SARAS 3

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On behalf of

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Udaya Shankar,

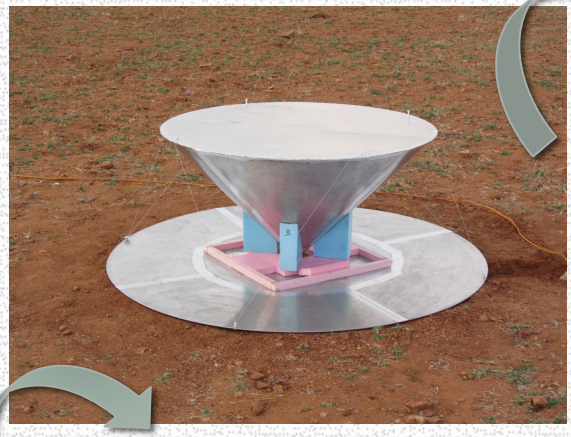
B S Girish, A Raghunathan, R Somashekar, K S Srivani.

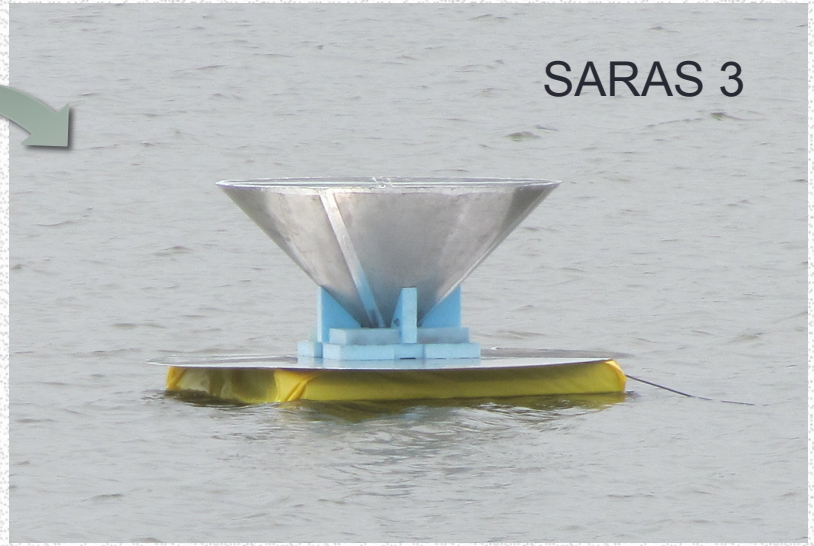
Who were all involved in design, building, system tests, algorithms, methods, analysis

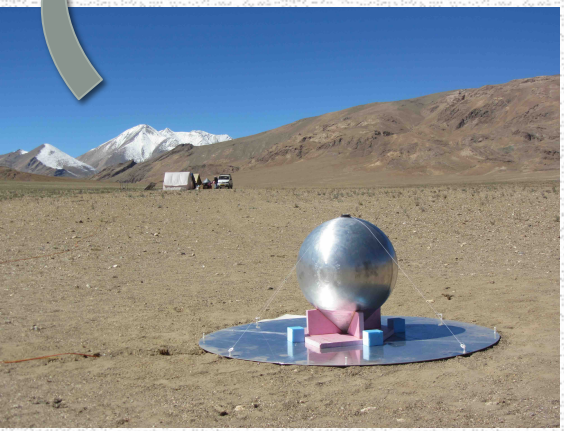
Raman Research Institute

Bangalore, India

Evolution in antenna design -

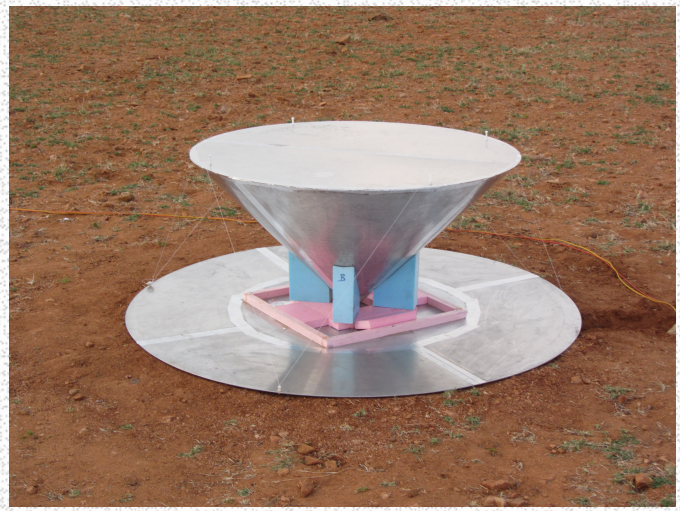






SARAS 1

Cone-disc antenna

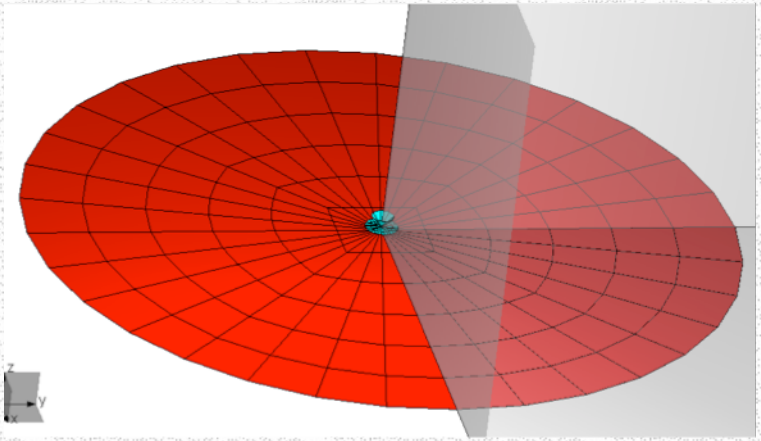


- Scaled up in size by factor of two
  from SARAS 2
- Optimized for the band 50-100 MHz
- Resonant frequency beyond 100 MHz
- Short monopole antenna in the 50-100 MHz band
- Frequency independent beam pattern

- Shaped to have

1) Maximally smooth reflection efficiency
2) As high an efficiency as possible at 50 MHz

