LOFAR subband statistics & station to CEP data coding

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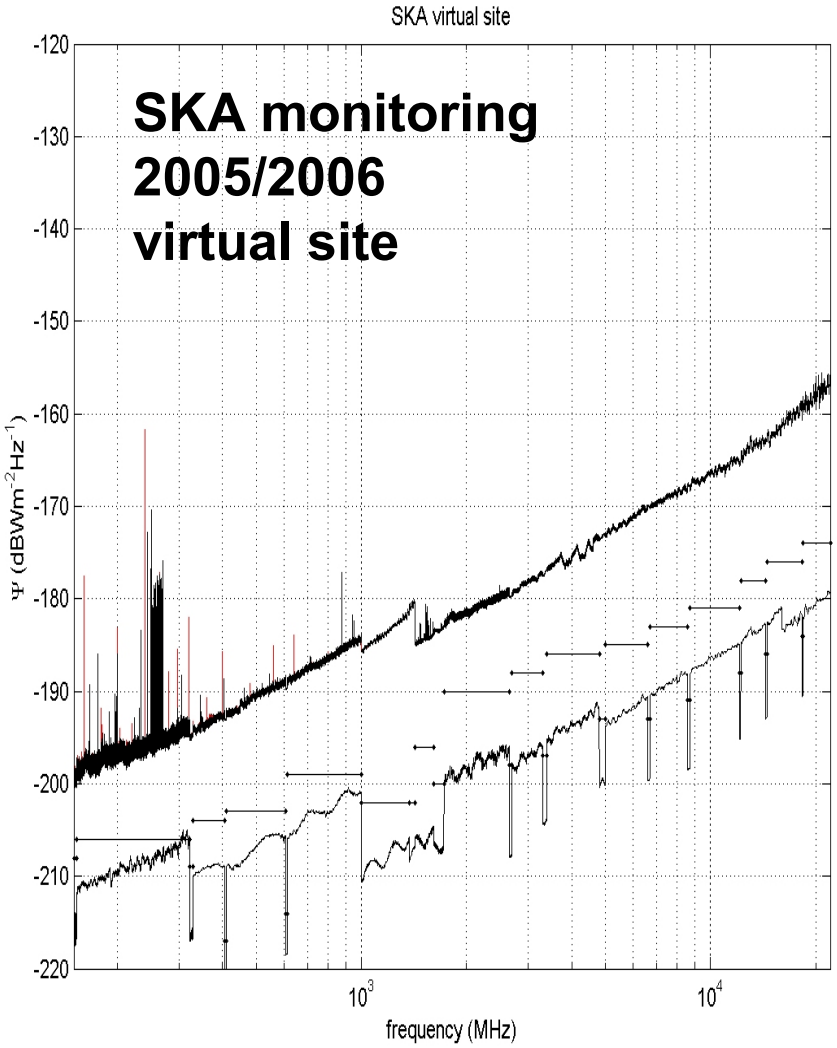
High sensitivity spectrum monitoring
- Measuring with sensitivitiues down to RA769
- LOFAR Core Station CS1 spectral occupancy statistics (ASTRON-JIVE daily image of 5-7-2007)

Reduction of data rates between stations and CEP
- Is 4 bits enough?

