Radio Interference versus Receiver Sensitivity
Christian Monstein

The e-Callisto network (*Nosengo*) composed of more than 22 nodes is distributed over the whole world with some exceptions (gaps) in the American-/Pacific region. For the scientist studying the observed solar radio bursts (currently in more than 60 countries) it is of high interest to know the data quality of the spectra. One of the quality parameters is the level of interference compared to the sensitivity of the receiver. To get an impression all hosts were requested to send in spectral overview data while observing the sky (V_Sky) and another observation under identical conditions but with a 50Ω resistor at the input of the preamplifier as reference noise source providing 300 Kelvin antenna temperature (V_Ref). Unfortunately only very few hosts responded to my request, so a worldwide overview cannot be provided yet. Nevertheless with only two observatories (Alaska and Russia) it is interesting to compare and to discuss possible improvements. Both observatories have identical antennas (CLP-5130), identical spectrometers (Callisto) and comparable preamplifiers.

Process to determine instrument sensitivity
Start an observation while pointing the antenna to the sky → V_Sky
Start another observations with a 50Ω resistor at the input of the preamplifier → V_Ref
Plot both voltages to check integrity of observed data (no gaps), see figure 1a and 1b.
Subtract reference measurement from sky measurement Δ_V = V_Sky - V_Ref [eq. 1]
Calculate the external interference based on the known sensitivity of the logarithmic detector AD8307 with ~25.4 mV/dB. Y_dB = Δ_V / 25.4 mV/dB [eq. 2]. Results, see figures 2a and 2b. These plots already allow to compare different observatories in terms of interference level (peak amplitude in dB and also occurrence of interference versus frequency.
The challenging problem is now on how to find the sensitivity of the instruments. Luckily other people have already discussed this issue. In the recommendation of ITU R-RA-769 there is a definition for the proposed gain of an antenna with respect to interference. Independent of the main beam gain of the antenna the gain with respect to interference is defined as to be G_rfi_dB = 0 dB [eq. 3] because interference is mainly coming from all sides and not through the main beam. In addition to this definition we need to make some assumptions about the radio telescope configuration.
The reference temperature of the 50Ω calibration resistor is assumed to in the order of T_ref = 300 Kelvin [eq. 4]
The noise figure of the preamplifier in the frontend including cable- and connector loss is assumed to be in the order of NF_dB = 2.0 dB [eq. 5]

From equations eq 4 and eq 5 we can derive the receiver temperature T_rx to
$T\_rx = T\_ref * 10^{(NF\_dB/10\ dB)}$ [eq. 6]

From equations 2 and 6 we directly get the antenna temperature of the interference
T_rfi = T_rx * (Y-1) [eq. 7] where

$Y = 10^{(Y\_dB/10\ dB)}$ [eq. 8]

In the next steps we need to know the effective aperture A_eff of the antenna. Thanks to R-RA-769 this is becoming an easy task.
$A\_eff = G\_rfi * \lambda^2 / (4*\pi)$ [eq. 9] where

λ = wavelength in meter = c/f [eq. 10] with
c = speed of light in vacuum = $3*10^8$ m/sec and f = frequency [Hz] and
G_rfi = $10^{(G\_rfi\_dB/10\ dB)}$

Now we have everything together to calculate the flux S_rfi of the incoming interference to
S_rfi = 2 * k * T_rfi / A_eff [eq. 11] where
k = Boltzman constant = $1.380682 * 10^{-23}$ J/K
The factor 2 is to take into account both polarizations.

Now we can generate a plot presenting interference flux S_rfi. By reason that the range of interference is huge and the values are extremely small, we plot S_rfi it in dB [W/m^2/Hz]
S_rfi_dB = 10 * log10(S_rfi) [eq. 12]. For results, see figures 3a and 3b.

