A Numerical Simulator for Noise Calibration Studies

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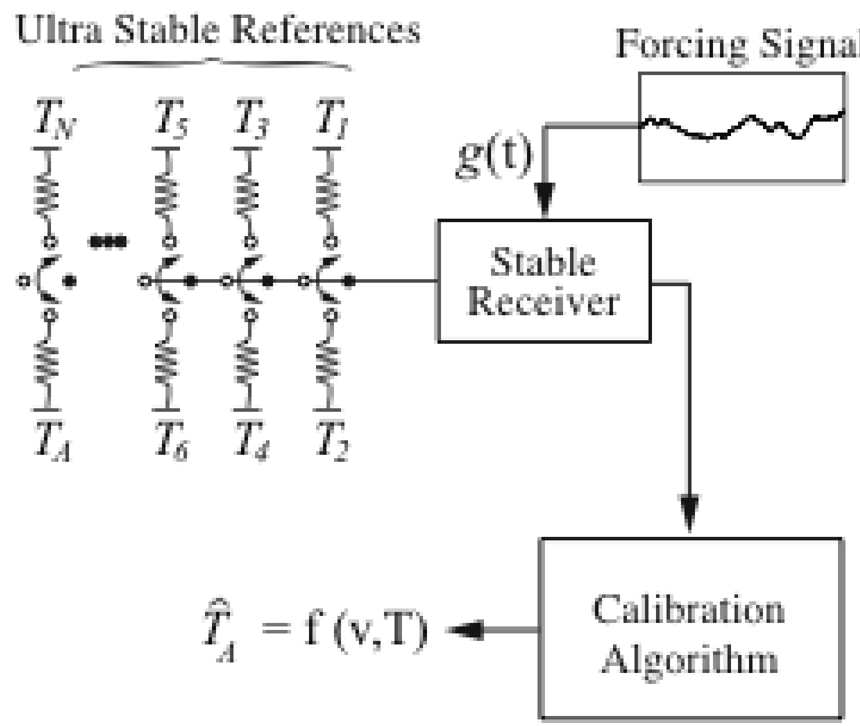
Outline

- Motivation, application and background
- NIST radiometer measurements
- Radiometer Simulator
- Comparison of simulator and measurement
- Summary



Radiometer Simulator Applications

- Rapid, cost-effective approach to prototyping and evaluating radiometer designs including calibration architectures and algorithms

- Development of calibration algorithms

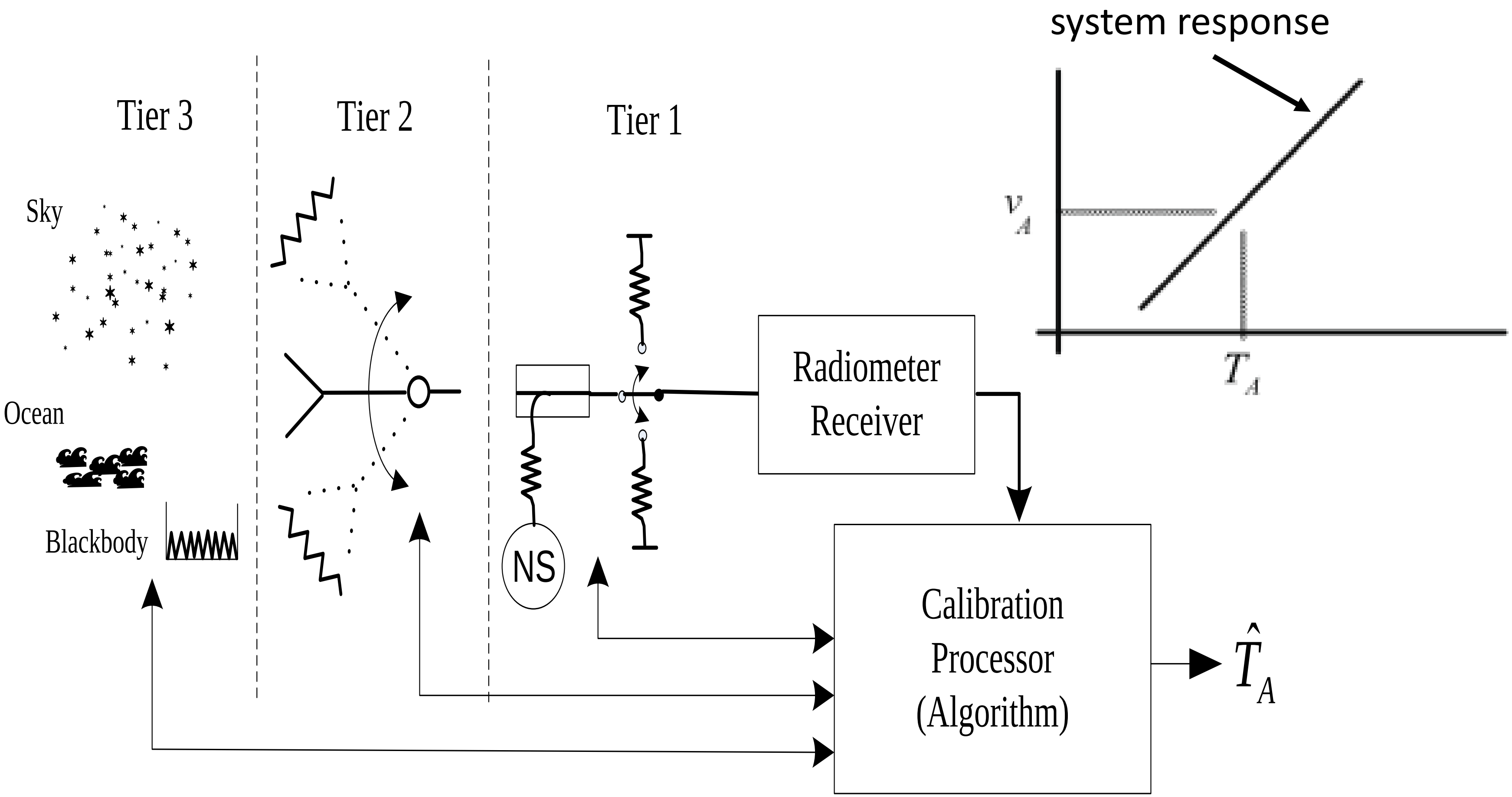
- Simulation and analysis of instrument lifecycle

