EDGES

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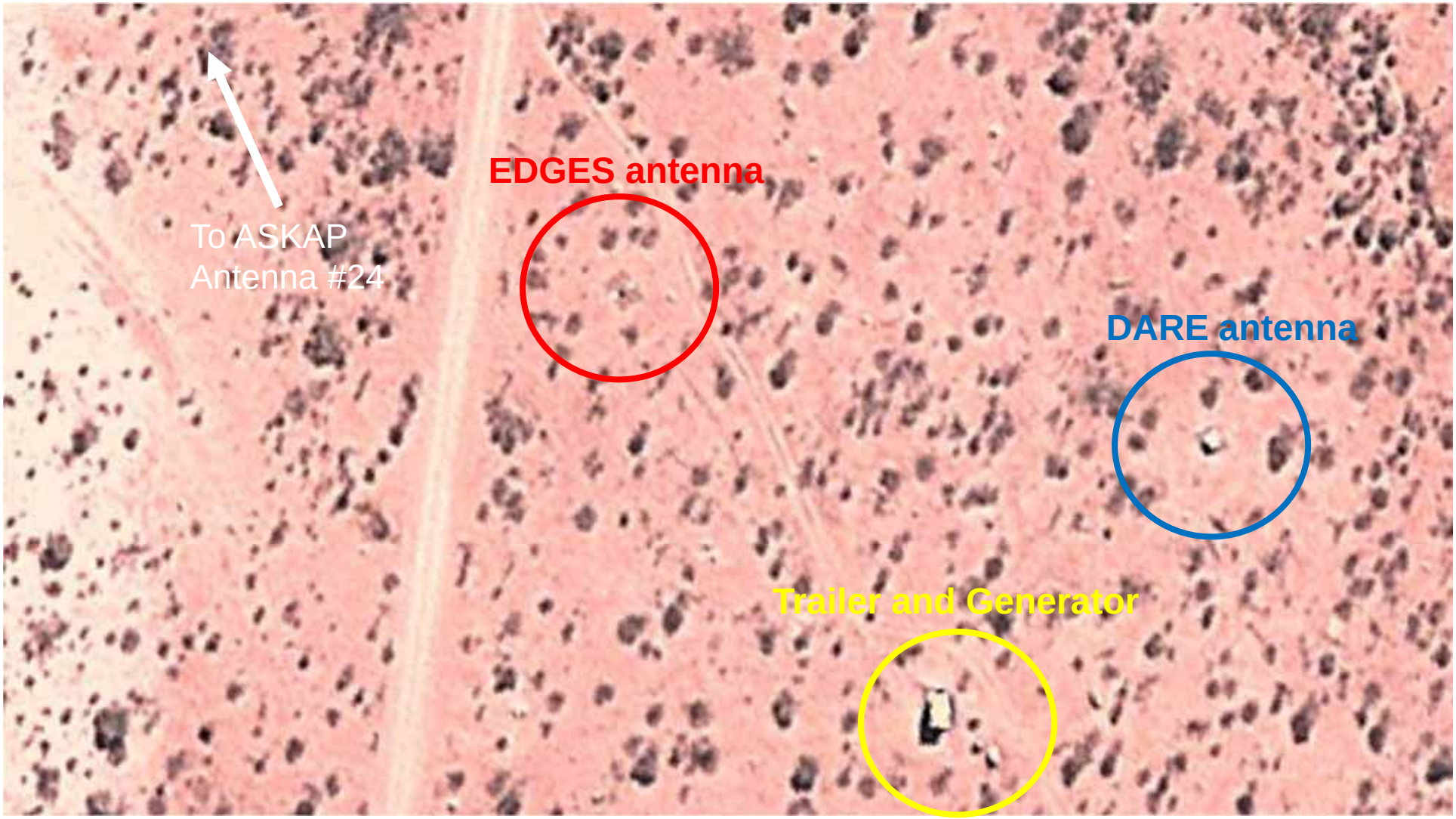
Outline