In addition to the interference flux S_rfi we are also interested in the best available sensitivity S_min of our instruments in case of no interference, just to compare level of interference with maximum sensitivity. To get this value we need more information about the instrument configuration. According to *Kraus* we get for the temperature resolution
$\Delta T = T\_rx * (B*\tau)^{-2}$ [eq. 13] where
B = radiometric bandwidth of the receiver, in case of Callisto B = 300 KHz and
τ = integration time of the receiver, in case of Callisto τ = 1msec
Now we need the effective aperture for the main beam which is a function of the gain, similar to eq. 9. In case of Alaska and Siberia the antenna has a gain of approximately Gm_dB = 6 dB where Gm = $10^{(Gm\_dB/10\ dB)}$ [eq. 14] and so we get Am_eff, the main beam effective aperture
Am_eff = Gm * λ^2 / (4*π) [eq. 15] where
λ = wavelength in meter = c/f with c = $3*10^8$ m/sec and f = frequency [Hz] and
G_rfi = $10^{(G\_rfi\_dB/10\ dB)}$ [eq. 16]
Now we have all parameter to derive the instrumental sensitivity S_min
S_min = 2 * k * ΔT / Am_eff [eq. 17] where
k = Boltzman constant = $1.380682 * 10^{-23}$ J/K
The factor 2 is to take into account both polarizations.
The plots of S_min are shown in figures 3a and 3b as calculated instrumental sensitivity assuming no interference (black dashed line). We can recognize that both observatories cannot 'see' quit sun at most of the frequencies within the spectrum of Callisto. The reasons are manifold:
a) gain of the main beam of Gm_dB = 6 dB is too small → larger antennas
b) Bandwidth B = 300 KHz is too small. But we do not want to make it broader otherwise we would lose information about dynamic solar radio bursts.
c) Integration time τ = 1msec is too small but we do not want to make it larger otherwise we would lose time resolution of dynamic solar radio bursts.
d) Noise figure NF = 2 dB is to large, but it's difficult to improve it significantly with small budget. Helium cooled frontend for radio amateurs is not yet an option nowadays.

For orientation also the quiet solar radio flux is plotted in figures 3a and 3b as flux (red dotted line) derived from theoretical studies (Benz in press).