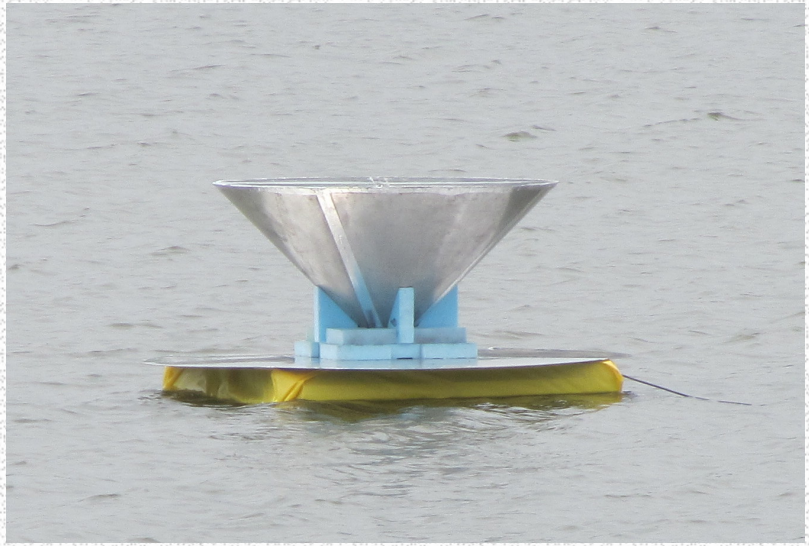
Cone-disc antenna



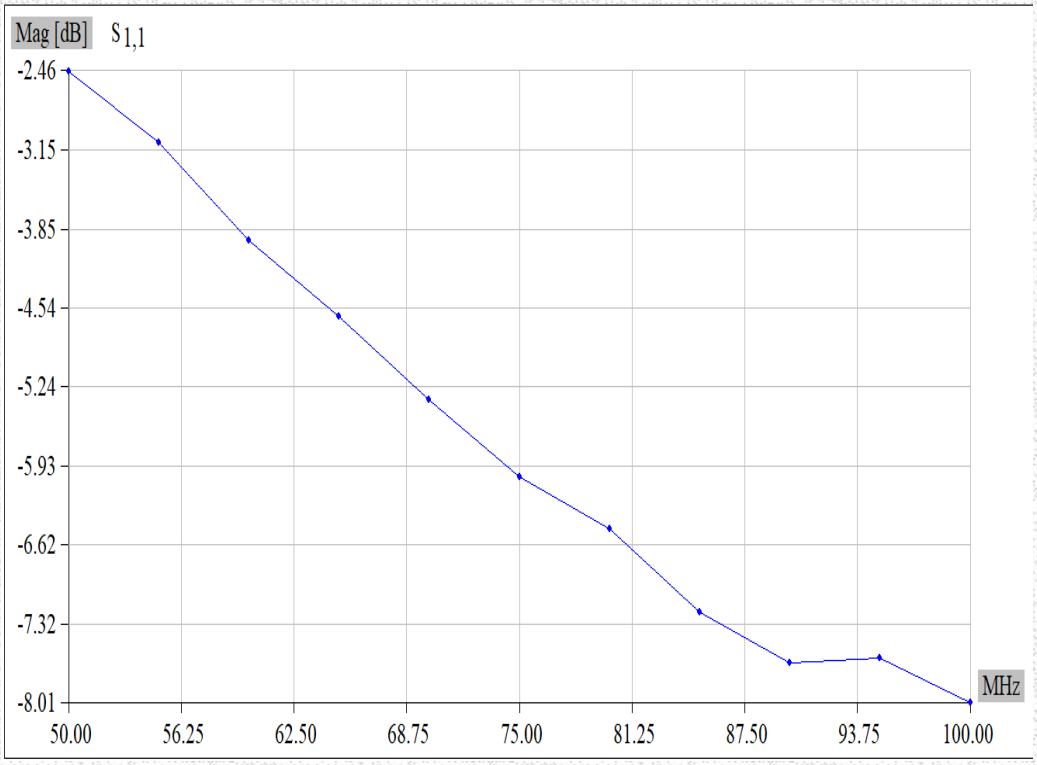
- Reflector disc radius 830 mm = cone slant height
- Cone angle 45 degrees

