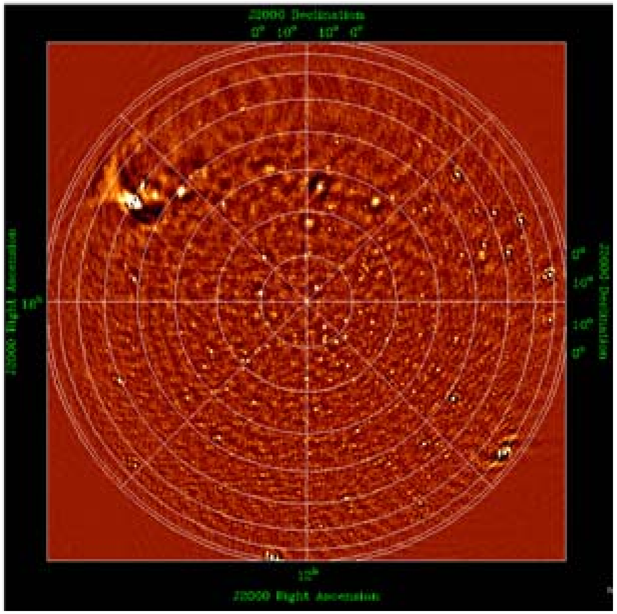
LOFAR imaging capabilities and system sensitivity



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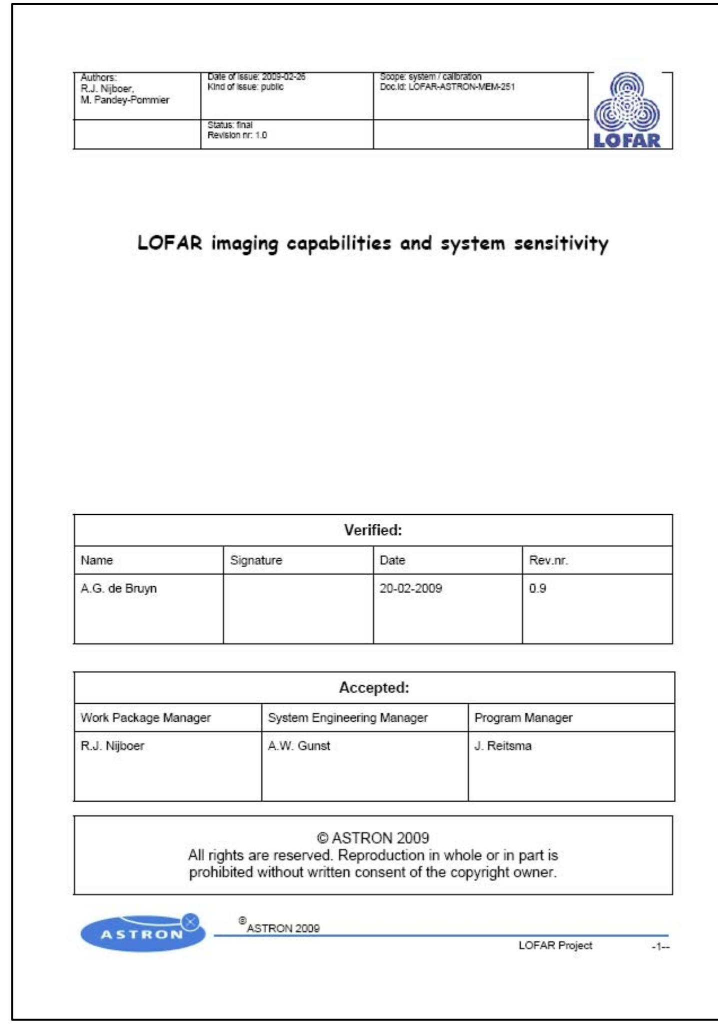
Contents

- LOFAR-ASTRON-MEM-251
- Available from:
  - LOFAR document server
  - LOFAR wiki TWG pages
- Station configurations
- Imaging capabilities
- Sensitivity
  - First order, to help planning



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	Status: final Revision nr: 1.0		

