VHF antenna calibration for RFI monitoring using sky signal

B. Censier (benjamin.censier@obs-nancay.fr), I. Thomas, G. Auxépaules, B. Flouret, P. Renaud

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Nançay Surveillance Antenna (NSA)

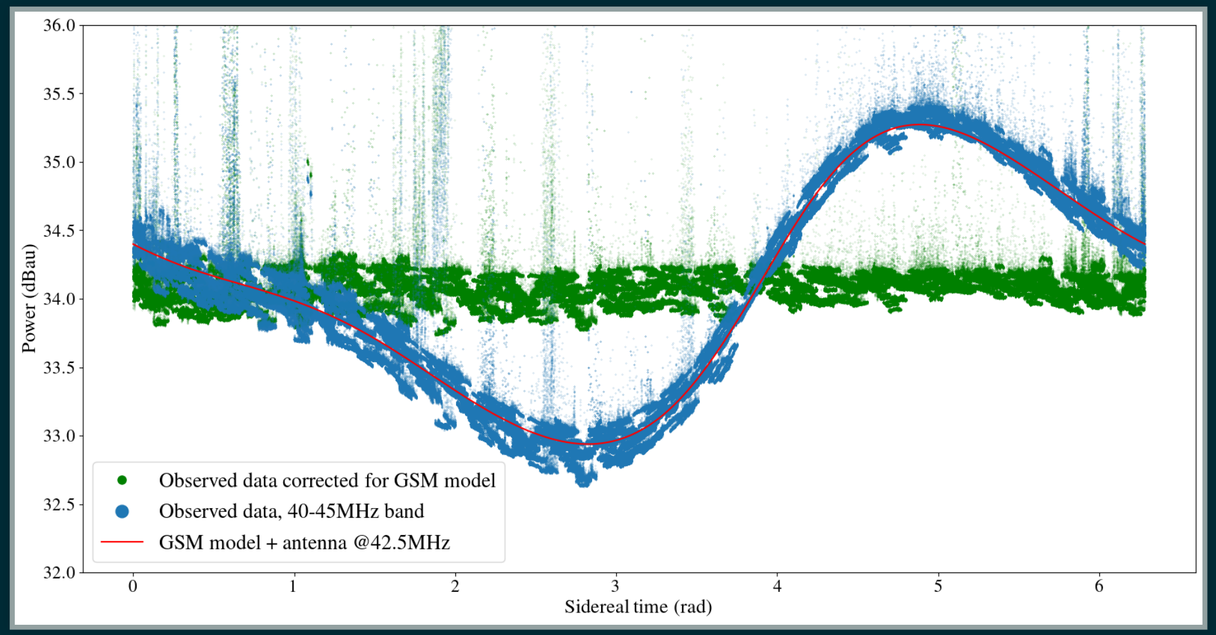
- Nançay : 150 ha in radio quiet zone (sologne forest, 200 km south of paris)
- NSA : Spectrum/RFI/satellite monitoring
- 10 MHz - 4 GHz in 3 bands (10 - 100 MHz, 100MHz - 1 GHz, 1 GHz - 4 GHz)

NSA LF part (10 - 100 MHz)

- Horizontal dipole, LWA-like Nenufar antenna with dedicated frontend + roach receptor
- no internal calibration source, no directionality, sky dominated, on the ground
- in practice : 20 - 80 MHz