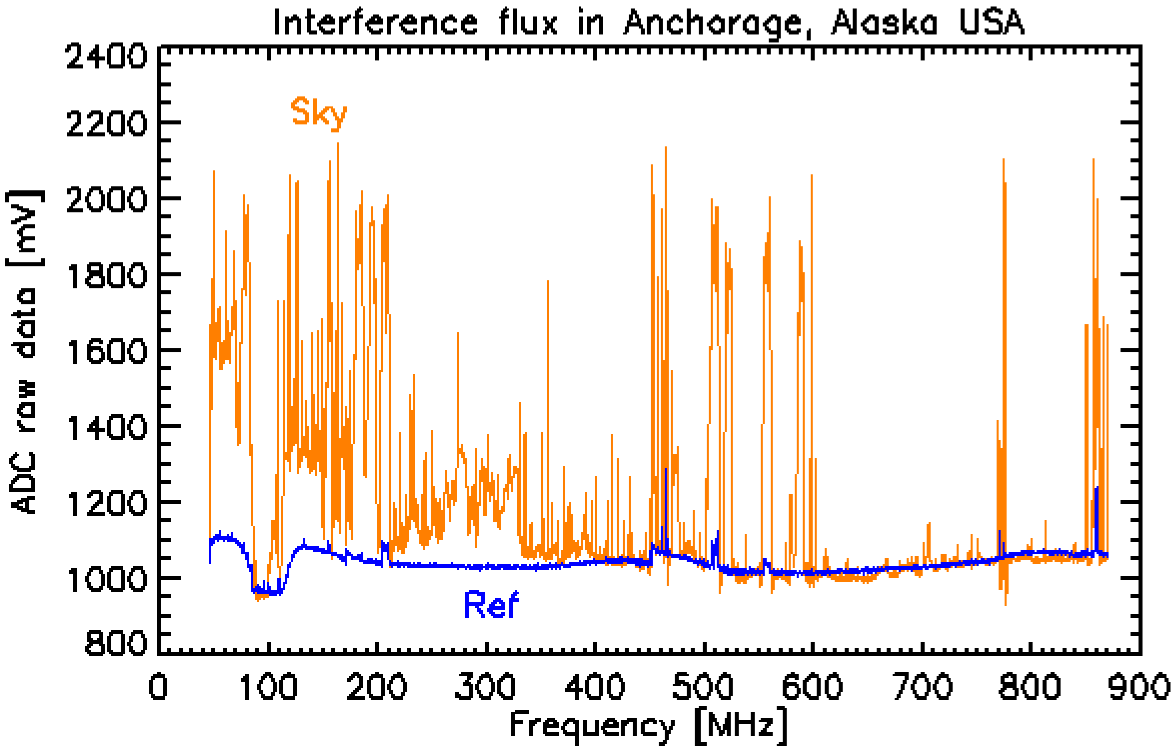

Figure 1a: Raw data of the spectral overview as captured by Callisto in Alaska. Orange plot denotes to data while observing the sky and blue plot denotes to the observation of a 50 Ω resistor. Y-axis shows measured voltages of the ADC expressed in mV versus the observed frequency in MHz. Anchorage is suffering from a lot of high level interference. Near 100 MHz the whole FM-range is suppressed ed with a notch-filter.

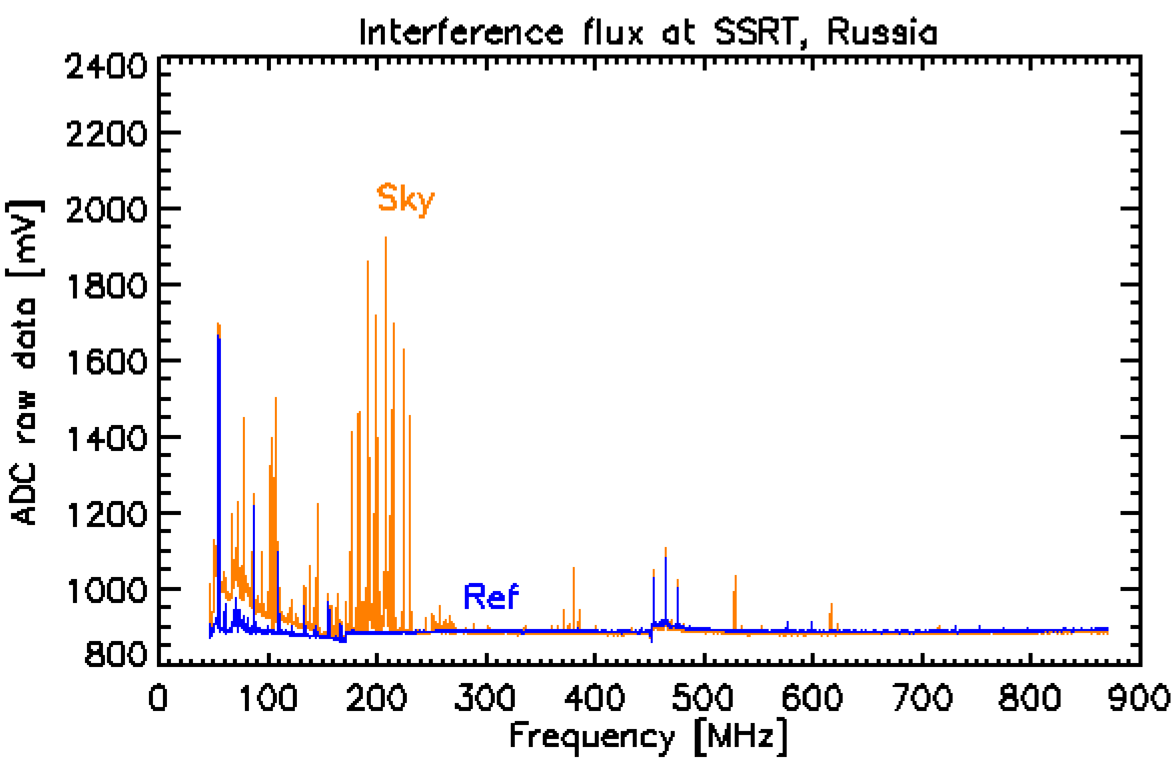

Figure 1b: Raw data of the spectral overview as captured by Callisto in Siberia. Orange plot denotes to data while observing the sky and blue plot denotes to the observation of a 50 Ω resistor. Y-axis shows measured voltages of the ADC expressed in mV versus the observed frequency in MHz. Badary in Siberia is suffering from only low level interference around 200 MHz.

