Cosmological Reionisation Experiment

CoRE Mk I

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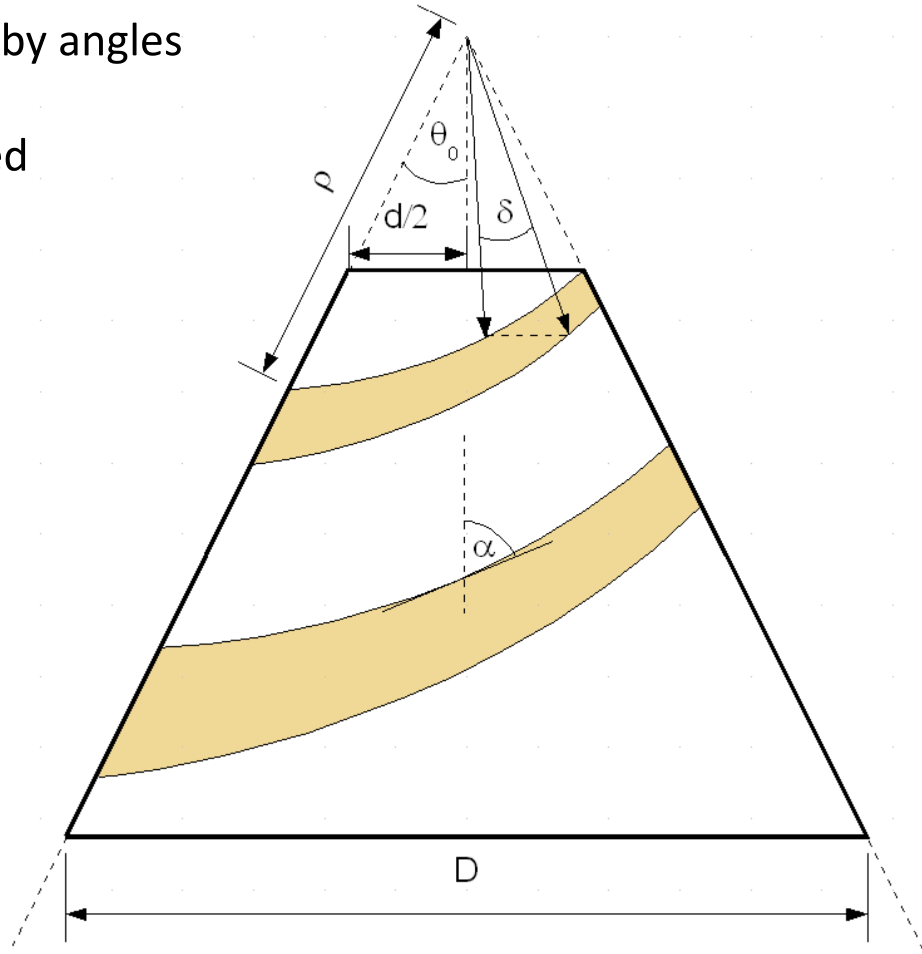
Overview

- Science
  - Expected Signal
    30 mK / 5 MHz (emission)
  - Design Target
    1 mK / 1 MHz target
- Instrument
  - Frequency Independent Antenna
  - 114-228 MHz
  - Correlation Spectrometer
- Results
  - System stability ~ 1%
  - ~ 10 K / 2.5 MHz residuals in bandpass calibration

Conical Log Spiral Antenna

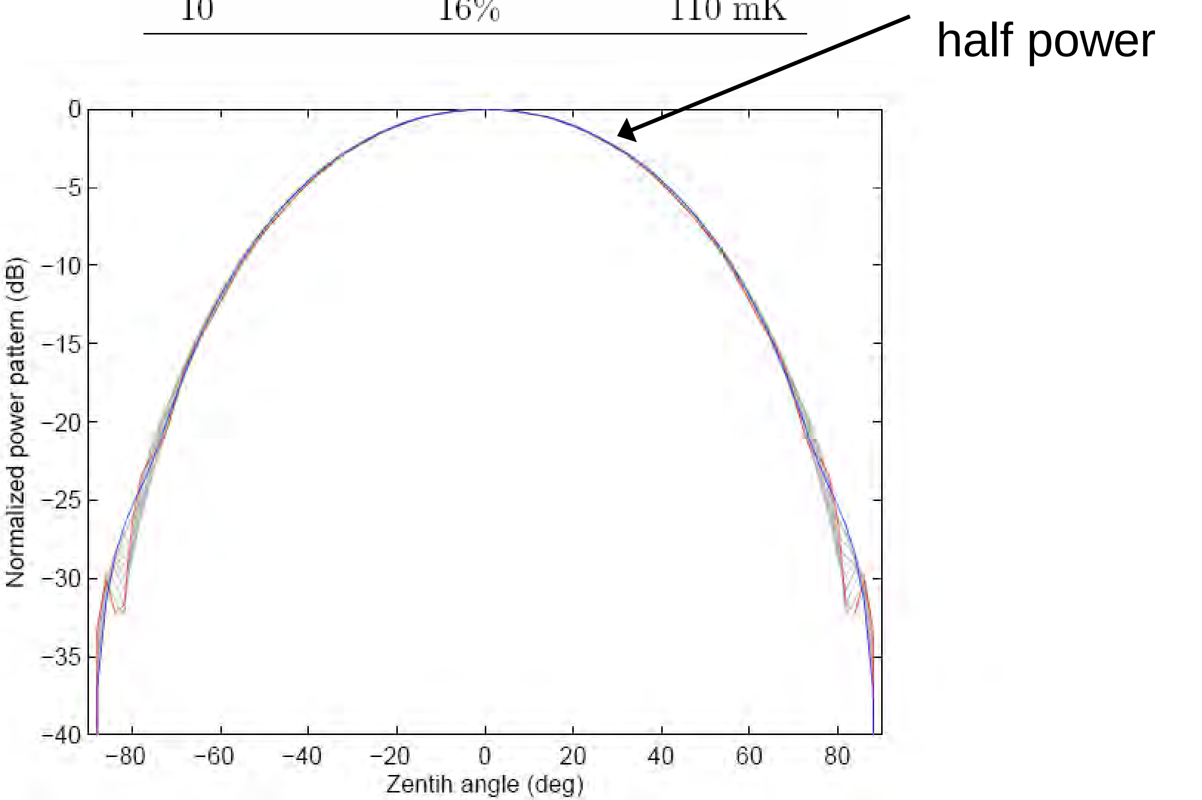
Geometry defined by angles

Strictly needs scaled resistivity

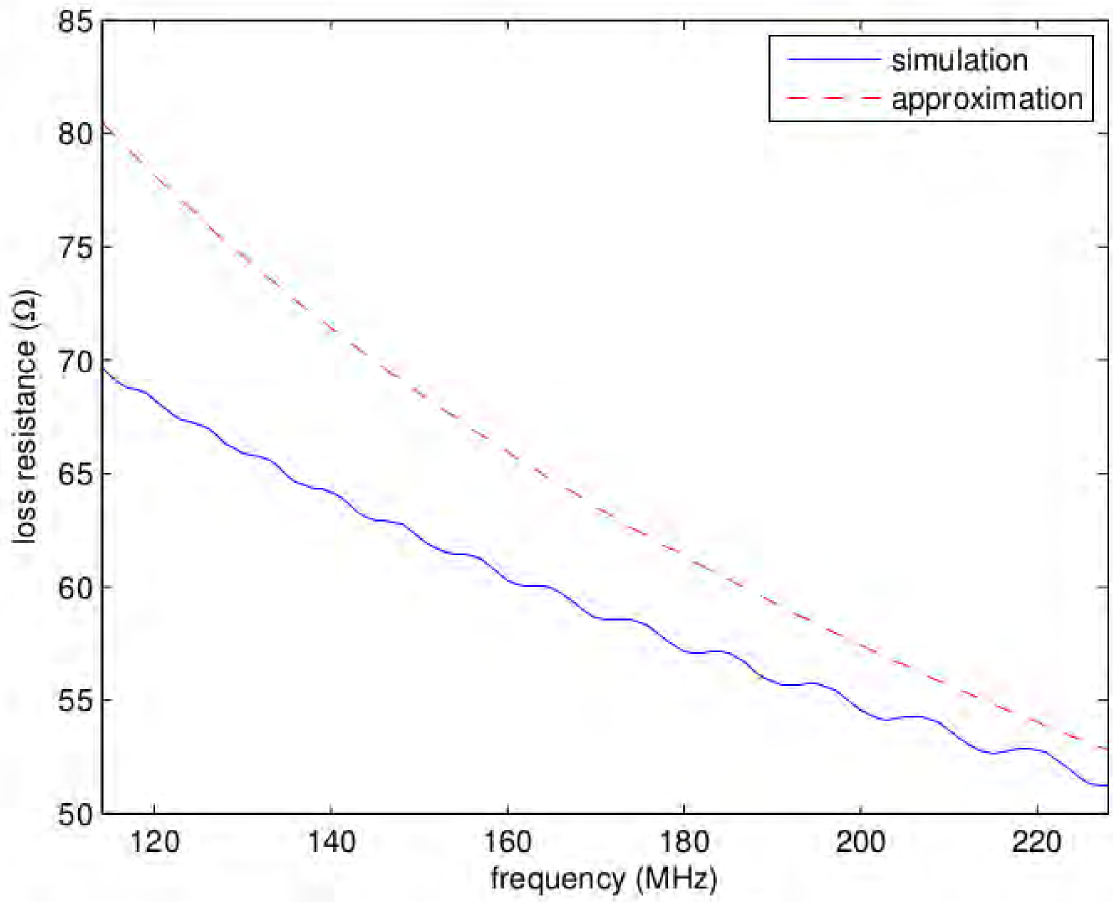


Frequency Independent Antenna

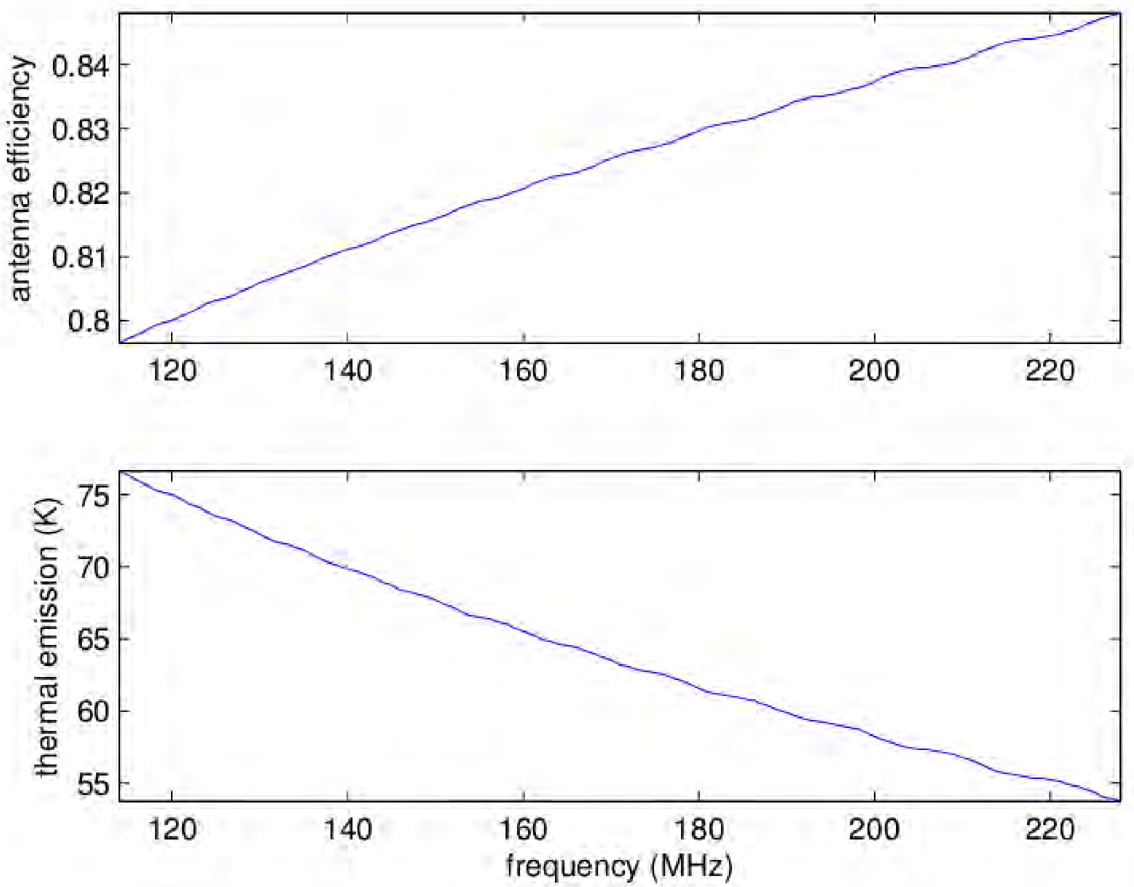
β	Directivity error at half power (pk-pk)	Bandpass error (pk-pk)
148	1.0%	0.07 mK
74	2.0%	0.50 mK
37	4.1%	3.6 mK
19	8.1%	22 mK
10	16%	110 mK