Sky temperature below 100 MHz

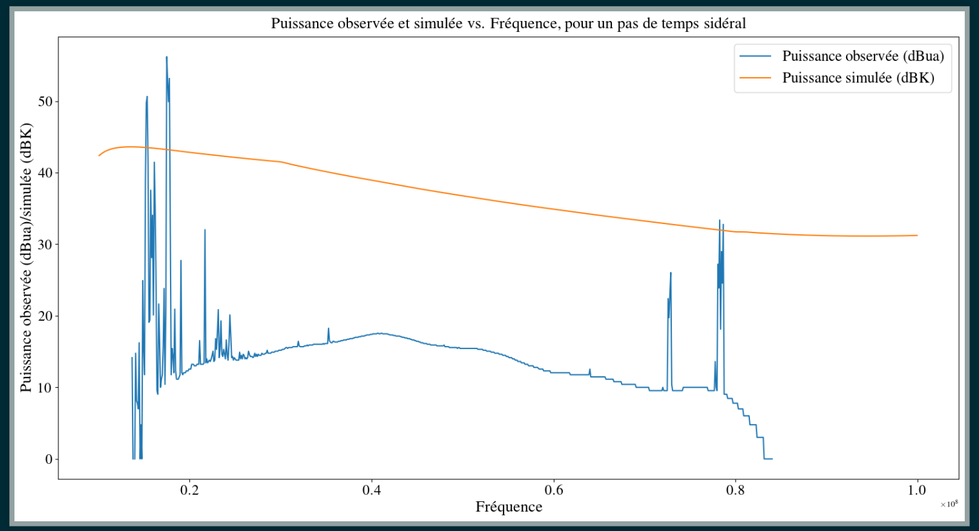
Time dependence



- Power observed on a single dipole antenna (Nenufar/LWA model)
- Essentially the sky signal integrated on the whole the antenna radiation pattern.
- periodic signal w.r.t. sidereal time
- $\approx$ 2.5 dB time variation @45MHz, rise towards low frequencies
- sky signal periodic variations may be evaluated with good precision on the data themselves on Power vs. sidereal time scatter plots

Sky temperature below 100 MHz

Frequency dependence



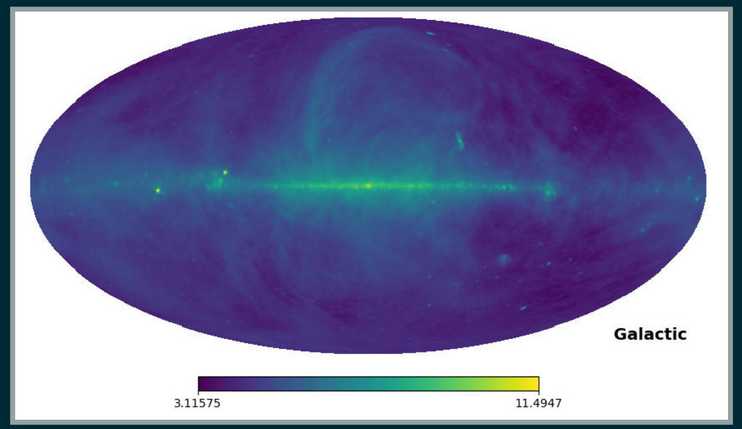
- Frequency dependence from antenna : maximum sensitivity below 20 MHz, decreasing toward both lower and higher frequencies
- frequency dependence from receiver : filtering + amplifier response
- frequency depedence from sky : simple power law decreasing towards high frequencies
- sky signal mixed up with unknown instrumental frequency dependencies, simulation required

Sky signal modeling

On the 15 - 80 MHz band:

- Brightness temperature of the sky $T_B(\theta, \phi)$: Global Sky Model (GSM)
- Antenna gain (radiation pattern) $G(\theta, \phi)$: NEC simulation
- Antenna temprature due to sky $T_A(t_s, F)$, with t_s the sidereal time and F the frequency, is computed as the integration of the sky signal punderated by the radiation pattern:

$$T_A(t_s, F) = \frac{1}{4\pi} \int_{4\pi} G(\theta, \phi, F) T_B(\theta, \phi, t_s, F) d\Omega$$



Simulated sky temperature, GSM model

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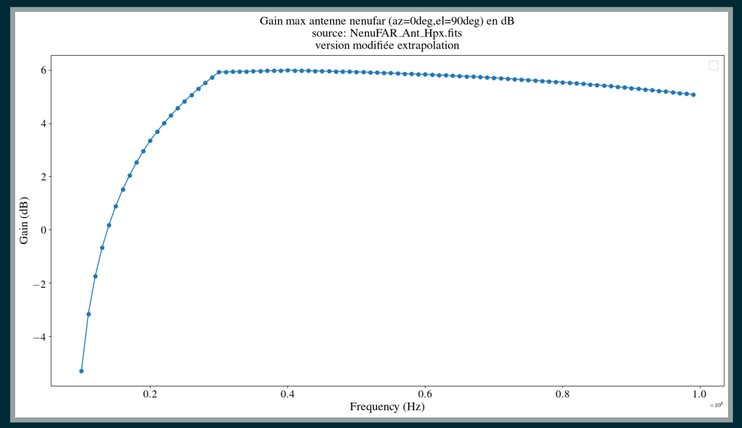