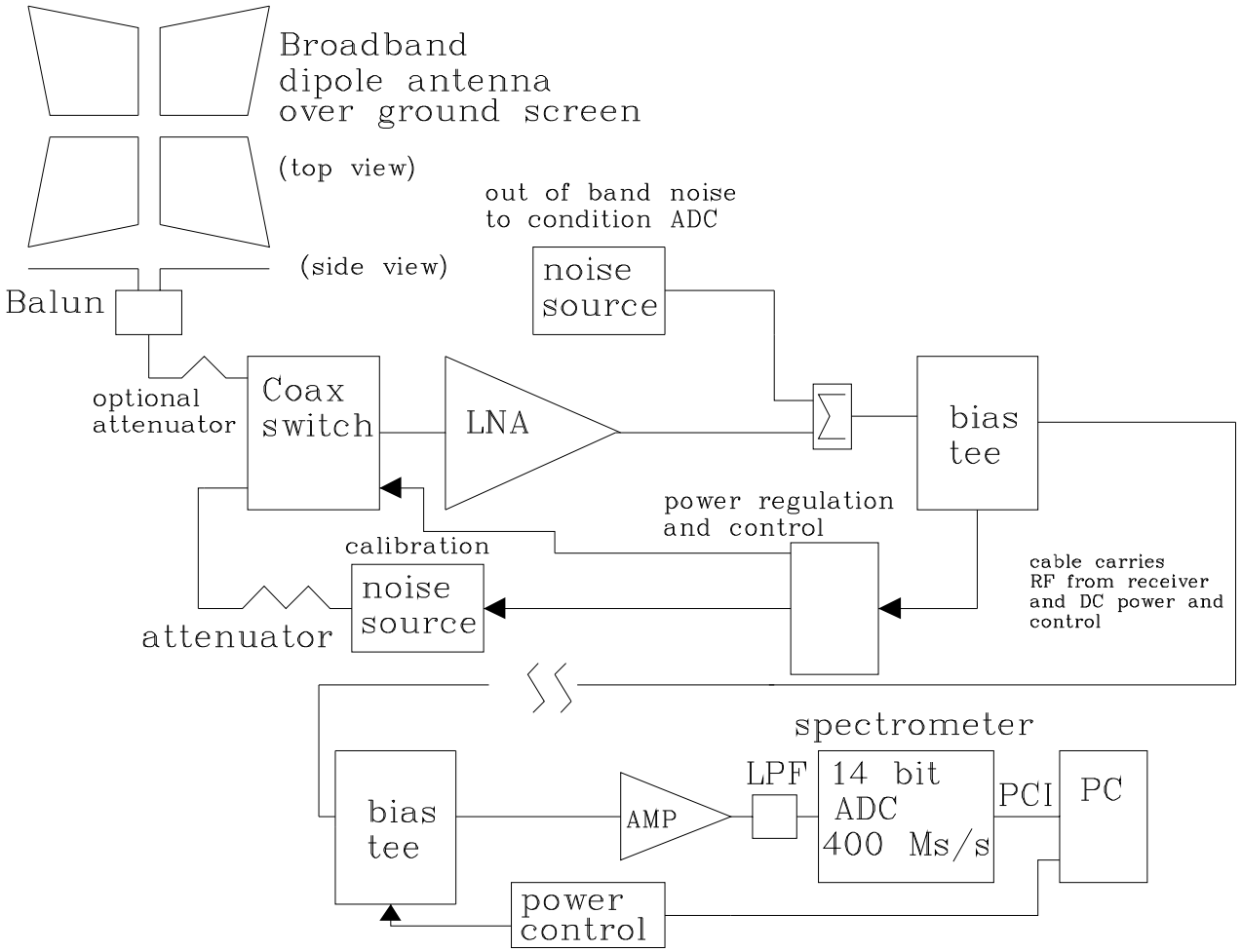
- Instrument overview
- Contributions to SKA
  - + Long-term data archive – a resource for characterizing MRO site
  - + Reionization science is possible from MRO site (EDGES-1)
  - + Absolute calibration looks feasible to high levels (EDGES-2)
- Summary