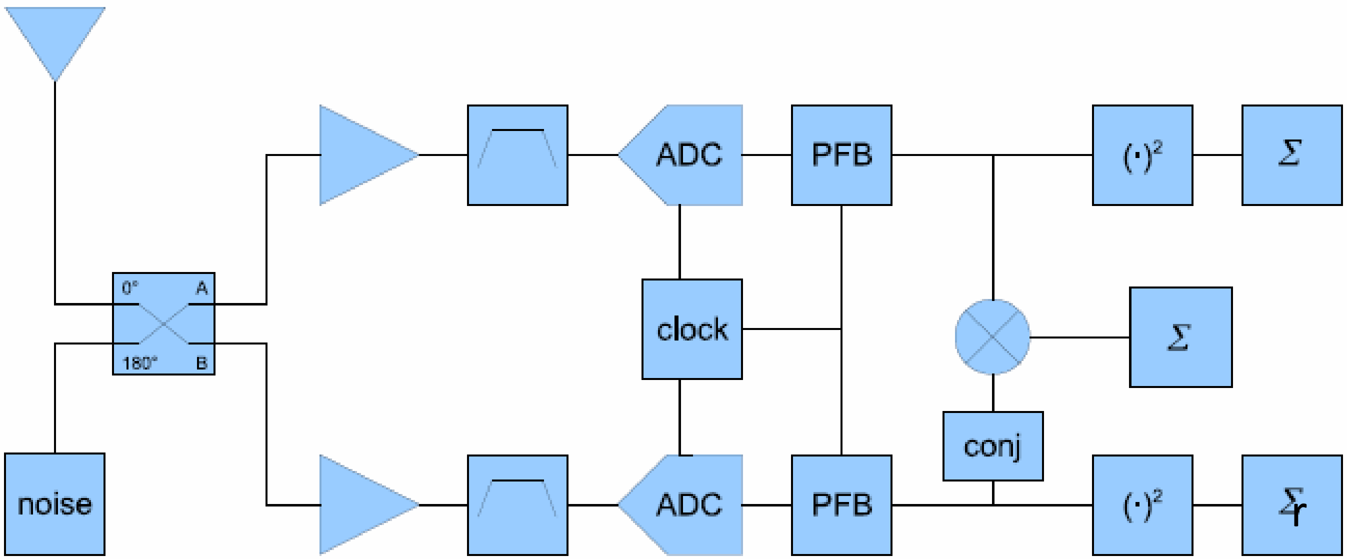
Antenna Loss Resistance



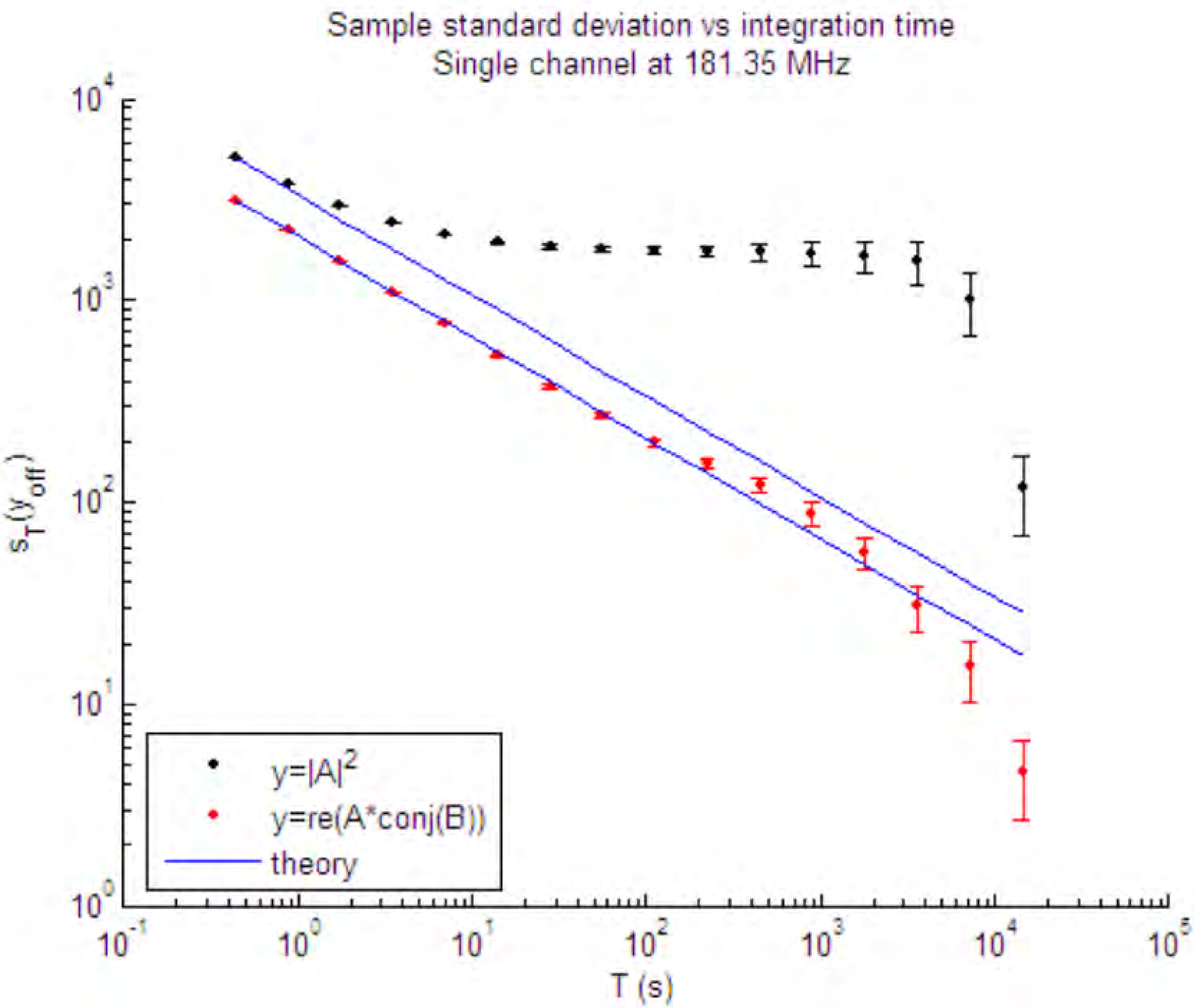
Antenna Thermal Emission



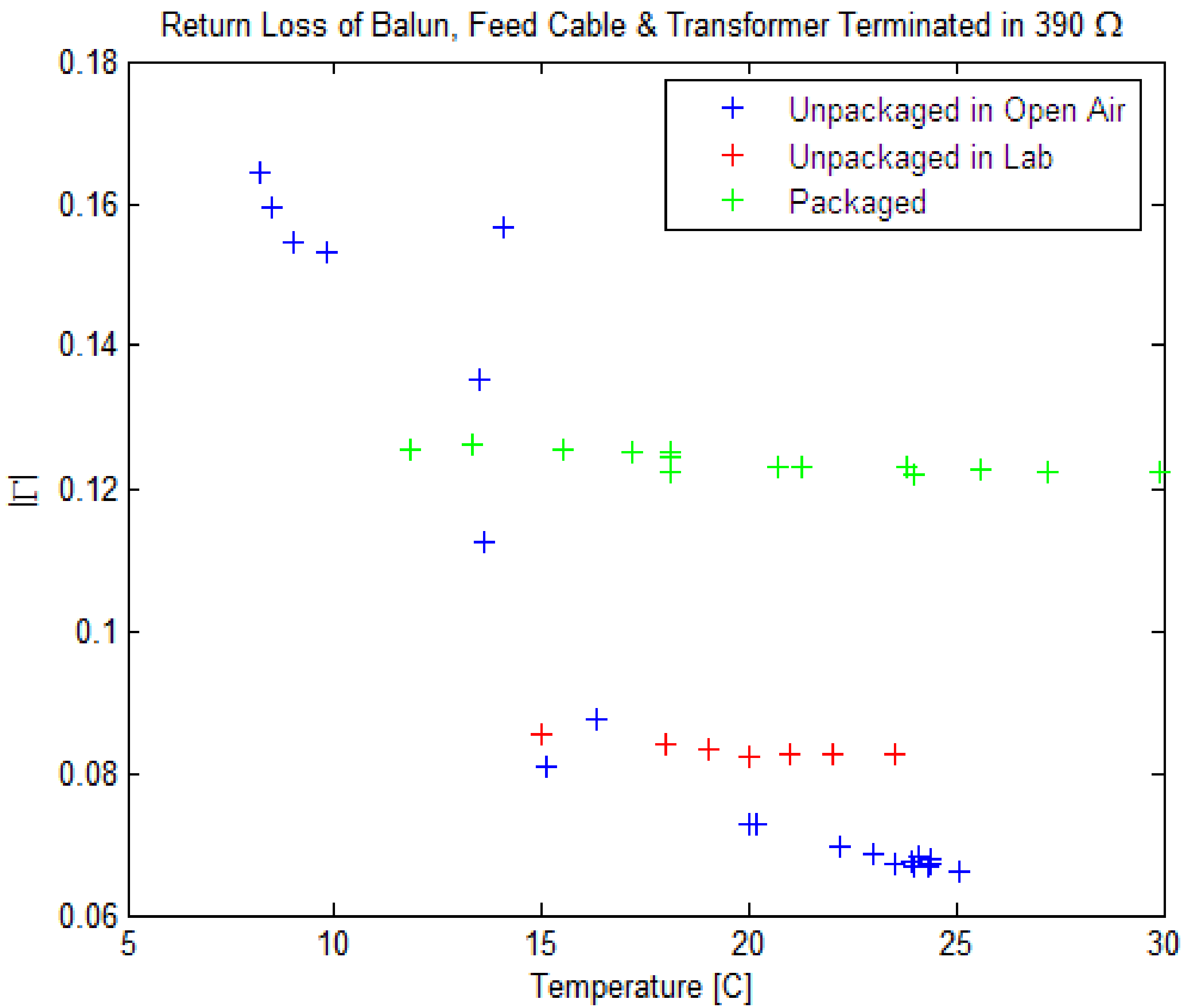
Correlation Receiver



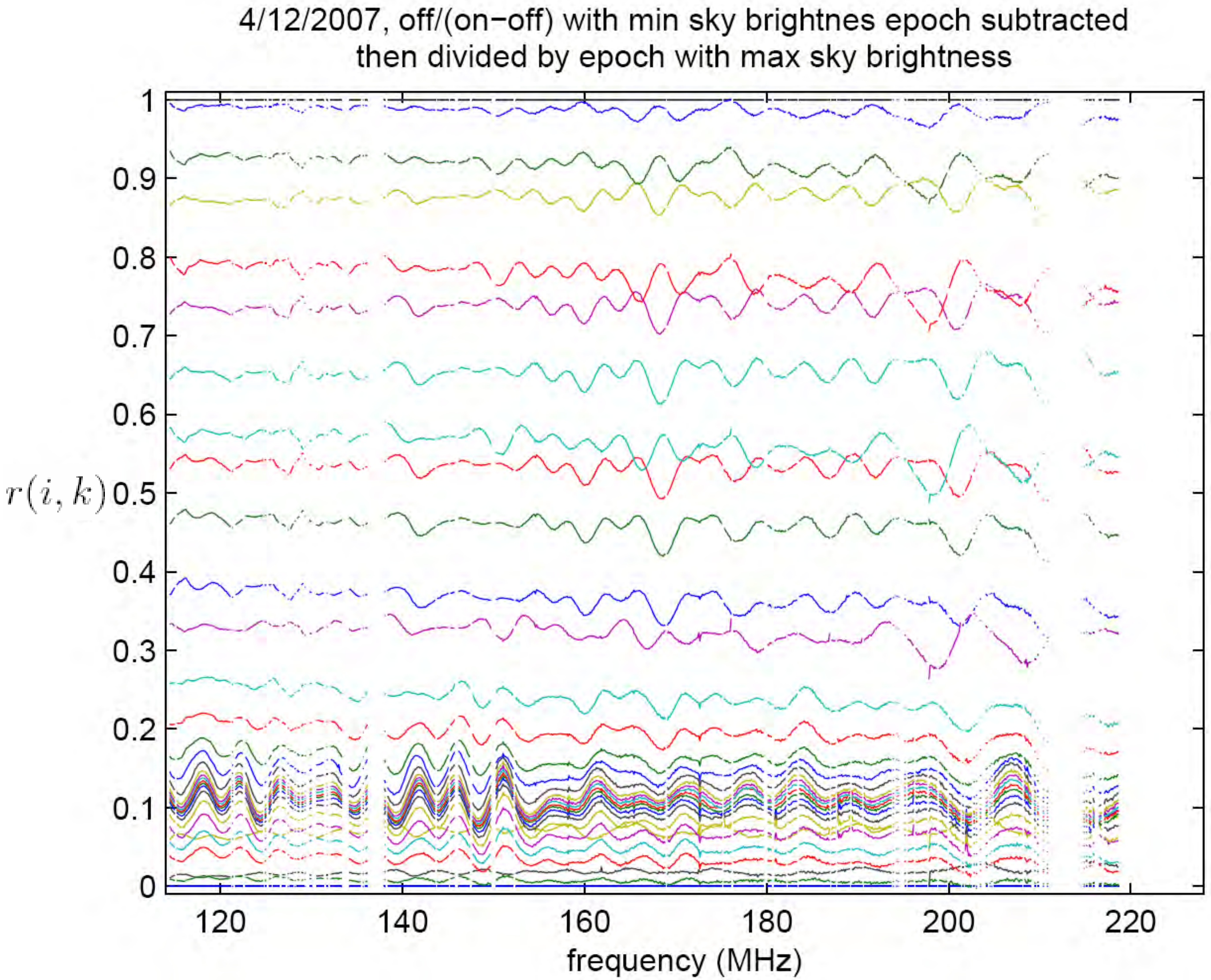
$$q(i,k) \equiv -\frac{r_{off}}{(r_{on-pre} + r_{on-post})/2 - r_{off})}$$



Sample standard deviation vs integration time
Single channel at 181.35 MHz
$s_T(y_{off})$
T (s)