LOFAR imaging capabilities and system sensitivity

Verified:			
Name	Signature	Date	Rev.nr.
A.G. de Bruyn		20-02-2009	0.9

Accepted:		
Work Package Manager	System Engineering Manager	Program Manager
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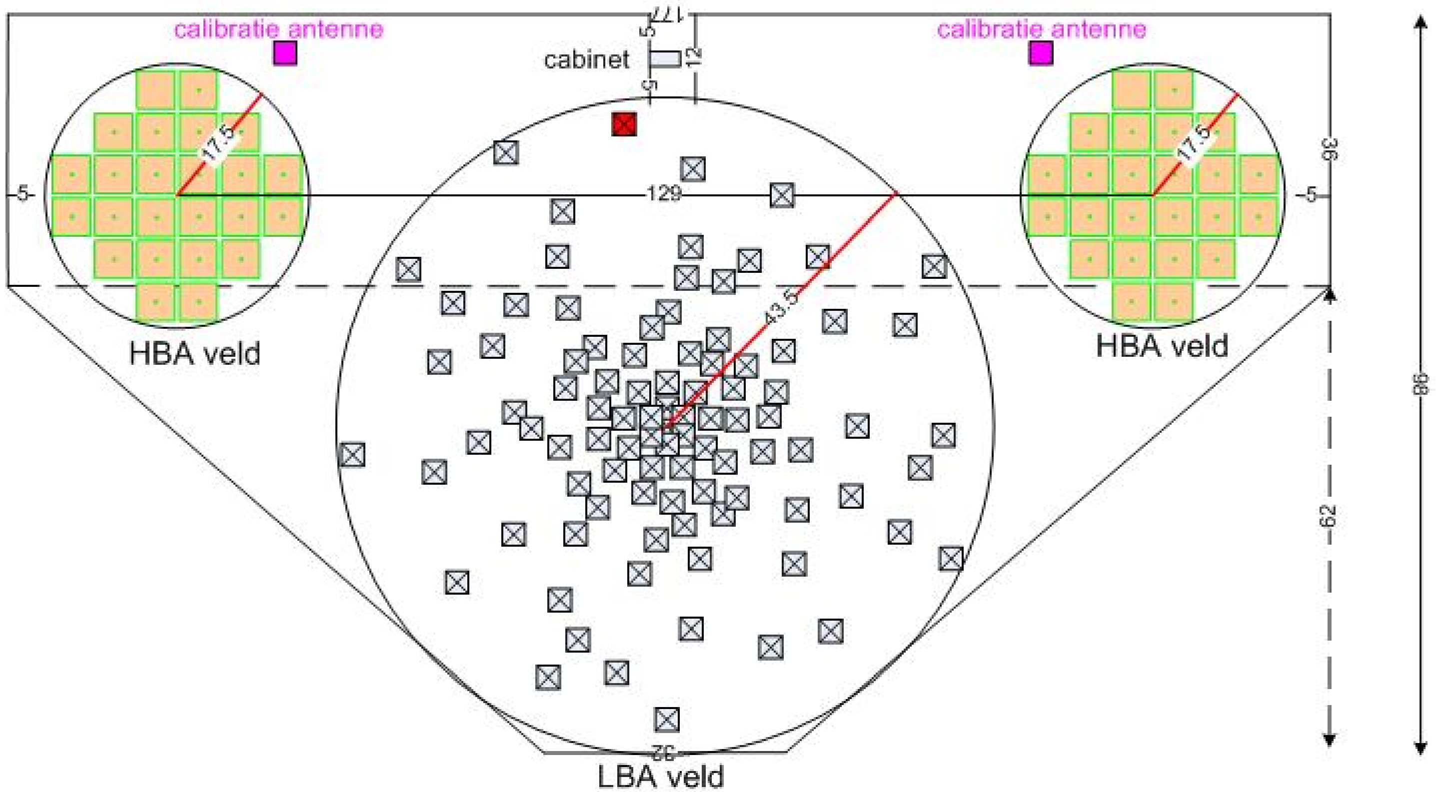
http://www.lofar.org/operations/doku.php?id=dmt:dmt_documents

