Calibratability of a SKA-size MFAA

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Calibratability

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Dynamic range is not a suitable figure-of-merit

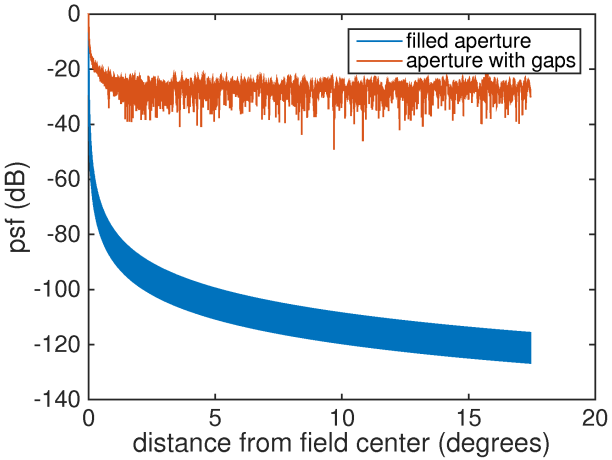
- no information on (structure in) the noise floor of the image
- strongly dependent on observed field

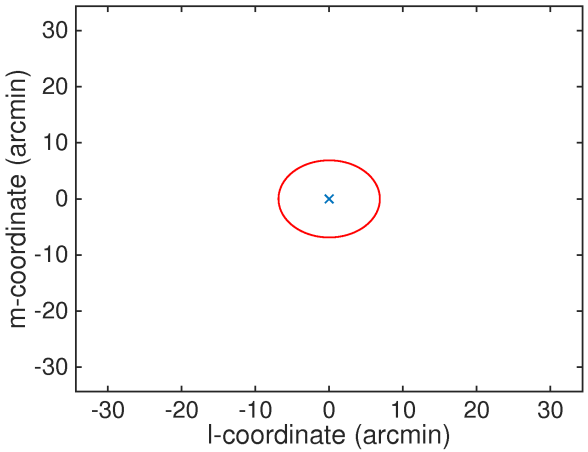
Effective noise

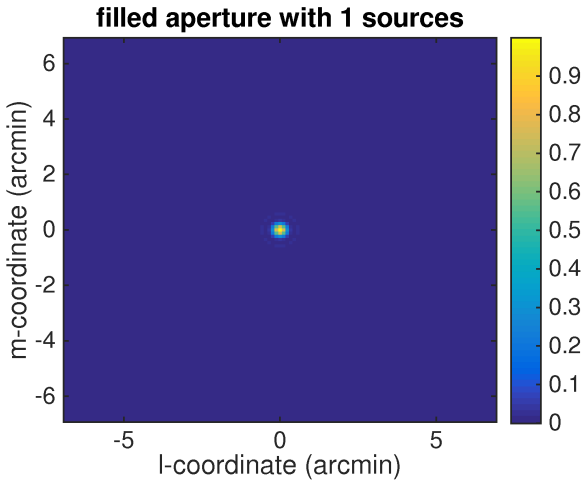
- thermal noise
- classical source confusion noise
- psf sidelobe noise (PSN)
- calibration noise (estimation noise + penalty for corrections)
- calibration artefacts

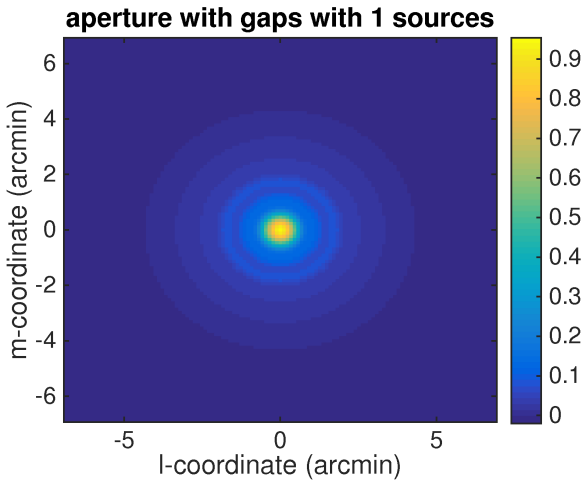
Last 4 factors can be mitigated by **design-for-calibratability**