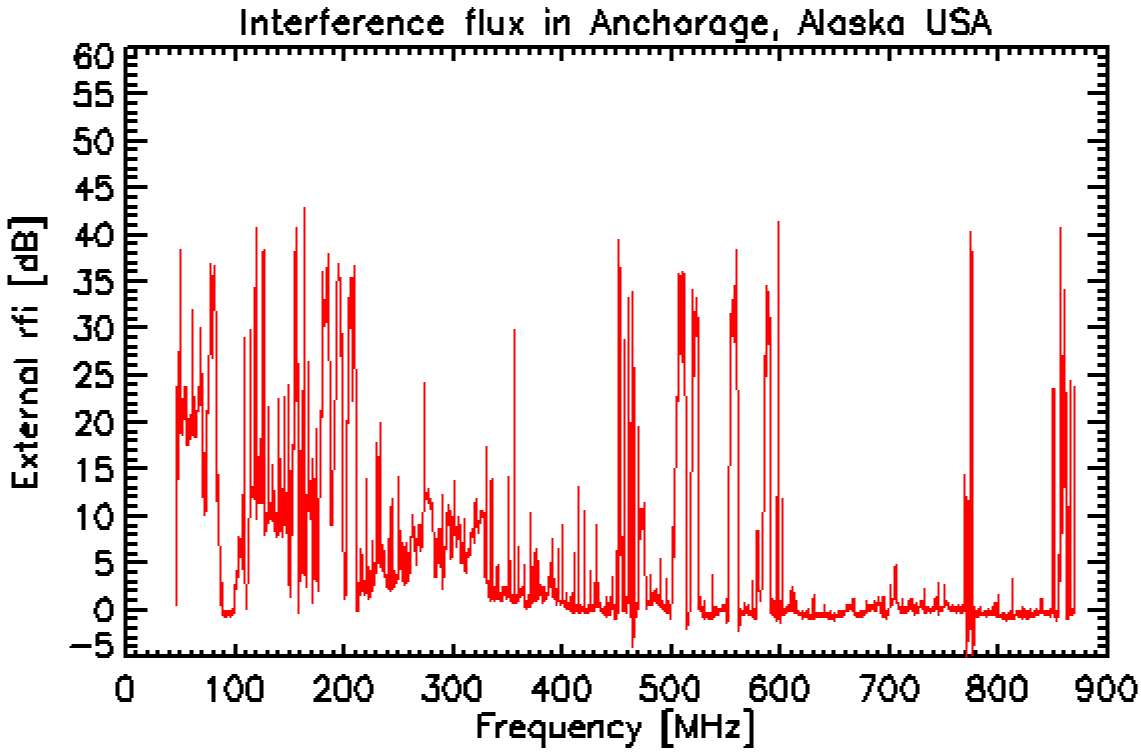

Figure 2a: Difference plot (V_Sky - V_Ref) from Anchorage expressed in dB versus frequency in MHz. This plot is named as external rfi because the internal noise and interference is subtracted from the sky-measurement.