- WIPL-D simulation with water to a radius of 18 metres

- Water relative permittivity 80
- Conductivity 0.06 S/m



Cone-disc antenna



WIPL-D EM simulation

Voltage reflection coefficient S11 goes from

-2.5 dB at 50 MHz

to

-8 dB at 100 MHz

Reflection Efficiency goes from

~45% at 50 MHz

to

~84% at 100 MHz

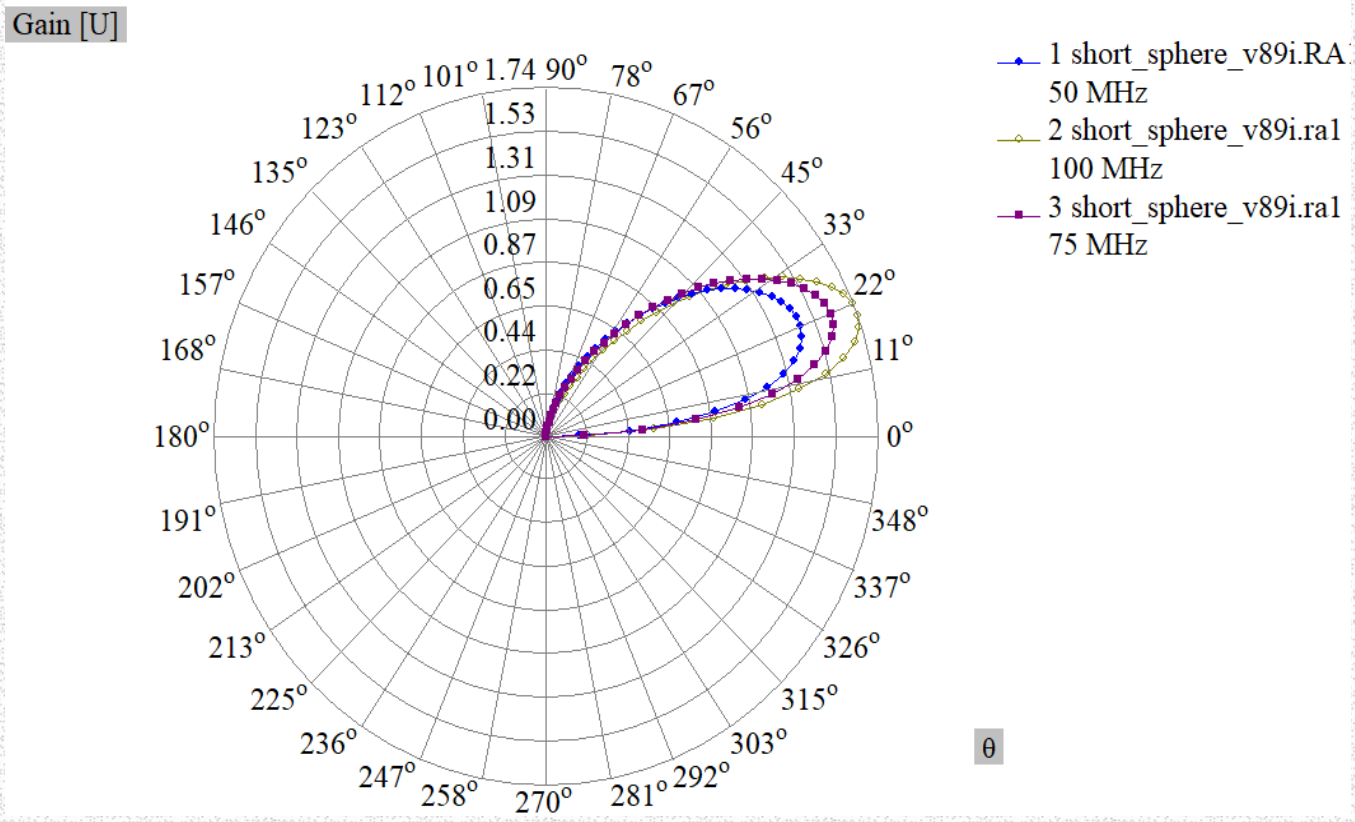
Cone-disc antenna

WIPL-D EM simulation

Beam pattern

Nulls at zenith and horizon

Peak at 22 degrees elevation

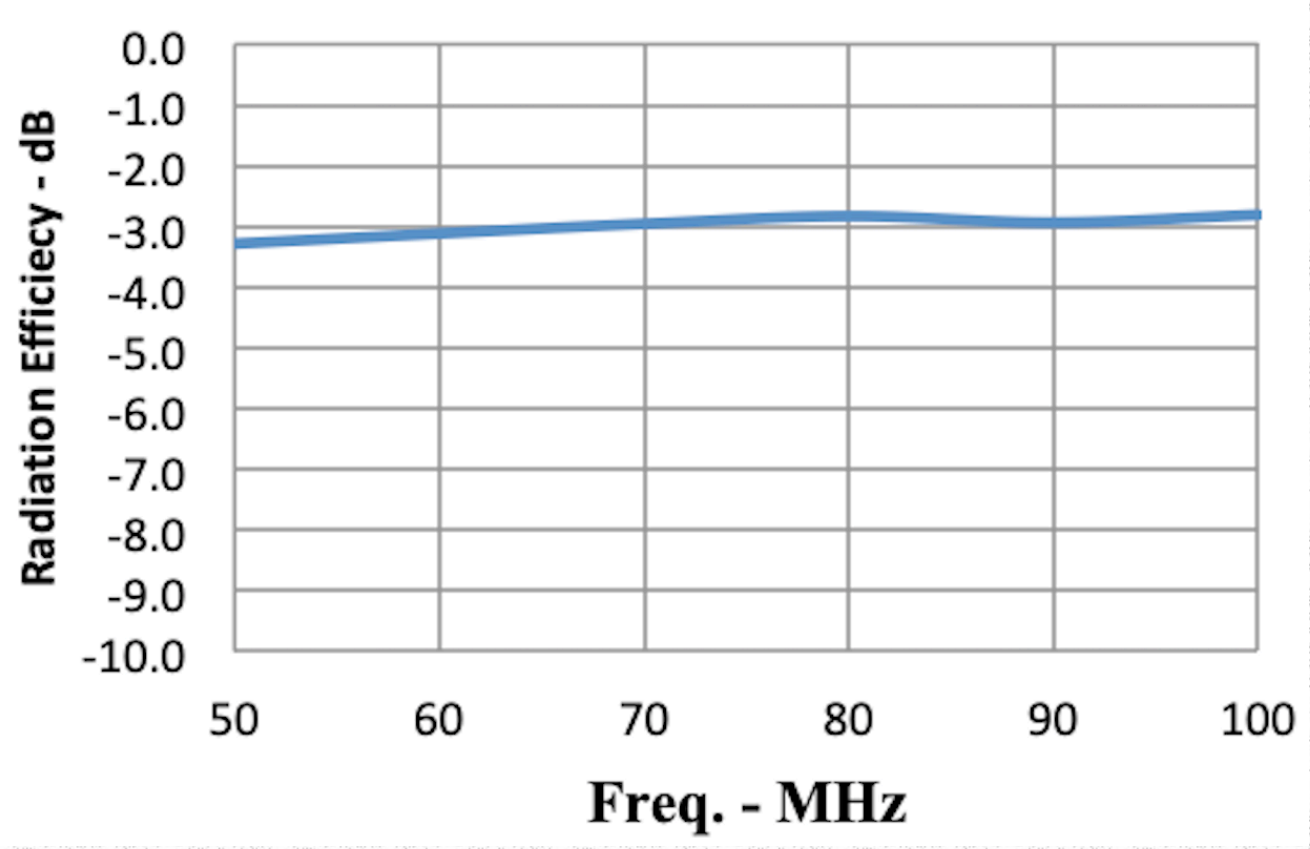


Cone-disc antenna

WIPL-D simulation

For antenna with reflector plate
200 mm above water surface

Radiation Efficiency ~ 50%



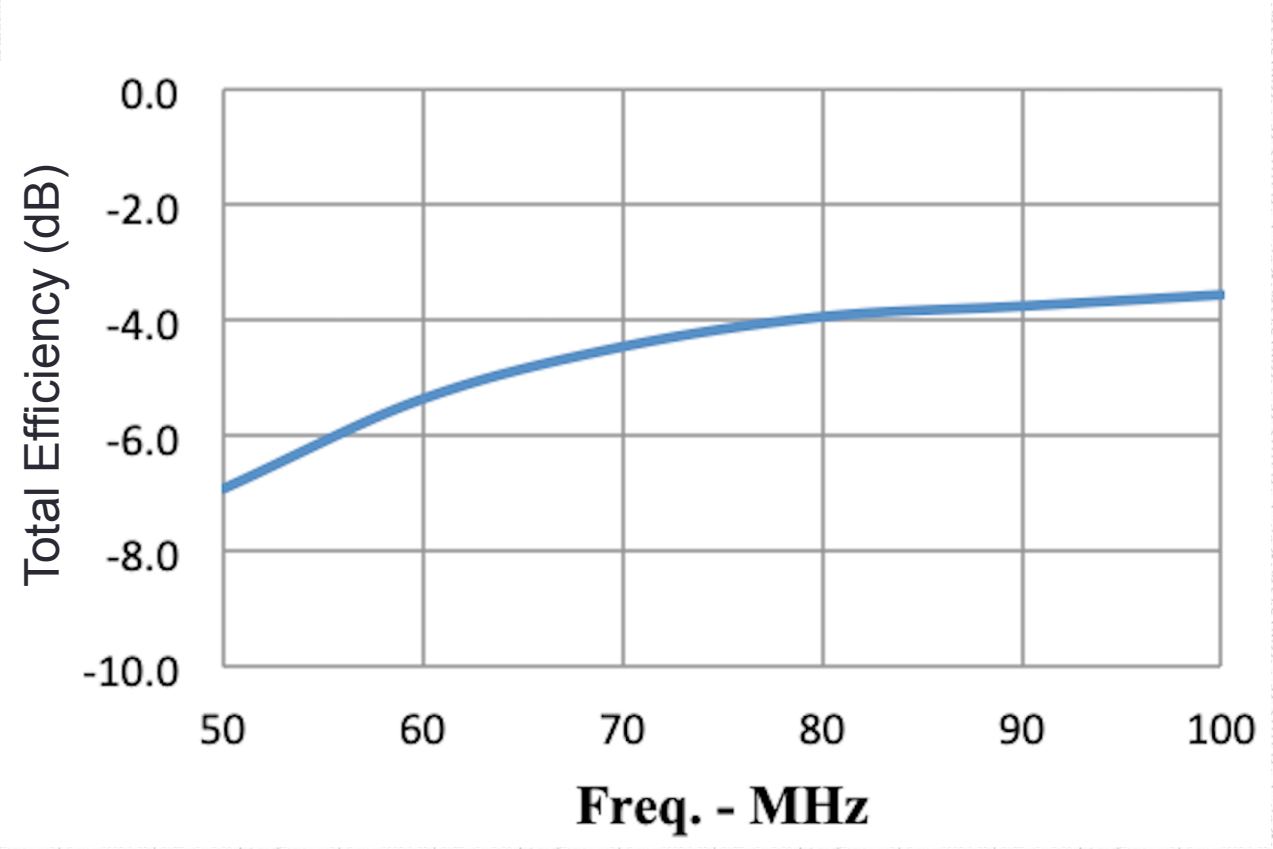
Cone-disc antenna

For antenna with reflector plate
200 mm above water surface

WIPL-D EM simulation:

Total Efficiency

~20% at 50 MHz
to
~45% at 100 MHz



SARAS 3: Cone-disc antenna on fresh water

Propagation loss (in dB) of EM in fresh water

$$\alpha_p = 10 \log_{10}\left(e^{-2\alpha d}\right)$$

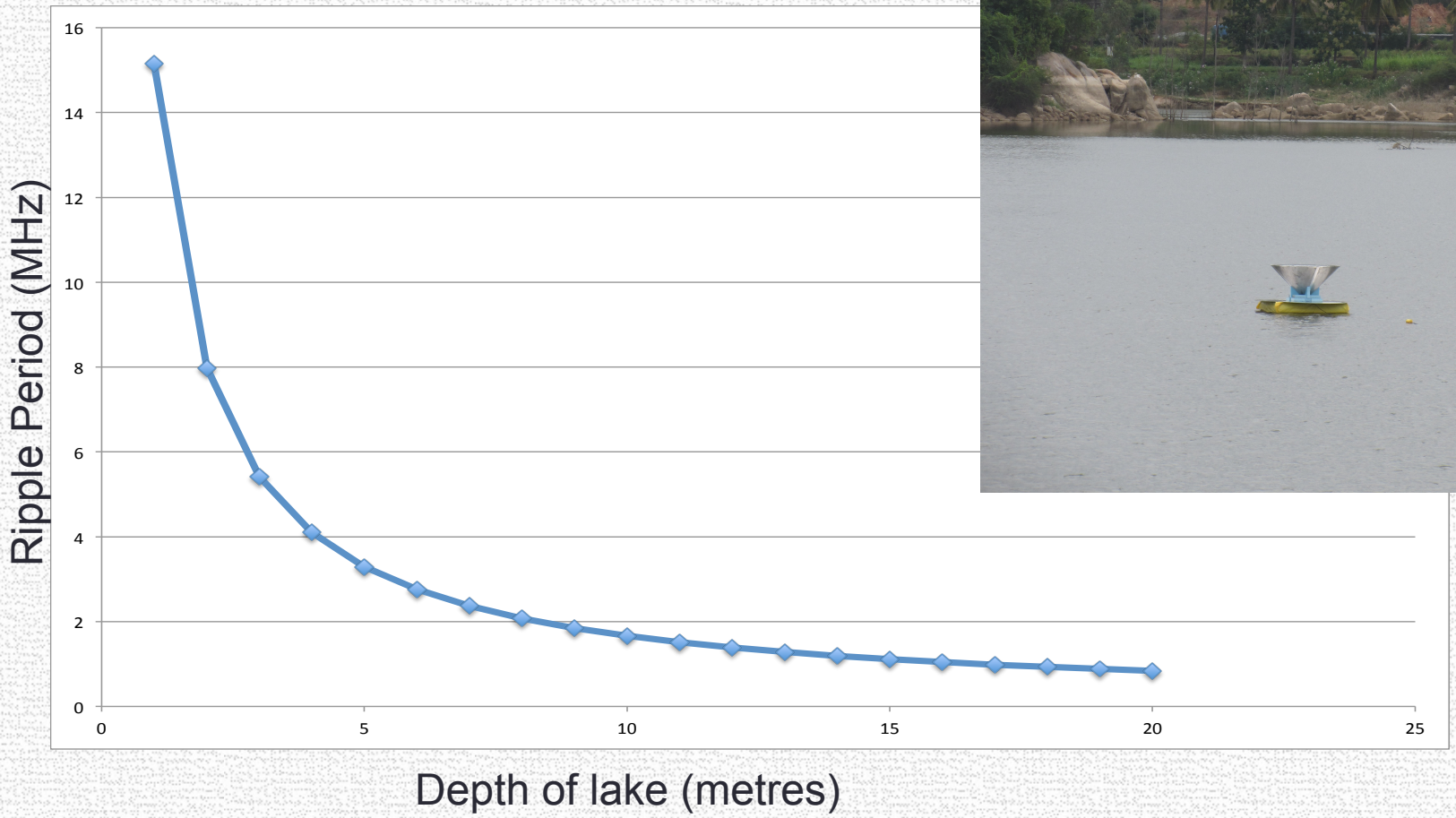
Where α at 75 MHz is

0.317 (for S = 0.015 S/m)
1.28 (for S = 0.06 S/m)
33.4 (for S = 4 S/m)

For S = 0.06 S/m (0.015 S/m)
Attenuation to depth of 2 metres is -22.2 dB (-5.5 dB)
3 metres is -33.3 dB (-8.3 dB)
4 metres is -44.5 dB (-11.0 dB)
5 metres is -55.6 dB (-13.8 dB)
Plus attenuation from impedance mismatch at air-water interface.

SARAS 3: Cone-disc antenna on fresh water

Large velocity factor for water decreases ripple period for reflections off lake bottom



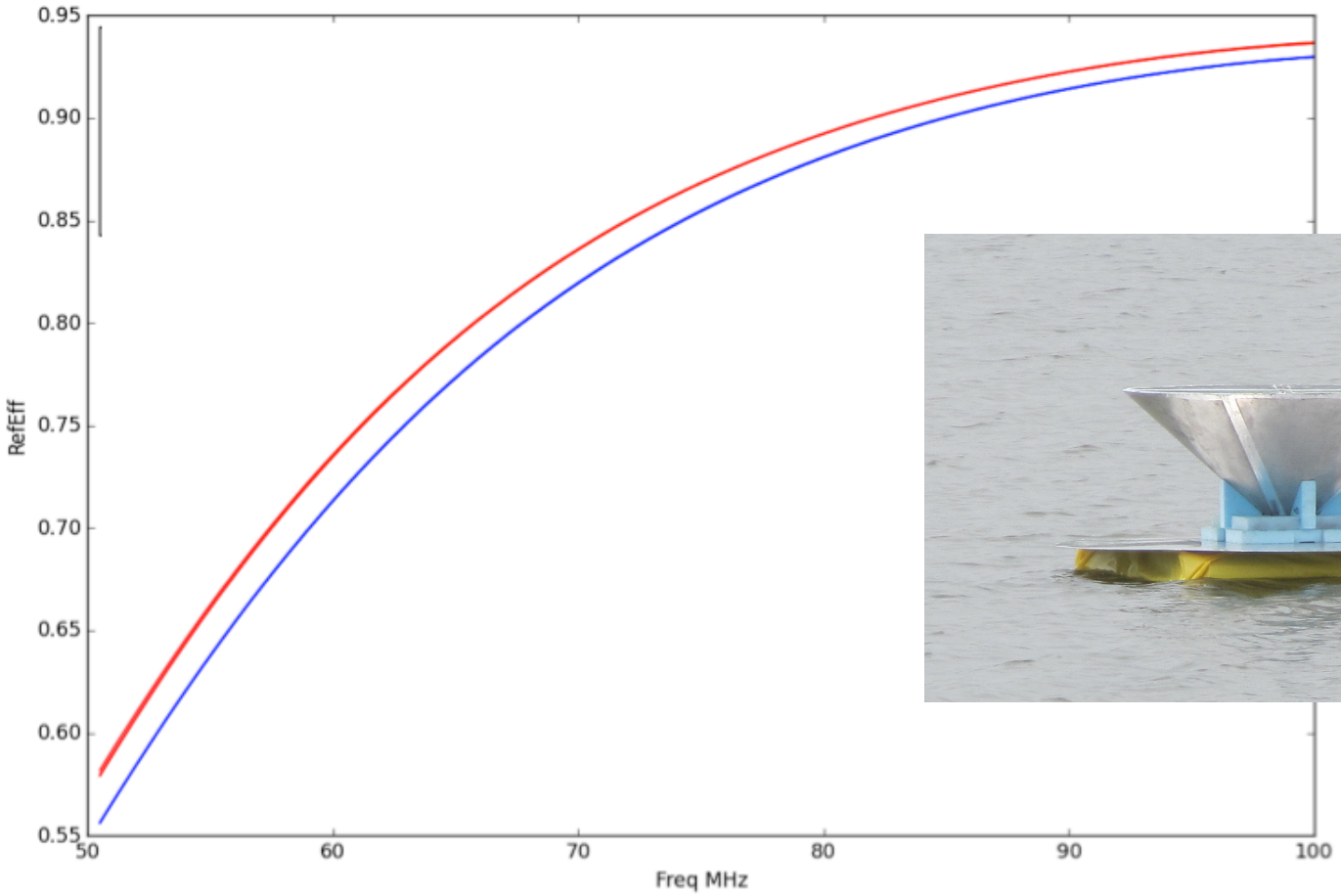
SARAS 3: Cone-disc antenna on fresh water