High sensitivity spectrum monitoring



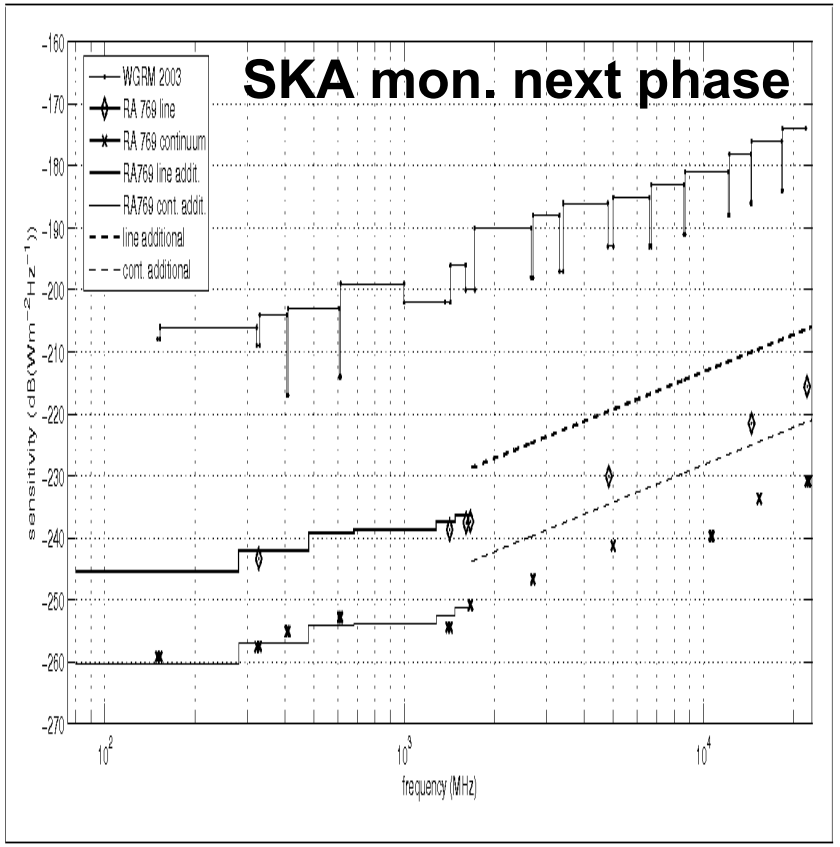
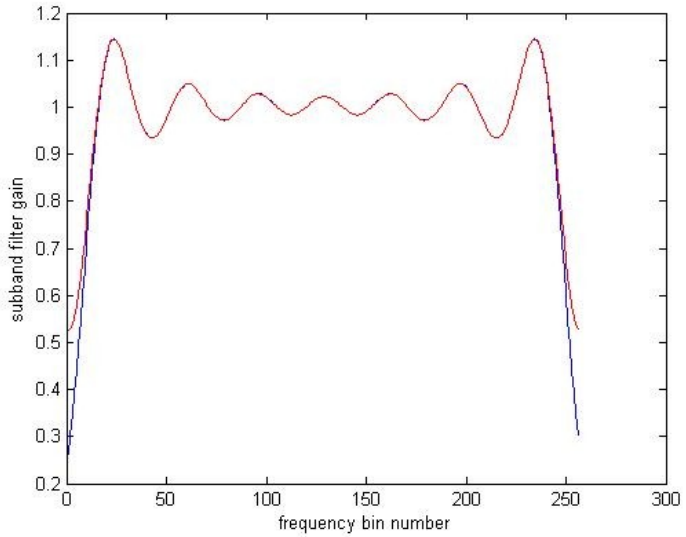
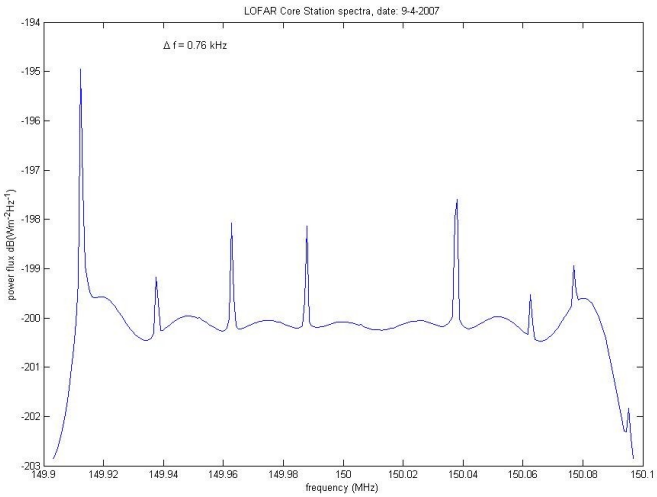


Figure 1: Comparison of sensitivity curves: mode two sensitivity curves from the 2003 RATF protocol[9], RA769 sensitivity curves (both line and continuum), and "RA769 line/cont. addit." curves