Psf Sidelobe Noise









Psf Sidelobe Noise

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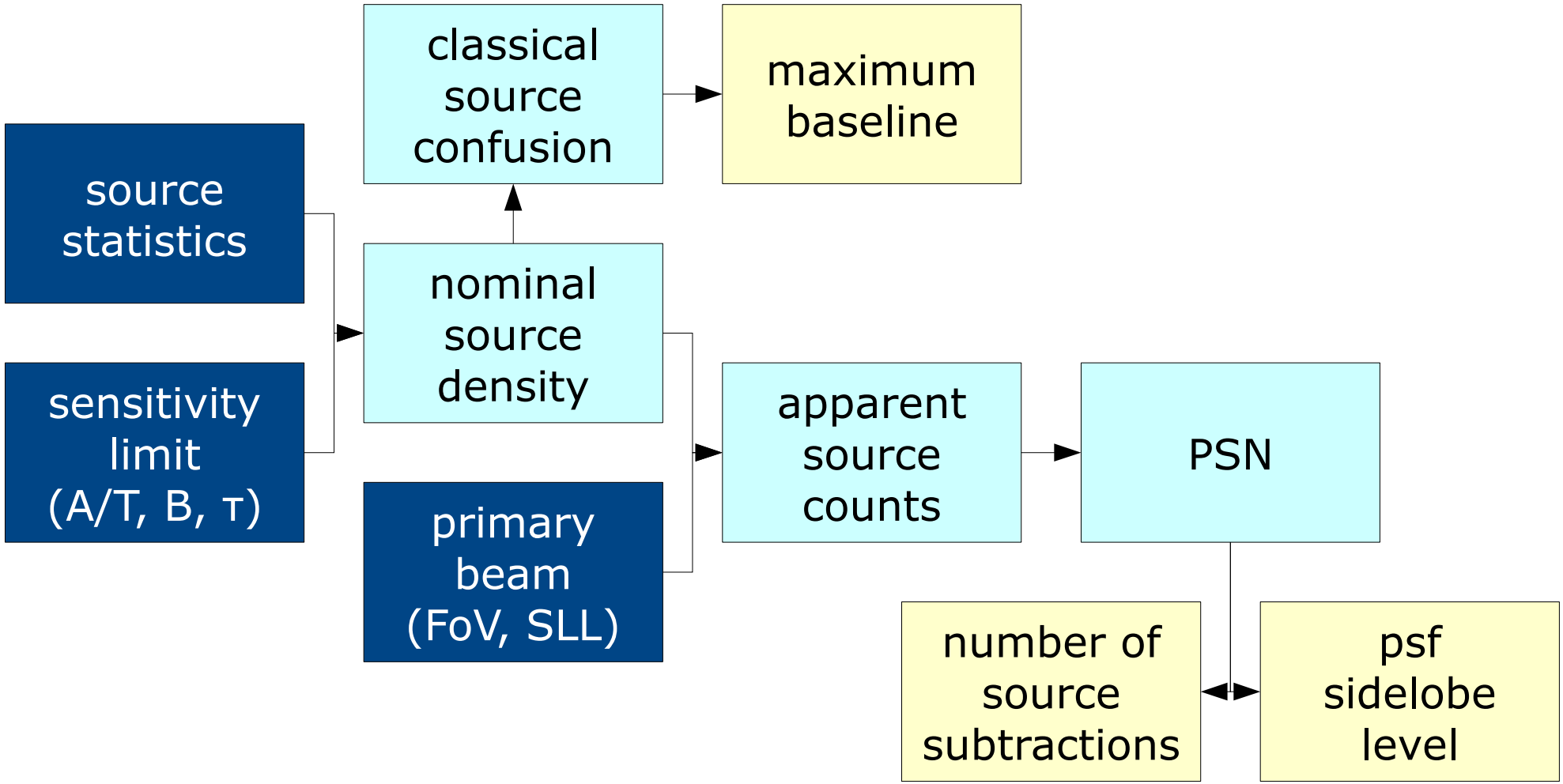
Flowchart confusion effects