Measurement of Reflection efficiency

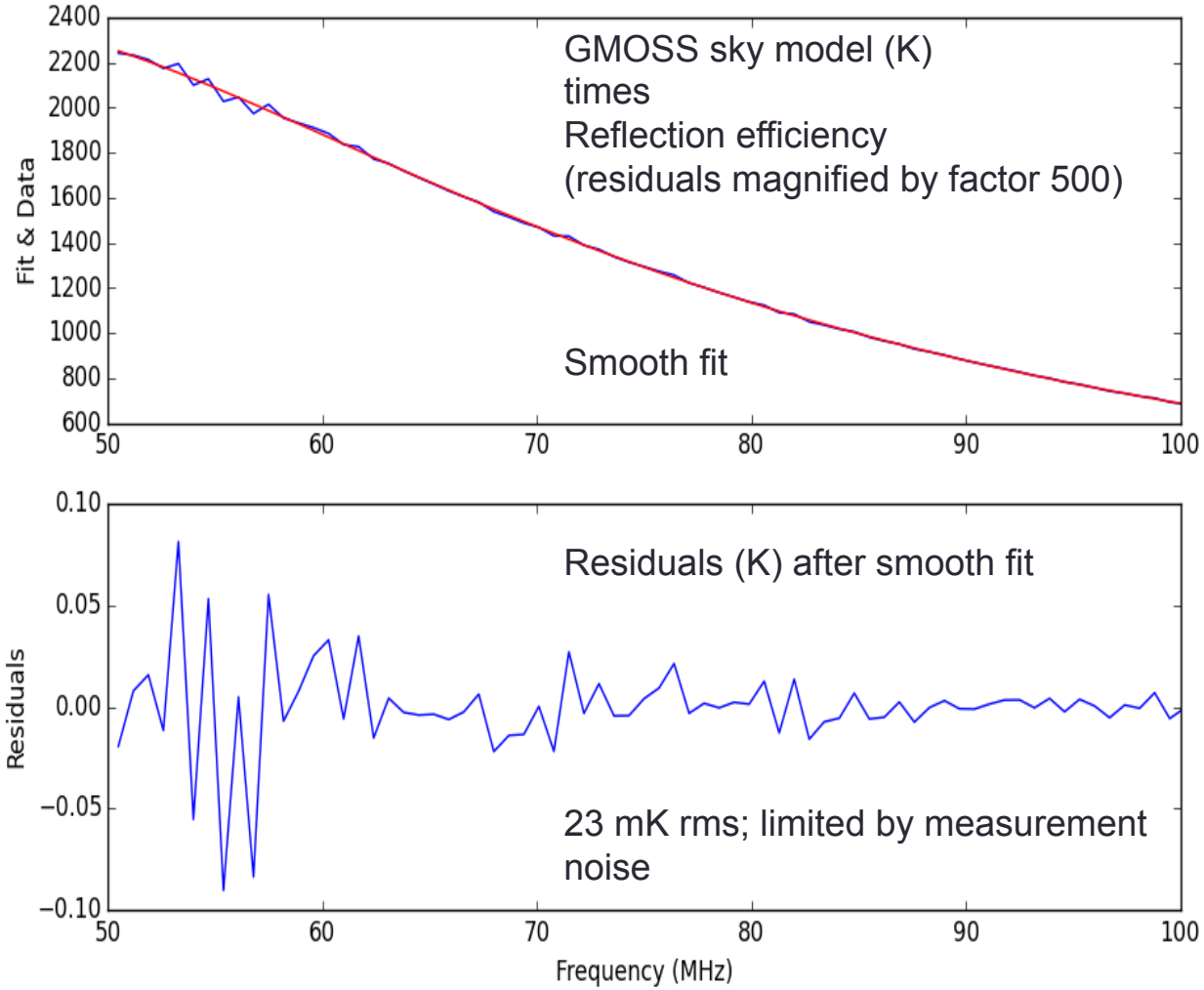
- Using a Network Analyser
- Placed just below the antenna on water
- Real-time calibration by cycling through
  - Antennna
  - Open
  - Short
  - Matched termination
- Traces read out on ethernet over fiber to a laptop on shore

SARAS 3: Cone-disc antenna on fresh water

Measured Reflection Efficiency 2+3 trials



SARAS 3: Cone-disc antenna on fresh water



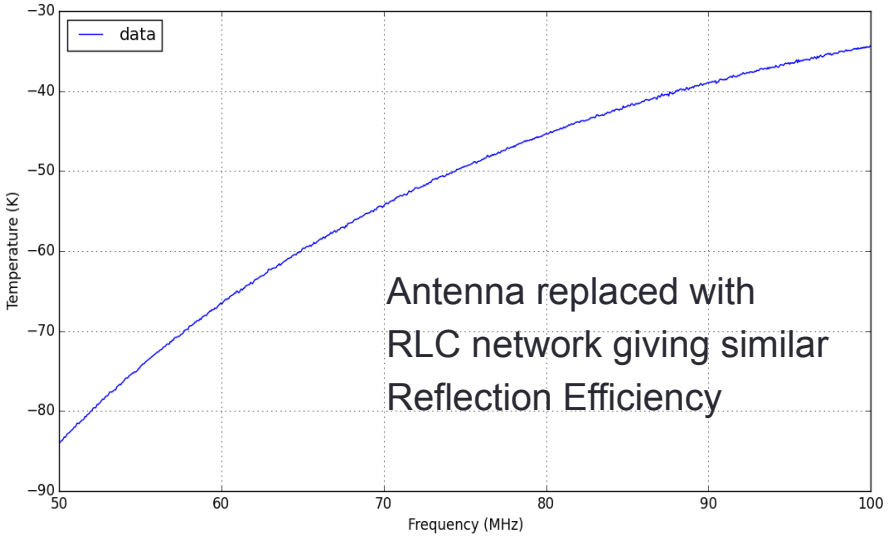
SARAS 3 Receiver:

Analog Signal Conditioning Unit
Digital spectrometer

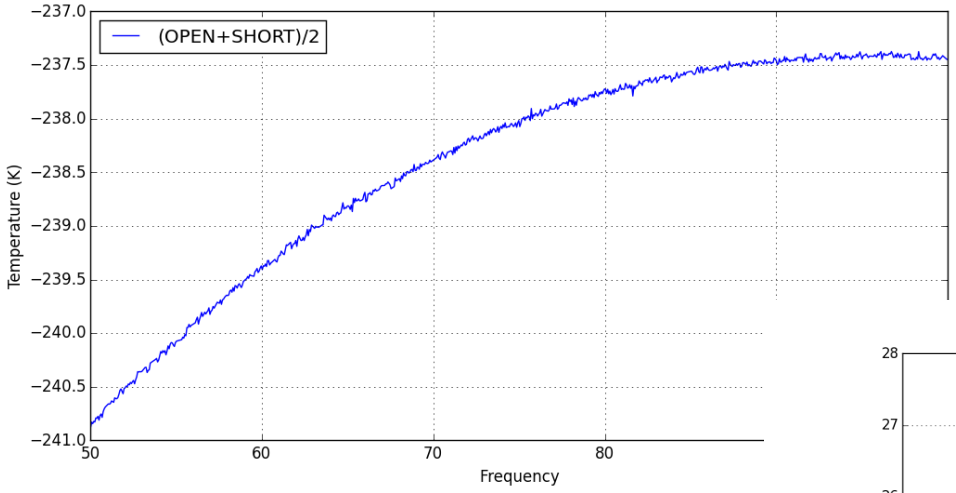
Virtex 6 FPGA
8192-point FFT

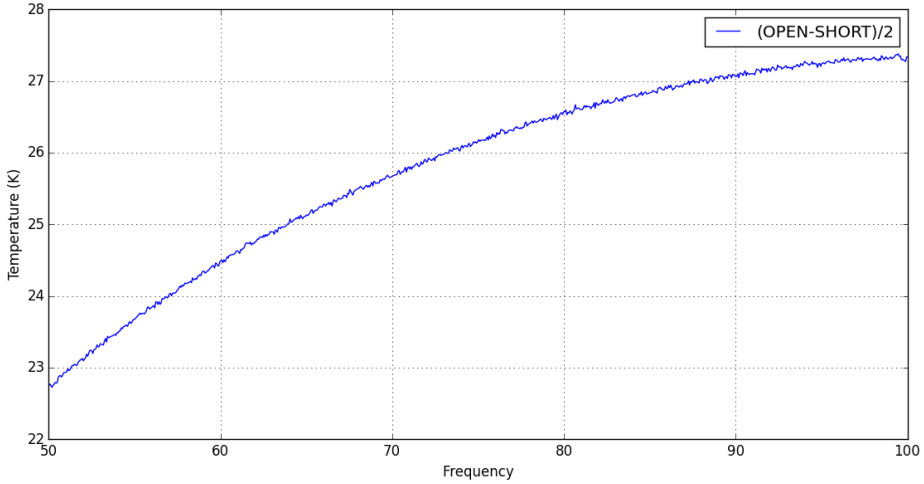
Switching between
antenna and termination
+
Phase switched
correlation receiver

Receiver qualification tests



Antenna replaced with RLC network giving similar Reflection Efficiency



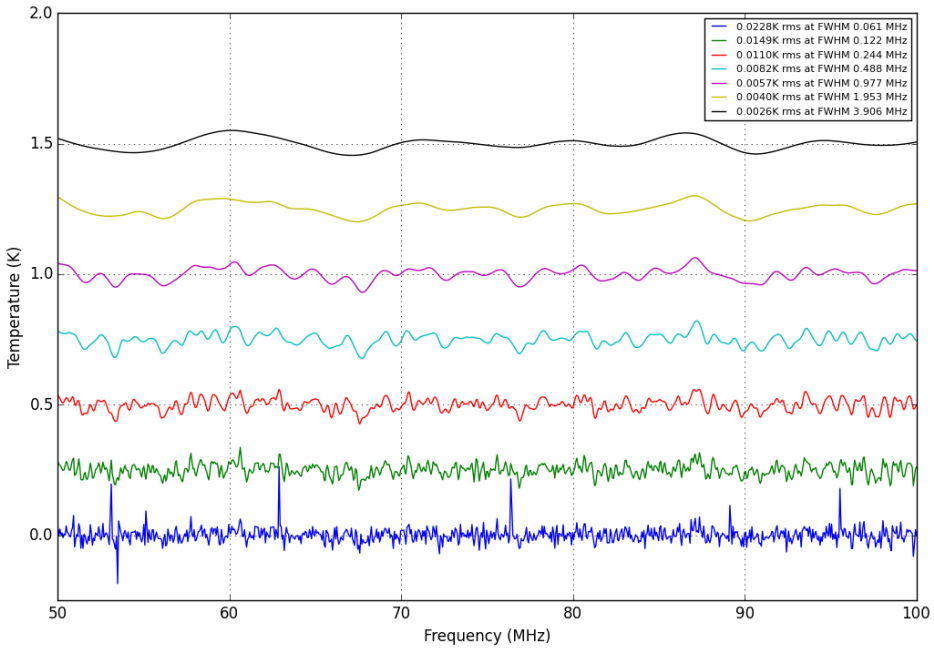


Antenna replaced with OPEN & SHORT
Data combined to give
spectra corresponding to
(OPEN+SHORT)/2 & (OPEN-SHORT)/2

