Calibratability-by-design for AERA^3

Stefan J. Wijnholds
e-mail: wijnholds@astron.nl

MIDPREP Meeting
Dwingeloo (The Netherlands), 1 April 2014

Introduction

Dynamic range is not a suitable figure of merit

Effective noise

- thermal noise
- classical source confusion noise
- calibration noise (estimation noise + penalty for corrections)
- calibration artefacts
- far sidelobe confusion noise (FSCN)
- psf sidelobe confusion noise (PSCN)

Last 5 factors can be mitigated by **design-for-calibratability**

Calibratability

Calibratability: ability to reach thermal noise limit

This requires

- sufficiently low psf sidelobes to avoid PSCN
- sufficiently low station sidelobes to avoid FSCN
- sufficiently long baselines to avoid classical source confusion
- sufficient system stability to calibrate with sufficient accuracy

Overall noise budget

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	Assumption	value
thermal noise		1σ
calibration noise	10% penalty for extraction of information in selfcal process	0.1σ
	20% penalty for calibraiton corrections	0.2σ
	thermal noise level after selfcal	***1.3σ***
source confusion	negligible	0
cal. artefacts	absent	0
PSCN	balanced with thermal noise	1σ
FSCN	balanced with thermal noise	1σ
	effective noise	***2.05σ***

African European Radio Astronomy AA

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Assumed specifications

- frequency range: 500 – 1500 MHz
- regular station array, spacing 13.3 cm (scan range 60°)
- A_{eff} = min(λ^2/3, 0.133^2) m^2 per antenna
- A_{phys} = ~5000 m^2 distributed over 14 stations
- station diameter: 21 m (~20k antennas per station)
- $T_{sys} = 1.1\ T_{sky} + 40 = 66\ \lambda^{2.55} + 40$ K
- maximum baseline: 1 km

Sensitivity of AERA³

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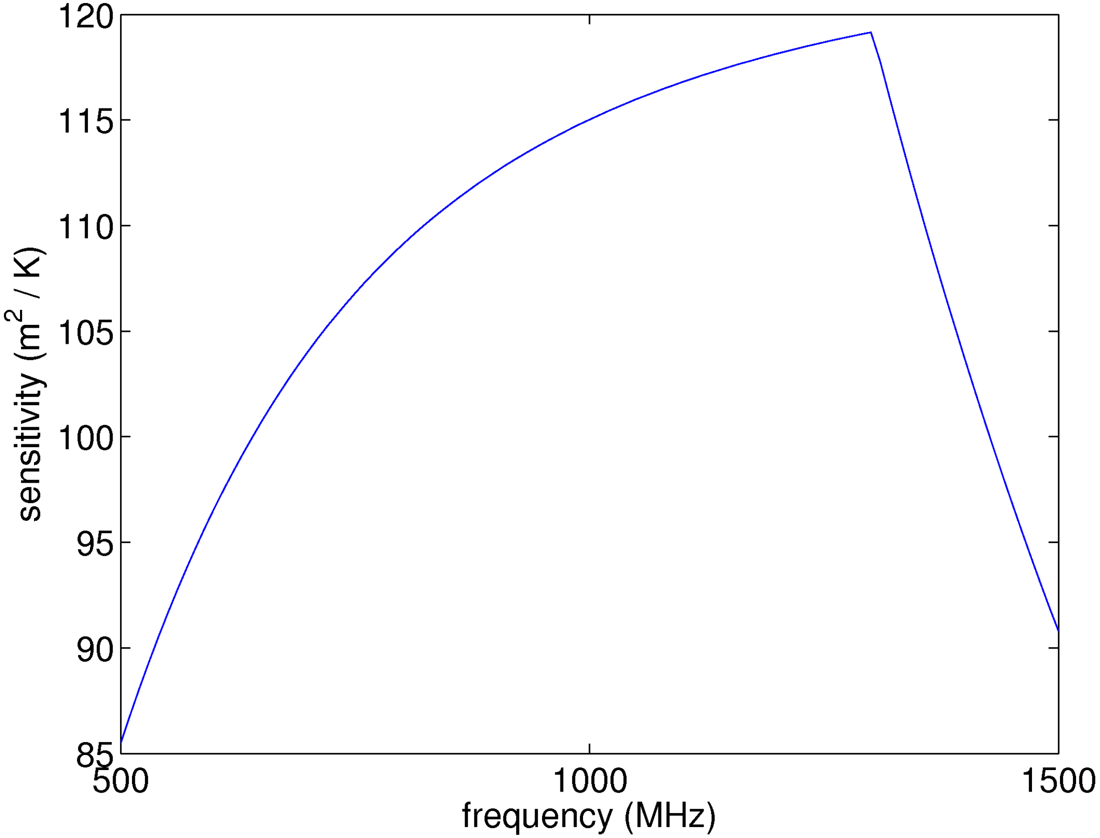
Sensitivity comparable to APERTIF and ASKAP