Antenna max gain vs. frequency as simulated with NEC2

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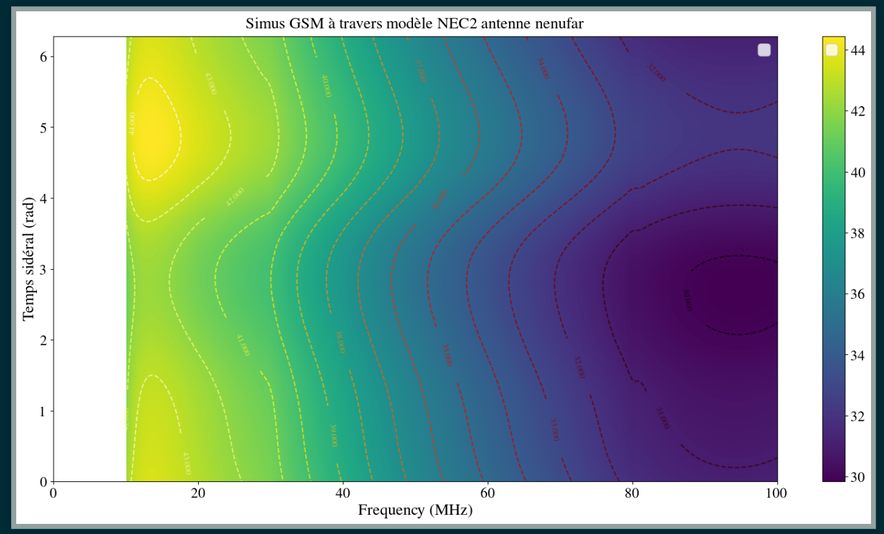
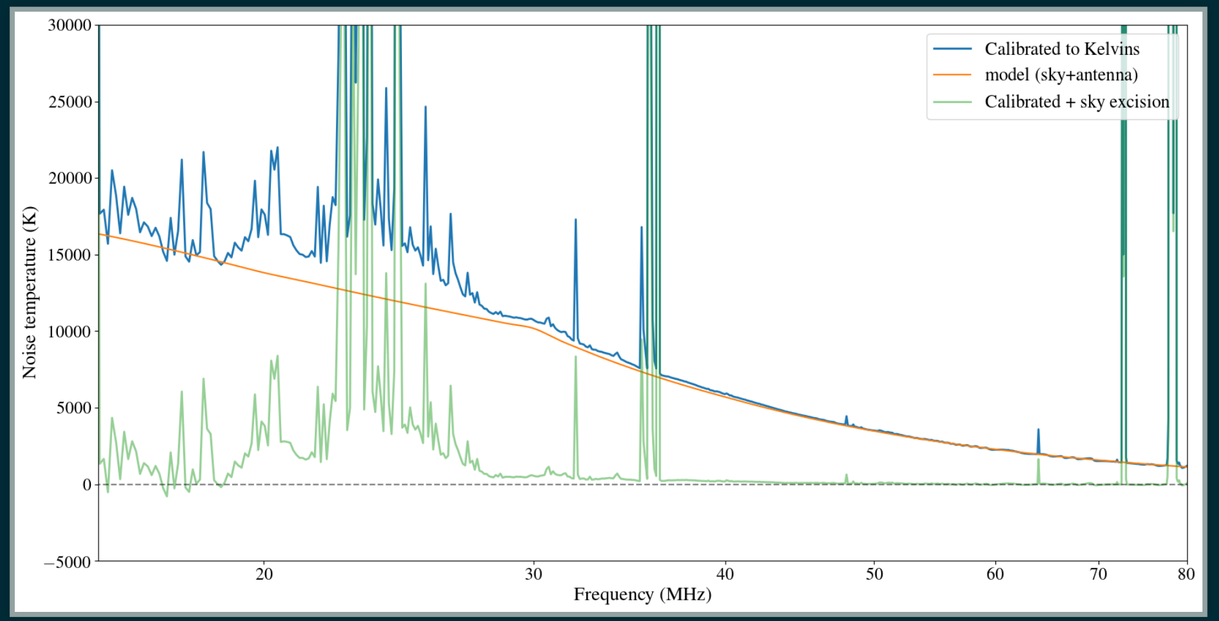