y=|A|^2
y=re(A*conj(B))
theory


Return Loss of Balun, Feed Cable & Transformer Terminated in 390 Ω
0.18
0.16
0.14
0.12
0.1
0.08
0.06
|Γ|
5
10
15
20
25
30
Temperature [C]
Unpackaged in Open Air
Unpackaged in Lab
Packaged

Bandpass Calibration Residuals

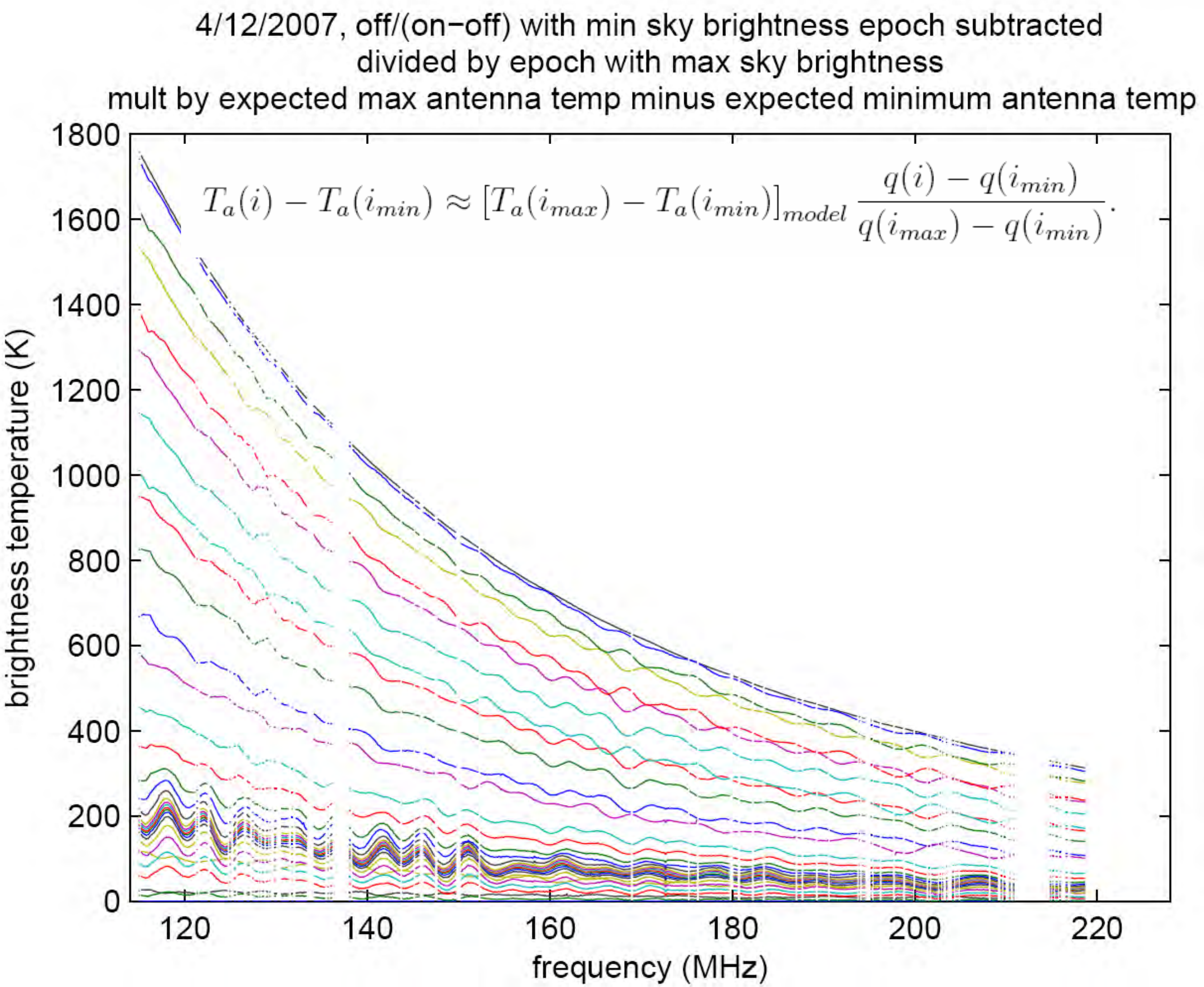


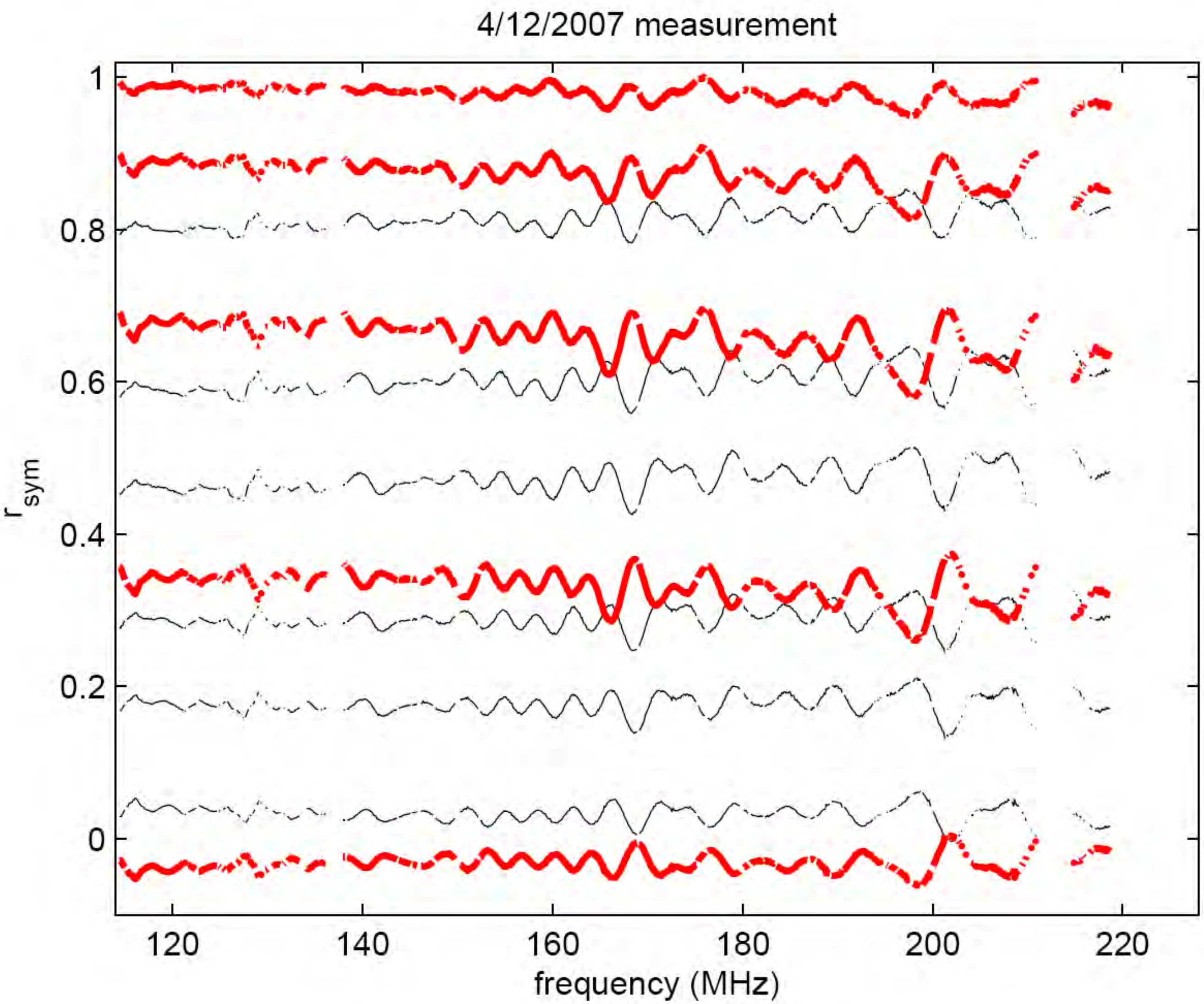
$$q(i,k) \equiv -\frac{r_{off}}{(r_{on-pre} + r_{on-post})/2 - r_{off})}$$