- Standards for specifying receiver stability

- Validating instrument design

- Noise assisted data analysis

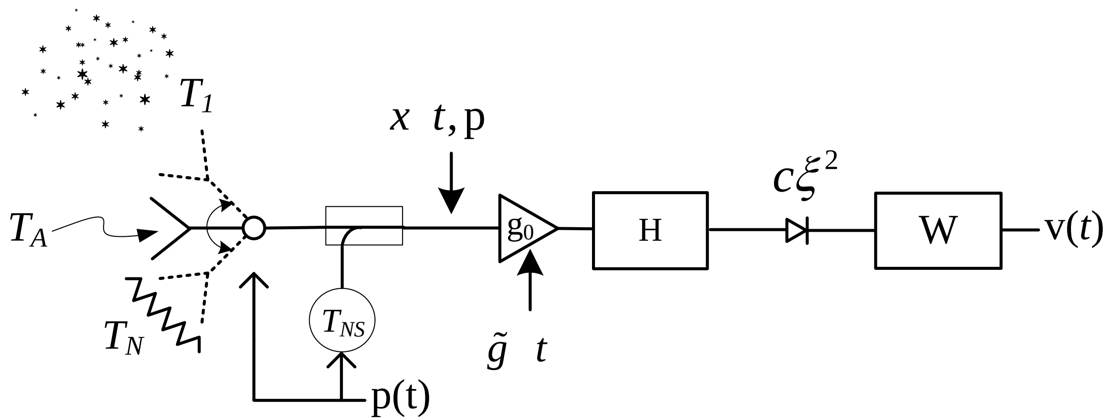
Generalized Radiometer Model



How do receiver fluctuations affect uncertainty in calibrated estimates?

Model Decomposition

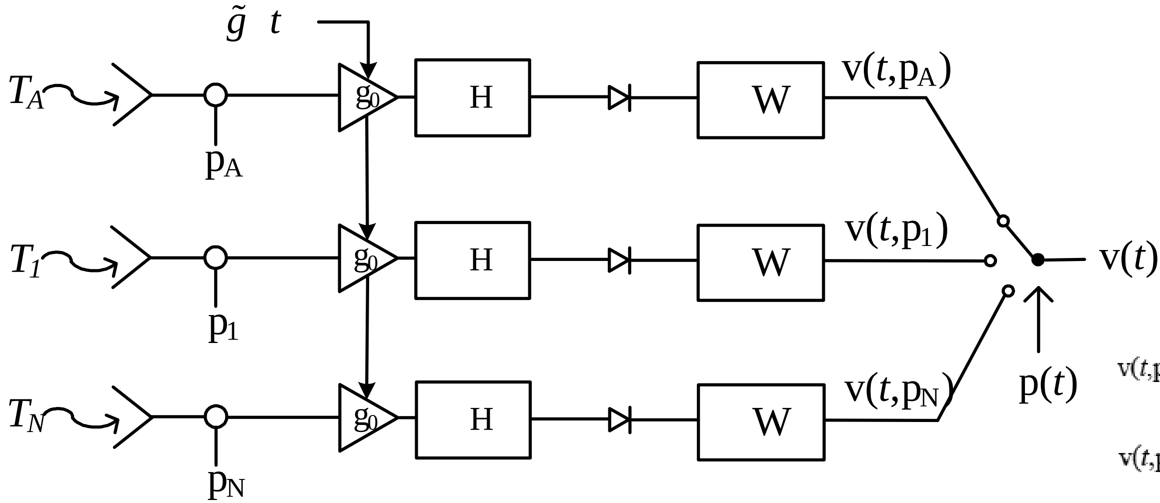
For a given radiometer architecture



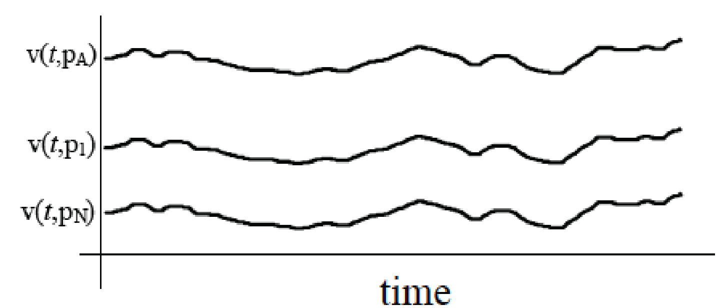
$$v(t) = (xg \otimes h)^2 \otimes w$$

$$v \propto x^2 g^2 \propto T_{sys}$$

Model is decomposed into a set of subsystems



Ensemble Set



Characteristic Equations & Estimator
(inverse calibration)