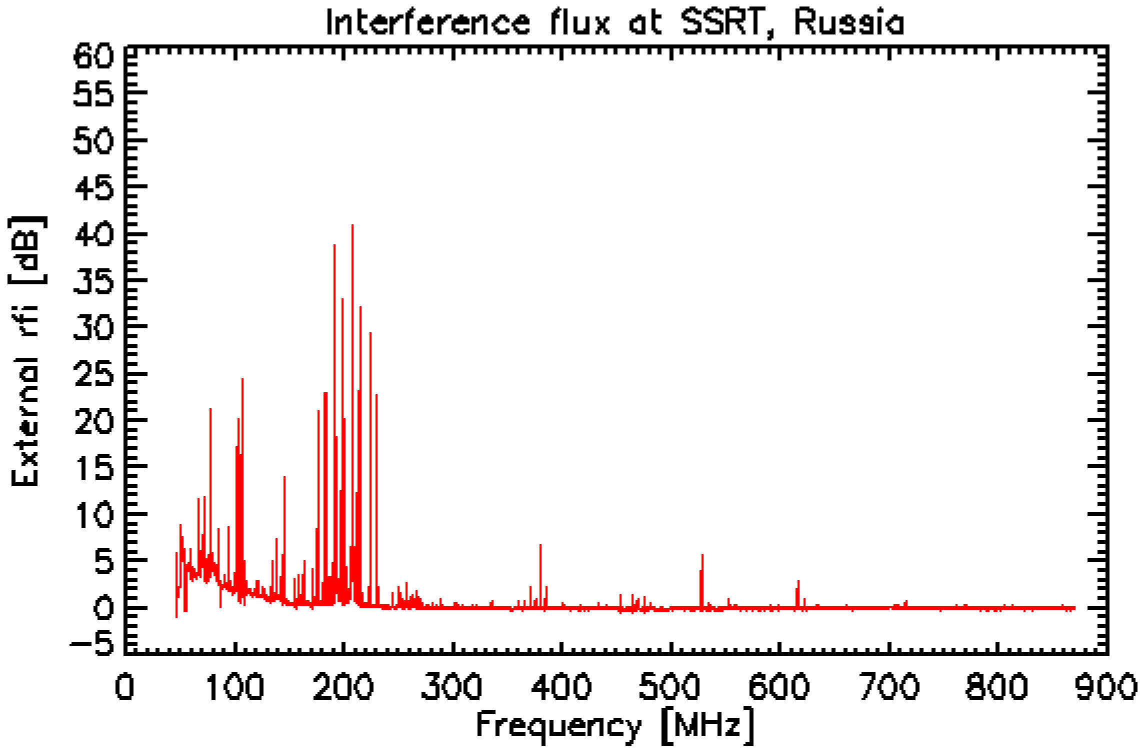

Figure 2b: Difference plot (V_Sky - V_Ref) from Siberia expressed in dB versus frequency in MHz. This plot is named as external rfi because the internal noise and interference is subtracted from the sky-measurement.