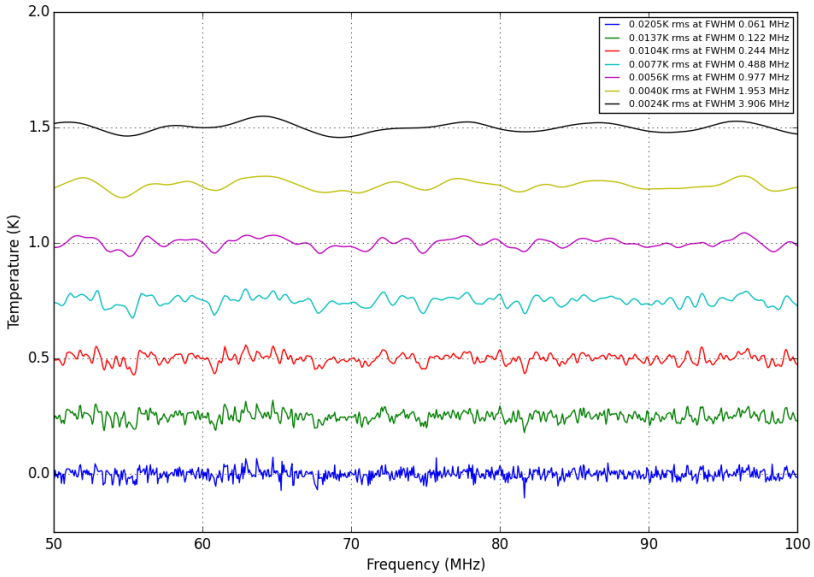
Receiver qualification tests

Fitting out Maximally Smooth polynomials to the calibrated spectra

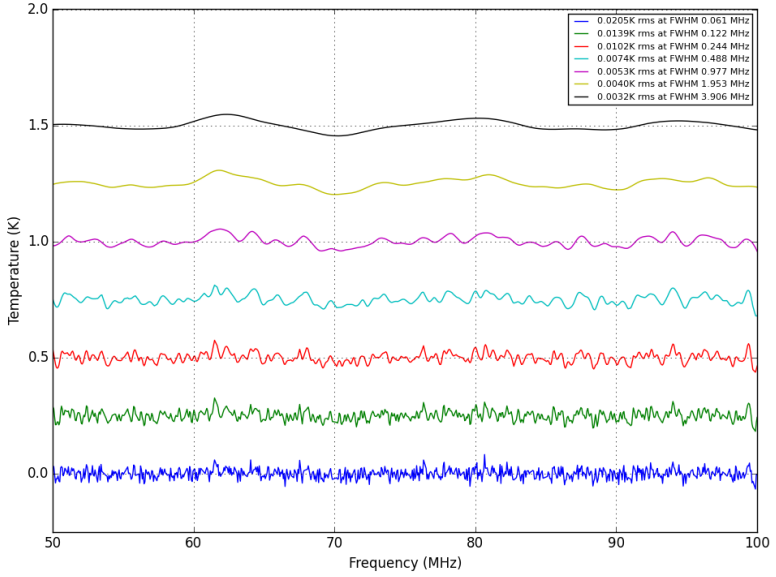
Residuals for RLC network spectra:
RMS goes from 23 mK for 61 kHz resolution to 2.6 mK for 3.9 MHz resolution



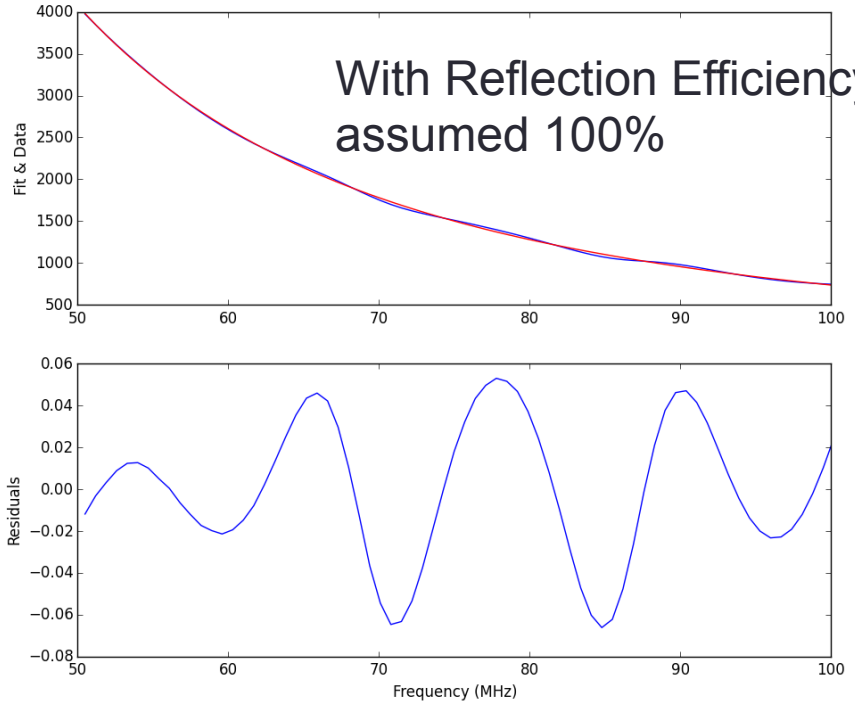
(O+S)/2 residuals: 20 mK ➔ 2.5 mK



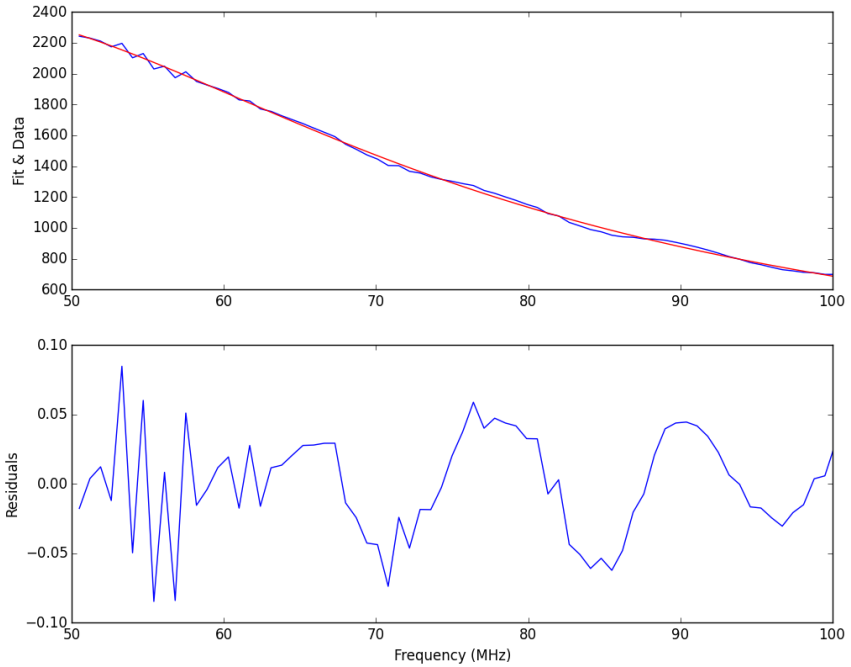
(O-S)/2 residuals: 20 mK ➔ 3.2 mK



Adopting sky model to be GMOSS + BD (with parameters from Bowman ++ Nature 2018)