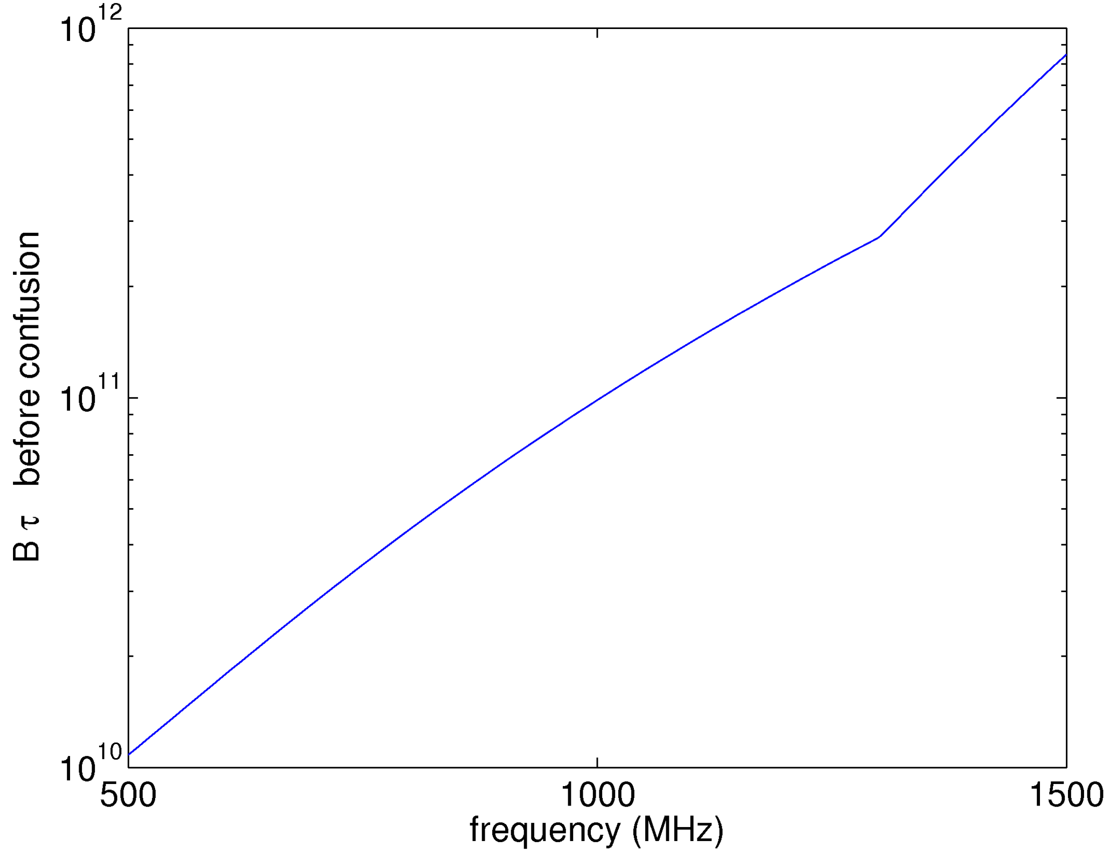


Classical source confusion

B τ product before hitting classical source confusion limit

If B = 1 MHz, ~3 h integration @ 500 MHz, ~240 h @ 1500 MHz

B = 160 MHz, τ = 12 h gives B τ = 7e12 → confusion limited

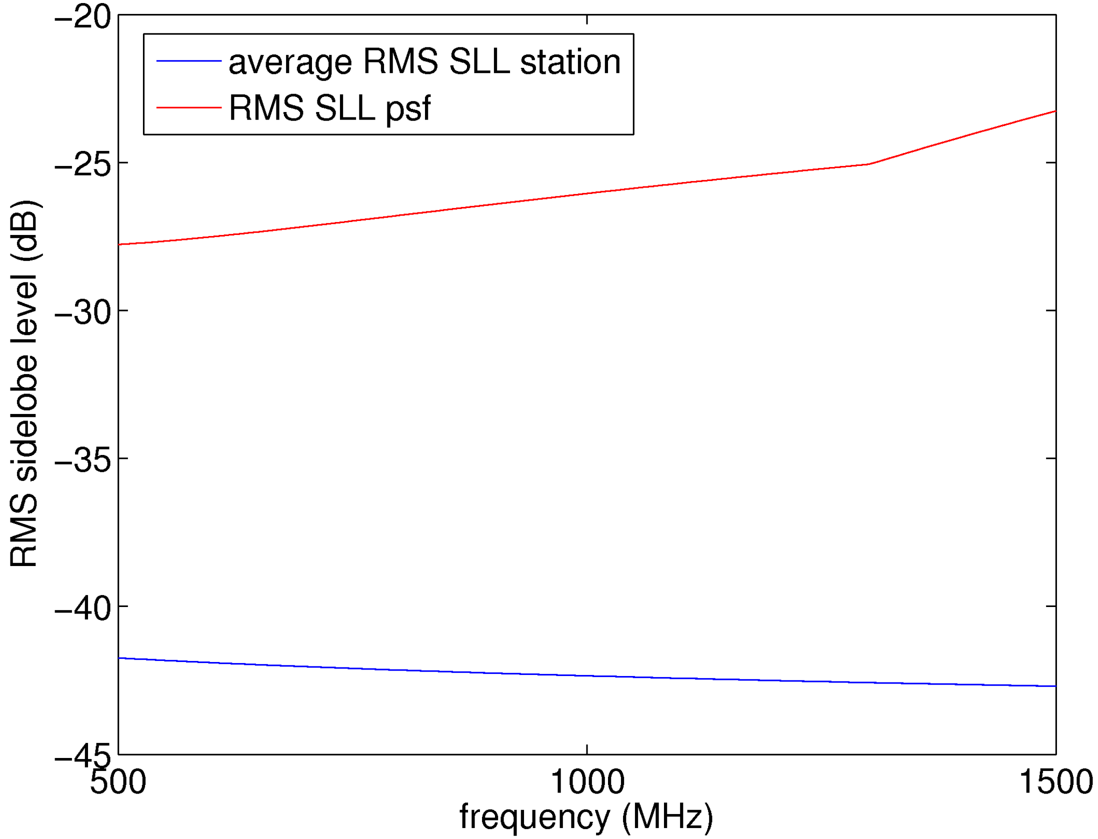


Sidelobe confusion noise

- PSCN inside FoV: individual subtraction down to 100σ
- FSCN outside FoV: 100 sources treated individually
- average station SLL of -42.5 dB, higher if synthesis psf SLL lower