Characteristic Equations

$$T_A = m(t_A)\mathrm{v}_A(t_A) + b(t_A) + \varepsilon_A(t_A, t_A)$$

$$T_1 = m(t_A)\mathrm{v}_1(t_1) + b(t_A) + \varepsilon_1(t_A, t_1)$$

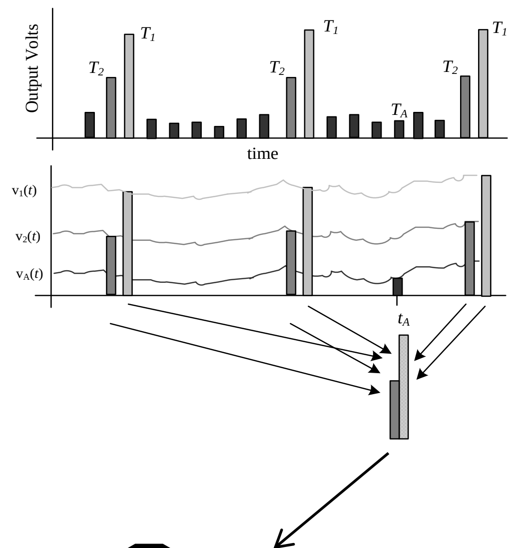
$$T_2 = m(t_A)\mathrm{v}_2(t_2) + b(t_A) + \varepsilon_1(t_A, t_2)$$