Configurations: Core



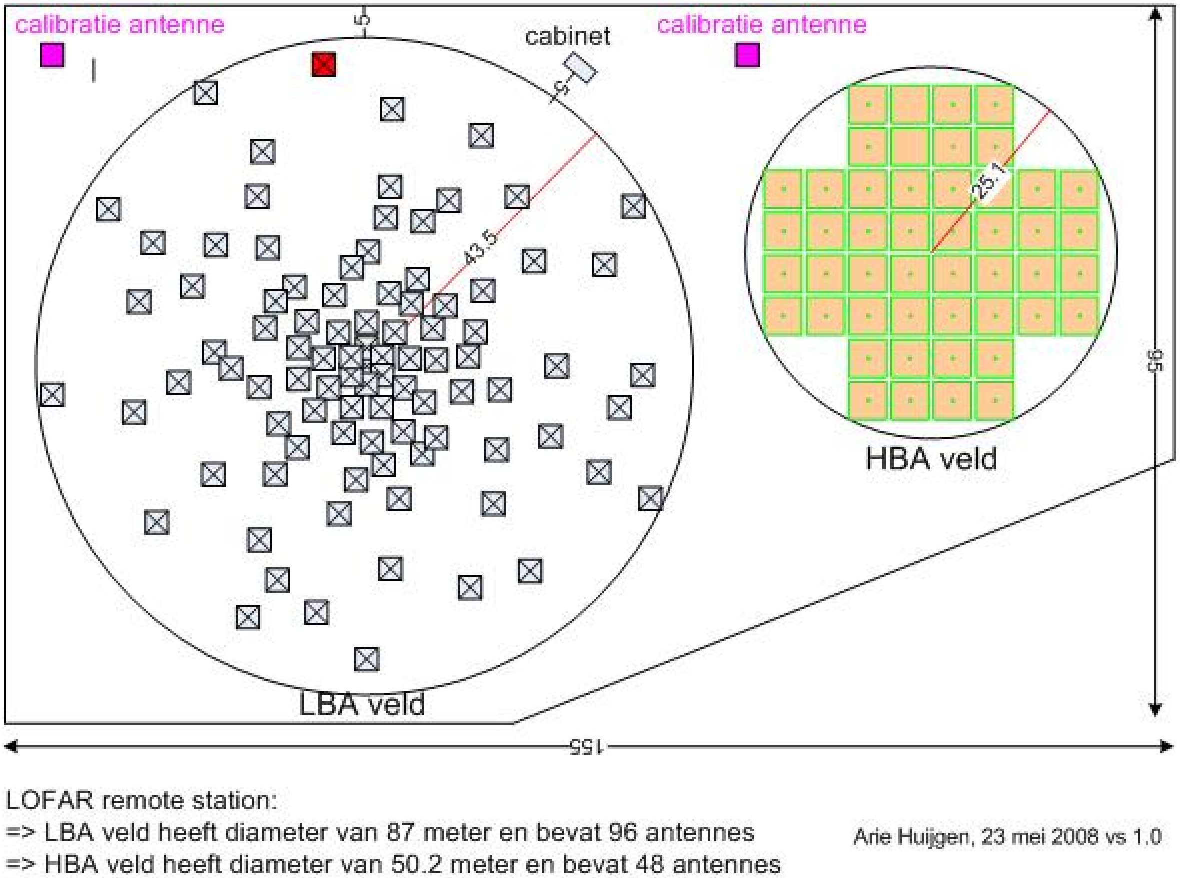
LOFAR CORE station:
=> LBA veld heeft diameter van 87 meter en bevat 96 antennes
=> 2 HBA velden (elk met een diameter van 35 meter) bevatten elk 24 antennes