which are "extrapolated" RA769 curves (also both line and continuum) for 80 MHz $\leq f \leq$ 1.4 GHz

Subband filter – passband shape





Theoretical passband shape

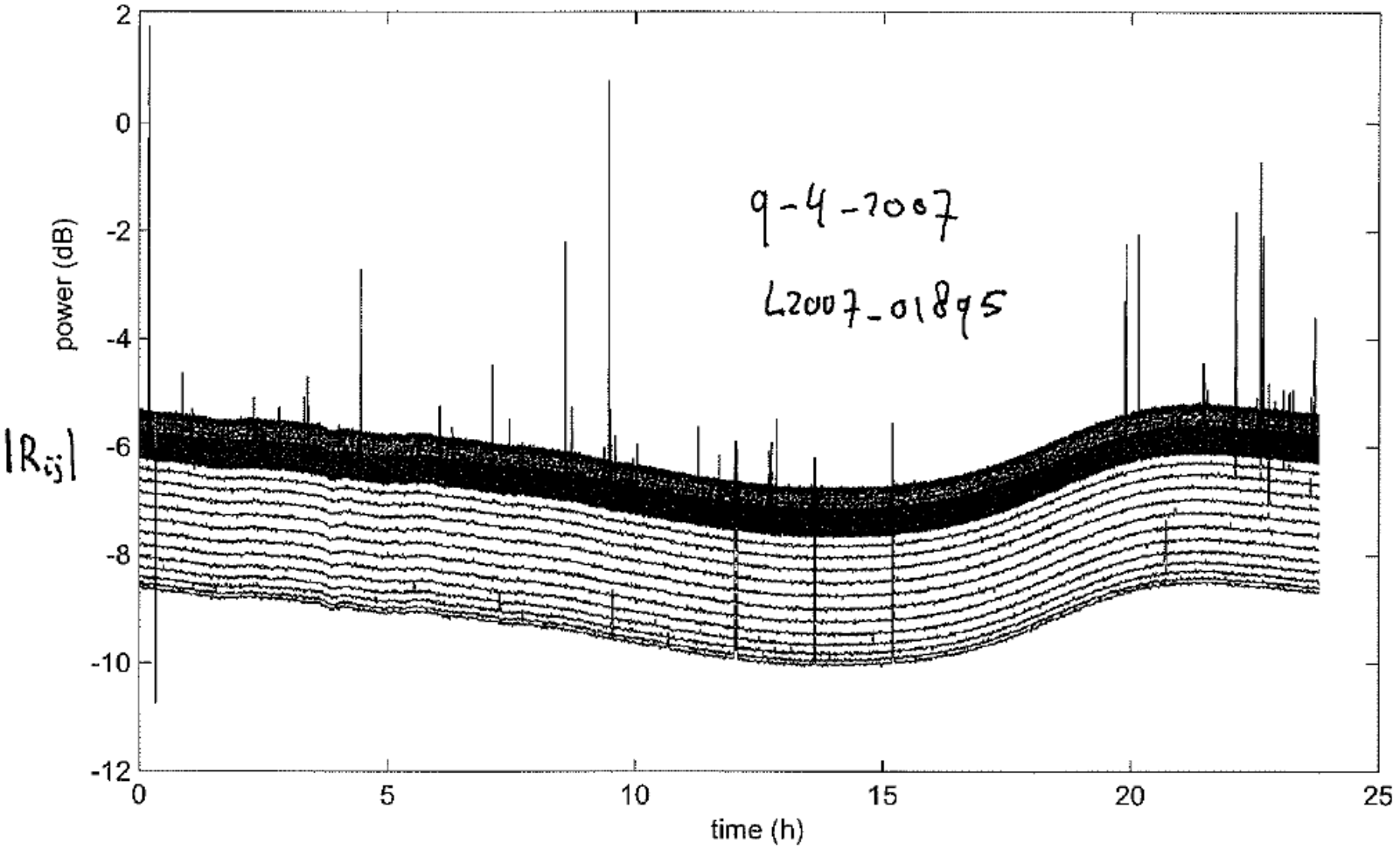
Blue: station subband filter
- 2^14 coefficients given
- FFT on 2^18 (zero-padded) points
- select 256 point of central passband
- Passband ripple ~1 dB

