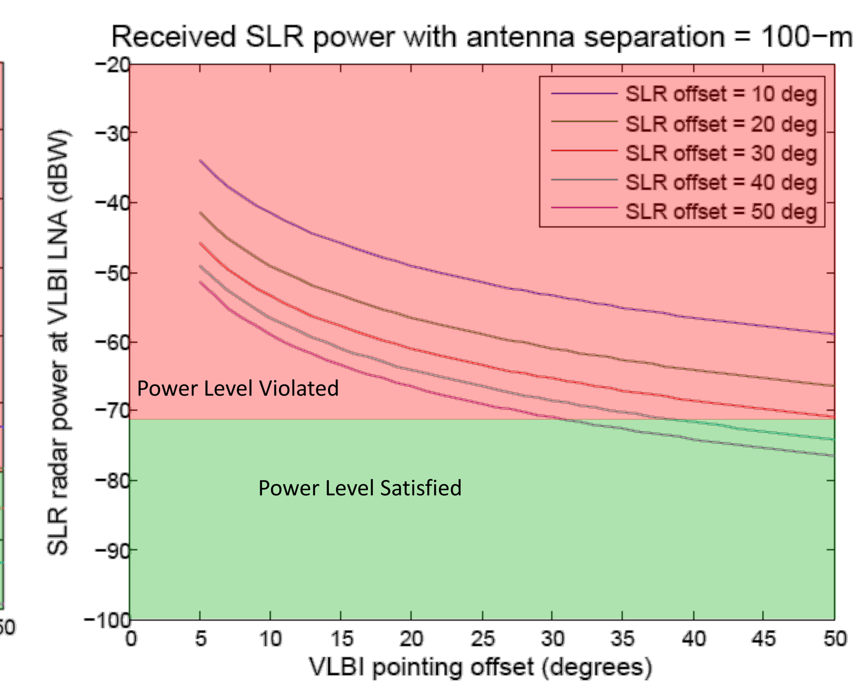

Figure 6. SLR radar Pointing Offset Requirements

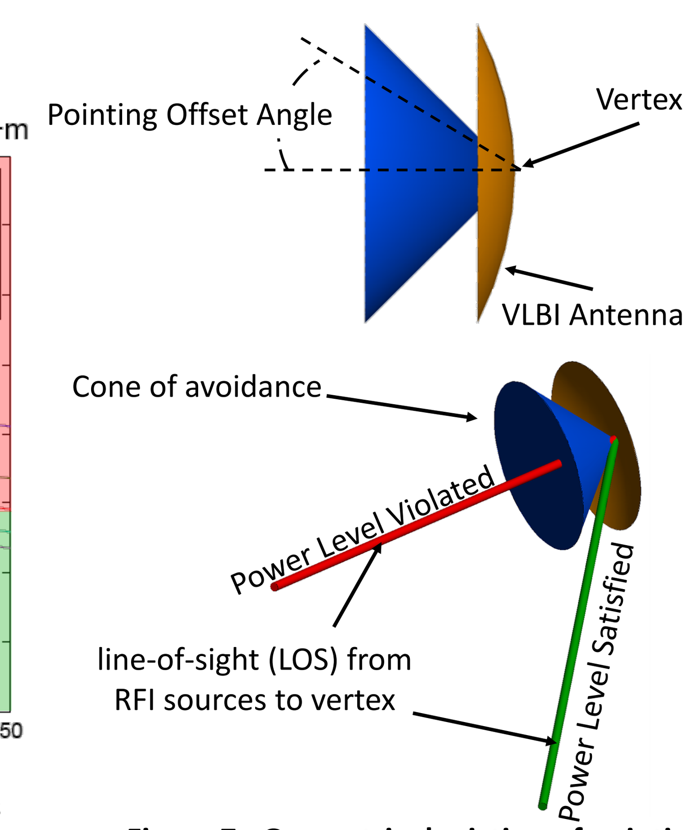

Figure 7. Geometric depiction of pointing angle offset requirement

6. Potential mitigation strategies

The results shown in figures 5 and 6 indicate that it will not be possible to operate the DORIS and SLR techniques within 100m of the VLBI antenna without significant loss in VLBI sky coverage. Table 2 outlines strategies to provide some relief to this situation.

Strategy	*Potential negative consequences*
Increase separation to > 100 m.	Degrades accuracy of local ties. Increases cost of land acquisition and maintenance.
Increase VLBI pointing offset limit to >10° .	Reduces VLBI mutual visibility with other stations. Increases estimation bias in VLBI position Cartesian coordinate parallel to VLBI-transmitter direction.
Increase radar pointing offset limit to >10° .	Decreases SLR sky coverage. Degrades SLR position & orbit determinations.
Insert radar notch filter in VLBI post-LNA electronics.	Filter width > radar BW → additional frequencies lost for VLBI observations.
Place a reflective or absorptive barrier between transmitter & VLBI antenna.	Too large a barrier may reduce sky coverage. Too small a barrier may be ineffective. Reflective barrier creates multipath. → DORIS precision may be degraded

Table 2. RFI mitigation strategies considered of DORIS and SLR radar

7. Conclusions and Future Work

- For a separation of 100 m and VLBI/radar pointing offset limits of 10 deg, an additional 20-30 dB of signal attenuation is needed.
- VLBI, DORIS, and SLR cannot operate effectively and simultaneously at separations of order 100 m without implementation of some type of RFI mitigation.
- Electromagnetic compatibility of various barrier types is currently being investigated, with the constraints that the impact on sky coverage be minimized for all techniques, and that multipath for DORIS be avoided. Preliminary simulation results for barriers providing the requisite attenuation are encouraging.