EDGES (and DARE) at MRO



26º 42’ 31 S, 116º 38’ 02 E

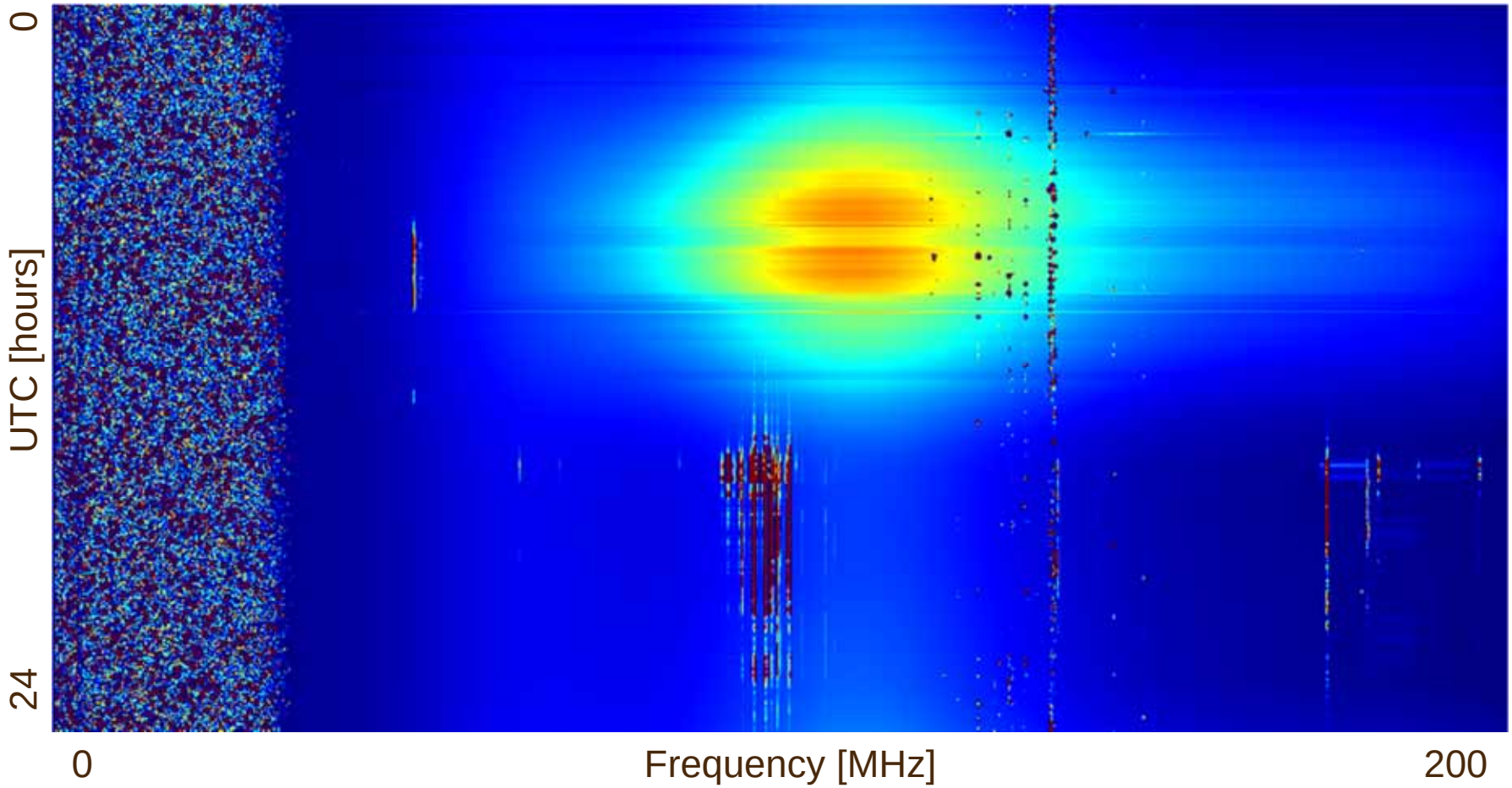
Simplified block diagram of EDGES



Example data

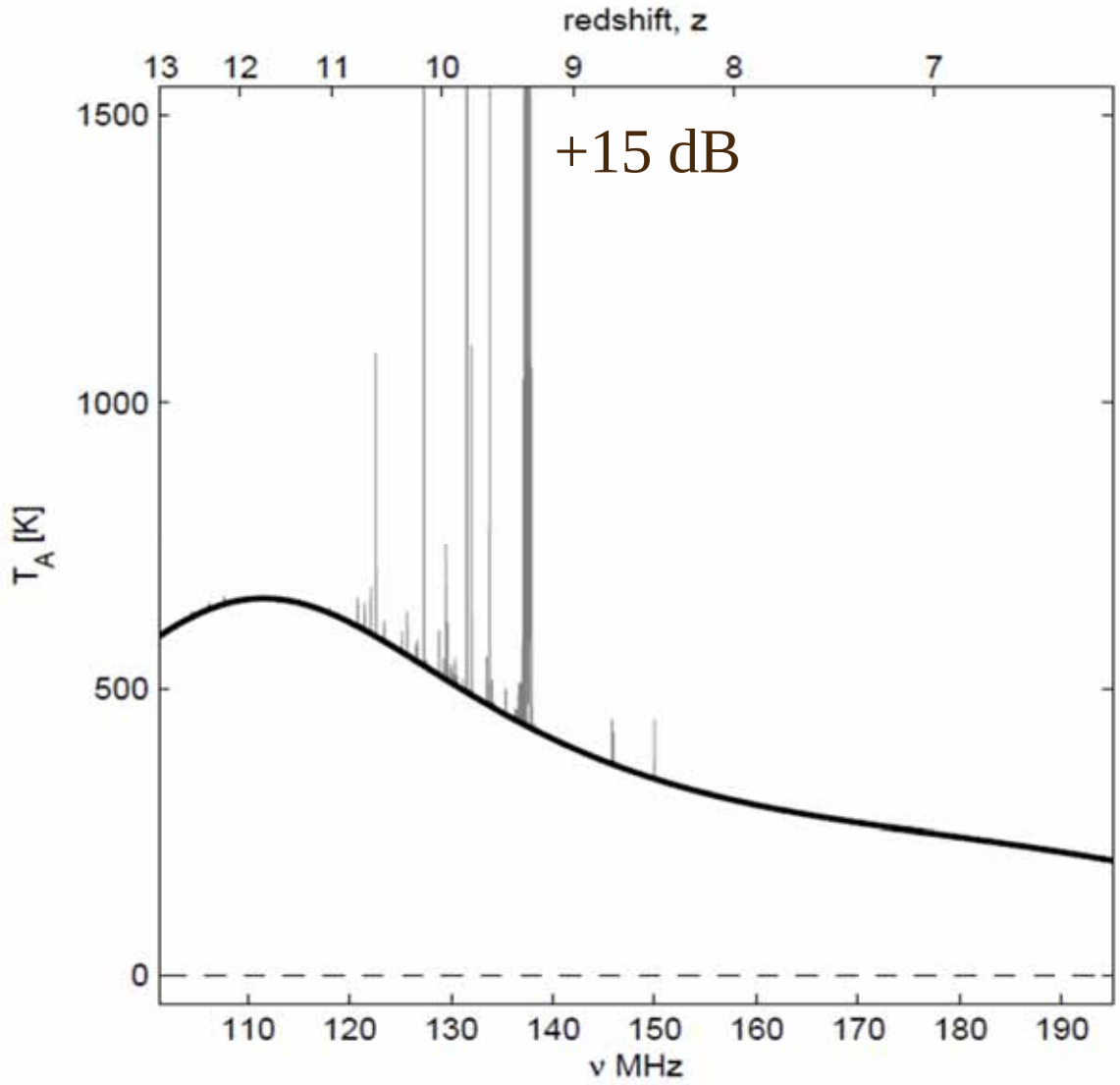
from ~2 years of nearly continuous measurements

07-Nov-2012
28-Oct-2012
21-Oct-2012



http://loco.lab.asu.edu/edges

EDGES-1 results



Murchison Radio-astronomy Observatory (MRO)