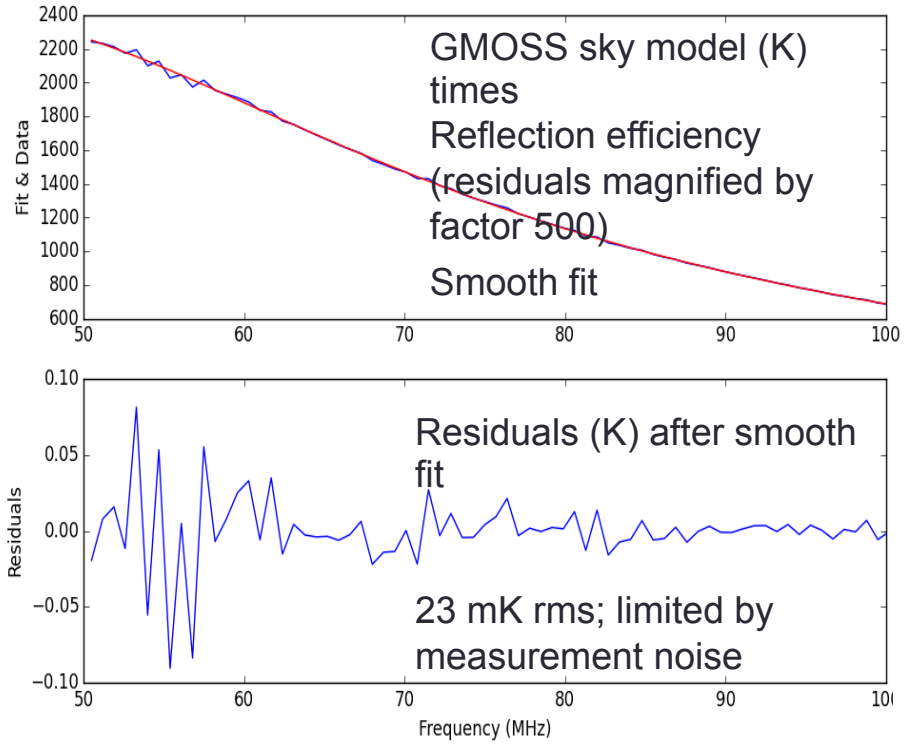
With measured Reflection Efficiency



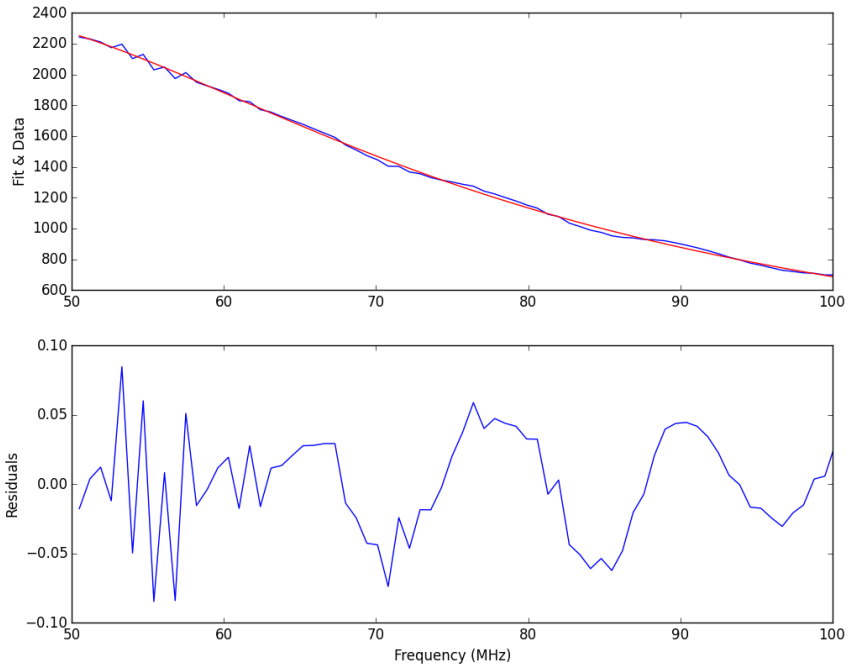
Expect 100 mK peak-to-peak residuals

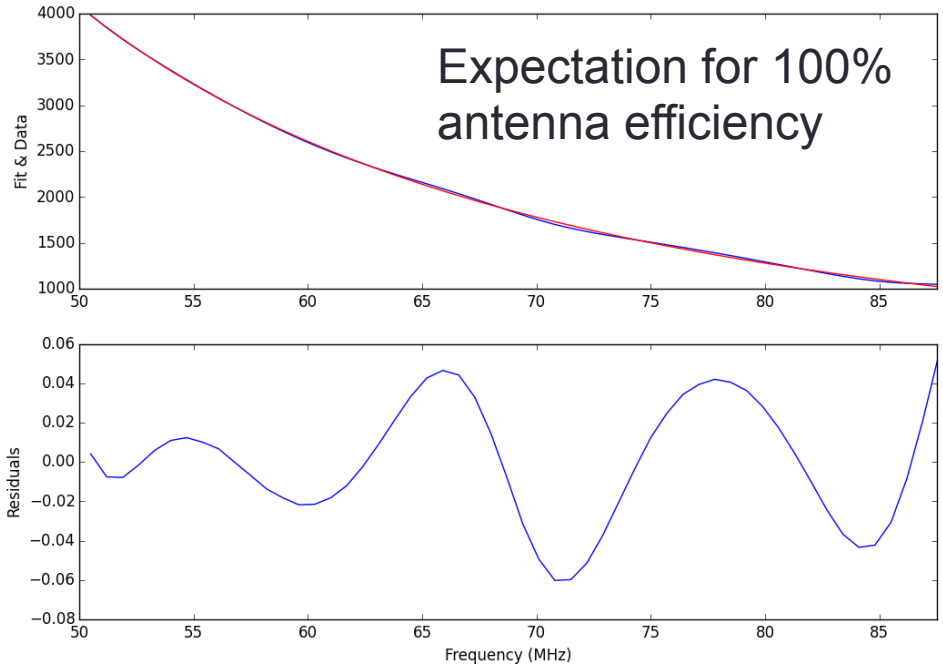
Mock data using measured antenna reflection efficiency & smooth function fit.

GMOSS without BD



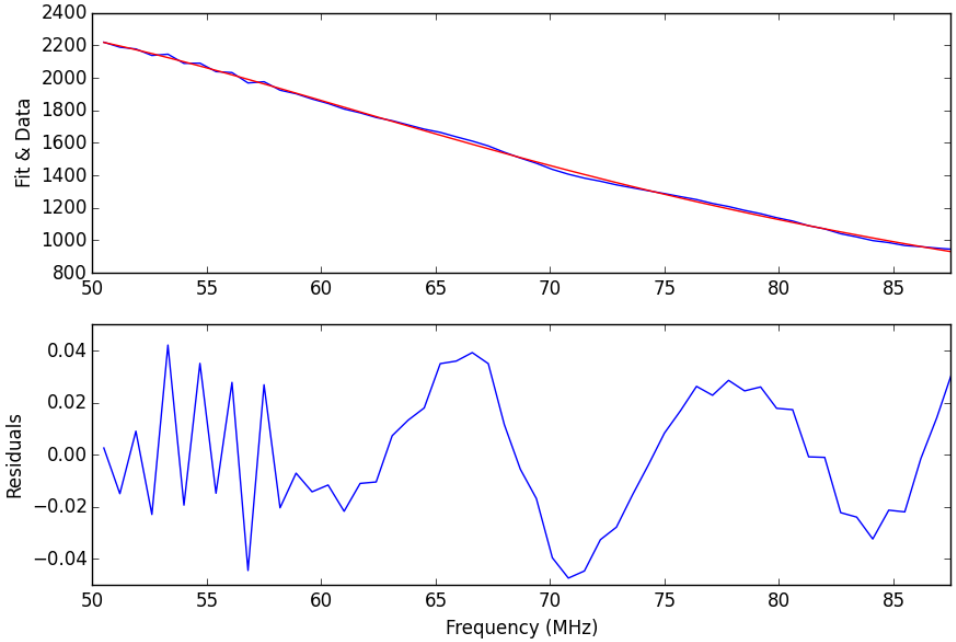
GMOSS with BD





Limited to 50-87.5 MHz
Omitting the FM band

Sufficient complexity in the BD signal to survive a smooth polynomial fit



SARAS 3

Looking for an RFI-free lake!

Scaled cone built for 100-200 MHz band, using same analog and digital receivers, and on fresh water.