Wijnholds, Bregman & Noordam, URSI GASS, 2014



A SKA-size MFAA

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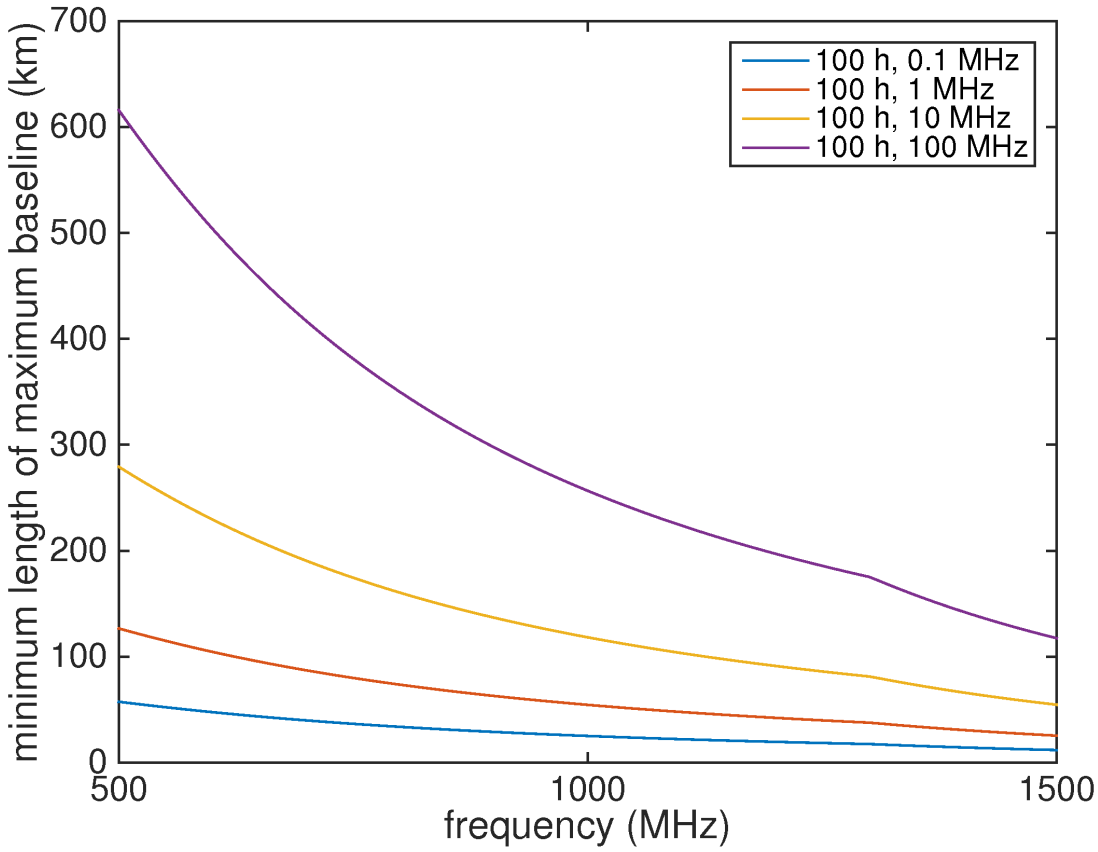
Assumed specifications