M

$$T_n = m(t_A)\mathrm{v}_n(t_n) + b(t_A) + \varepsilon_n(t_A, t_n)$$

Mean system response at t_A

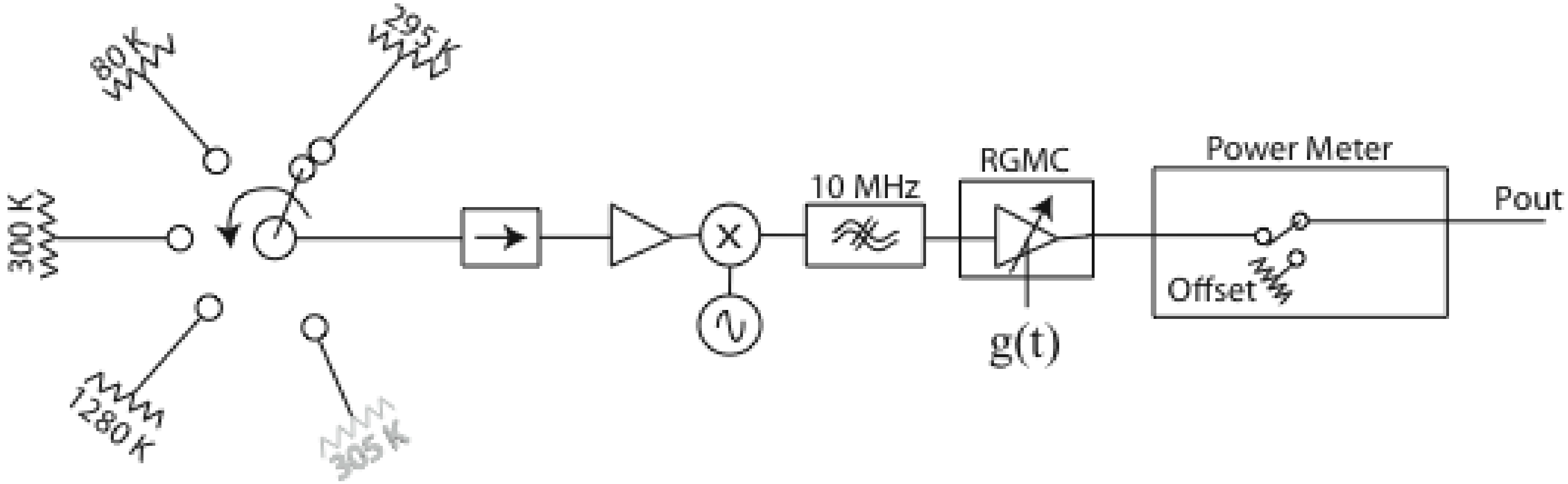
Estimator



$$\hat{T}_A = f(\mathbf{v})$$

$$\sigma^2_{\hat{T}_A} = E\left(\hat{T}_A - T_A\right)^2$$

NIST Experiments



NIST NFRad – two sets of experiments using Radiometer Gain Modulation Circuit

~May 2010 – four references ~ 295K, 80K, 300K, and 1280K

~February 2011 – five references ~ 295K, 80K, 300K, 1280K, 305K

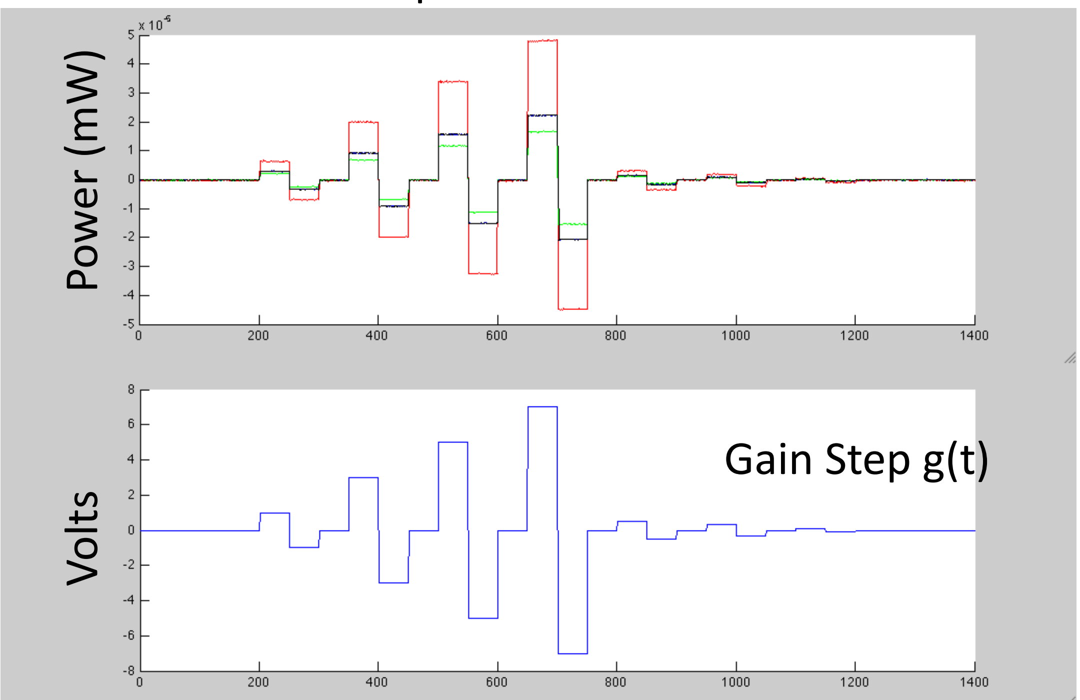
Gain modulation

- Constant, stepped, sinusoidal, random

NFRad Data Stepped Gain

5/13/10

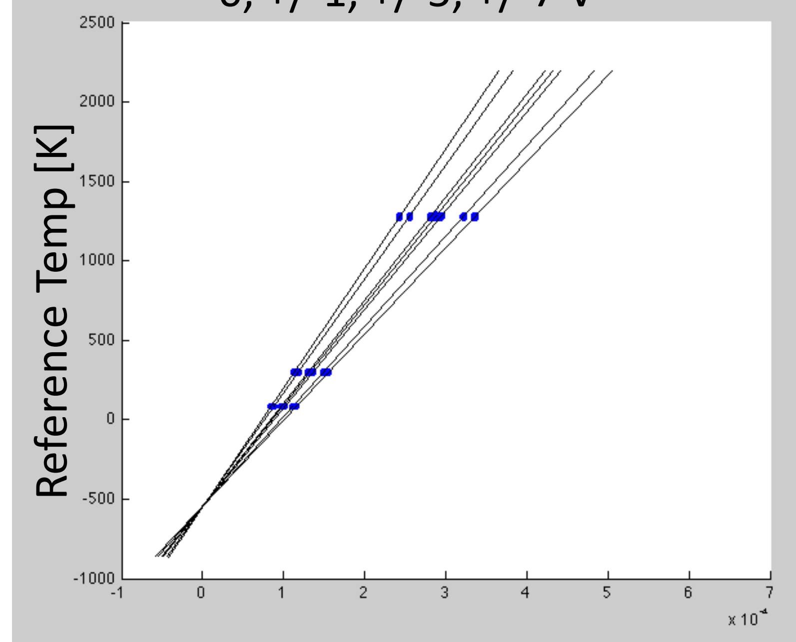
measured power minus mean



Time (index)

Response to stepped gain

0, +/-1, +/-5, +/-7 V

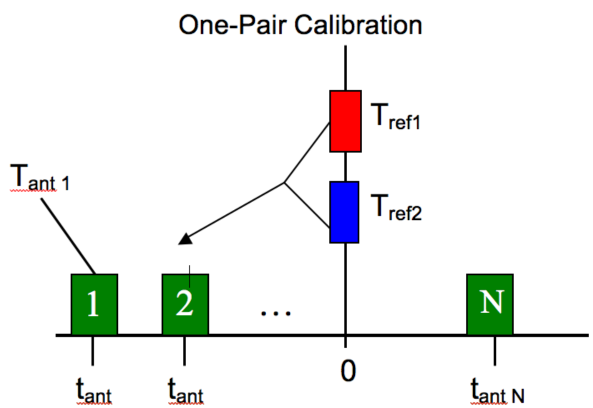


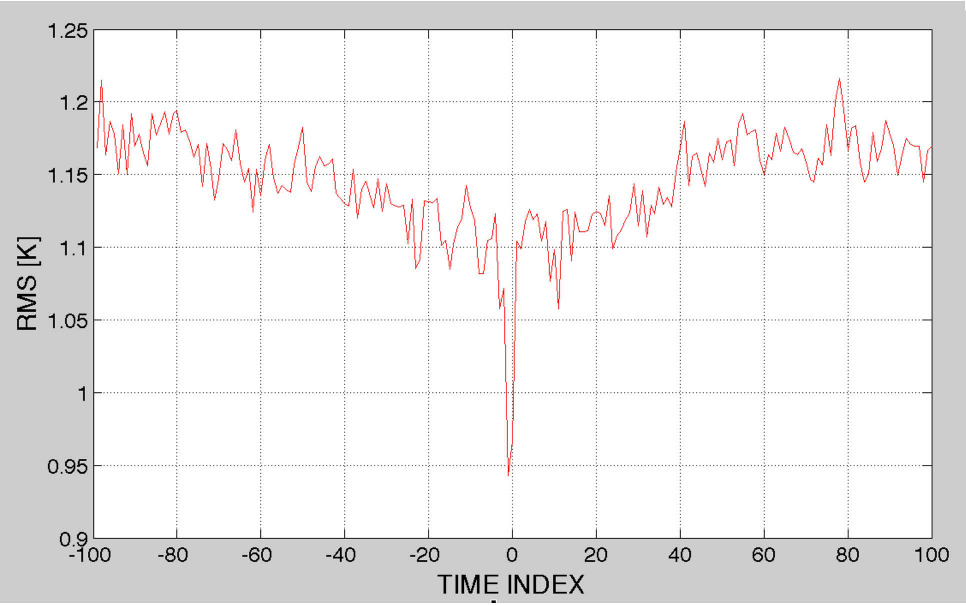
Power(mW)