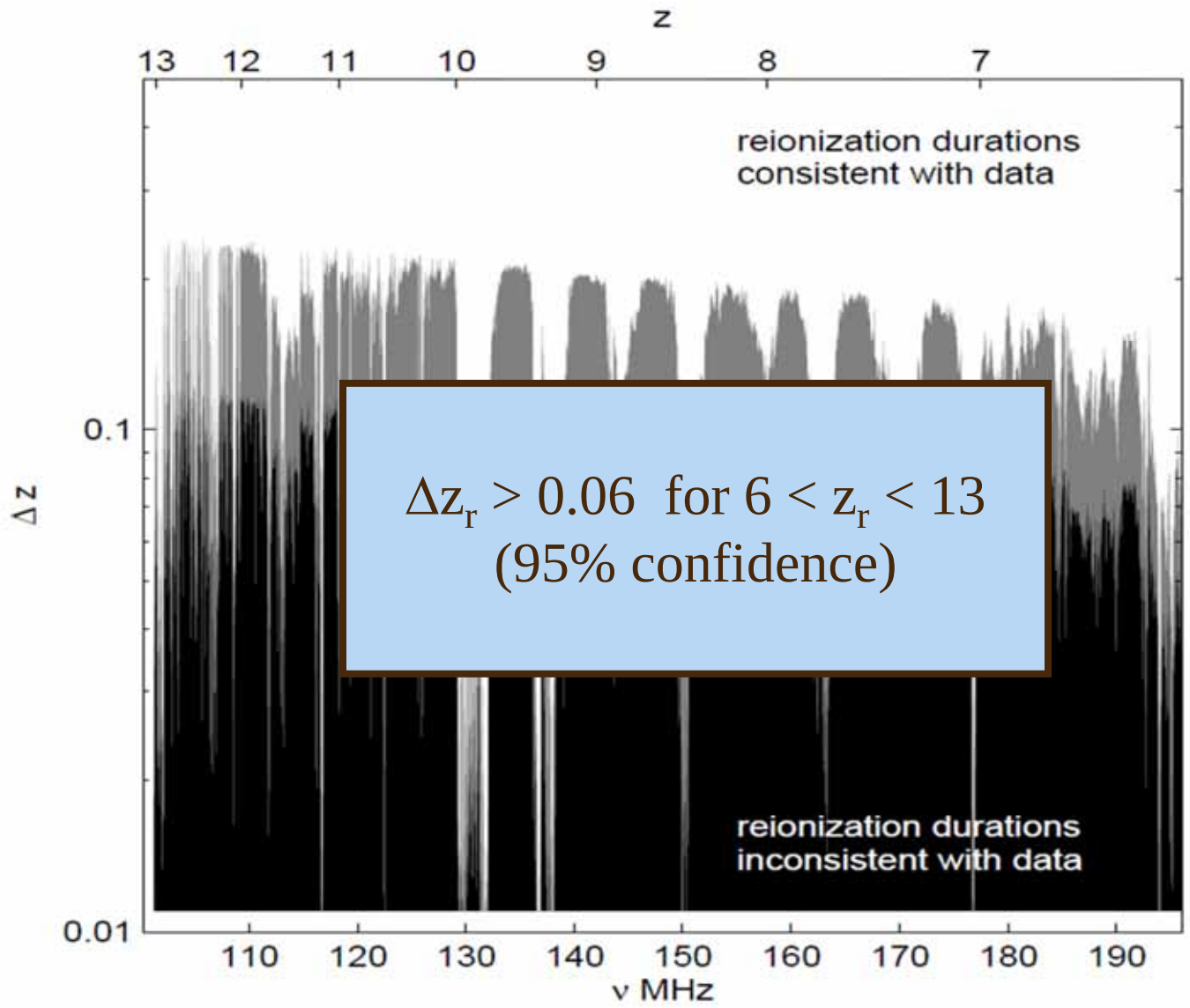
Aug 20 – Oct 20, 2009

1440 wall-clock hours on sky

500 hours after RFI cuts

50 hours eff. integration

EDGES-1 results



Bowman & Rogers, Nature, 468, 7325, pp. 796-798 (2010)

EDGES-2: Absolute Calibration

Details in Rogers, A.E.E., Bowman, J.D., 2012 "Absolute calibration of a wideband antenna and spectrometer for accurate sky noise temperature measurements," Radio Science, 47, RS0K06, doi: 10.1029/2011RS004962

Goal: Science performance improvement of 10, dual-band (50-100, 100-200 MHz)

In the Field:

- 3-position switched spectra from antenna
- S11 measurement of antenna (during installation)

In the Lab:

- Ancillary 3-position switched spectra from external ambient and hot loads for calibration of internal noise diode
- Ancillary spectrum of an open cable for measurement of LNA noise waves
- Ancillary S11 measurements of ambient and hot loads, LNA input, and open cable used for noise wave measurements
- Measurements done at 2 temperatures for temperature coefficients
- Lab performance verification using “artificial antenna”

Lab testing – work in progress

Use an “artificial antenna” to test accuracy

Assumes:

- A mismatched load at uniform temperatures is precisely equivalent to a lossless antenna observing a uniform sky at the same temperature

Caveat:

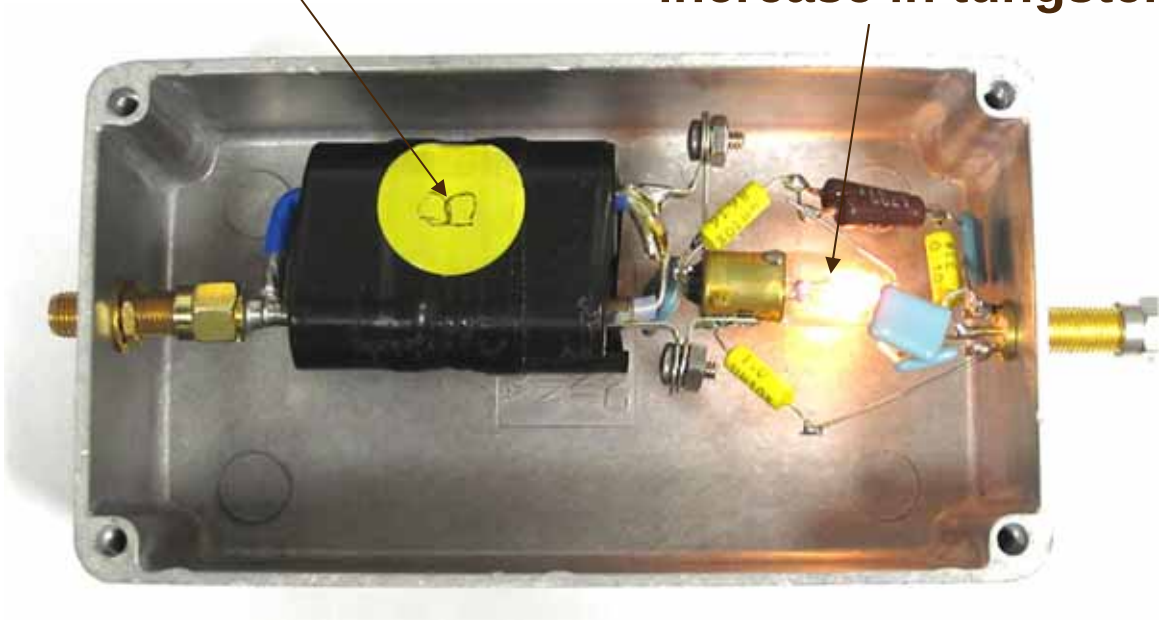
- Corrections have to be made for the non-uniform temperature of a hot tungsten filament source (although corrections are small ~ less than 1 K; see EDGES memo 100)