- frequency range: 500 – 1500 MHz
- regular station array, spacing 13.3 cm (scan range of 60°)
- $A_{eff} = \min(\lambda^2/3.\ 0.133^2)\ m^2$ per antenna
- 1024 circular stations with 35 m diameter
  → ~10^6 m^2 physical collecting area, ~54k antennas per station
- $T_{sys} = 1.1\ T_{sky} + 40\ K = 66\ \lambda^{2.55} + 40\ K$
- deepest integration for continuum survey: 100 hours
- calibration of station beam shape / pointing every 10 minutes

Required maximum baseline

- Resolution is needed to avoid classical source confusion
- limited to 100 h, since deepest observations will likely be line obs.
- strong extrapolation of source statistics → 200 km probably ok



Required psf sidelobe level

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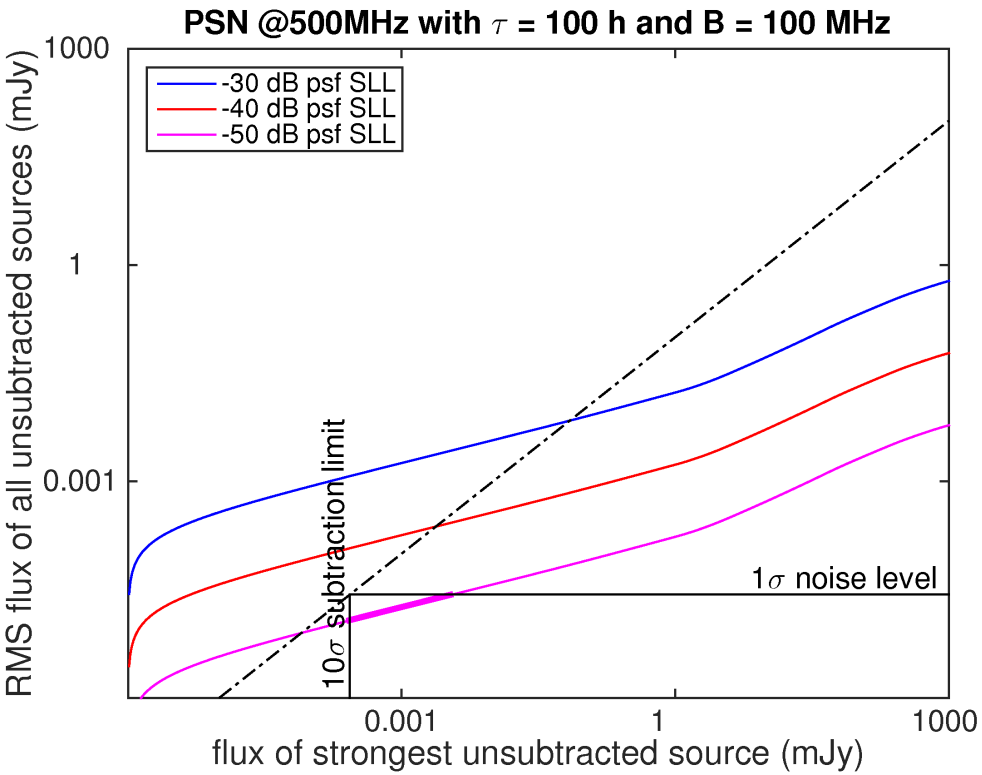
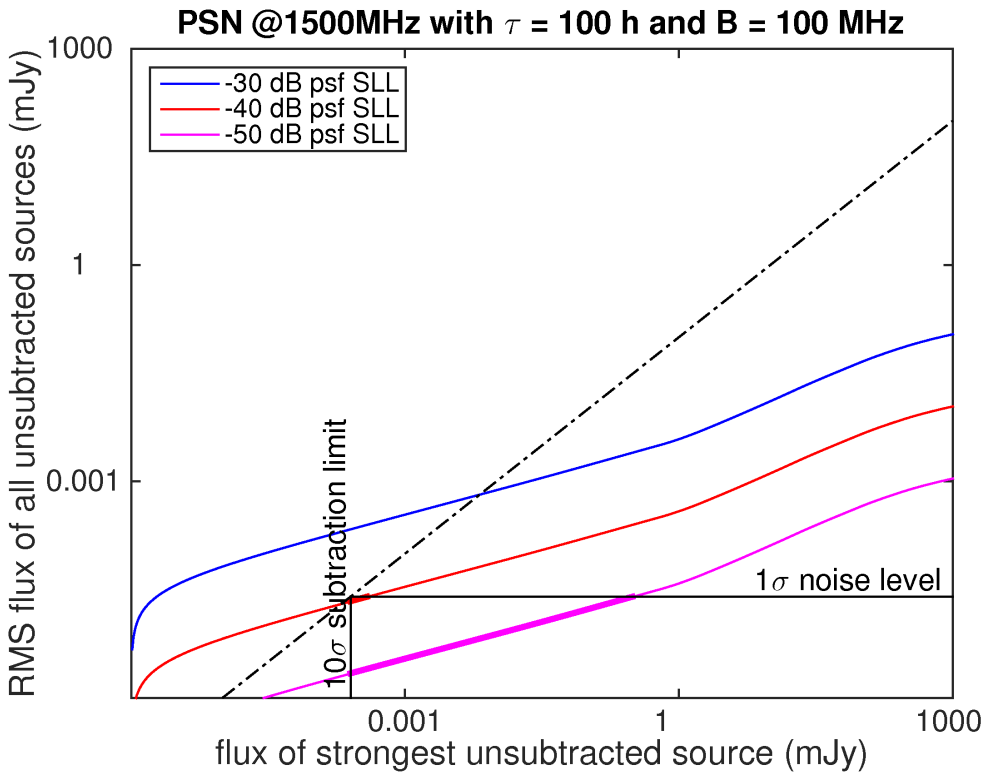
- Low sidelobe level is needed to avoid PSN
- Calculated for 100 h, 100 MHz at 500 MHz (l) and 1500 MHz (r)
- psf RMS SLL needed of ~-45 dB @ 500 MHz / ~-40 dB @ 1.5 GHz