Red: include noise aliasing

LOFAR CS1 HBA CEP measurement

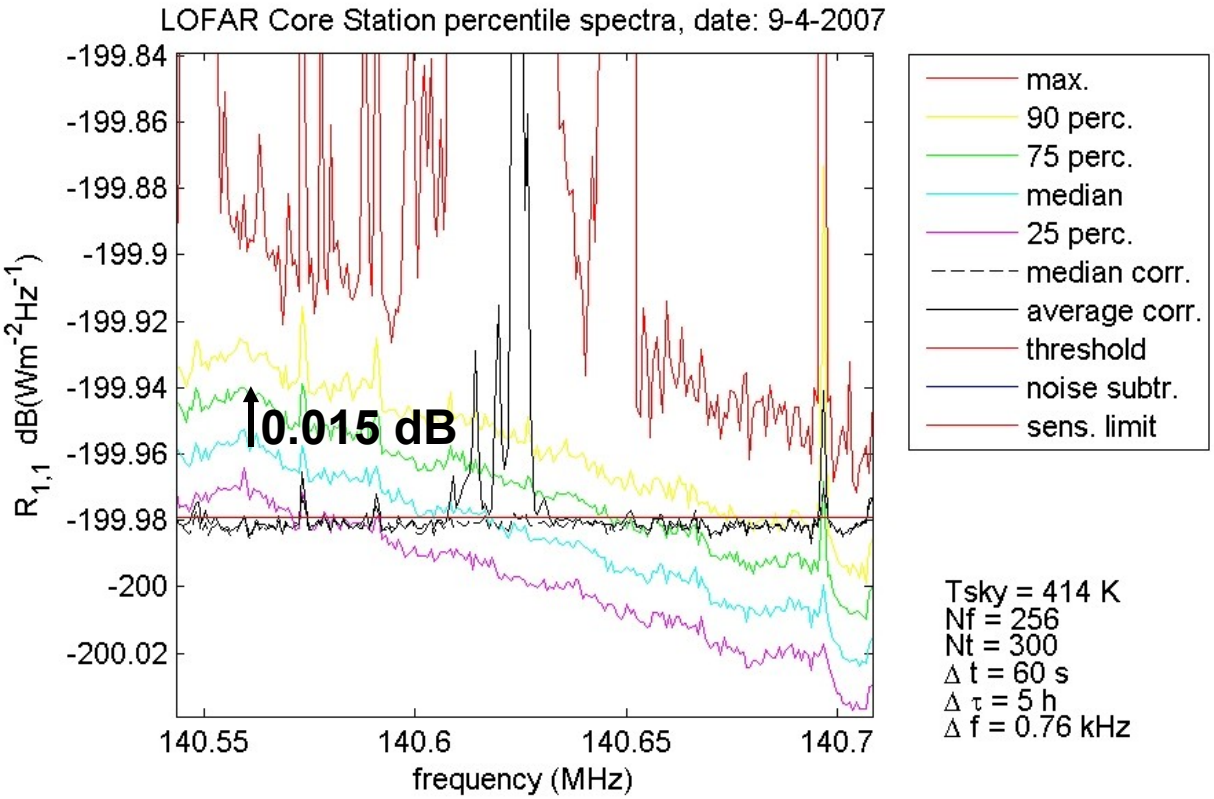
Some specs:
- f =150.000 MHz,
- df = 760 Hz
- dt = 60 s
- T = 24h
- Fs = 200 MS/s (flipped band)
- MS April 9 2007: L2008_01895

Power time variability, HBA, R_{11} @ CEP



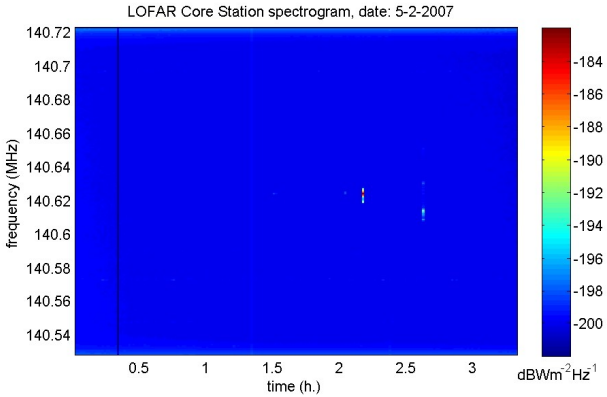
Autocorrelation R_{11} measured at CEP, all 256 f-bins