Assumptions

- B = 1 MHz
- τ = 100 h

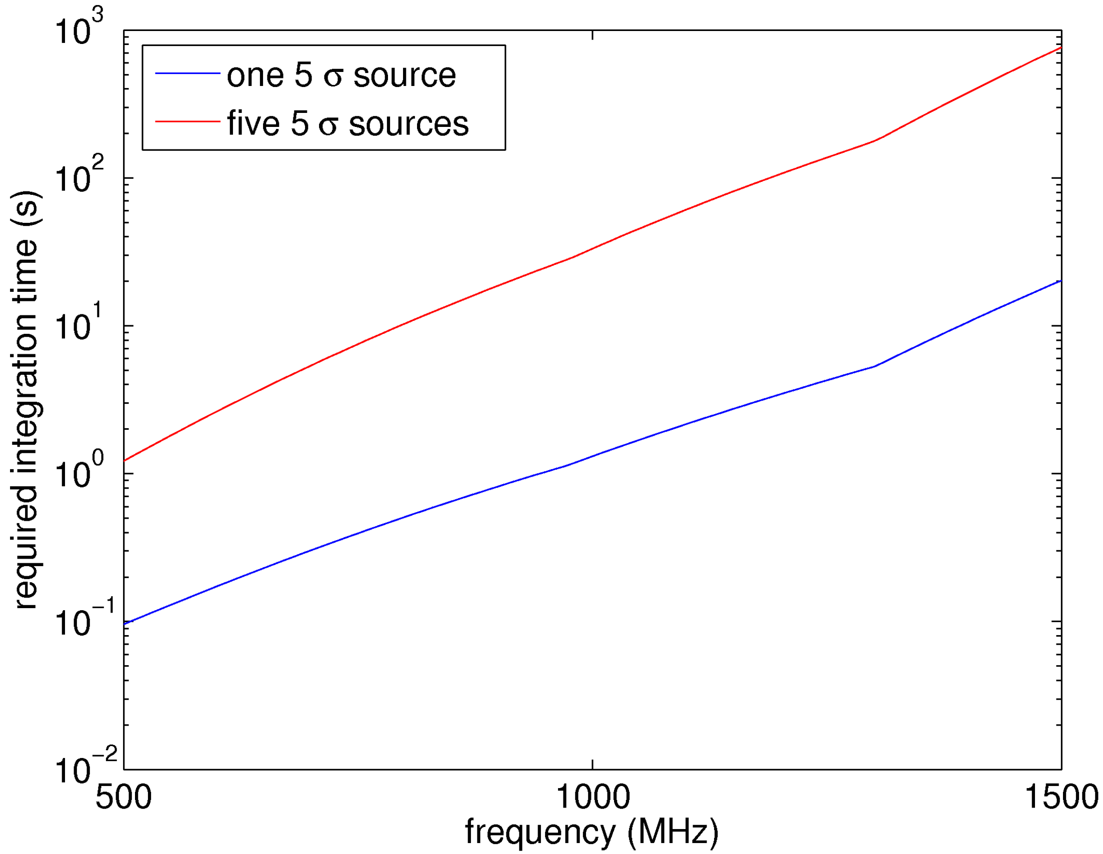


Calibration update rate

one calibration source inside FoV allows update rate < 20 s

five calibration sources requires ~12 min @ 1.5 GHz

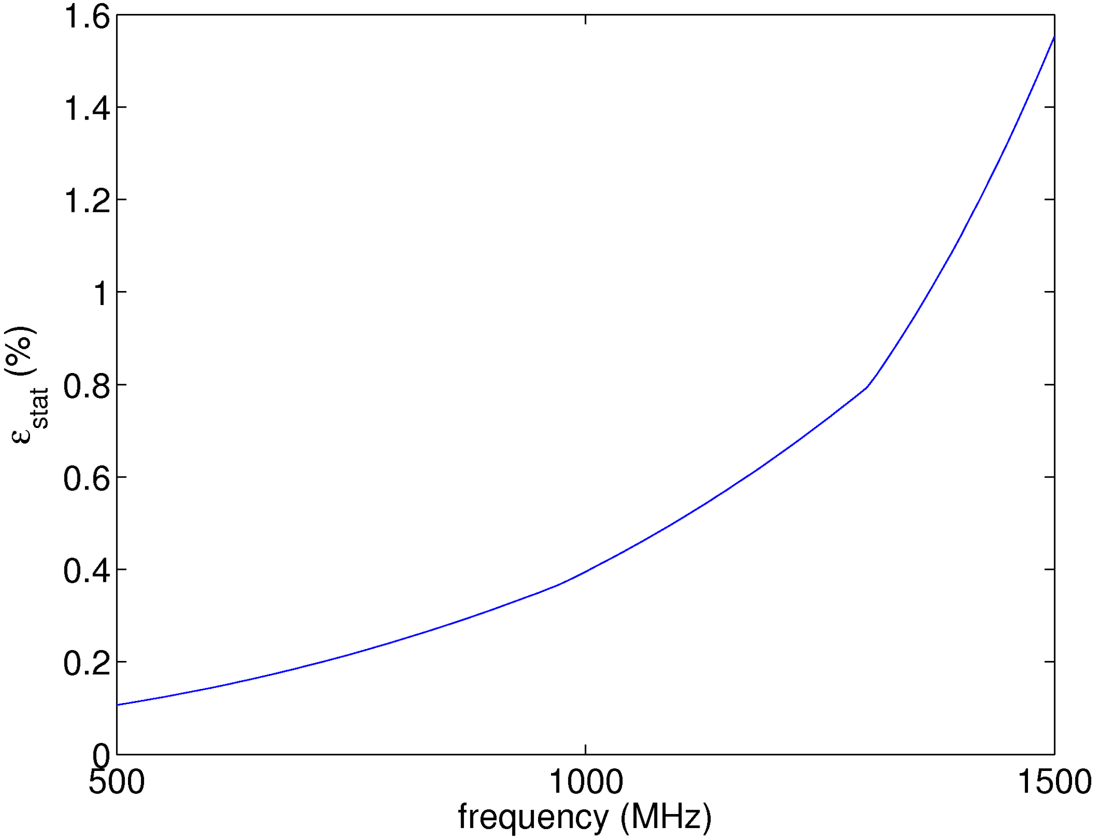
Self-calibration scheme similar to WSRT feasible



Beam accuracy and stability

based on DDE calibration accuracy over 1 MHz after 20 minutes

AERA[3] should not have beam accuracy or stability issues



Conclusions

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The envisaged AERA^3 system...

- has sensitivity comparable to ASKAP and APERTIF
- may hit confusion limit in envisaged deep observations
- requires achievable RMS station sidelobe level of -42.5 dB
- is not likely to suffer from PSCN or FSCN
- is calibratable on timescales of
  - < 20 s for station based effects like clock drifts
  - < 12 min for DDEs like pointing errors
- poses only mild requirements on station beam accuracy