Arie Huijgen, 23 mei 2008 vs 1.0

LBA 81 m diameter
HBA 30 m diameter

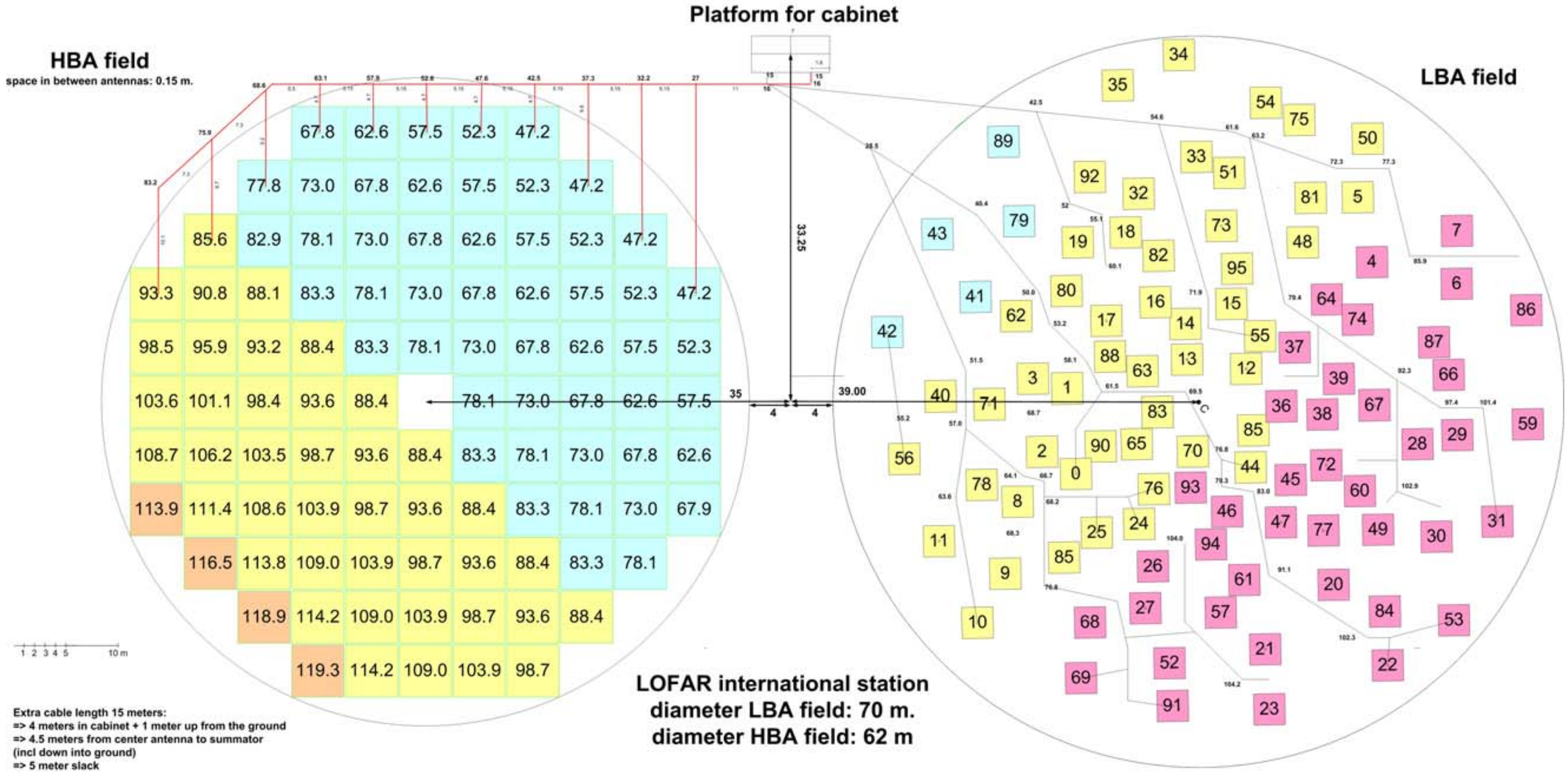
CS302

Configurations: Remote



LBA 81 m diameter
HBA 41 m diameter

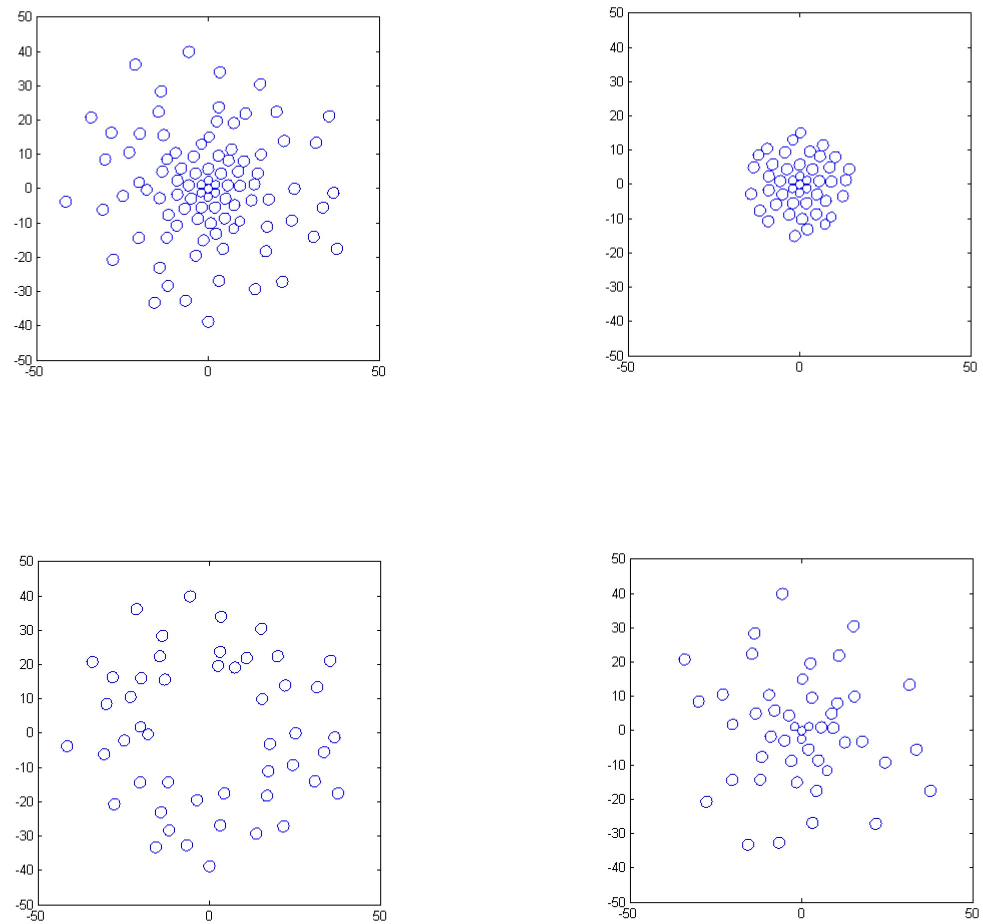
Configurations: European



LBA 65 m diameter
HBA 56 m diameter

Configurations: LBA dipole selection

- Inner array:
  32 m diam.
- Outer array:
  81 m diam.
- Sparse array:
  81 m diam.
- All X array:
  81 m diam
- All Y array:
  81 m diam.



Imaging capabilities (1)

Freq (MHz)	λ (m)	Stat. diam. D (m)		FWHM (deg)		FoV (sq.deg.)		# pointings all sky Nyquist sampled	
15	20.0	32.3	81.3	46.2	18.3	1676	263	38.7	246
30	10.0	32.3	81.3	23.1	9.16	419	65.8	155	984
45	6.67	32.3	81.3	15.4	6.10	186	29.3	348	2214
60	5.00	32.3	81.3	11.6	4.58	105	16.5	619	3936
75	4.00	32.3	81.3	9.24	3.66	67.0	10.5	967	6149
120	2.50	30.8	41.1	6.06	4.54	28.8	16.2	2250	4009
