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Measuring RFI data loss

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ITU-R Regulatory Conditions

- RR 5.340 - All emissions are prohibited in selected bands bands like 1427 MHz
- RR 5.149 - Administration take all practical steps to protect operations of the Radio Astronomy Service in the following bands:
- ITU-R RA.769-2 - these are the thresholds above which interference is detrimental for spectral line and continuum observations
- ITU-R RA.1513 – in primary bands of the RAS 2% data loss in time is allowed for single system and 5% for the aggregate

Practical Thresholds (from RA.769-2)

- ITU-R RA.769-2 puts into words variation of radiometer noise of a standard RAS system with $T = T_A + T_R$

$$\Delta P/P = \Delta T/T = 1/\sqrt{(\Delta t\ \Delta f)}$$

- Assuming a harmful threshold of 10% error of radiometric power:

$$\Delta P_H = 0.1\ \Delta P\ \Delta f = 0.1\ k\ \Delta T\ \Delta f$$
$$= 0.1\ k\ T(sys)\ \Delta t^{-1/2}\ \Delta f^{1/2}$$

- Adopting values for Tsys and reference values for bandwidth Δf and for integration time Δt of 2000 sec

- Harmful pfd: $S_H \Delta f = \Delta P_H + 10 \log f(Hz) - 158.5$ (dB(W/m^2))
- Harmful spfd: $S_H = \Delta P_H + 5 \log f(Hz) - 158.5$ (dB(W/m^2/Hz))

RA.769-2 thresholds for RAS antenna

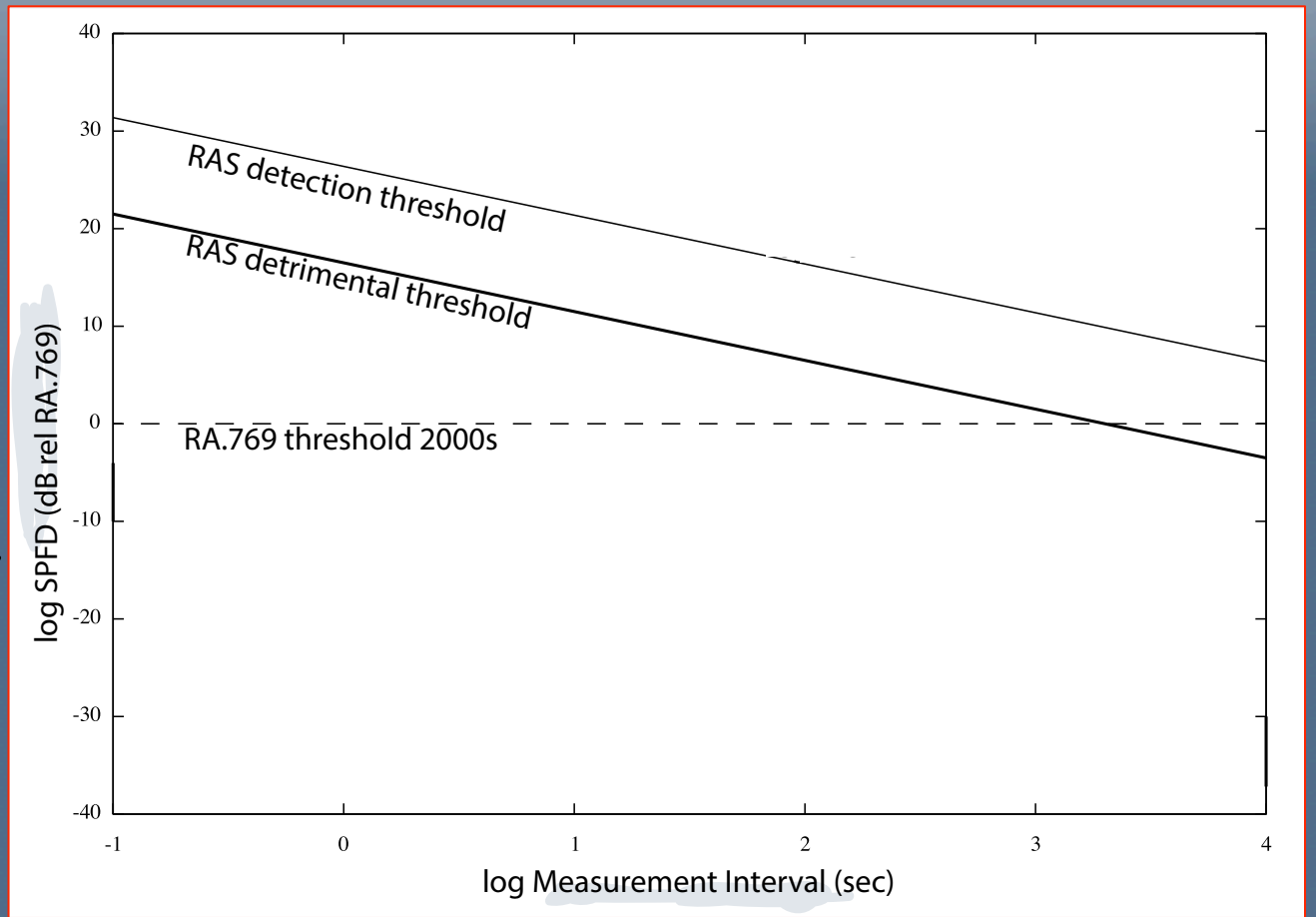
$$T_{spec}(\Delta t, \Delta f) = spfd_{spec}(RA.769, \text{table 2}) + 5 \log ((\Delta f/\Delta f_{ref})(2000/\Delta t)) \quad (dB(W/m^2/Hz))$$