Simulated sky signal (dBK color scale) in the sidereal time/frequency plan.

Calibration/sky signal excision

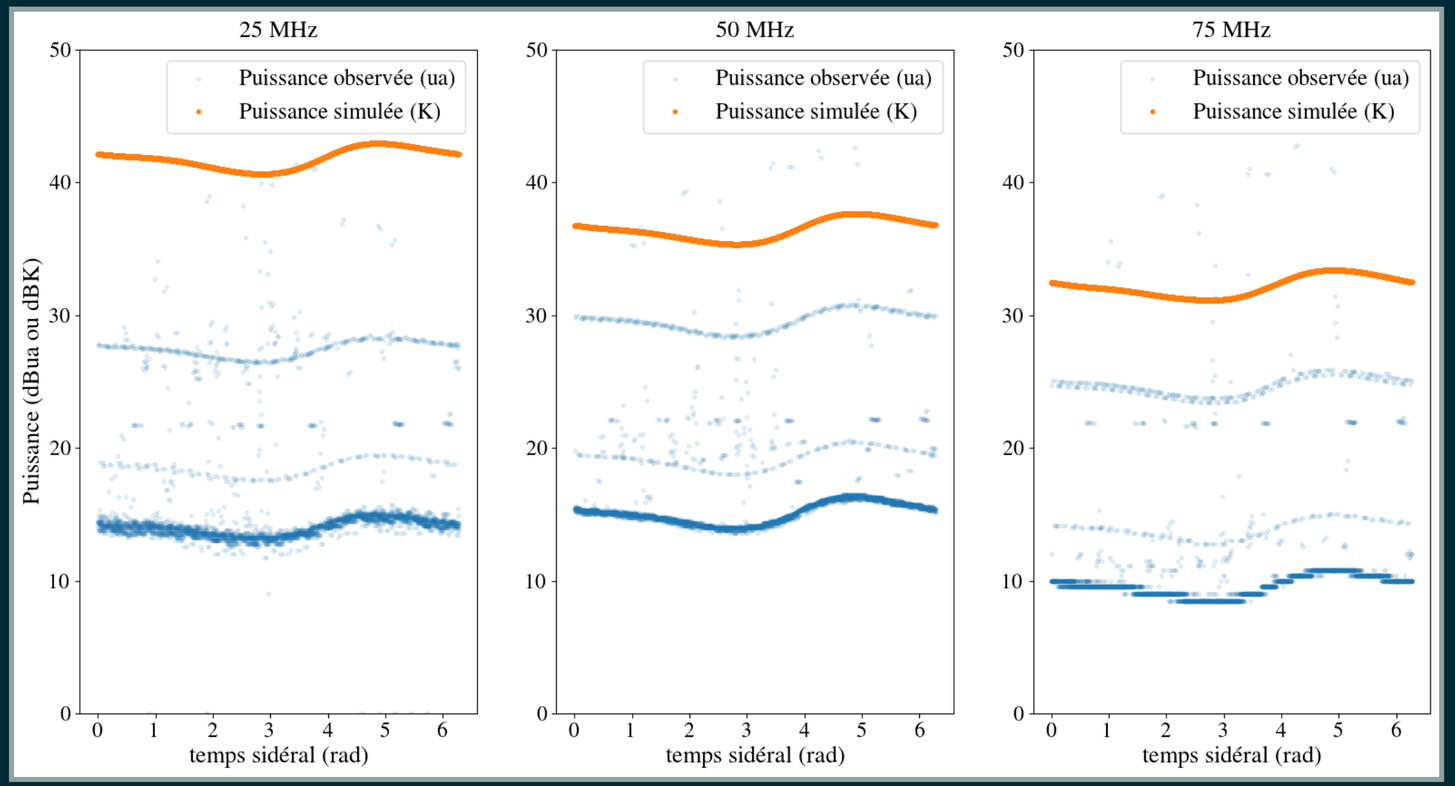
1st approximation : $\frac{P_{obs}}{P_{model}}$ ratio