Temporal Dependent Algorithms

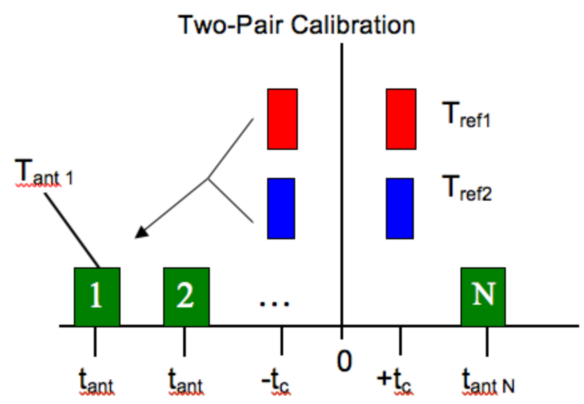
NFRad Data 05/10/10 (no gain modulation)

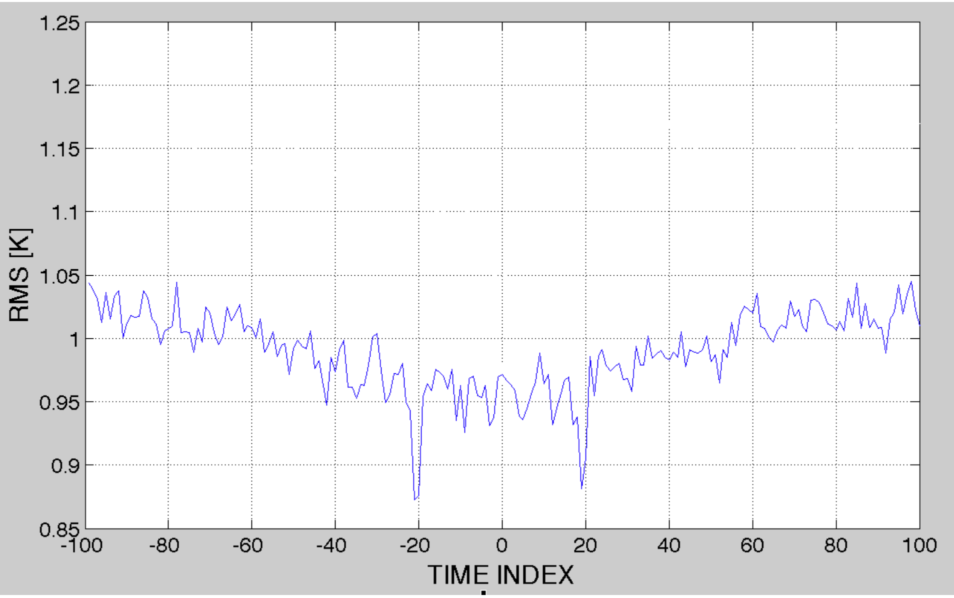
V - Curve





W - Curve



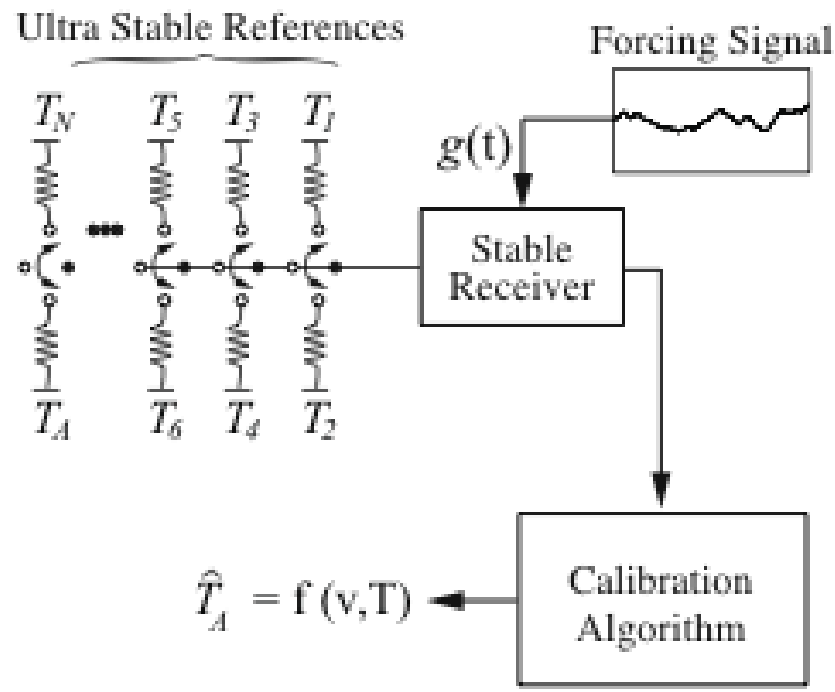


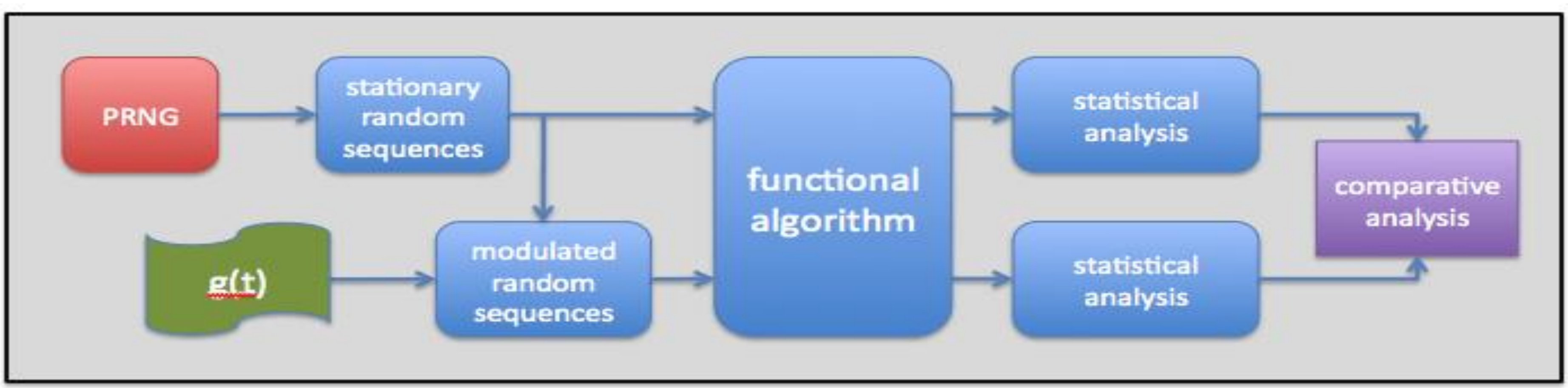
Radiometer Simulator

Noise references simulated using Gaussian Random Sequences

References modulated by stochastic forcing signal, g(t)