$$T_{cont}(\Delta t, \Delta f) = spfd_{cont}(RA.769, \text{table 1}) + 5 \log ((\Delta f/\Delta f_{b})(2000/\Delta t)) \quad (dB(W/m^2/Hz))$$

spfd for RA.769-2 varies w measurement Δf and Δt

Time interval of 2000s and frequency channel of 20 kHz are *reference values*

=> NOT 'holy numbers'



The Measurement System

- Detector system with forward gain G and equal/inferior Tsys

- Sensitivity dependence to measurement Δf and Δt remains same
- System G gives vertical scaling of detection noise floor

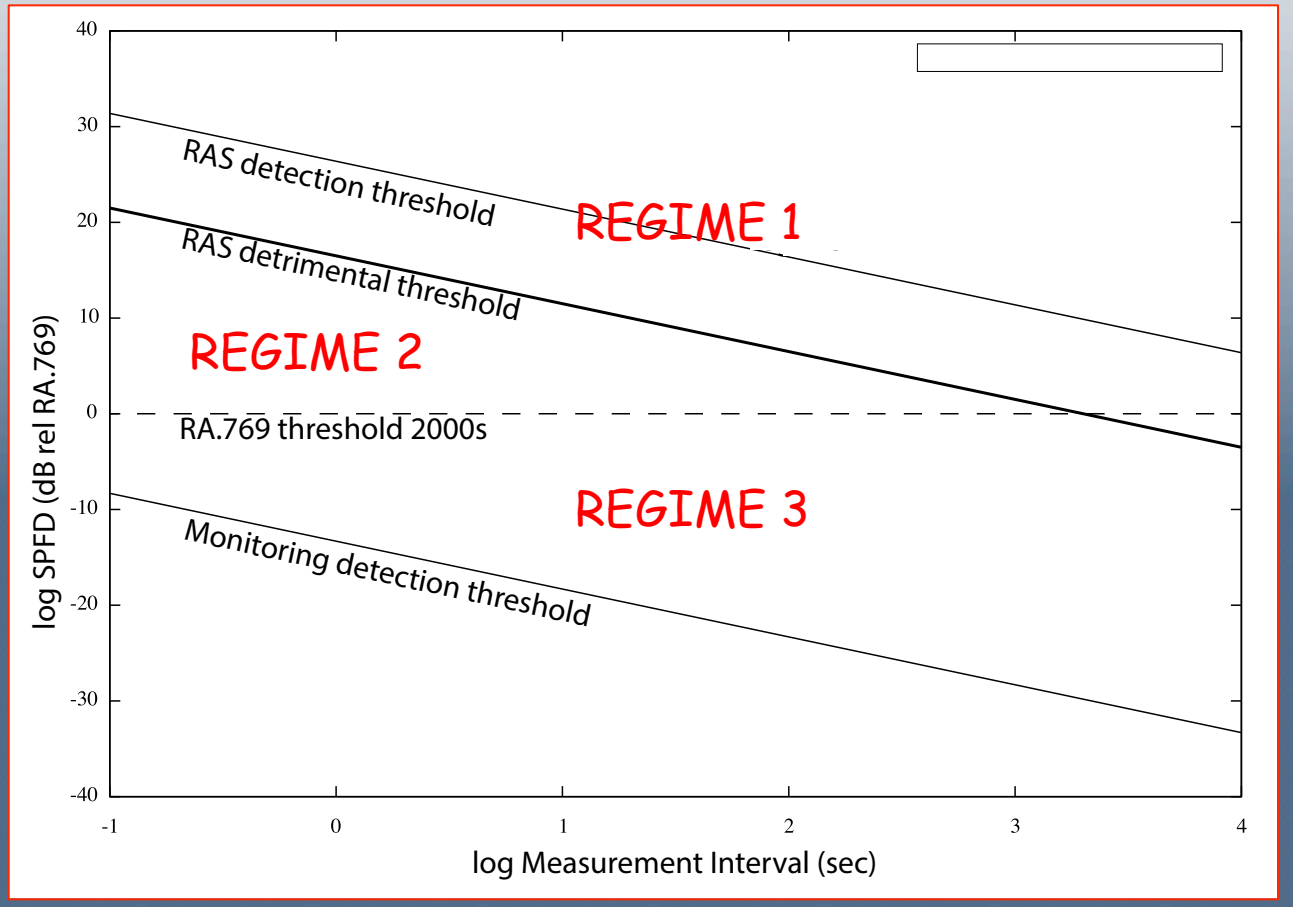
$$S_{spec}(\Delta t, \Delta f) = -(G+10) + [10 \log (Tsys,ref/Tsys,mon)] + T_{spec}(\Delta t, \Delta f) \quad (dB(W/m^2/Hz))$$

$$S_{cont}(\Delta t, \Delta f) = -(G+10) + [10 \log (Tsys,ref/Tsys,mon)] + T_{cont}(\Delta t, \Delta f) \quad (dB(W/m^2/Hz))$$

The Measurement Antenna

Antenna lowers the detection threshold

Three distinct RFI regimes



Methodology

- Calibrate the measurement system
- => calibrate T_A conversion to Jy or dB(W/m^2/Hz)
- => example: ON-OFF on source with know flux density (Cas A or Cen A) and find Jy/K ratio
- Identify interference characteristics (variability in time & freq)
- Take time-series with taking small Δt and appropriate Δf
- => longer than characteristic time/freq variability timescale
- => choice of Δt and Δf affects the percentage data loss
- Determine percentage of time where RFI exceeds the corrected RA.769 threshold levels
- Determine integrated RFI over long time interval
- => for primary bands and RR 5.340 bands
- => $N\Delta t$ long enough to cover variability (e.g. 2000s)