150	2.00	30.8	41.1	4.84	3.63	18.4	10.3	3515	6265
180	1.67	30.8	41.1	4.04	3.02	12.8	7.18	5062	9021
210	1.43	30.8	41.1	3.46	2.59	9.40	5.28	6890	12279
240	1.25	30.8	41.1	3.03	2.27	7.20	4.04	8999	16038

$$FWHM = \alpha_1 \frac{\lambda}{D}, \qquad \alpha_1 = 1.3, \qquad FoV = \pi \left(\frac{FWHM}{2} \right)^2$$

Imaging capabilities (2)

Freq. (MHz)	λ (m)	Resolution L = 2 km (arcsec)	Resolution L = 10 km (arcsec)	Resolution L = 80 km (arcsec)
15	20.0	1650	330	41.3
30	10.0	825	165	20.6
45	6.67	550	110	13.8
60	5.00	413	82.5	10.3
75	4.00	330	66.0	8.25
120	2.50	206	41.3	5.16
150	2.00	165	33.0	4.13
180	1.67	138	27.5	3.44
210	1.43	118	23.6	2.95
240	1.25	103	20.6	2.58

$$\alpha_2 \frac{\lambda}{L}, \qquad \alpha_2 = 0.8,$$

System Equivalent Flux Density

- System Equivalent Flux Density (SEFD):

$$S_{sys} = \frac{2\eta k}{A_{eff}} T_{sys}$$

- System Temperature:

$$T_{sys} = T_{sky} + T_{instr}$$

- Sky Temperature:

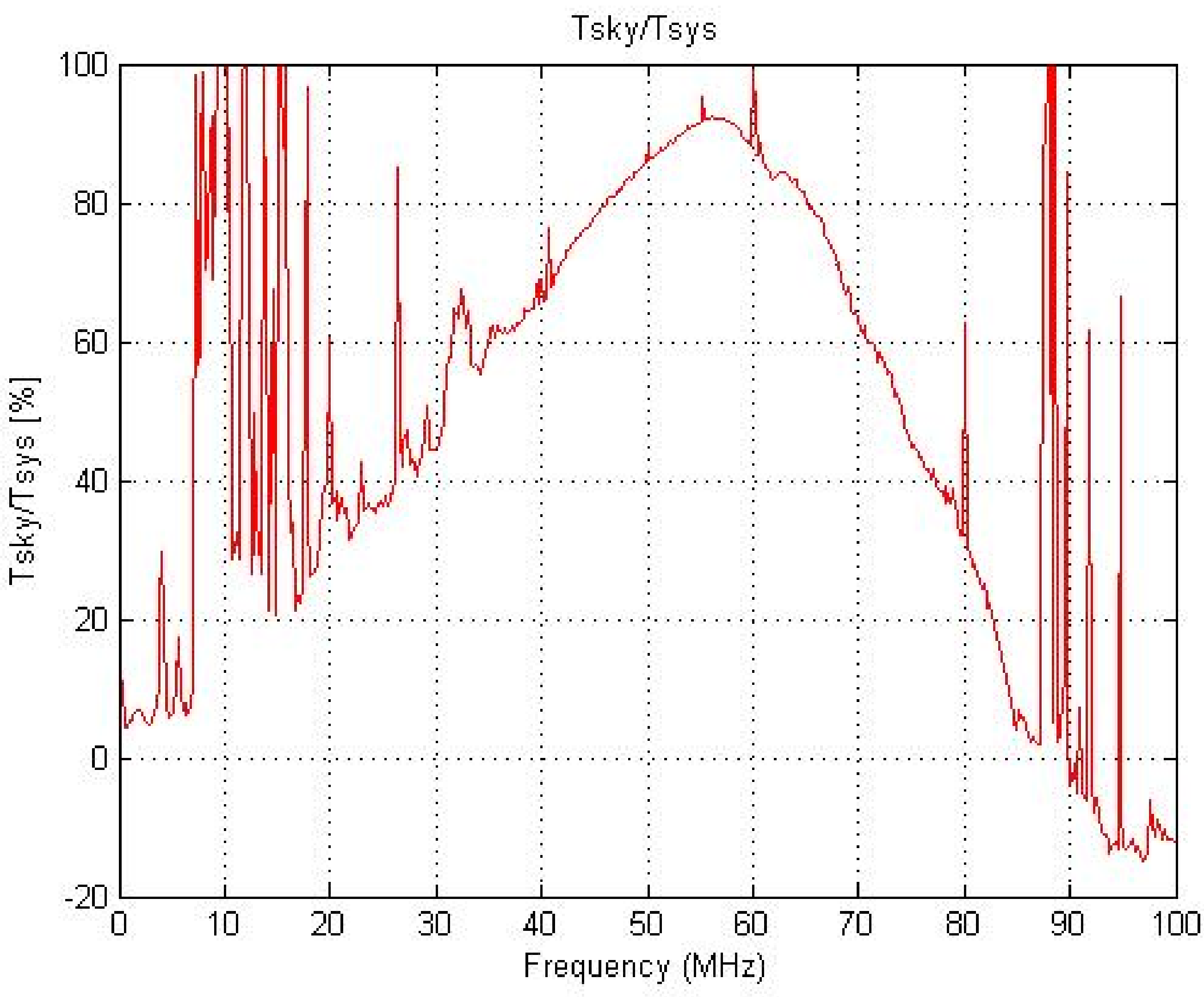
$$T_{sky} = T_{s0} \lambda^{2.55}$$

T_{s0} = 60 ± 20 K

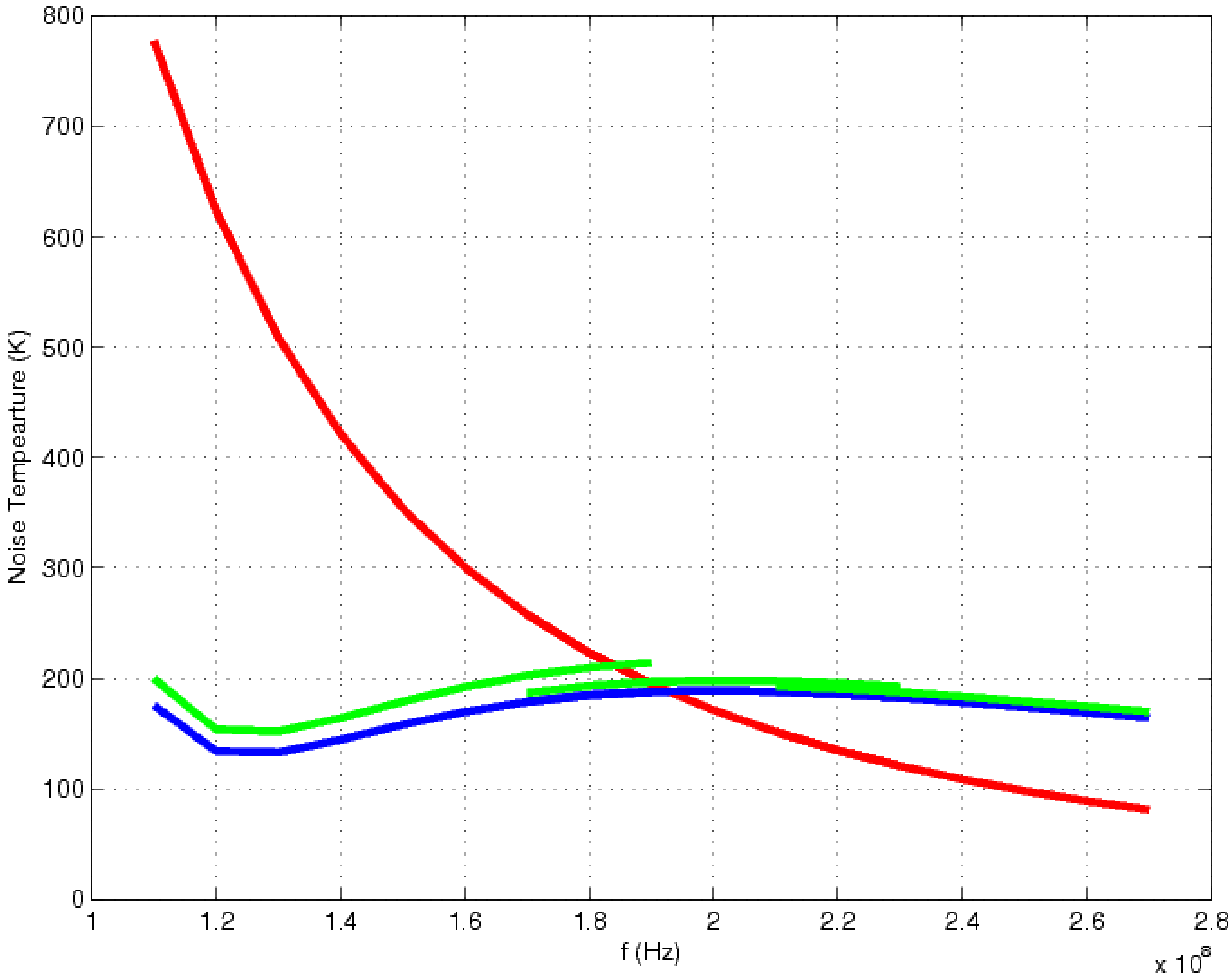
- Effective Area