$$q(i,k) = |g_{ant}|^2 \frac{T_a}{T_{cal}} - \frac{T_{pad}}{T_{cal}}.$$

$$r(i,k) \equiv \frac{q(i,k) - q(i_{min},k)}{q(i_{max},k) - q(i_{min},k)}$$

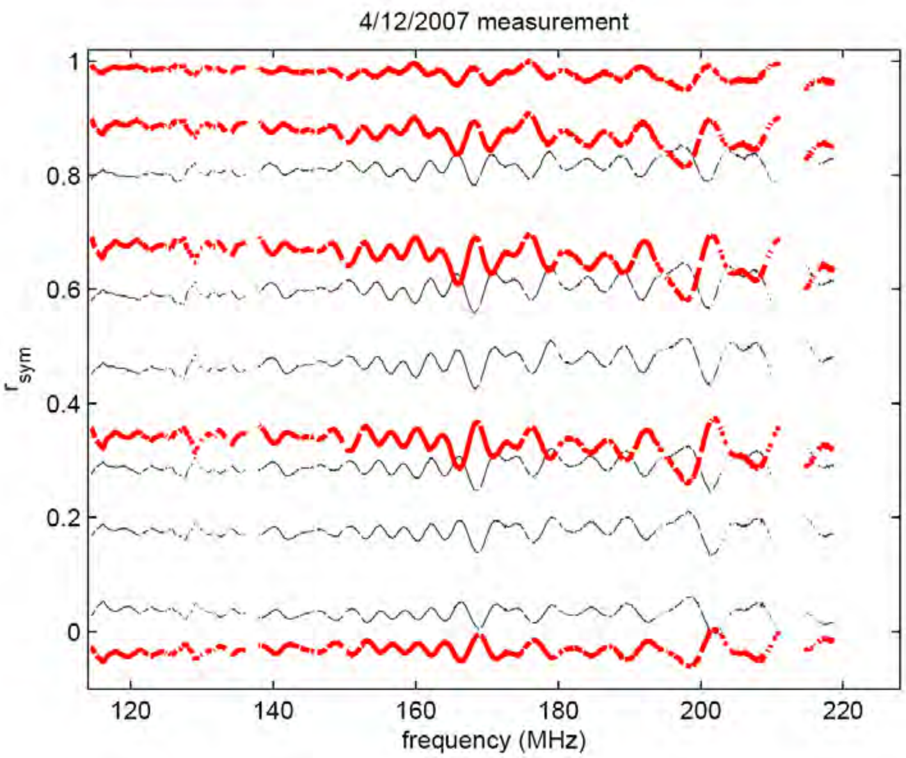
Denormalized Bandpass Residuals ~ 10 K

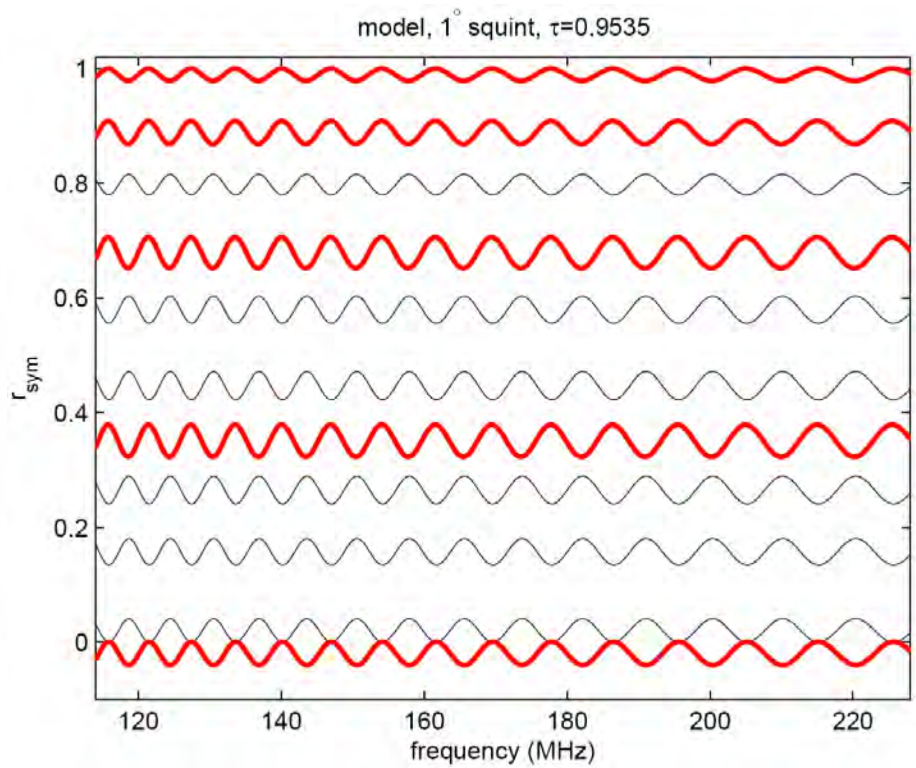


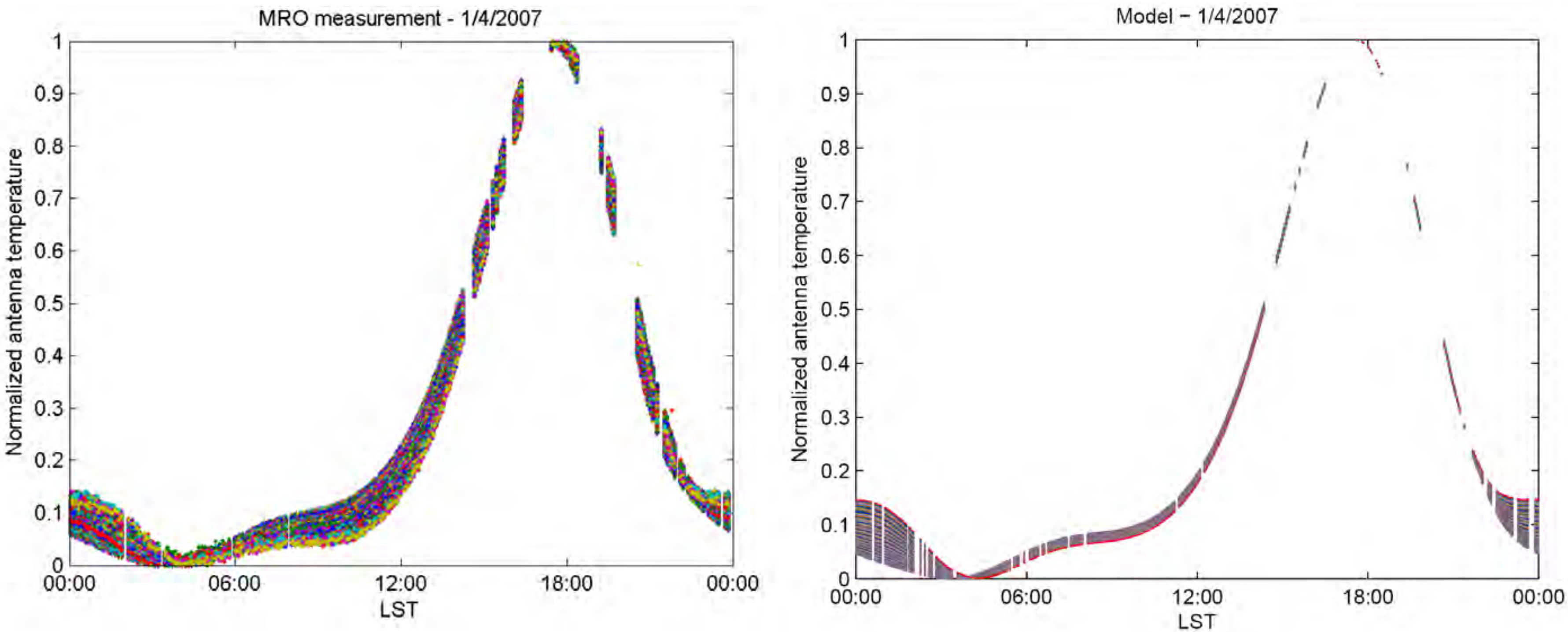


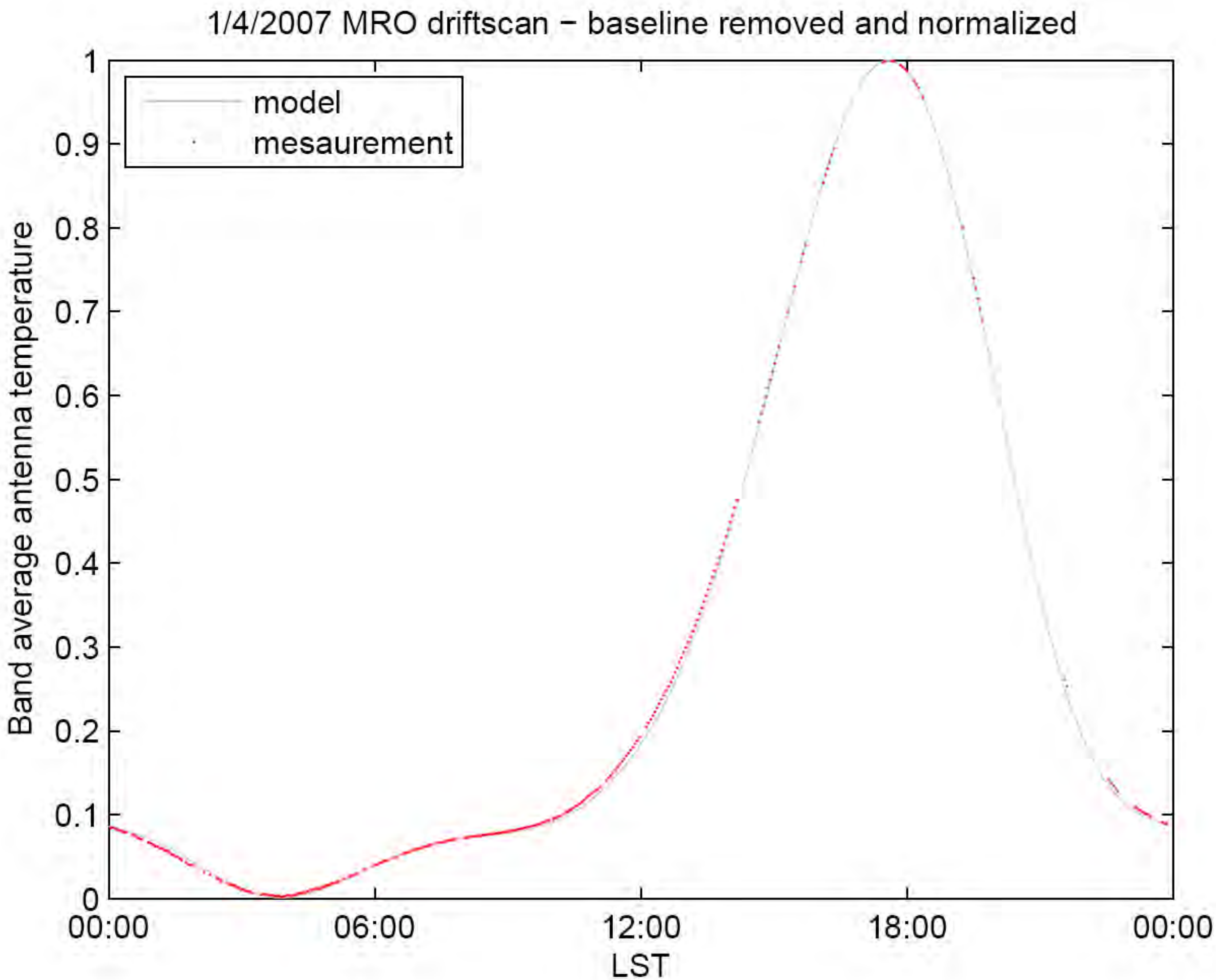
$$r_{sym}(i,k) \equiv \frac{q(i,k) - \bar{q}_{min}(k)}{q(i_{max},k) - \bar{q}_{min}(k)}$$

$$\bar{q}_{min}(k) = \frac{q(i_{min,A},k) + q(i_{min,Z},k)}{2}.$$


4/12/2007 measurement
r_sym
frequency (MHz)
120
140
160
180
200
220
0
0.2
0.4
0.6
0.8
1