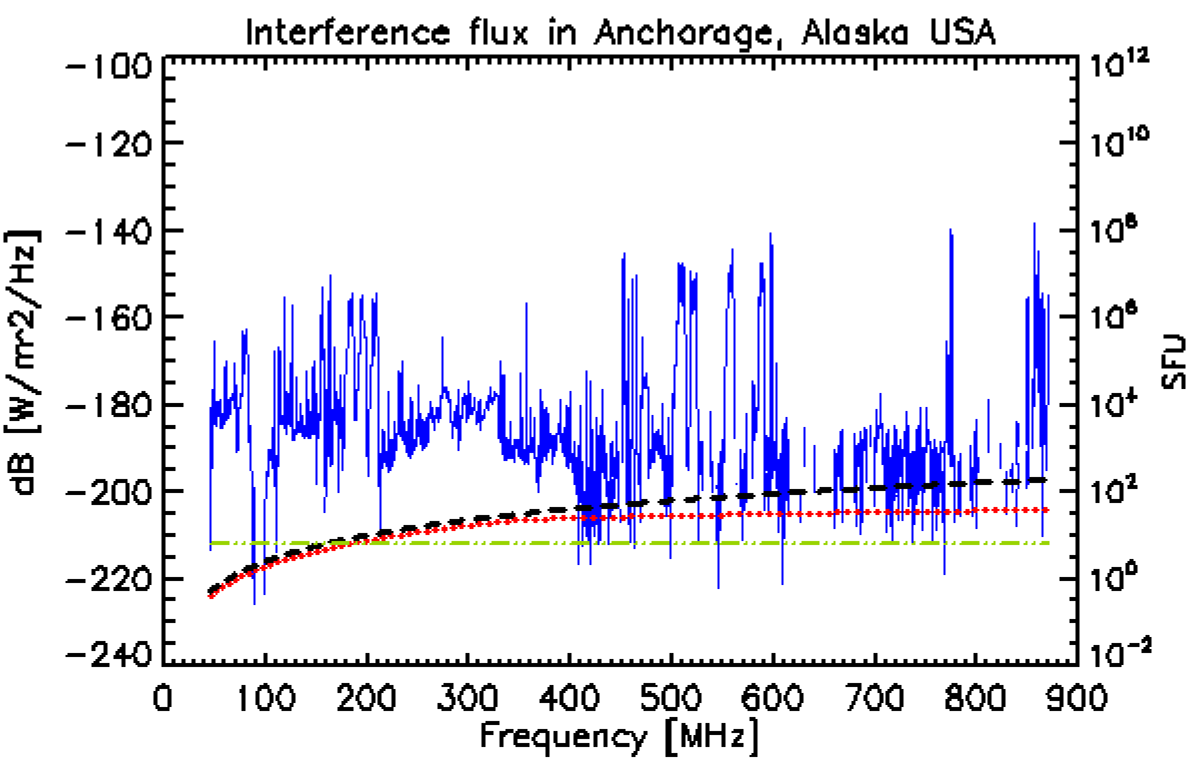

Figure 3a: Measured sensitivity of the instrument in Anchorage (blue solid line), quiet solar flux (red dotted line), calculated instrumental sensitivity assuming no interference (black dashed line) and upper limit for VLBI observations at 325.3 MHz (green dashed/dotted line). Only a very few frequencies near 400 MHz and between 600 MHz and 750 MHz can be used to detected quiet solar radio flux in Anchorage under the current conditions.

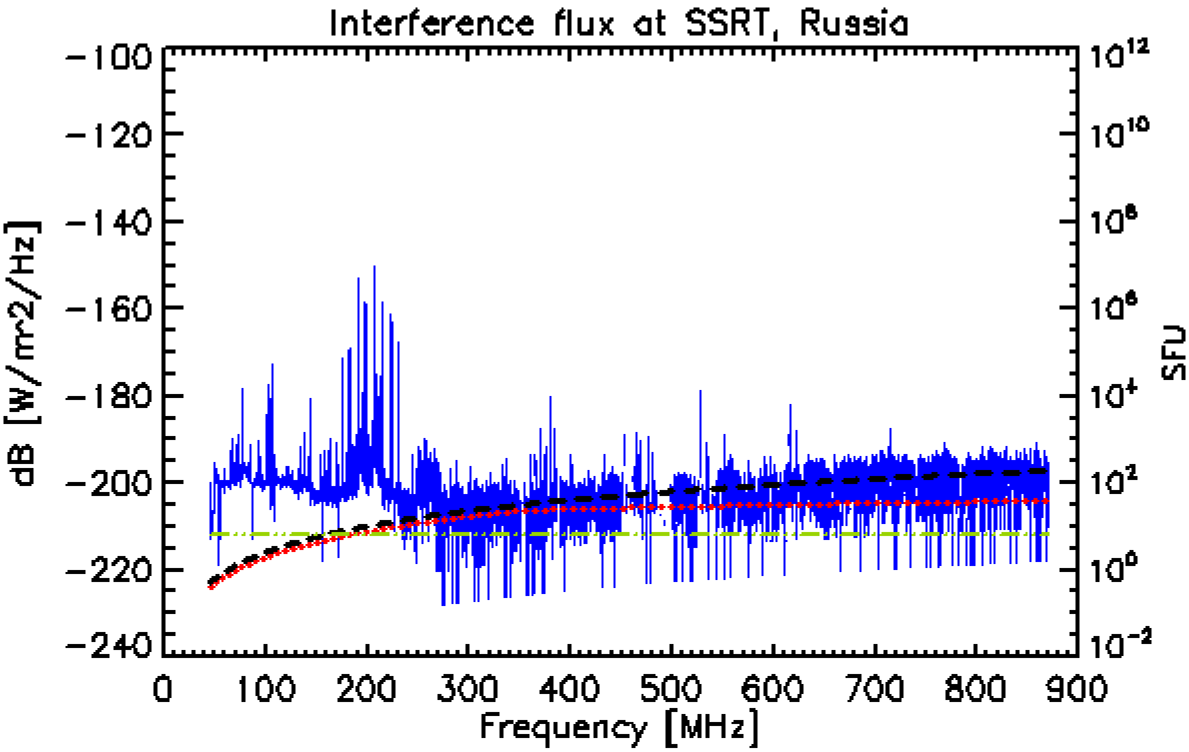

Figure 3b: Measured sensitivity of the instrument in Badary/Siberia (blue solid line), quiet solar flux (red dotted line), calculated instrumental sensitivity assuming no interference (black dashed line) and upper limit for VLBI observations at 325.3 MHz (green dashed/dotted line). Many frequencies above 300 MHz can be used to detected quiet solar radio flux in Siberia under the current conditions. Near 240 MHz we can detect transponders signals from military satellites.

References, further reading:

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Kraus: John D. Kraus, Radio Astronomy, 2nd edition, Cygnus - Quasar Books 1986

R-RA-769 : Protection criteria used for radio astronomical measurements
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