$$A_{eff}$$

SEFD: LBA Dipole System Temperature



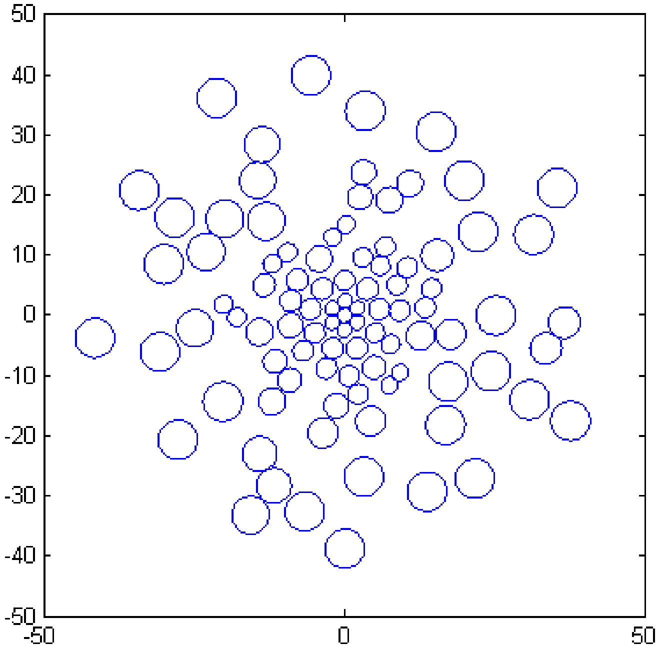
SEFD: HBA Tile System Temperature



SEFD: Effective Area

- LBA:

$$A_{eff,dipole} = \min\left\{\frac{\lambda^2}{3}, \frac{\pi d^2}{4}\right\}$$



30 MHz

- HBA:

$$A_{eff,dipole} = \min\left\{\frac{\lambda^2}{3}, 1.5625\right\}$$

SEFD: Effective Area

Freq (MHz)	λ (m)	Aeff inner (46)	Aeff outer (48)	Aeff sparse (48)	48 * Aeff_dipole
15	20.0	419.77	1973.4	1148.6	6400.0 *
30	10.0	419.77	1343.5	869.14	1600.0
45	6.67	415.83	693.61	558.64	711.11
60	5.00	347.37	398.18	371.19	400.00
75	4.00	239.67	256.00	247.43	256.00

Freq. (MHz)	λ (m)	Core	Remote	European
120	2.50	600	1200	2400
150	2.00	512	1024	2048
180	1.67	356	711	1422
200	1.50	288	576	1152
210	1.43	261	522	1045
240	1.25	200	400	800

SEFD (single polarization)

Freq (MHz)	NL-Core (kJy)	NL-Remote (kJy)	EU-Remote (kJy)
15	483	483	519
30	89	89	41
45	48	48	19
60	32	32	15
75	51	51	25
120	3.6	1.8	0.89
150	2.8	1.4	0.71
180	3.2	1.6	0.81
210	3.7	1.8	0.92
240	4.1	2.0	1.0

Sensitivity

$$\Delta S = \frac{W}{\sqrt{2(2\delta\upsilon\delta t)\left\{\frac{N_c(N_c-1)/2}{S_{core}^2} + \frac{N_c N_r}{S_{core}S_{remote}} + \frac{N_r(N_r-1)/2}{S_{remote}^2}\right\}}}$$

Freq. (MHz)	λ (m)	ΔS_{13+7} (mJy)	ΔS_{13+7} Tapered (mJy)	ΔS_{18+18} (mJy)	ΔS_{25+25} (mJy)
15	20.0	201		110	79
30	10.0	37		20	15
45	6.67	20		11	7.8
60	5.00	13		7.2	5.2
75	4.00	21		12	8.4
120	2.50	0.74	0.89	0.41	0.29
150	2.00	0.58	0.71	0.32	0.23
180	1.67	0.67	0.81	0.37	0.26
210	1.43	0.76	0.91	0.42	0.30
240	1.25	0.84	1.0	0.46	0.33

Table 10 LOFAR sensitivity for 1 hour integration time, an effective BW of 3.57 MHz, and dual polarization. A weighting factor of 1.3 is applied. 13+7 denotes 13 core + 7 remote stations, while 18+18 denotes 18 core stations + 18 remote stations and 25+25 denotes 25 core stations + 25 remote stations. The "Tapered" column has the remote stations tapered to core size for use during the Million Source Shallow Survey (MSSS).

Cautionary notes

- Definite values for α_1 and α_2 have to be determined during the commissioning of LOFAR.
- The sky brightness varies with factors of a few. Furthermore, the very bright galactic plane will contribute quite a lot of power through side and, in some cases, grating lobes increasing the effective visibility noise.
- The inner sidelobes of a (HBA) station need to be suppressed to reduce scattered sidelobe noise. This will be done by tapering the station beam which has the drawback that the sensitivity will be reduced by 30-50%.
- The sensitivity is varies with azimuth and elevation. Current values are averaged over azimuth and elevation.
- Dynamic range may be limited by self-cal performance. To what extent needs to be determined during commissioning.
- The effect of mutual coupling on the sensitivity is yet unknown.

Verification and acceptance

- The current numbers are first order estimates, to be used for initial planning of (commissioning) observations
- The actual sensitivity of a LOFAR station needs to be determined during the station acceptance procedure
  - Station acceptance
    - Station validation
    - Station design verification
      - Determination of Station Sensitivity (Aeff / Tsys)
  - CEP acceptance
  - Commissioning acceptance