Occupancy statistics, R_{11} @ CEP



Tsky = 414 K
Nf = 256
Nt = 300
Δ t = 60 s
$\Delta \tau$ = 5 h
Δ f = 0.76 kHz

LOFAR MS
L2007-01895
9-4-2007
using
MS2MATLAB converter



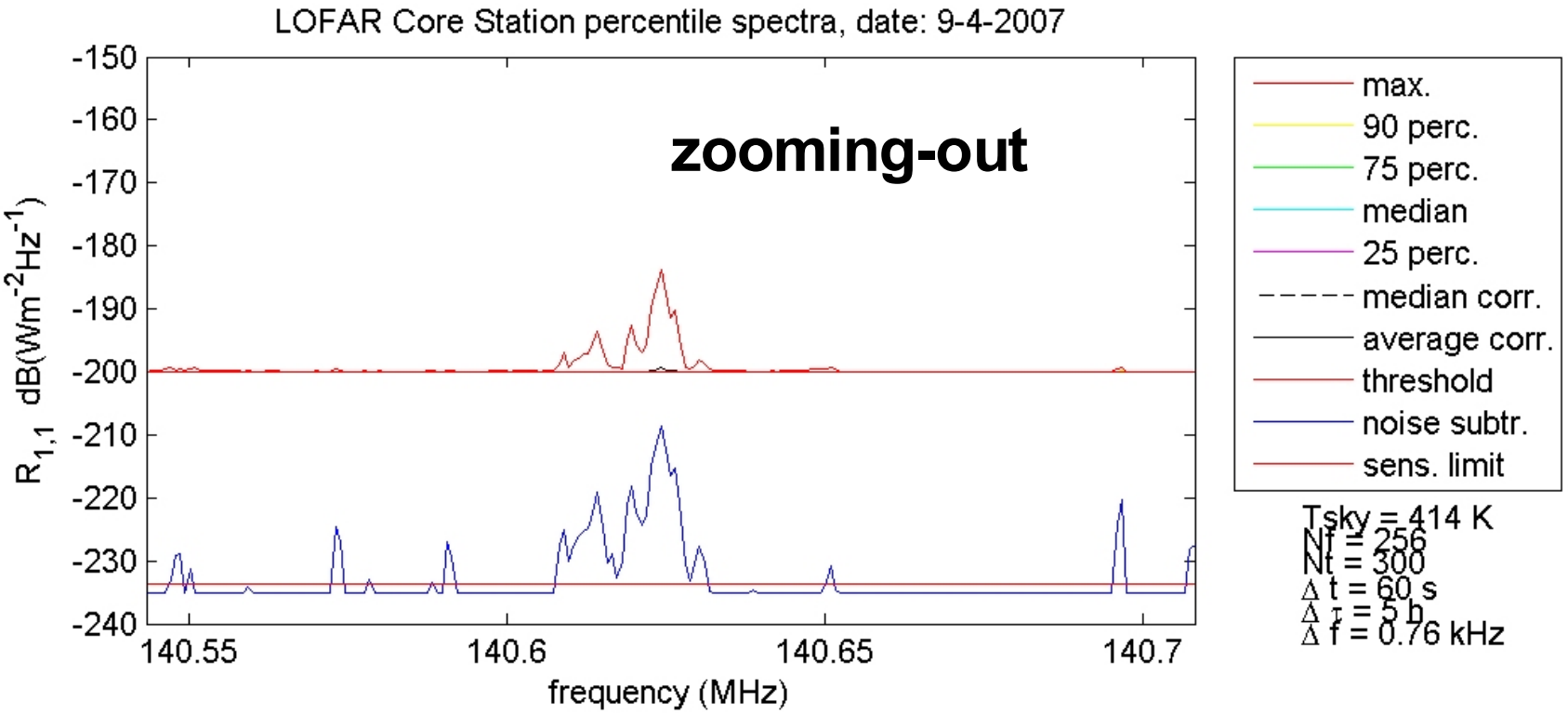
$\text{var}(R_{11}) = \sigma^4 / N$

$10 \log_{10}(\sigma^2 + \sigma^2/\sqrt{N}) \sim 10 \log10(\sigma2) + (10/\ln(10)) / \sqrt{N}$ (dB)

1 minute: $(10/\ln(10)) / \sqrt{N} \sim 4.34 \sqrt{(760 \,.\, 60)} \sim$ **0.02 dB**

5 hours: $(10/\ln(10)) / \sqrt{N} \sim 4.34 \sqrt{(760 \,.\, 60.60.5)} \sim$ **0.0012 dB**