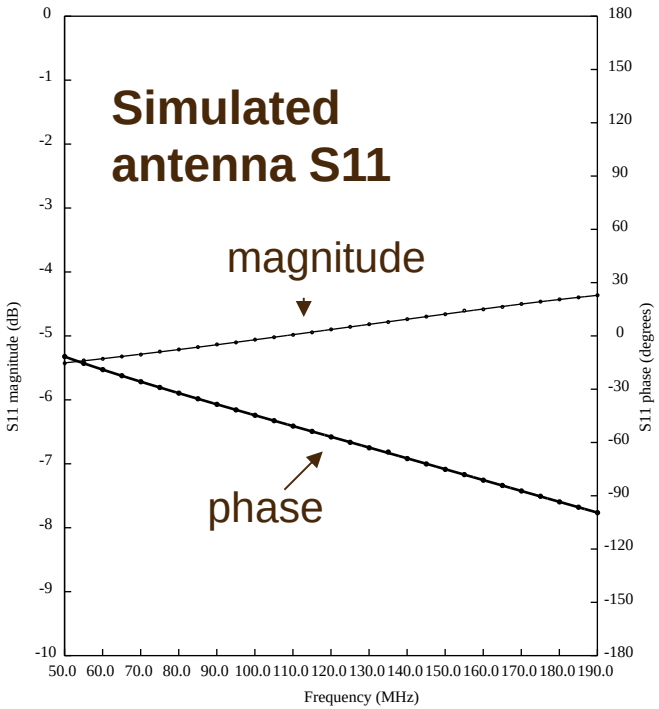
Artificial Antenna

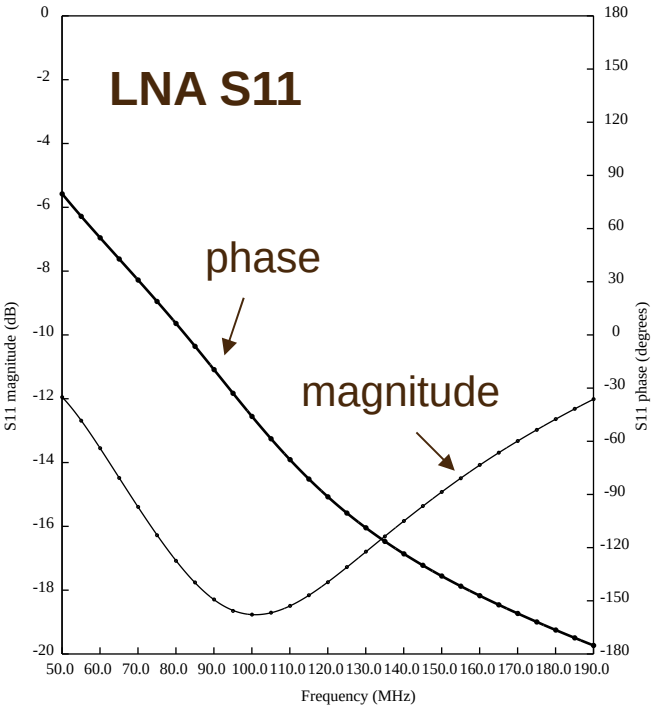
Simulator of antenna looking at sky temperature of 1670K +/- 30K