- Calibration model : $T_{Receiver}(F) = G(F).T_{sky}(F) + T_{noise}(F)$
- estimated T_{noise} of the order of 100K for most of the band, some 1000s K for the sky
- T_{noise} is neglected
- the unknown instrumental gain G is simply computed using the $\frac{T_{Receiver}}{T_{sky}}$ ratio (i.e. observed data/simulated data ratio)

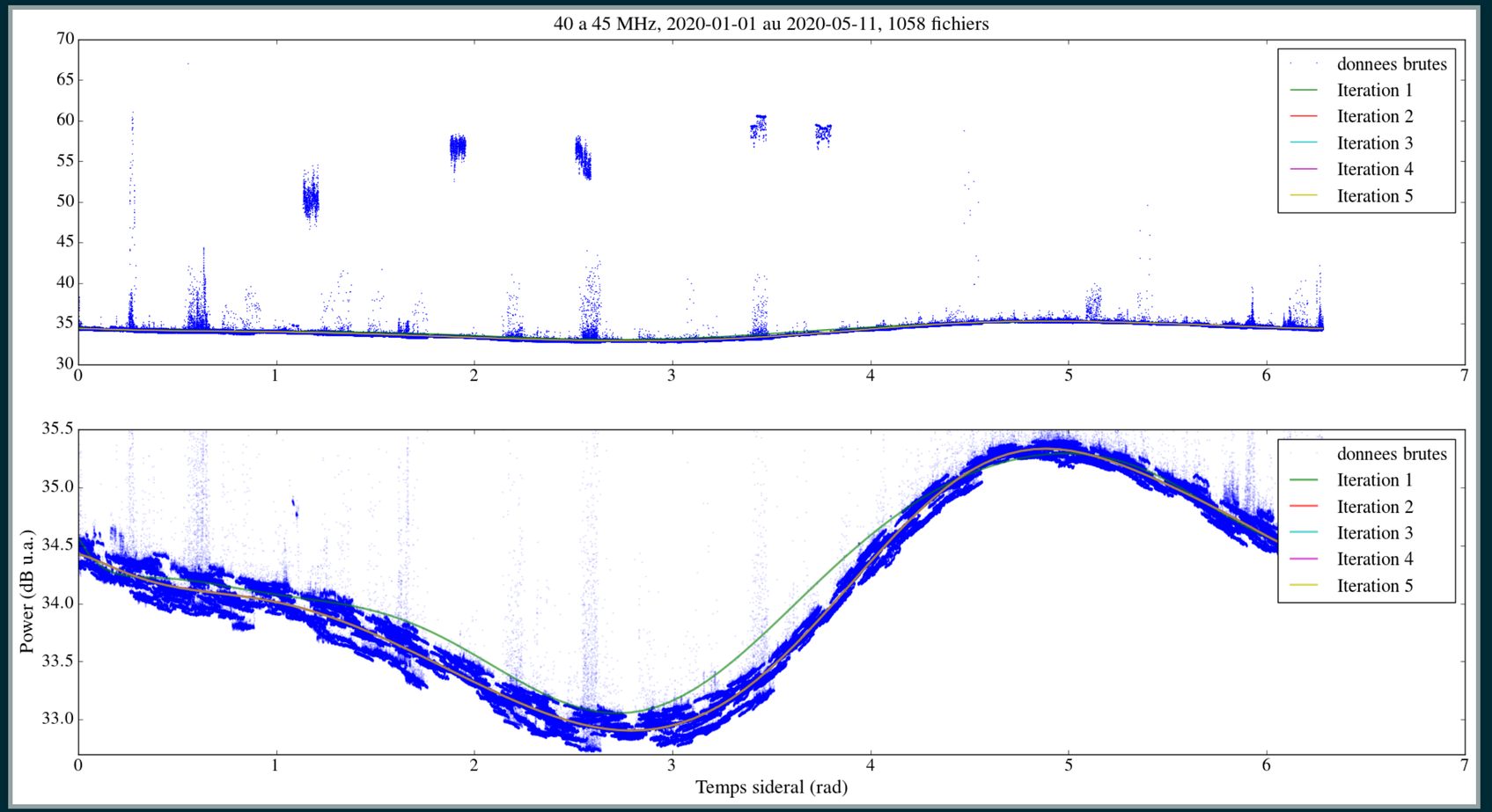


Model fit

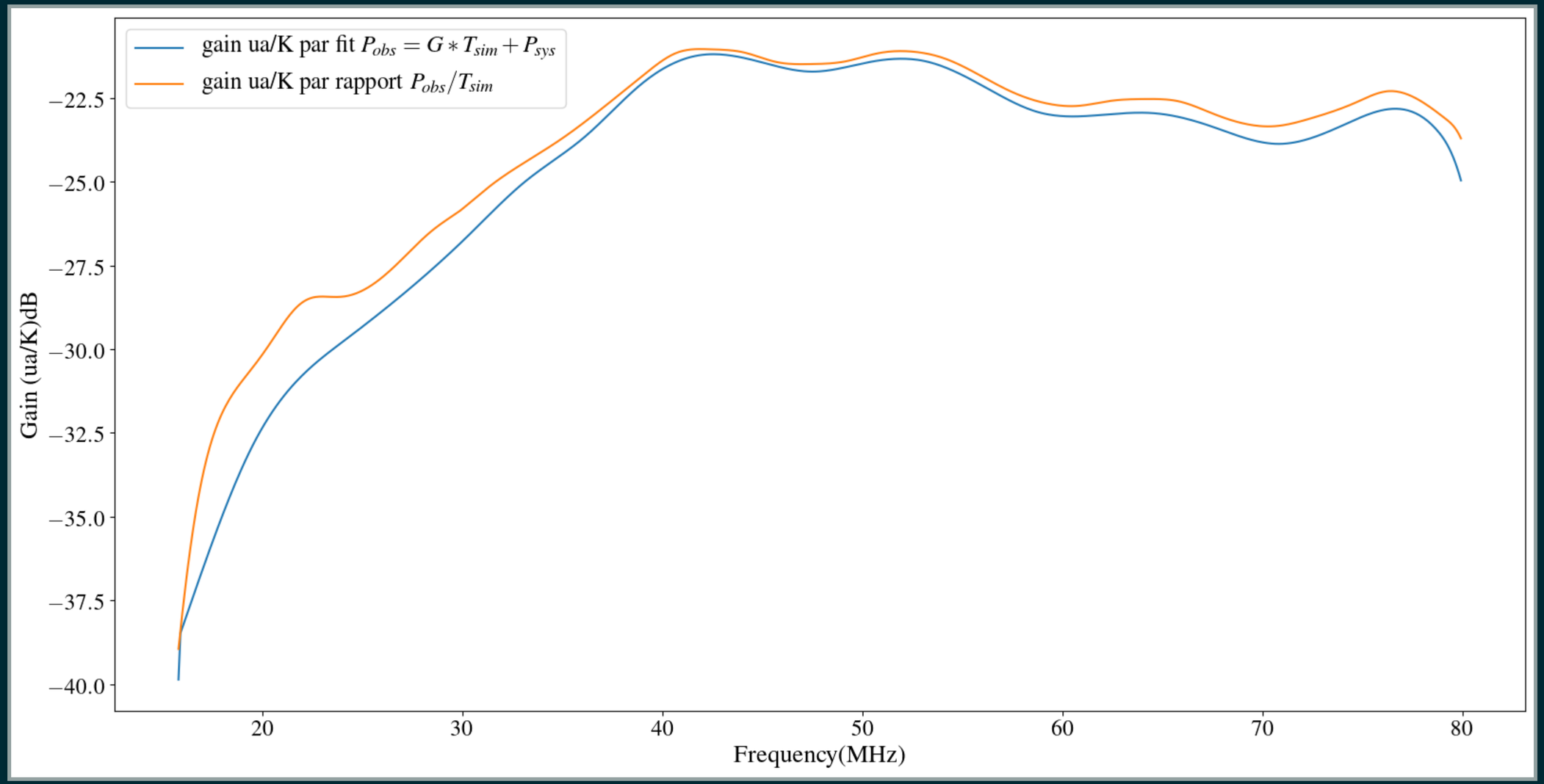
Refined model : sidereal time-template fit on data for both G and T_{noise} determination