Required beam stability

Wijnholds, SKA-TEL.LFAA.SE.CAL-AADC-TN-001, Jan. 2014
Wijnholds, AAVP Workshop, Dec. 2011

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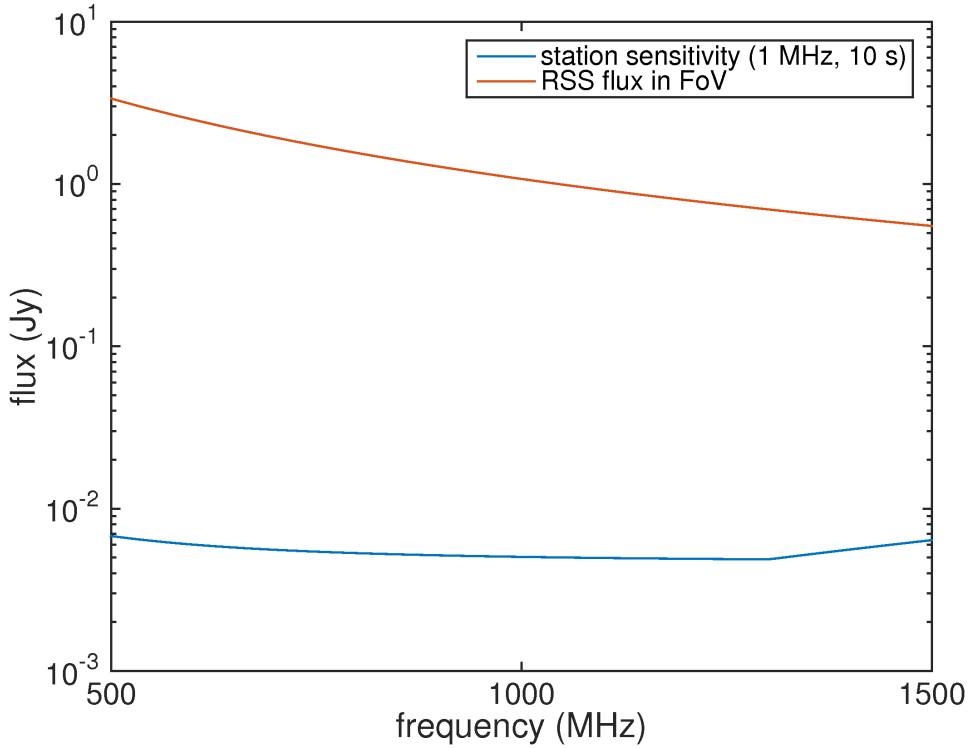
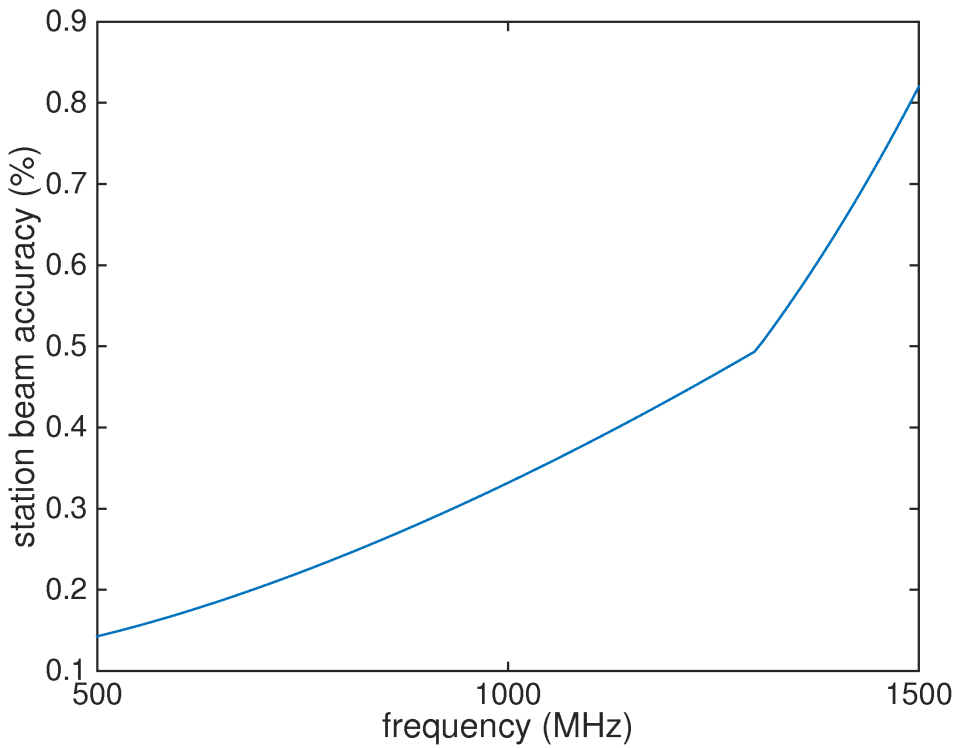
Allowed station beam error:

$$\epsilon_{stat} = \frac{1}{\sqrt{2}} \frac{\Delta S_0 / \sqrt{B\tau}}{S_{rss}}$$

easy with ~54k antennas/station → 1-bit beamformer?





Conclusions

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- **B_{max}=200 km probably sufficient to avoid classical confusion**
  - deepest observations likely to be line observations
- **psf RMS SLL needed of ~-45 dB to avoid PSN**
  - requires complete (u,v)-coverage
  - 1024 stations should be enough to achieve this
- **required station beam accuracy: 0.15% – 1%**
  - allows cost reduction by using 1-bit beamformer
- **Requirements for MFAA are less stringent than for LFAA**
  - we should exploit this to reduce costs