'Calibration algorithms' applied to stationary and modulated reference sequence





Radiometer Simulator

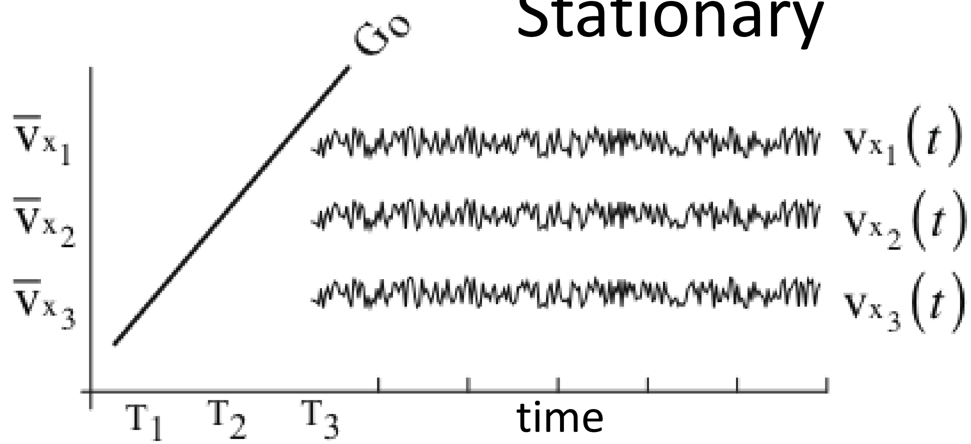
Constant Gain

$$v_{x_i}(t) = x_i G_0 \qquad x_i \equiv GRV$$

$$\bar{v}_{x_i}(t) = T_i + T_{rec}$$

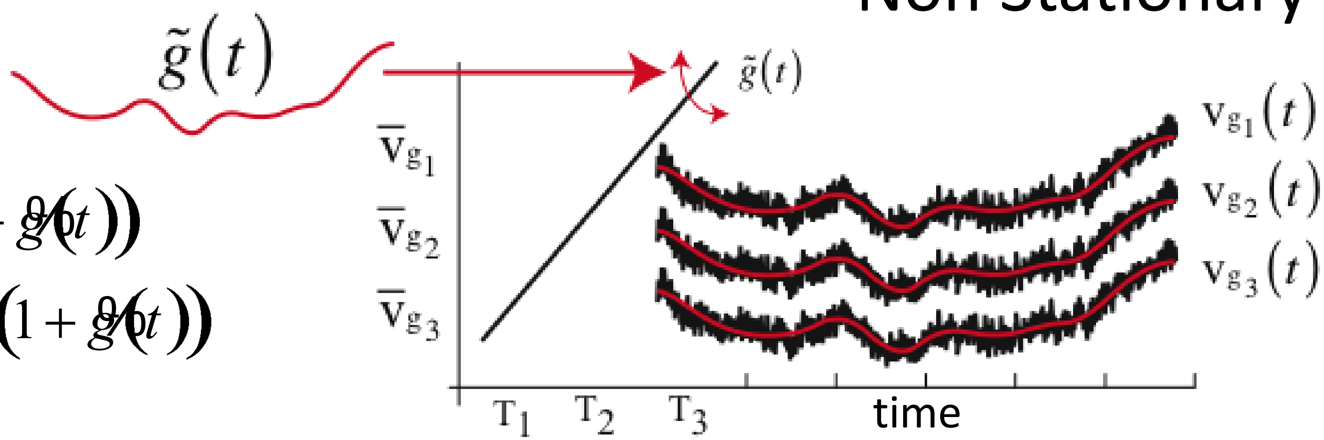
$$\sigma_{v_{x_i}}(t) = T_{sys} / \sqrt{B\tau}$$