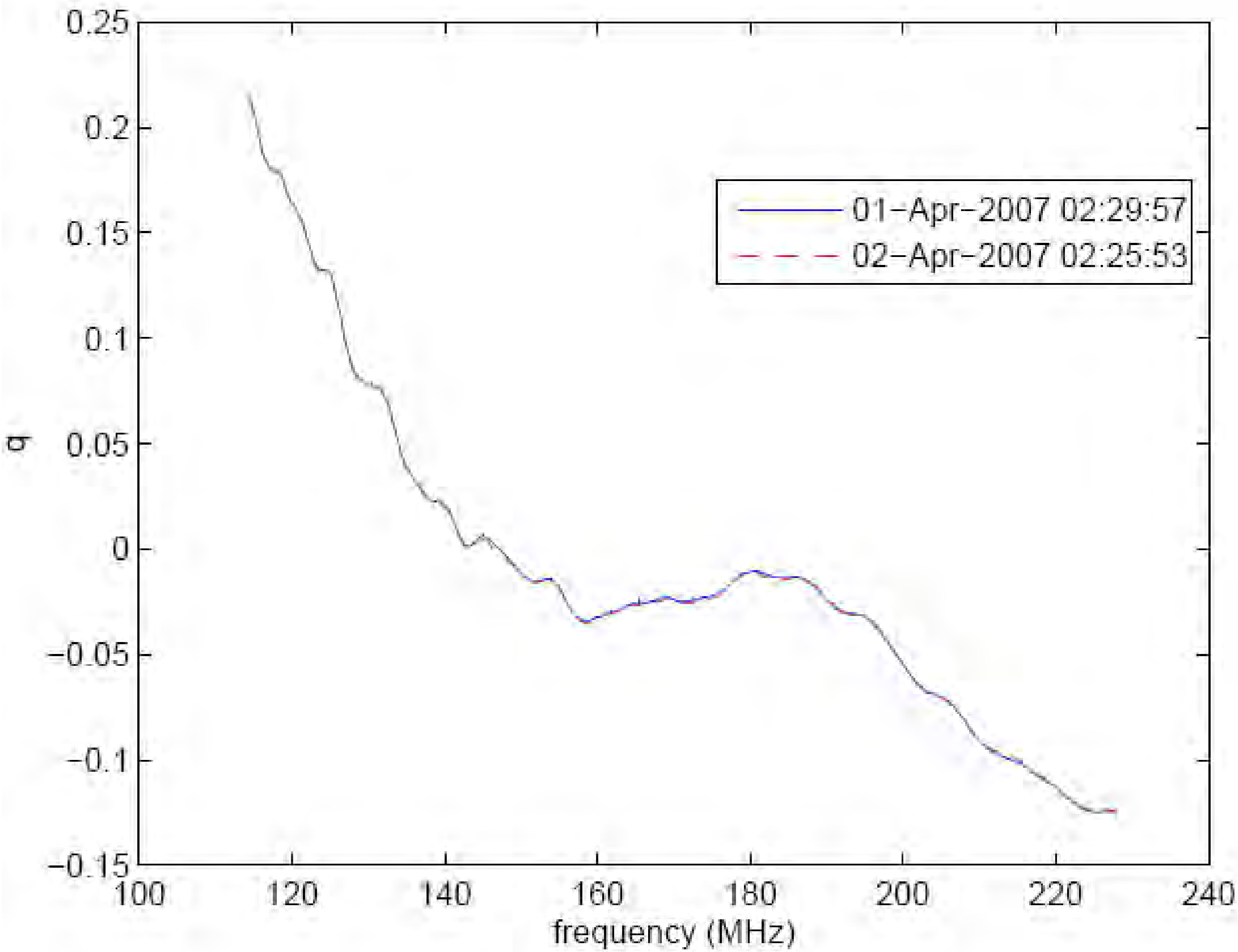

model, 1° squint, τ=0.9535
r_sym
frequency (MHz)
120
140
160
180
200
220
0
0.2
0.4
0.6
0.8
1


MRO measurement - 1/4/2007
Normalized antenna temperature
LST
Model – 1/4/2007
Normalized antenna temperature
LST


1/4/2007 MRO driftscan − baseline removed and normalized
model
mesaurement
Band average antenna temperature
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
00:00
06:00
12:00
18:00
00:00
LST

System Stability ~ 1% or better

$$q(i,k) \equiv -\frac{\langle v_A^* v_B \rangle_{off}}{\langle v_A^* v_B \rangle_{on} - \langle v_A^* v_B \rangle_{off}}$$



$$q(i,k) = |g_{ant}|^2 \frac{T_a}{T_{cal}} - \frac{T_{pad}}{T_{cal}}.$$

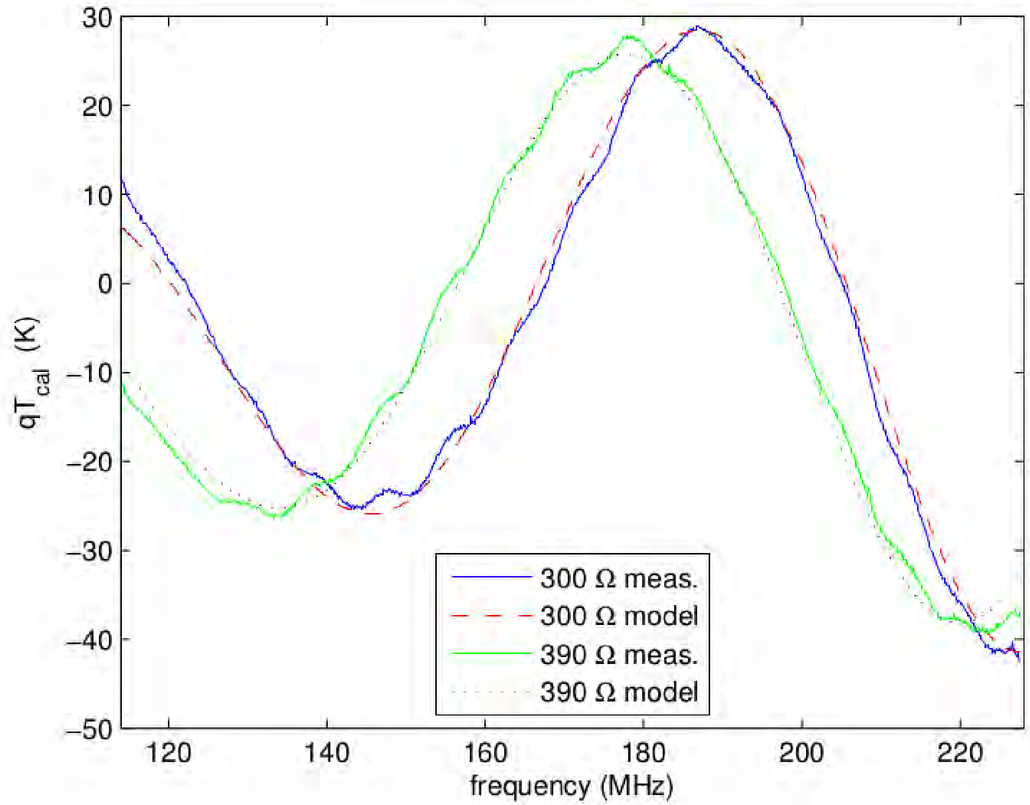


Fig. 7.14: Joint fitting of Eq. (7.26) to measurements where the antenna is replaced by 300 Ω and 390 Ω resistors.

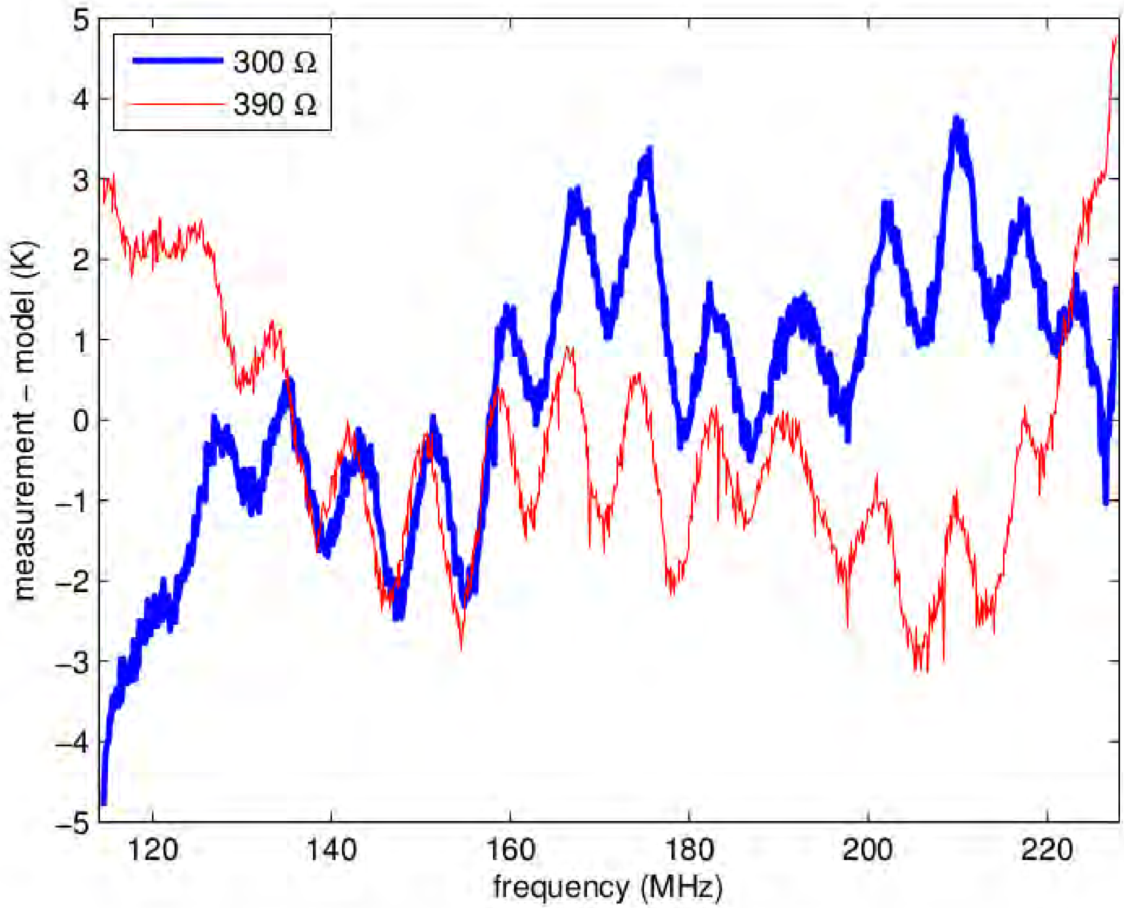
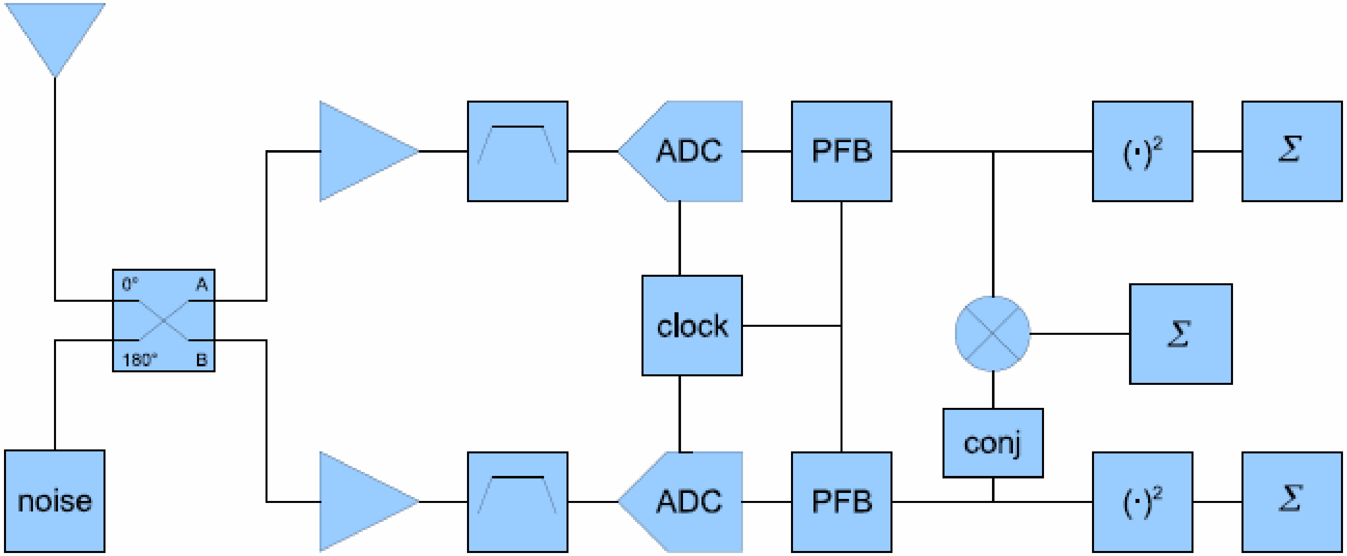