Evaluation of Results

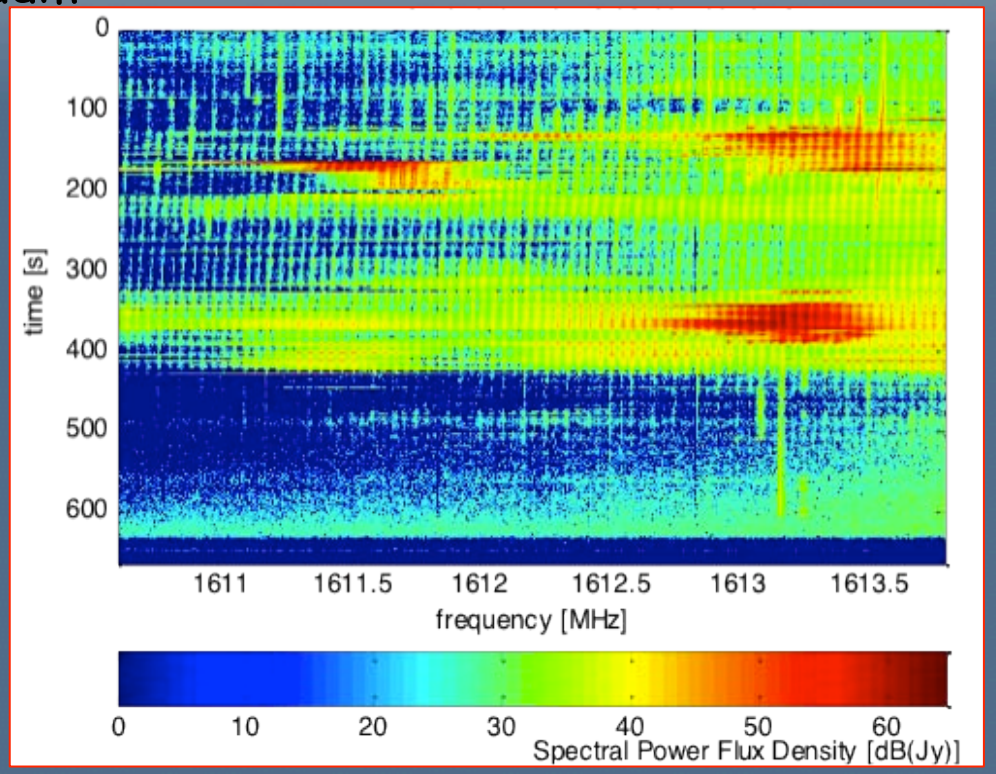
- Primary bands – is the percentage of time larger than corrected RA.769 threshold more than designated by RA.1513 ?

  => separate evaluation for continuum and spectral line
- RR 5.340 bands – in addition: is the integrated RFI larger than appropriate values from RA.769 ?

  => spectral line & continuum

Time-frequency occupancy diagram of unwanted emissions in a single passage of a LEO MSS satellite. Diagram contains N = 630 data records with $d\Delta t$ = 1s and M = 420 spectral channels with $d\Delta f$ = 6.1 kHz within the RAS band. The percentage varies from about 30% to 100%

ECC Report (09)02
(Leeheim - BNetzA and MPIfR)



Determining Percentages

- **Time series analysis**
- *P* = number of affected records from total *N* records
- => percentage = *P*/*N* x 100% valid for large *N*
- => *N* needs to be large for small percentages
- For relatively small *N* and unpredictable RFI
- => percentage = (*P* + 1)/(*N* + 2) x 100%
- => probability of random RFI to enter into *P* out of *N*

- **Time-occupancy analysis**
- P = number of affected (Δt, Δf) elements in *N* x *M* pixels
- => percentage = (*P* / *N***M*) x 100%
- => regridding of frequency axis conform ITU-R RA.769
- => coarser Δt & Δf raise the percentage data loss

The Impact of RFI on data

- Straight forward measurements do not reflect the impact

- Impact of RFI is different for spectral line and continuum data
- Time and frequency variability ?
- Location of RFI inside spectrum important for spectral line but not for continuum

- This is not discussion (yet) on translation of percentage data loss into actual data loss
- => how much can we flag ?
- => what is really lost with 2% and 5% in time ?
- => collateral damage from weaker sidebands & spurious ?

ITU-R action

- Procedures outlined here are submitted as document 7D/48-E (2013) to ITU-R WP7D
- Revised version of the PDNR by NL & GER