Occupancy statistics, R_{11} @ CEP



$T_{sky} = T_0 (c/f)^{2.55}$; $T_0 = 60$ K

$\Psi_{sky} = 2k(f/c)^2 T_{sky} \Omega$ $(Wm^{-2}Hz^{-1})$; $\Omega = 4$ Sr

Low RFI levels: horizon effect

LOFAR HBA, July 2006

Percentile example: Lofar HBA tile

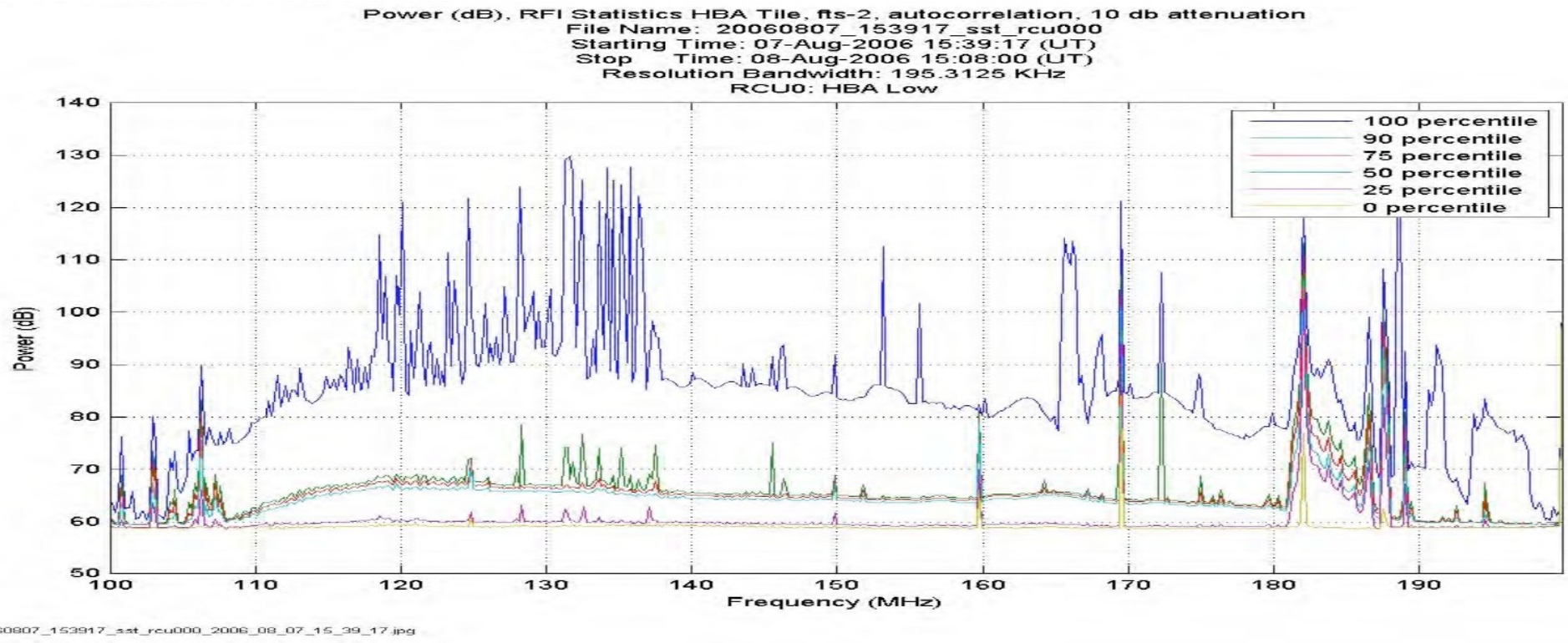
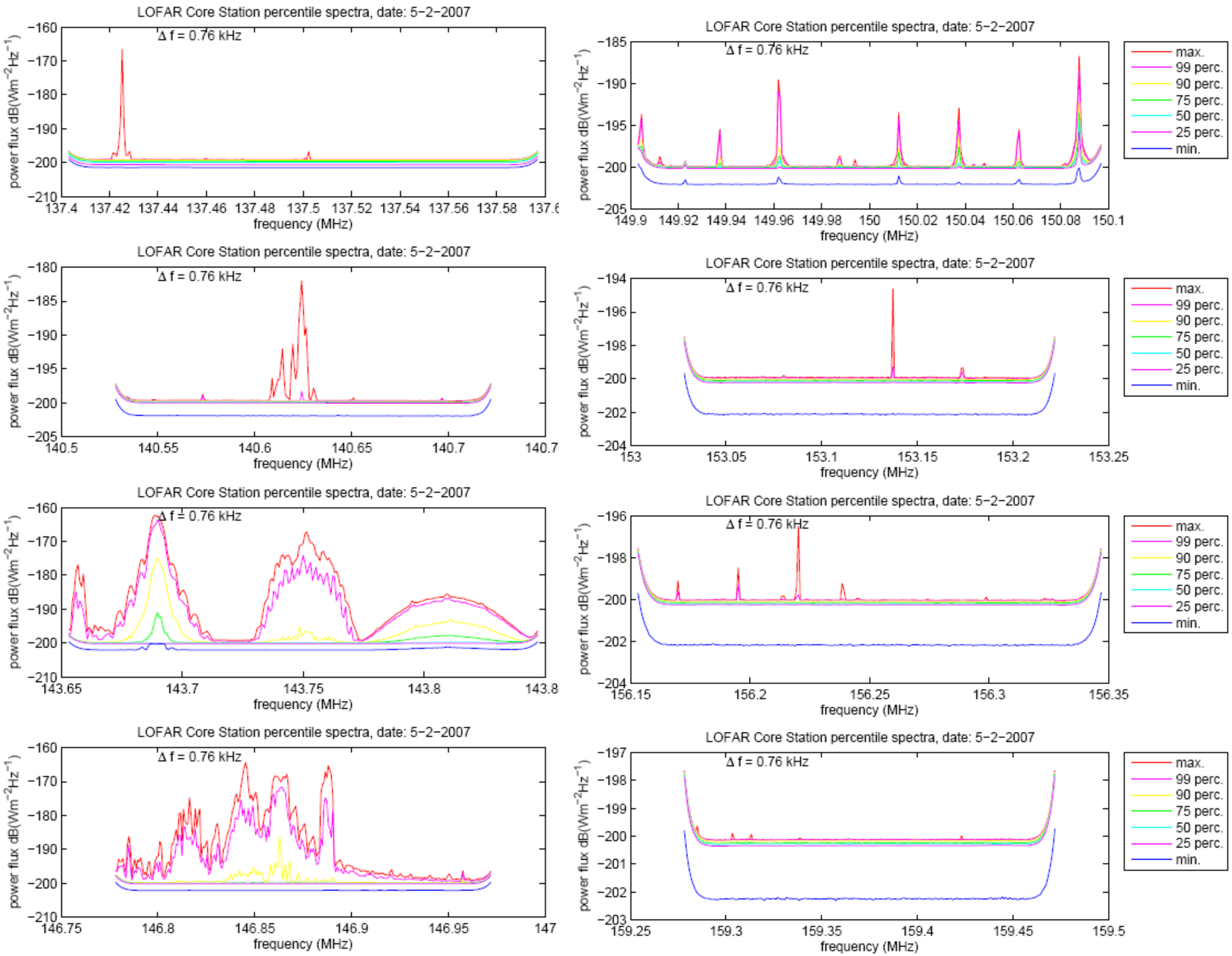
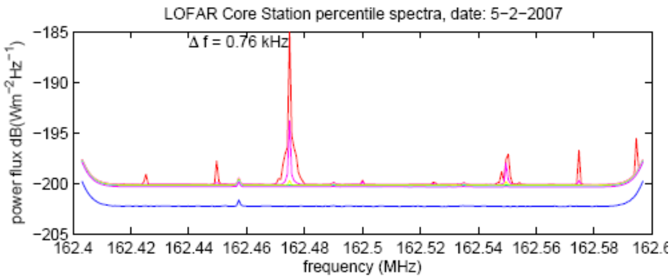