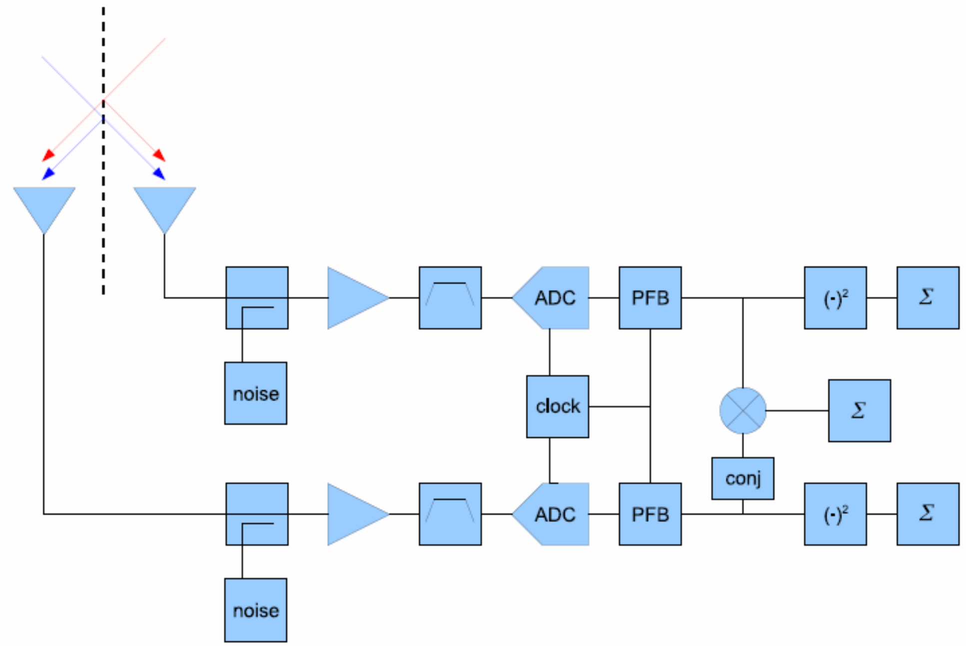
Fig. 7.15: Residuals from joint fitting of Eq. (7.26) to measurements where the antenna is replaced by 300 Ω and 390 Ω resistors.

Correlation Receiver



Future

- Future work:
  - rotating antenna
  - split in free space (CoRE Mk II / SARAS)
  - simple 1 antenna system
    detailed model of simplest system
    antenna impedance match monitoring (See Keith Bannister's Talk)

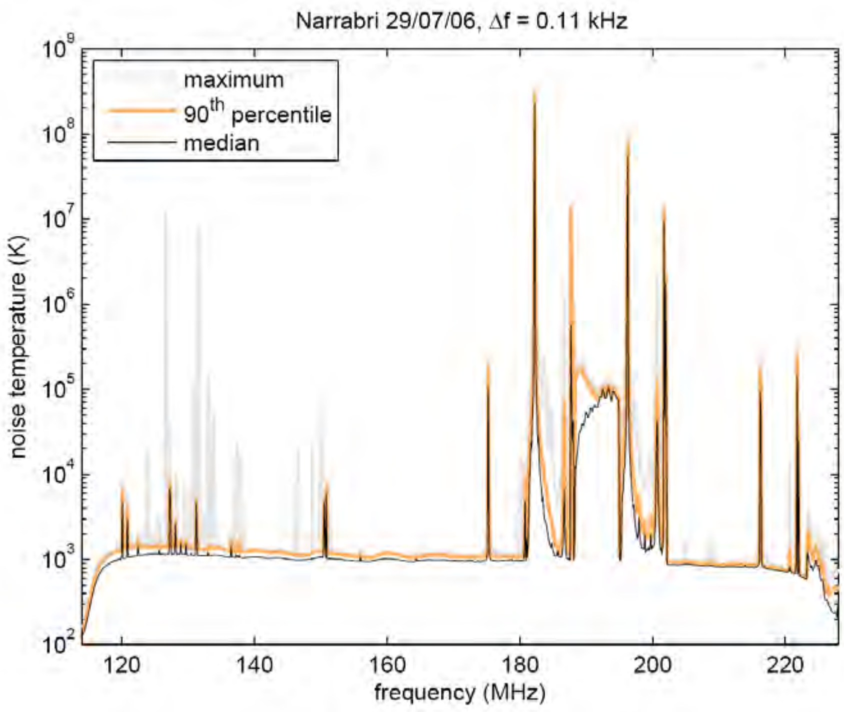


The End

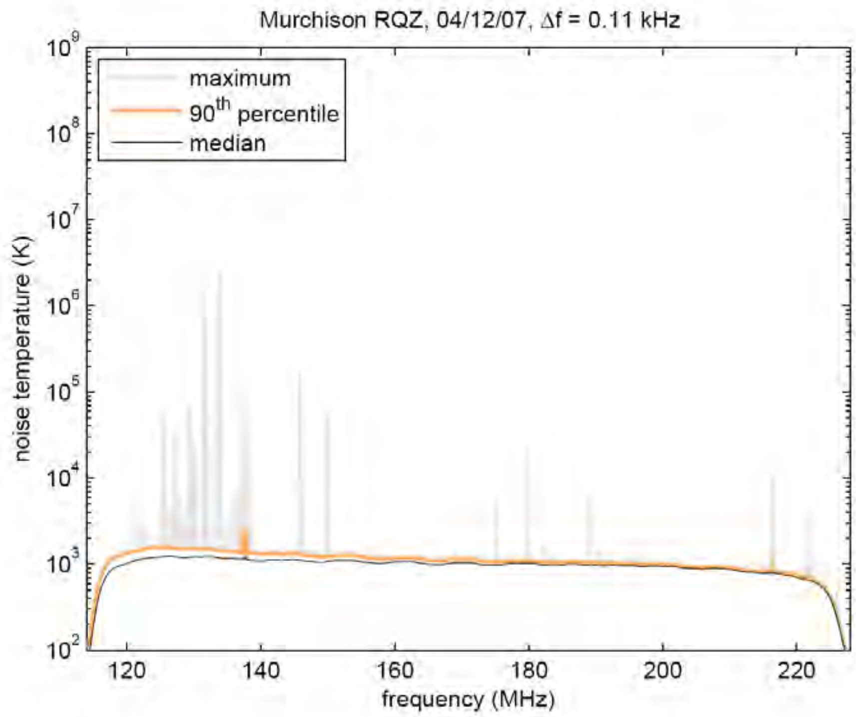
- End of main presentation
- Design detail follows for discussion

Spectrum Comparison

Culgoora, Narrabri (pop. 6000)



Murchison (pop. 110)



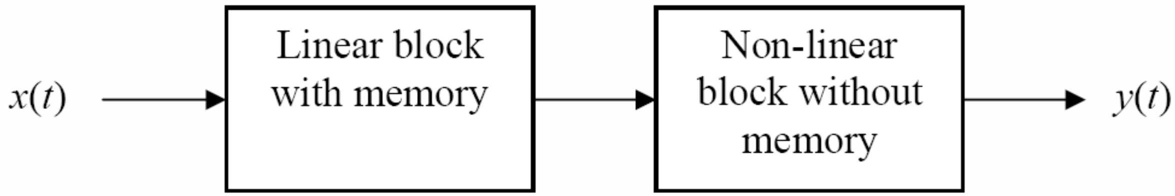


Fig. 6.6: The Wiener model.

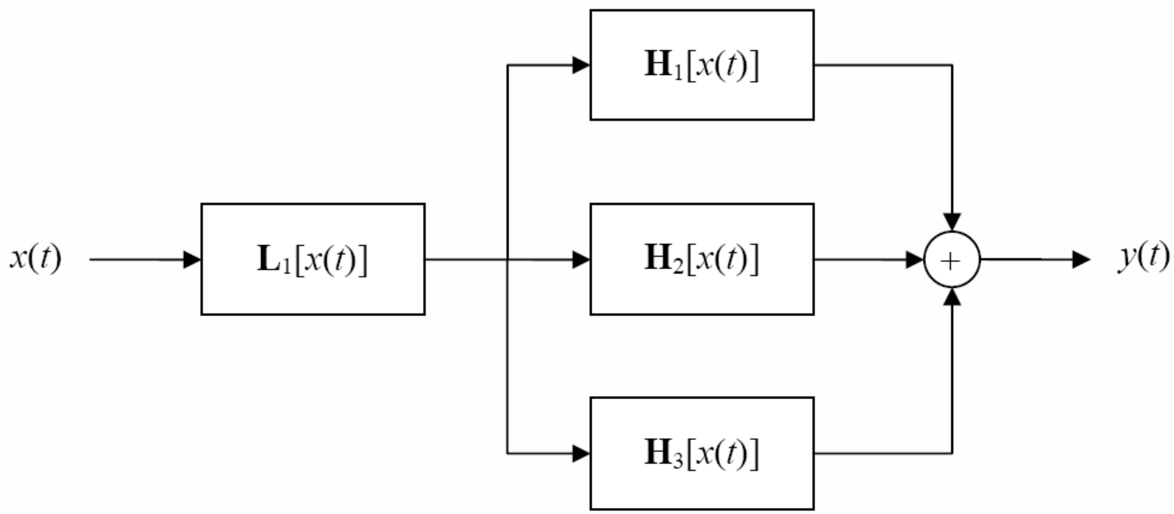


Fig. 6.7: Wiener model with third order non-linear block.

$$\mathbf{H}_n[x(t)] = \int_{-\infty}^{\infty} \cdots \int_{-\infty}^{\infty} h_n(\tau_1, \ldots, \tau_n) x(t-\tau_1) \cdots x(t-\tau_n) d\tau_1 \cdots d\tau_n$$