Stationary



Fluctuating Gain

Non Stationary

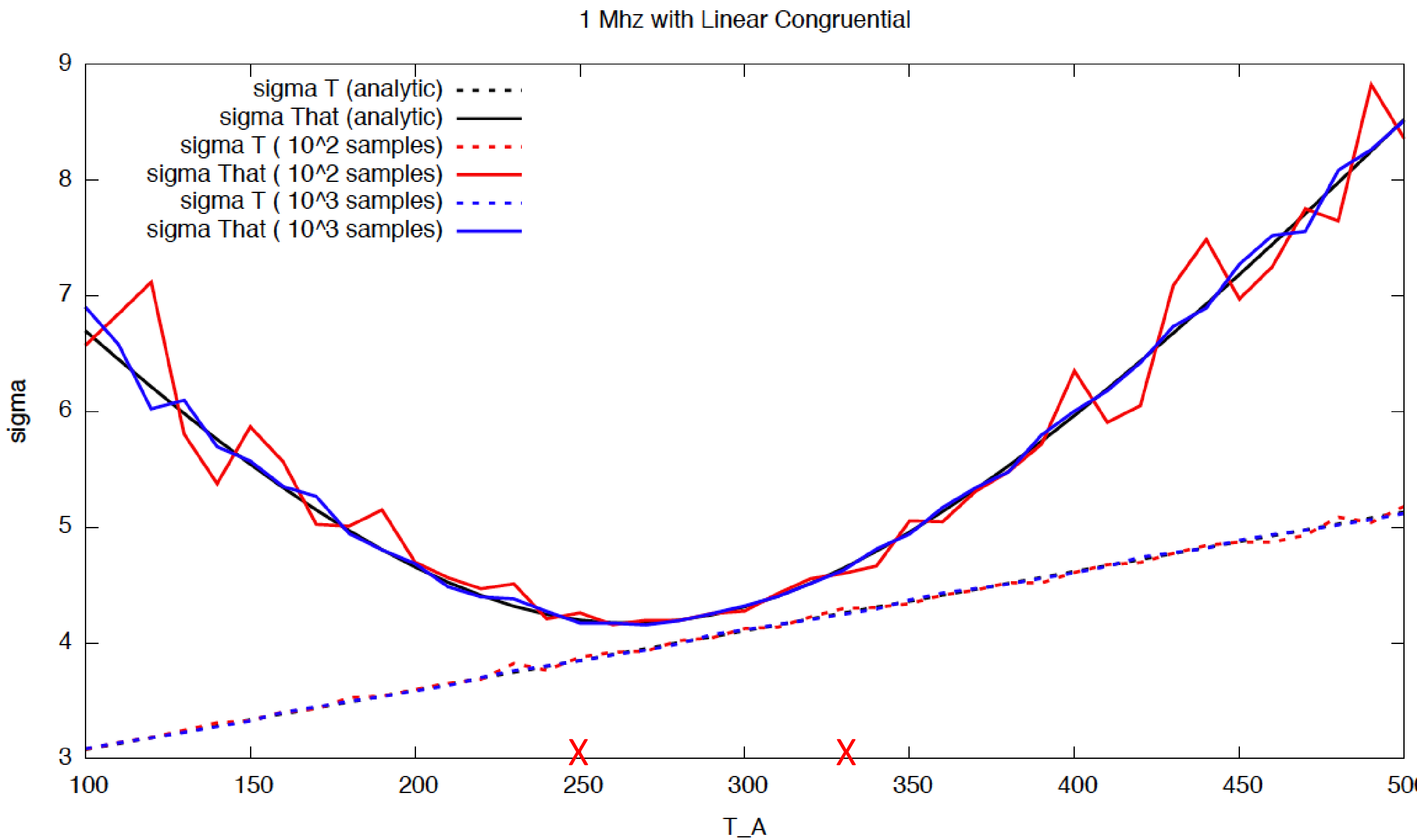


$$g(t) = G_0\left(1 + \tilde{g}(t)\right)$$

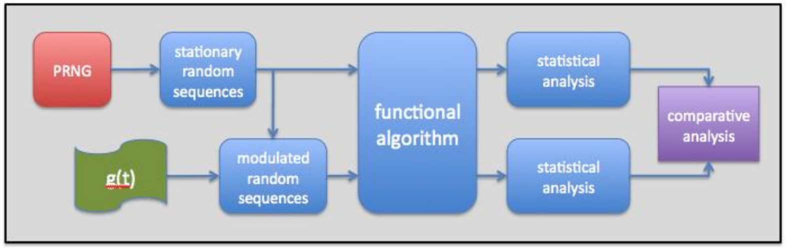
$$v_{g_i}(t) = x_i G_0\left(1 + \tilde{g}(t)\right)$$

Radiometer Simulator: Constant Gain

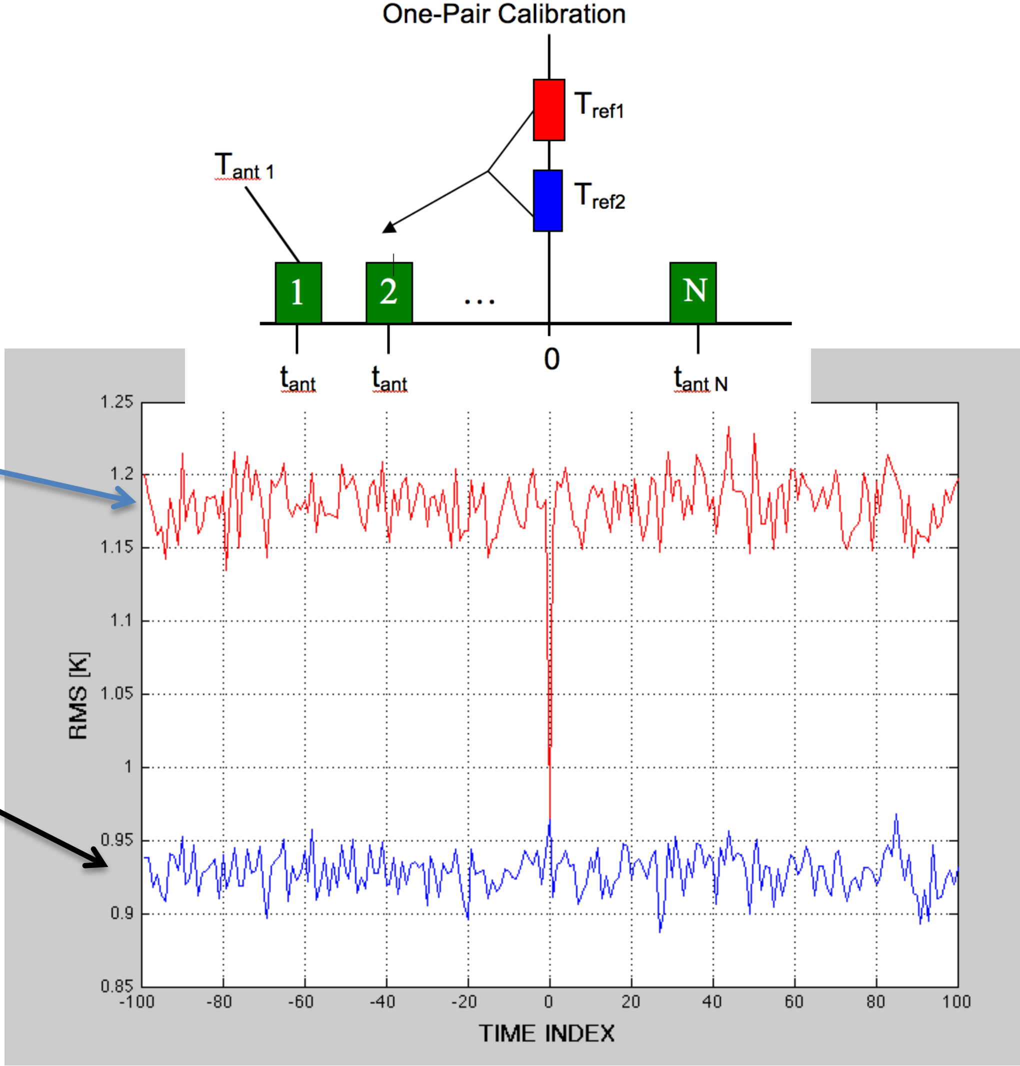
Interpolating and extrapolating calibration data in temperature. Two calibration references (Tcold = 250K, Twarm = 330K) are used to estimate T_A.