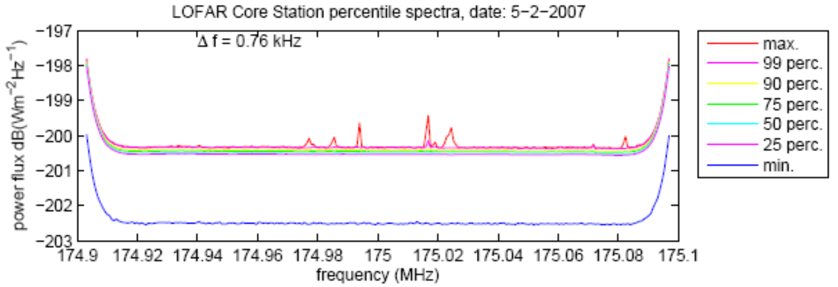
Figure 21. HBA tile measurement.

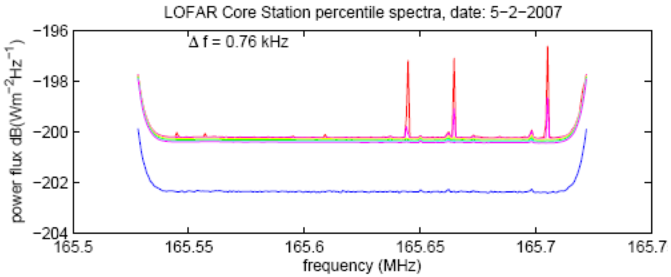
Occupancy HBA, L2007-01895, 9-4-2007

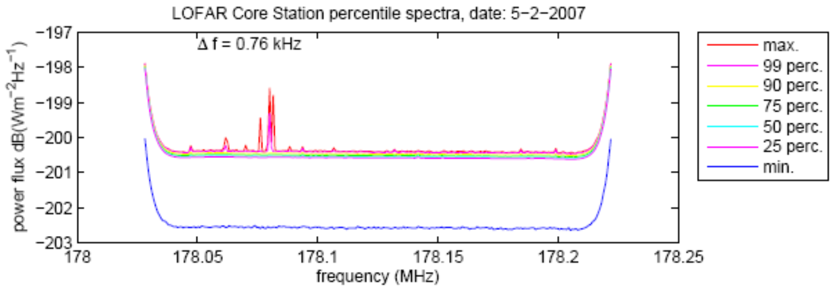


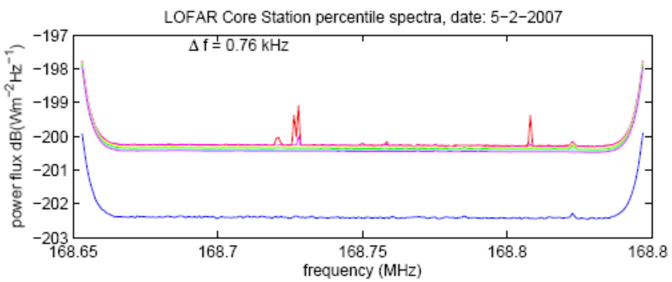
Occupancy HBA, L2007-01895, 9-4-2007

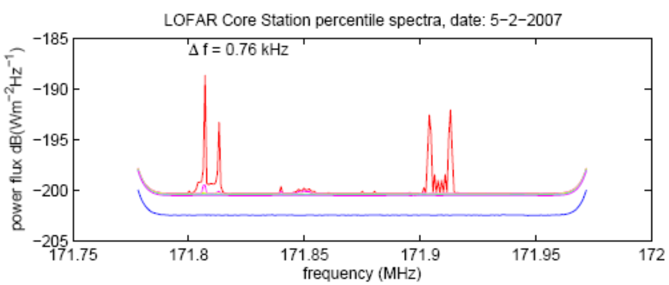








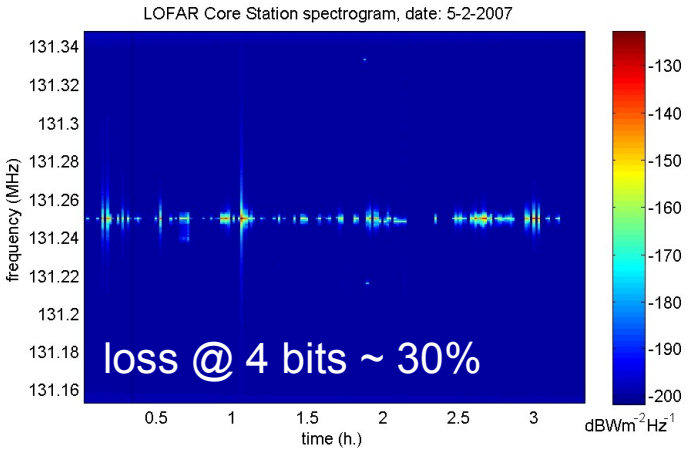


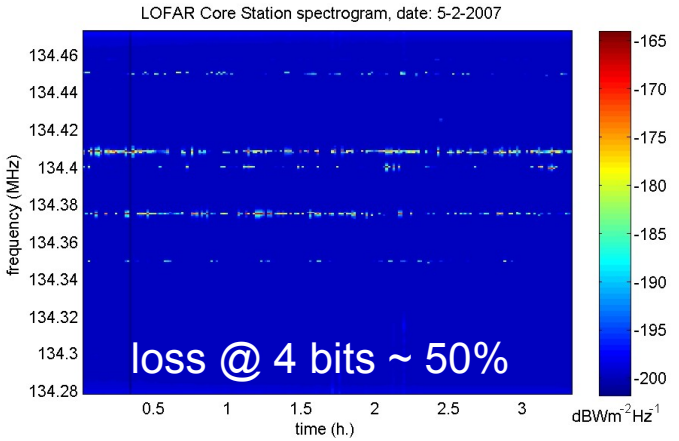


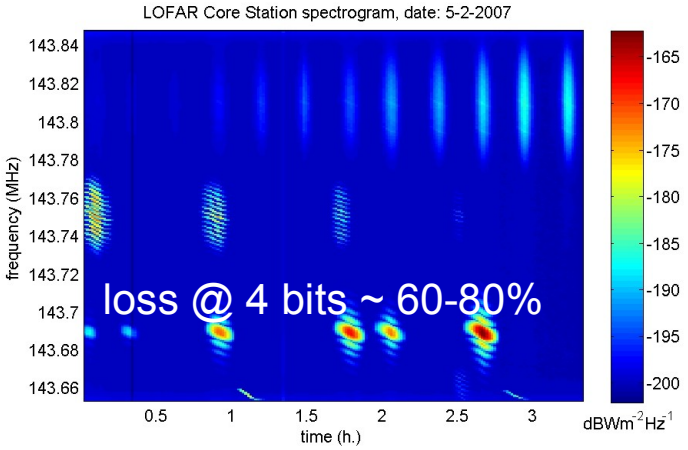
Note:

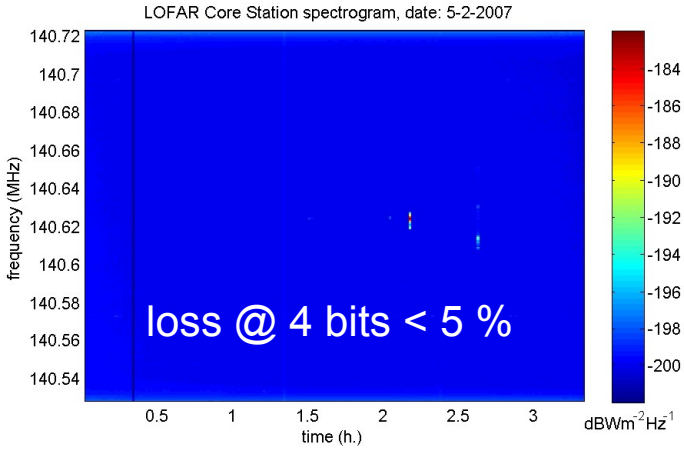
L2007_01895: 118.75-190 i.s.o. 170-230 MHz,
also: bandflip
L2007_01893: 175-232 MHz i.s.o. 110-190 MHz