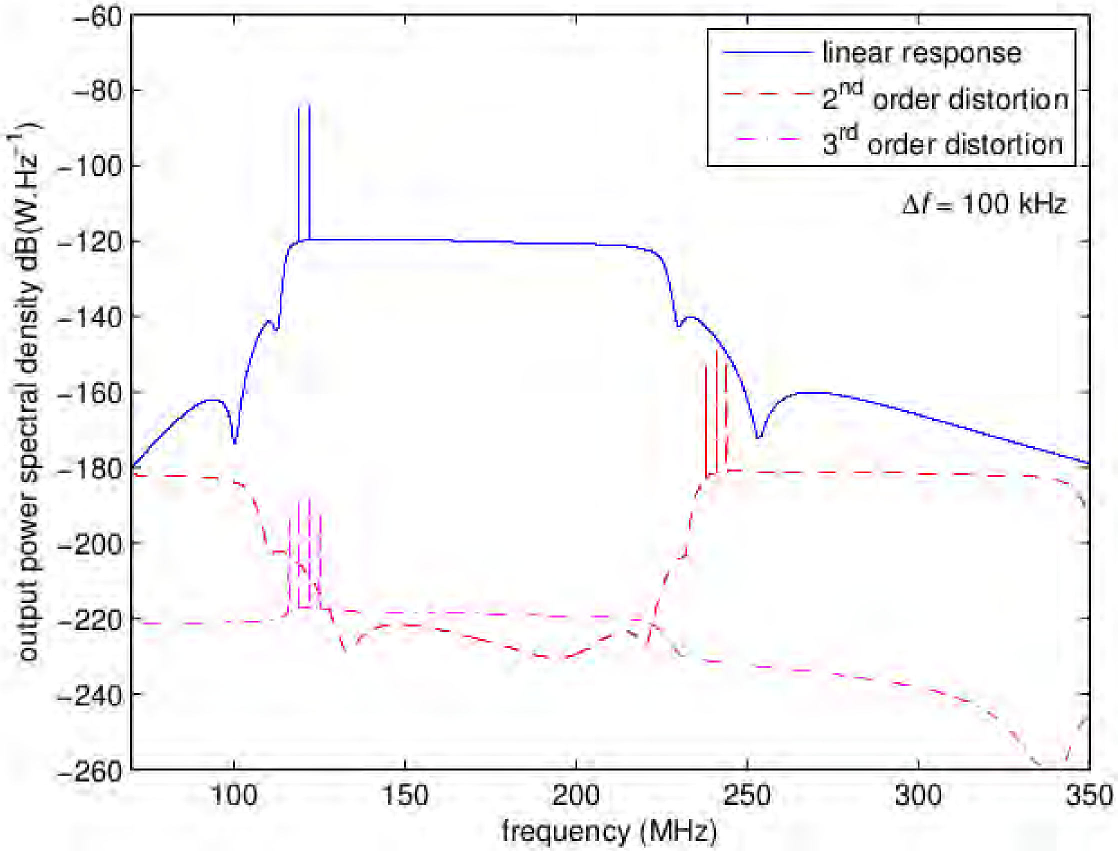


Fig. 5.9: Wiener model response for QB300 amplifier for two -160 dBW.Hz^{-1} $\times$ 100 kHz interferers and peak galactic noise expected at galactic transit. This interference level corresponds to the strongest interference at the MRO.

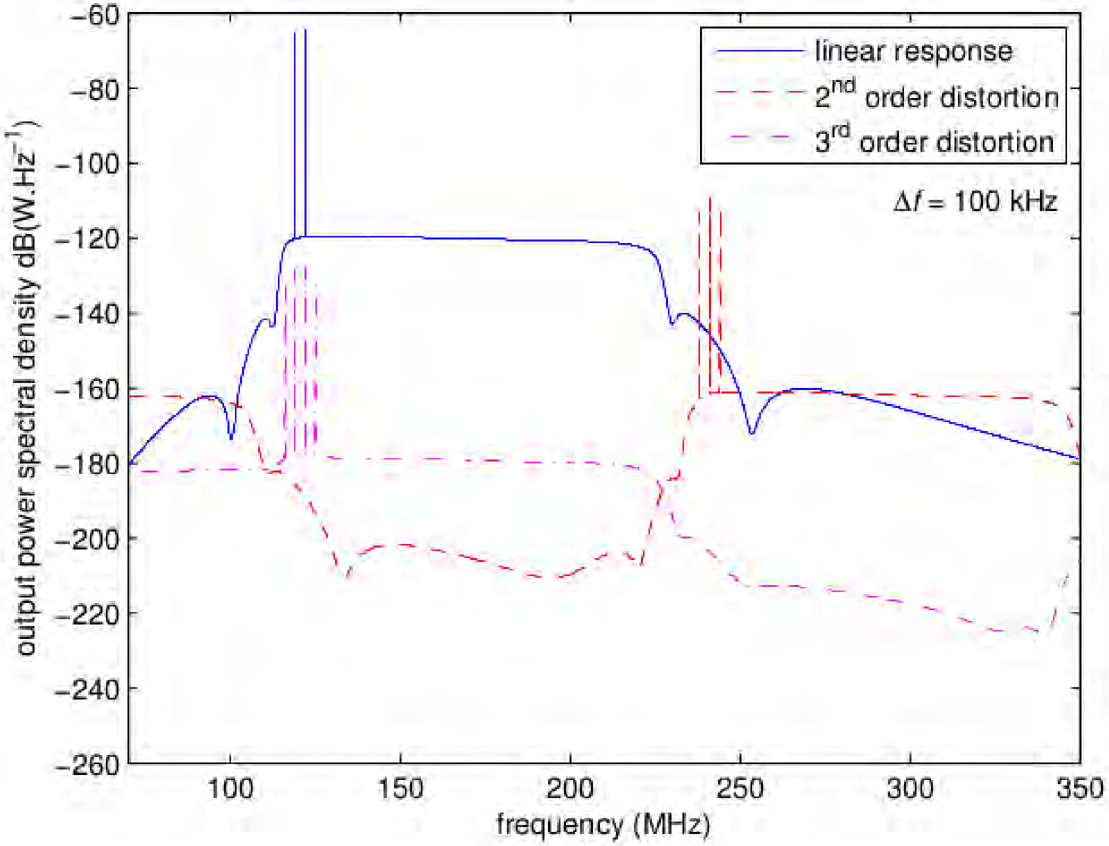
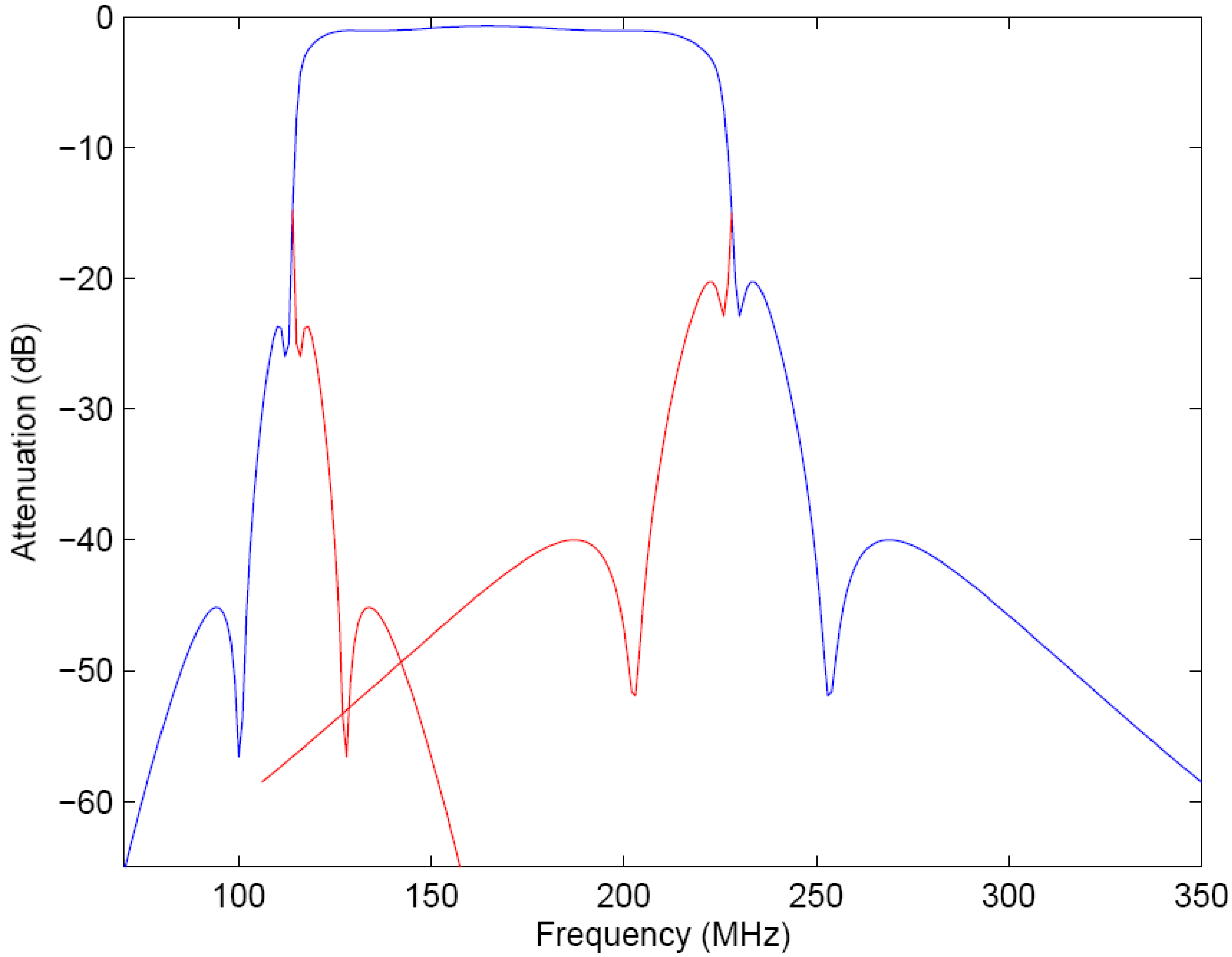


Fig. 5.10: Wiener model response for QB300 amplifier for two -140 dBW.Hz$^{-1} \times 100$ kHz interferers and peak galactic noise expected at galactic transit. This interference level corresponds to typical interference at Narrabri.