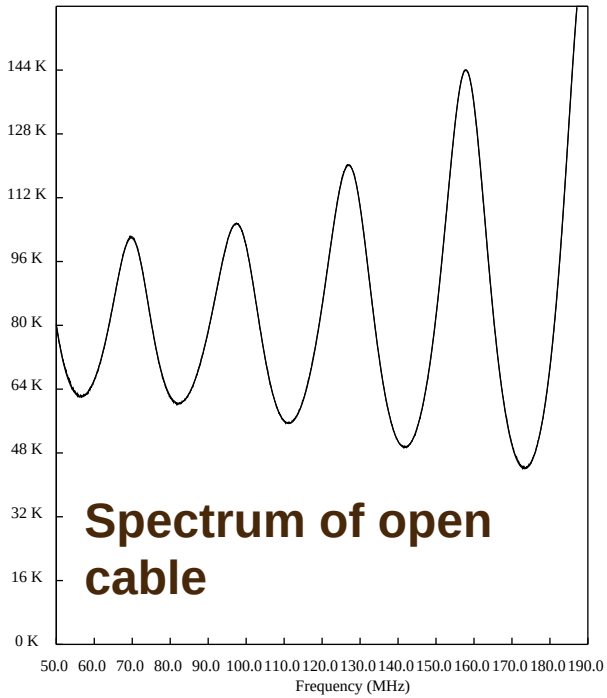
balun at ambient temperature

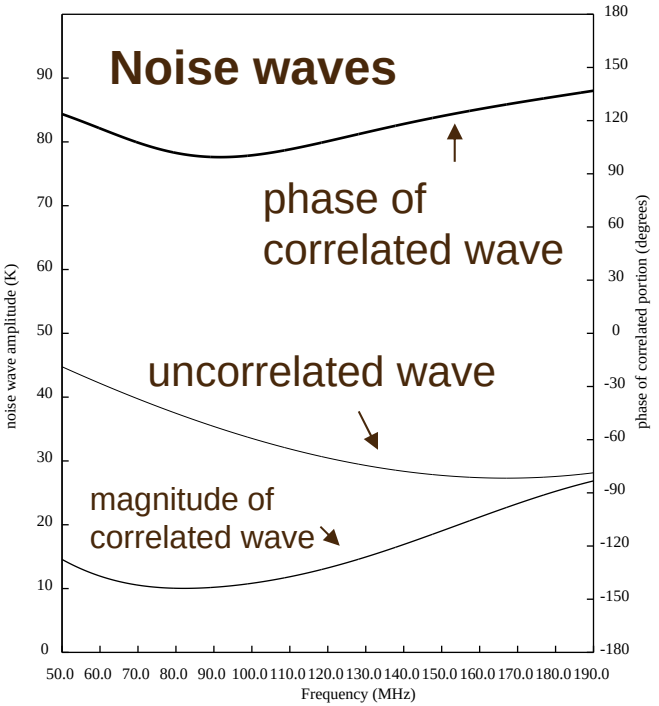
Lamp filament of 1670K +/- 30K estimated from 8.26 fold increase in tungsten resistance




Simulated antenna S11
magnitude
phase
S11 magnitude (dB)
S11 phase (degrees)
Frequency (MHz)


LNA S11
phase
magnitude
S11 magnitude (dB)
S11 phase (degrees)
Frequency (MHz)


Spectrum of open cable
Frequency (MHz)