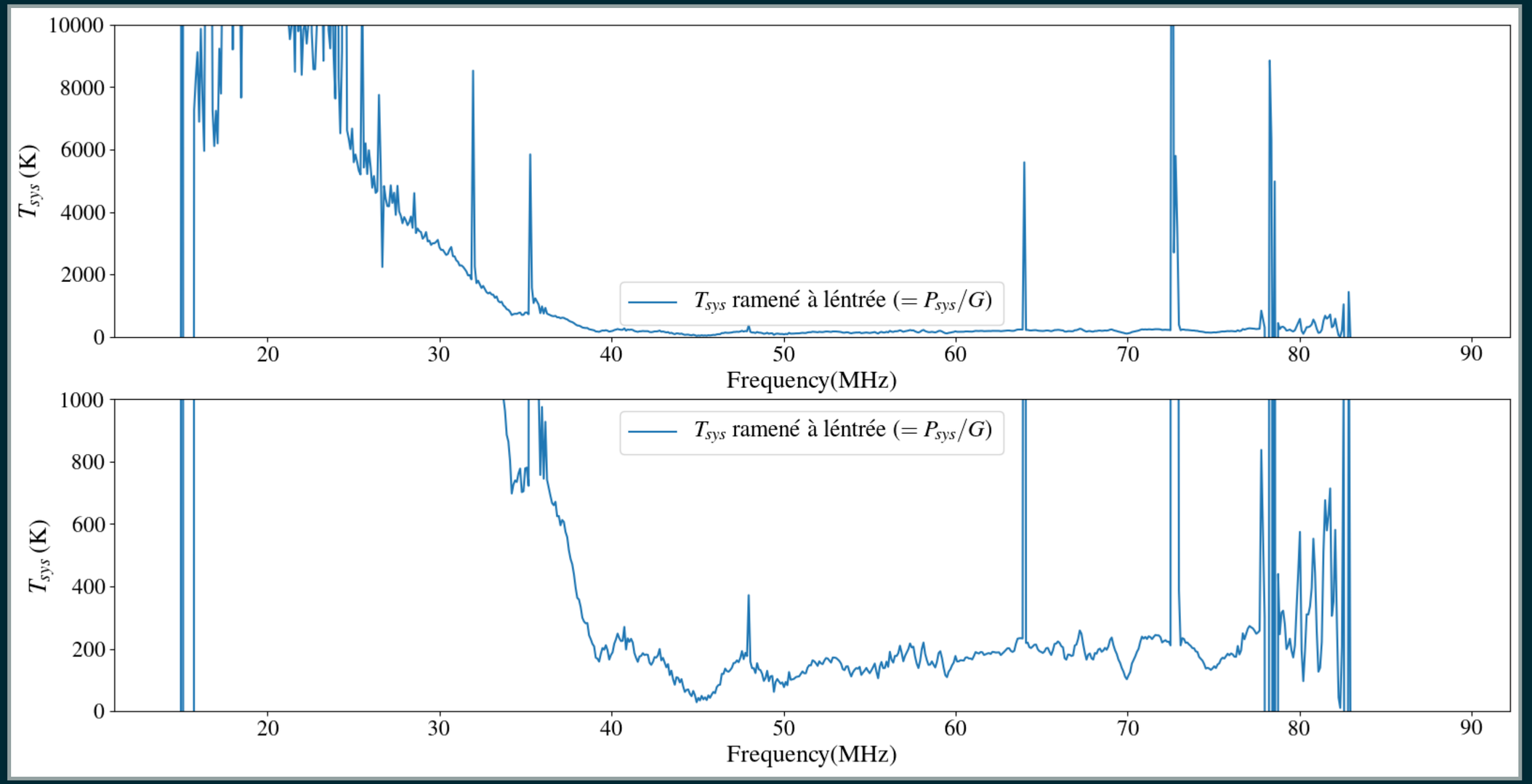
Model fit


40 a 45 MHz, 2020-01-01 au 2020-05-11, 1058 fichiers
donnees brutes
Iteration 1
Iteration 2
Iteration 3
Iteration 4
Iteration 5
Power (dB u.a.)
Temps sideral (rad)

Estimated gain

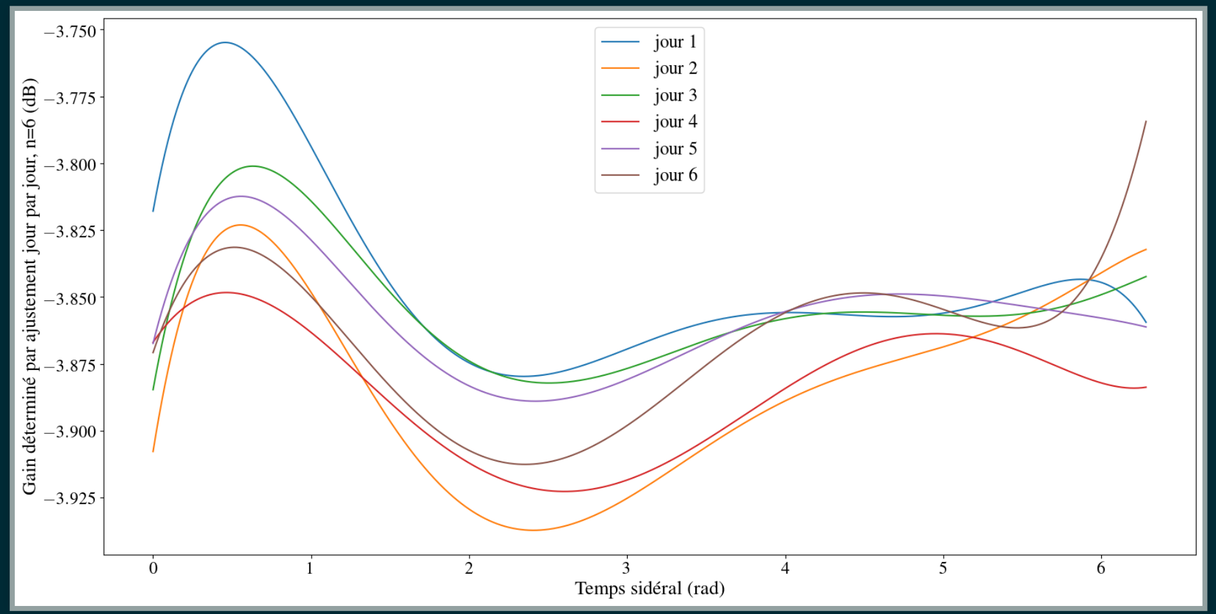


Estimated T_{noise}



Conclusions and perspectives

- Sky signal well detected in data/well modeled by antenna + sky
- can be used for gain and Tnoise calibration (100s of Kelvins dispersion though)
- room for improvements:
  - refining the model : environment (trees), instrumental response, long term and/or periodic variations
  - study of residuals vs. sidereal time : possible data based correction of the model
  - Lowest Frequencies (<30 MHz) : variability to be quantified on longer term



6-th order polynoms used for intra-day Gain correction