0
−10
−20
−30
−40
−50
−60
Attenuation (dB)
100
150
200
250
300
350
Frequency (MHz)

1-bit Sampling

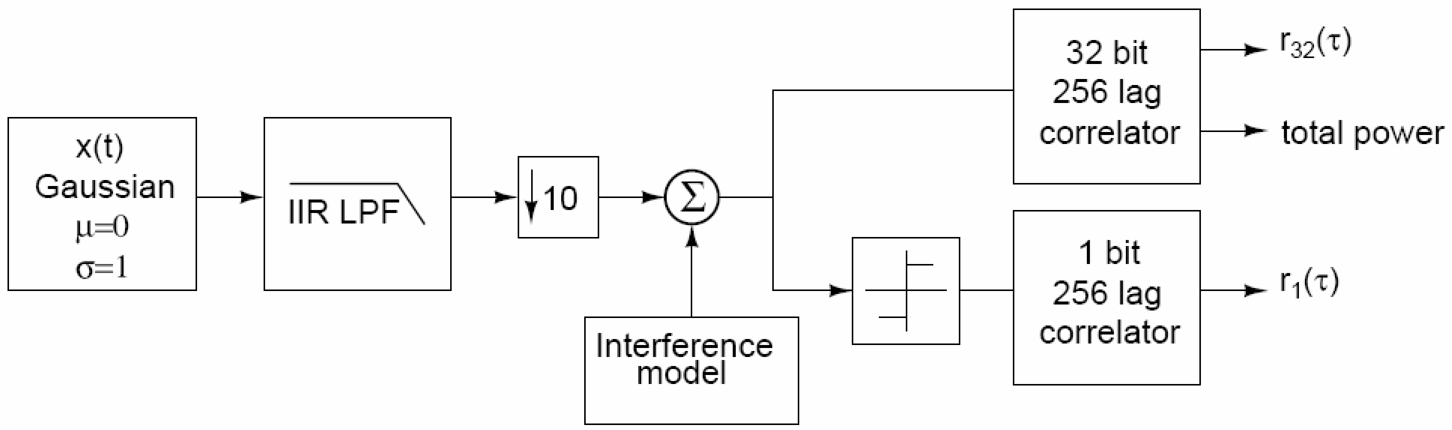
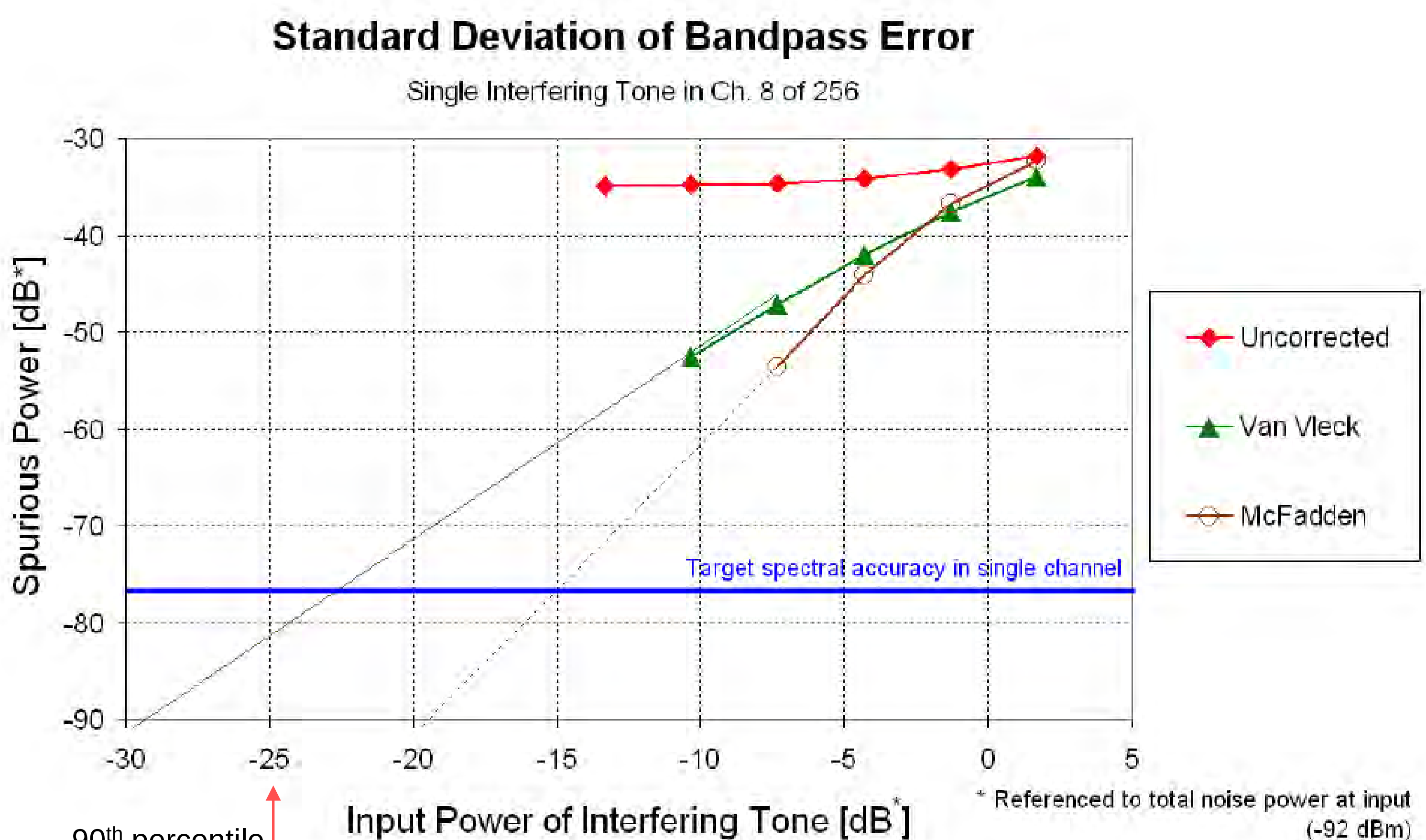


Fig. 7.1: Block diagram of correlator simulation.

1-bit Sampling with RFI



90th percentile at MRO

50th percentile at Narrabri

a=25 dB*

$$a = \frac{\text{total RFI power}}{\text{total noise power}}$$

N-bit Samping with RFI

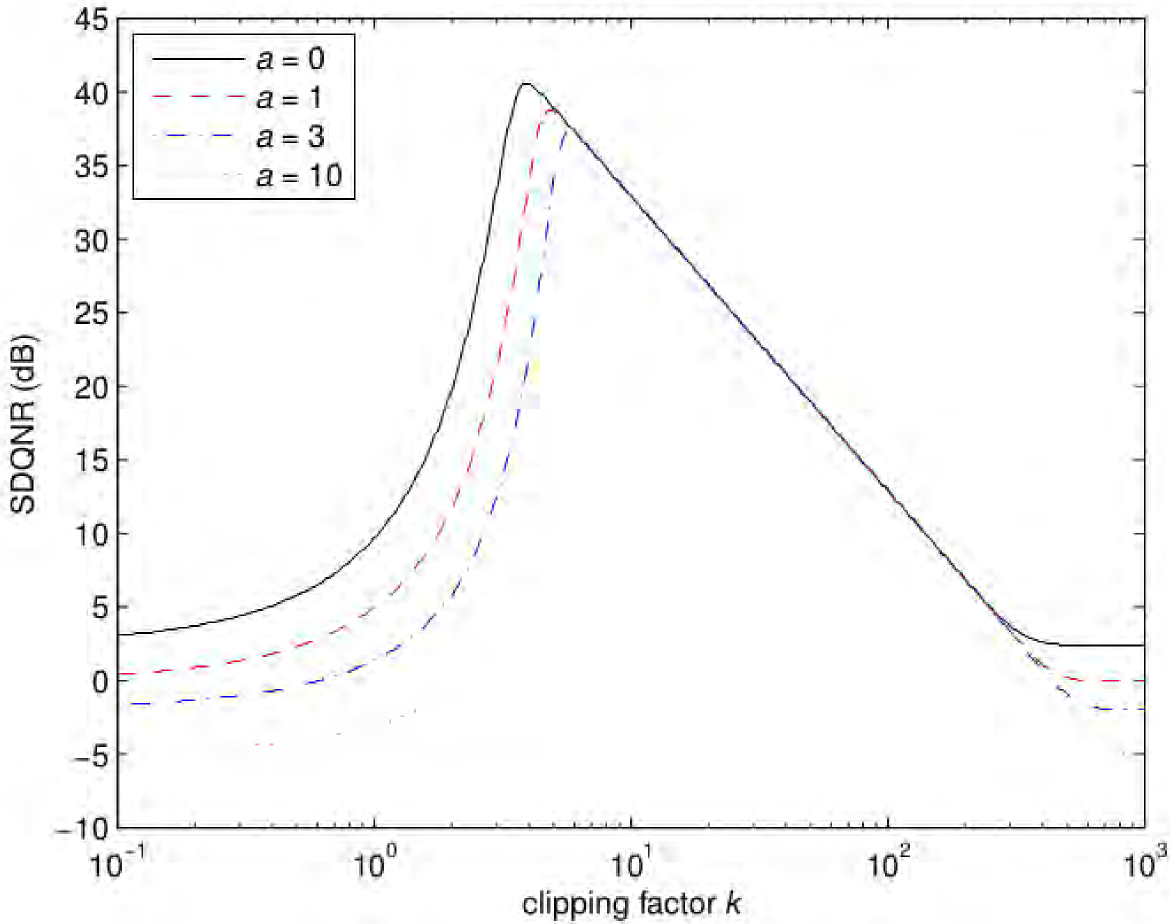
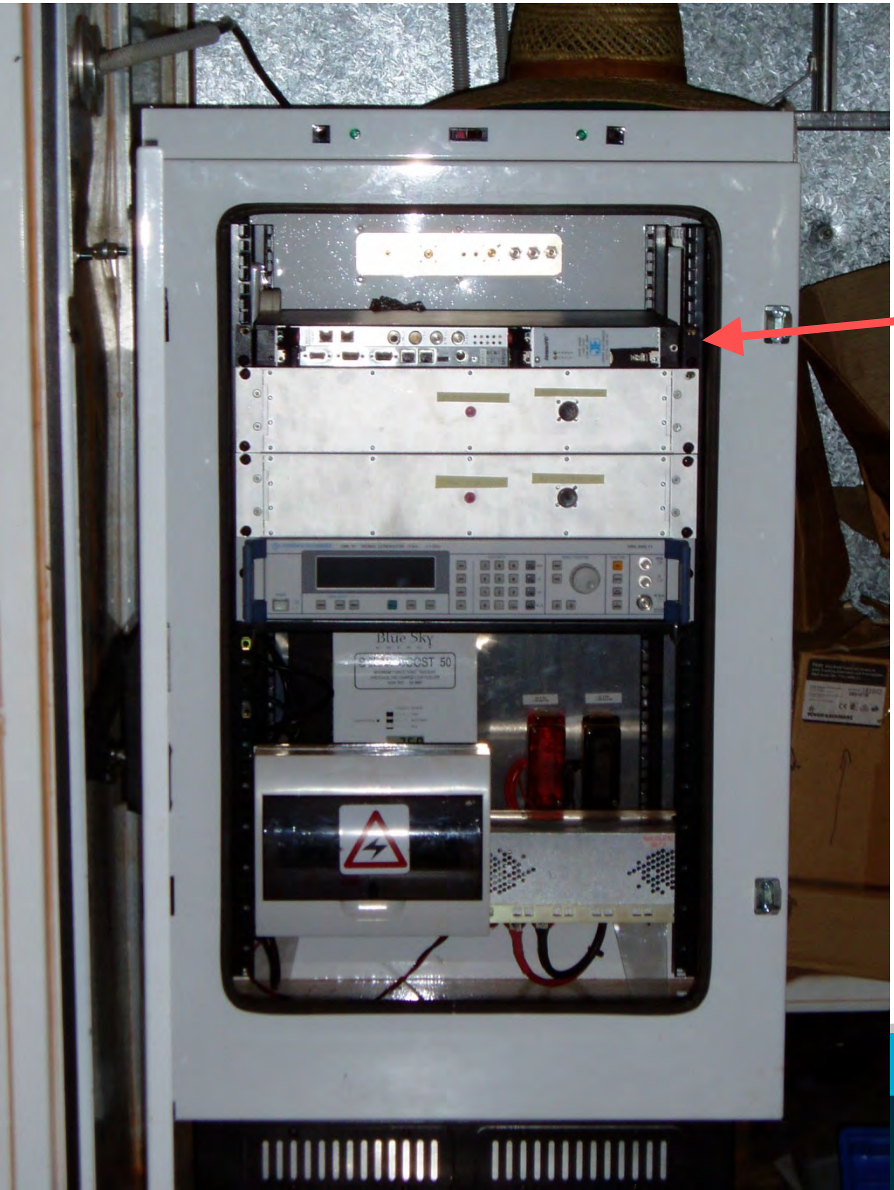


Fig. 6.6: Signal to distortion and quantisation noise ratio (SDQNR) versus clipping factor for 8-bit quantisation of Gaussian noise plus a sinusoid. Repeated for various interference to noise power ratios a.

Receivers and Correlator



Correlator

Thank you

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