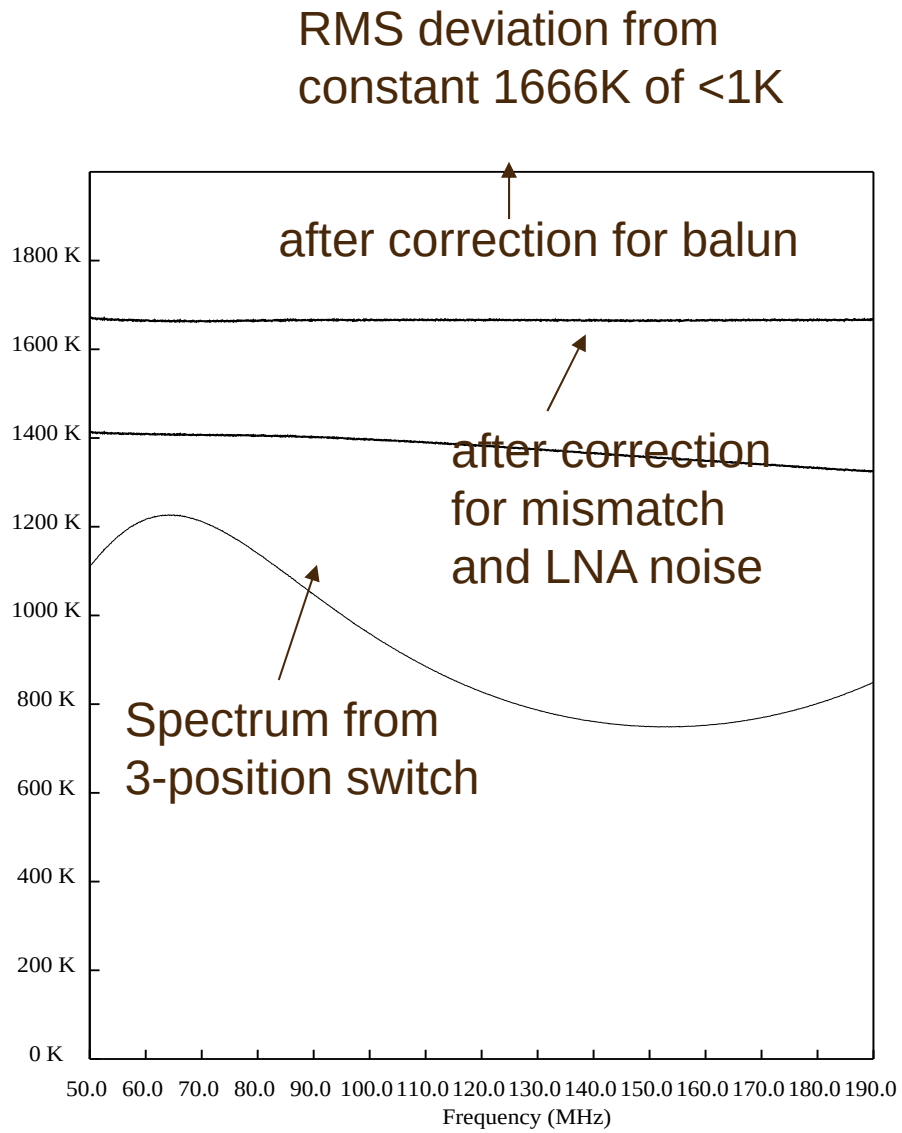

Noise waves
phase of correlated wave
uncorrelated wave
magnitude of correlated wave
noise wave amplitude (K)
phase of correlated portion (degrees)
Frequency (MHz)

Lab demonstration of absolute calibration

Estimate absolute calibration of better than 1 part in 3000 currently

Some uncertainty due to corrections for non-uniform temperature of tungsten filament, working on improved modeling

Believe 1 in 10 000 possible with technique in near future



Estimates of the sources of error and their magnitude expressed as the residuals to fits with increased numbers of parameters along with the bias in EOR estimation

		Residual mK				EoR mK			Note
Error source	Assumed error	A	B	C	D	E	F	G	
Antenna S11	0.01 dB, 0.1°	26	23	16	0	0	0	0	5
LNA S11	0.01 dB, 0.1°	20	18	18	0	0	0	0	6
Antenna loss	0.1%	130	0	0	0	0	0	0	2,4,10
Antenna beam	Fourpoint	500	300	0	0	5	5	2	7
Ionosphere	0.015 dB @ 150 MHz	1500	22	0	0	8	9	2	1
Sky spectral index	0.05	2800	200	1	1	6	12	4	
Spectral index steepening "gamma"	0.12	9000	2500	1	1	40	60	20	8
Slope in antenna loss	0.1% per 50 MHz	80	74	2	1	30	30	10	3
Slope in antenna S11	0.01 dB per 50 MHz	12	11	10	5	300	25	3	
Slope in LNA S11	0.01 dB per 50 MHz	11	10	6	4	300	25	9	
Temperature	1° K	700	10	10	0	30	10	2	9

Table 1A

A	Rms residual following removal of scale
B	Rms residual following removal of scale and offset
C	Rms residual plus removal of f^{-2} and $f^{-4.5}$
D	Rms residual plus functions for additional errors listed in table 2
E	Bias in EoR for 10 parameter solution
F	Bias with 10´ added cable
G	Bias with EoR width reduced by factor of 2

Table 1B

Parameters of 10 parameter solution:

1] EoR signature (30 mK, 50@145MHz)

2] scale (assumes spectral index of -2.5)

3] constant (ground emission)

4] frequency $^{-2}$ (ionosphere emission)

5] frequency $^{-4.5}$ (ionosphere absorption)

6] Magnitude of antenna S11

7] Magnitude of LNA S11

8] S11 phase error

9] S11 delay error

10] temperature scale

Estimate of errors using simulations – for more details see EDGES memo 99

EDGES summary

- EDGES-1 successfully demonstrated viable limits on reionization with only 3-position calibration (no accounting for reflection terms) and polynomial fitting
- Nearly 2-years of RFI (and other event) monitoring at MRO, posted at http://loco.lab.asu.edu/edges, ongoing analysis of RFI correlation with weather, ionosphere, meteors, etc.
- EDGES-2 attempting absolute calibration, 1 part in 10 000 appears within reach, expect first deployment by 2013-Q3. Should constrain reionization duration to dz >1
- Spin-offs include improved calibration and characterization of VNAs at low-frequencies, calibration of noise diodes, “artificial antenna”, real antenna stability (sensitivity to perturbations, temperature, etc.)
- Lessons: Incremental development useful. Keep active memo series