Occupancy HBA, L2007-01893, 8-4-2007





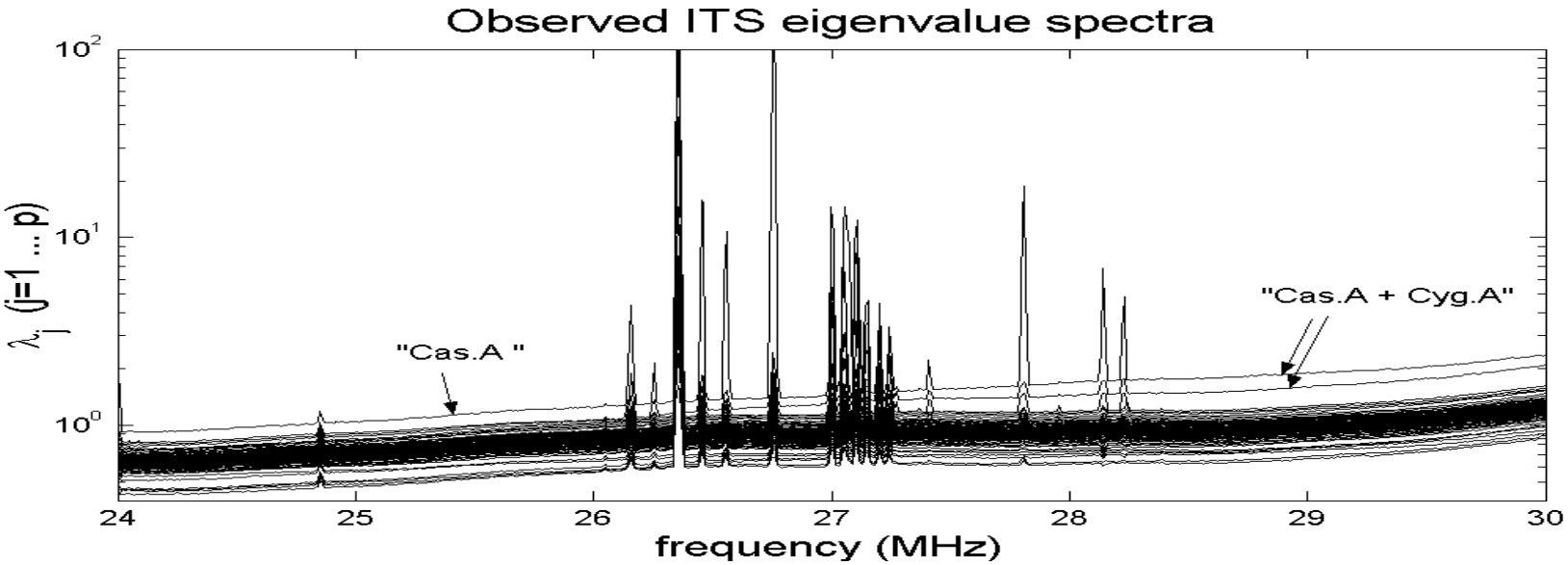


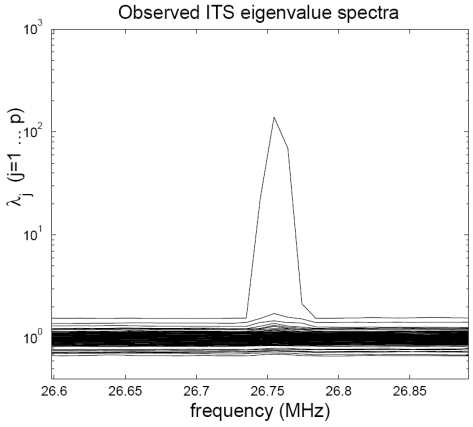


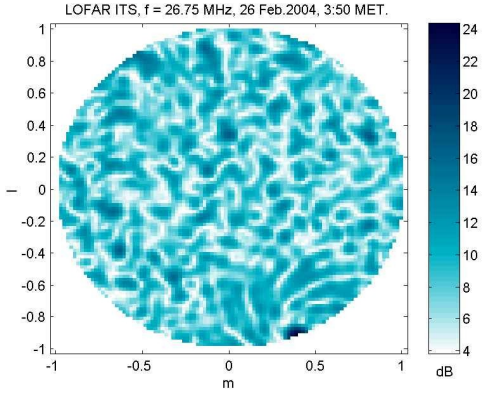
$\Psi_{rfi} << \Psi_{sys} + 10 \log_{10}(Nch)$ dB

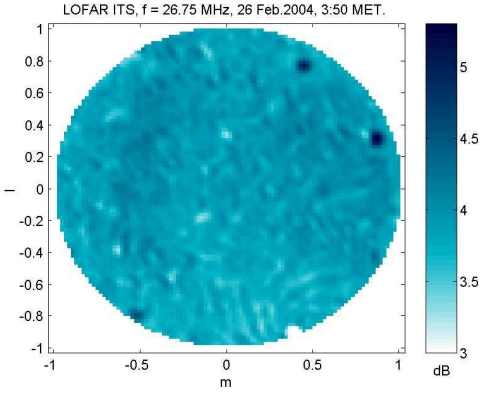
$\Psi_{rfi} << \Psi_{sys} + 24$ dB for $N_{ch} = 256$, and assuming RFI is located in one f-bin ony

Spatial filtering, ITS station results 2004









Conclusions

Spectrum monitoring

- LOFAR “monitoring measurements”:
  30-50 dB more sensitive than previous campaigns using standard mon. equipment
- Very few weak transmitters found which are not visible in 1 min. integrations (horizon effect)

HBA station to CEP data coding

- L02895 (112-181 MHz), using 4 bits: 16 bands unaffected, 8 bands affected (10-80%)
- L02893(174-232 MHz), using 4 bits: 21 bands unaffected, 3 bands affected (1-5%)
- Note: L02893 and L02895 were selected because of low level of RFI occurrence,

LBA station to CEP data coding

- 4 bit coding below 30 MHz difficult; spatial filtering difficult (multiple, varying transmissions)
- 4 bit coding in band 30-80 MHz: seems feasible in large fraction of t-f space

Reducing RFI levels by spatial filtering

- Part of the bands can be recovered by fixed nulls (≈ 20 dB)
- Even some satellite bands can be recovered if varying nulls (<≈1 deg/s) are accepted

Next steps

- More detailed occupancy statistics needed:
  - better time resolution (1s in stead of 1 min) and freq. Band coverage
  - compare subband satistics with CEP data
- Investigate certain features (passband residual, repetitive spectral features)
- Investigate Matlab access to MS data (HDF5 or MS2MATLAB conversion on CEP)