Simulating Gain Fluctuations



V-Curve



Gaussian gain Fluctuations

Radiometer with constant gain is impervious to temporal information in estimating algorithms

Comparisons of simulator with measurements

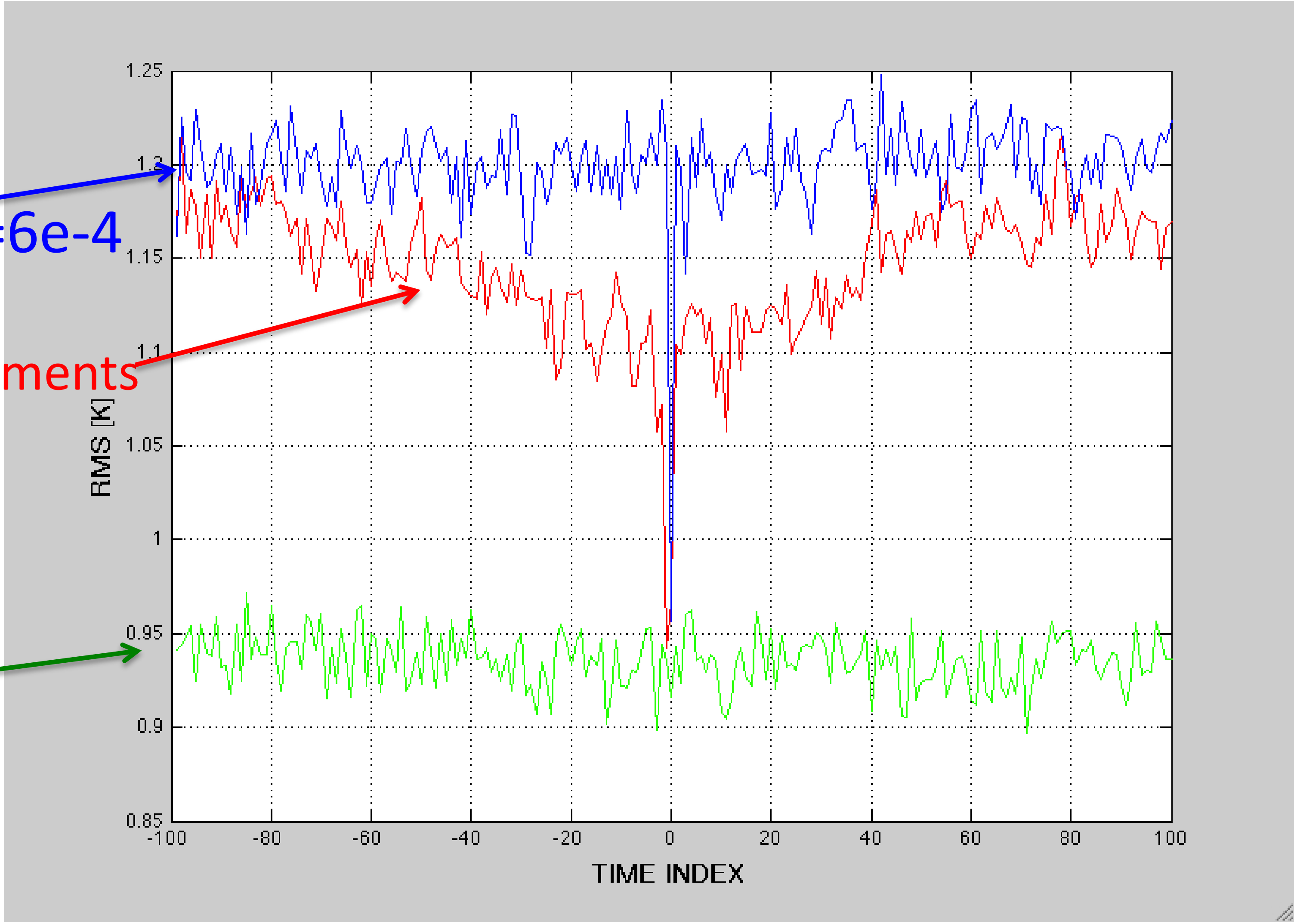
sqrt(Btau) = 1300

G = 250e7

Simulator σ_g=6e-4

NFRad Measurements 5/10/10

Constant gain



Summary

- A numerical radiometer simulator has been developed
- Stationary simulations yield consistent results with theory
- Simulator provides the means of modeling random and systematic error
- Good agreement with radiometric measurements