Calibration of MIAWARA:
Middle Atmospheric Water Vapour Radiometer

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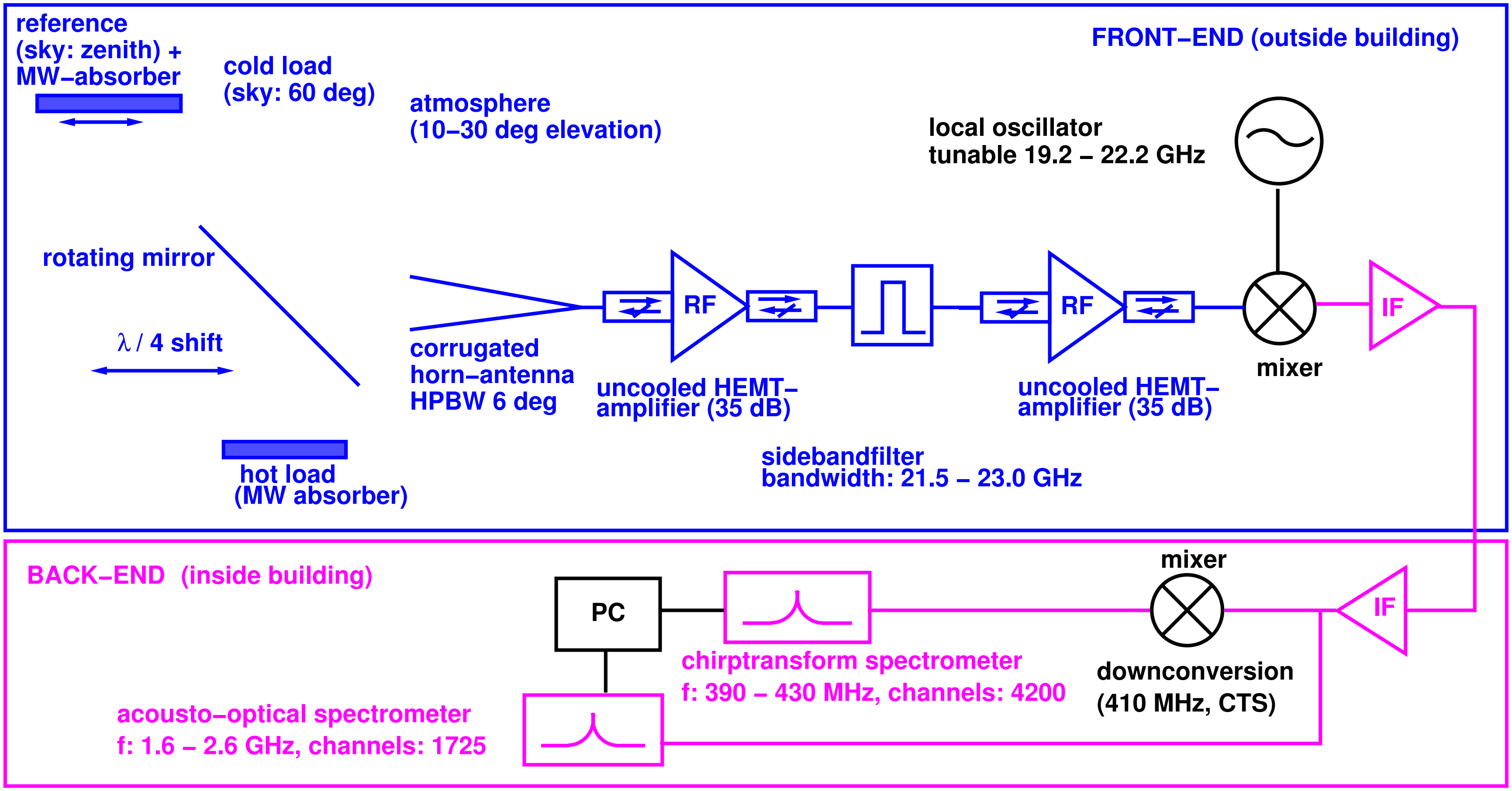
MIAWARA: Middle Atmospheric Water Vapour Radiometer

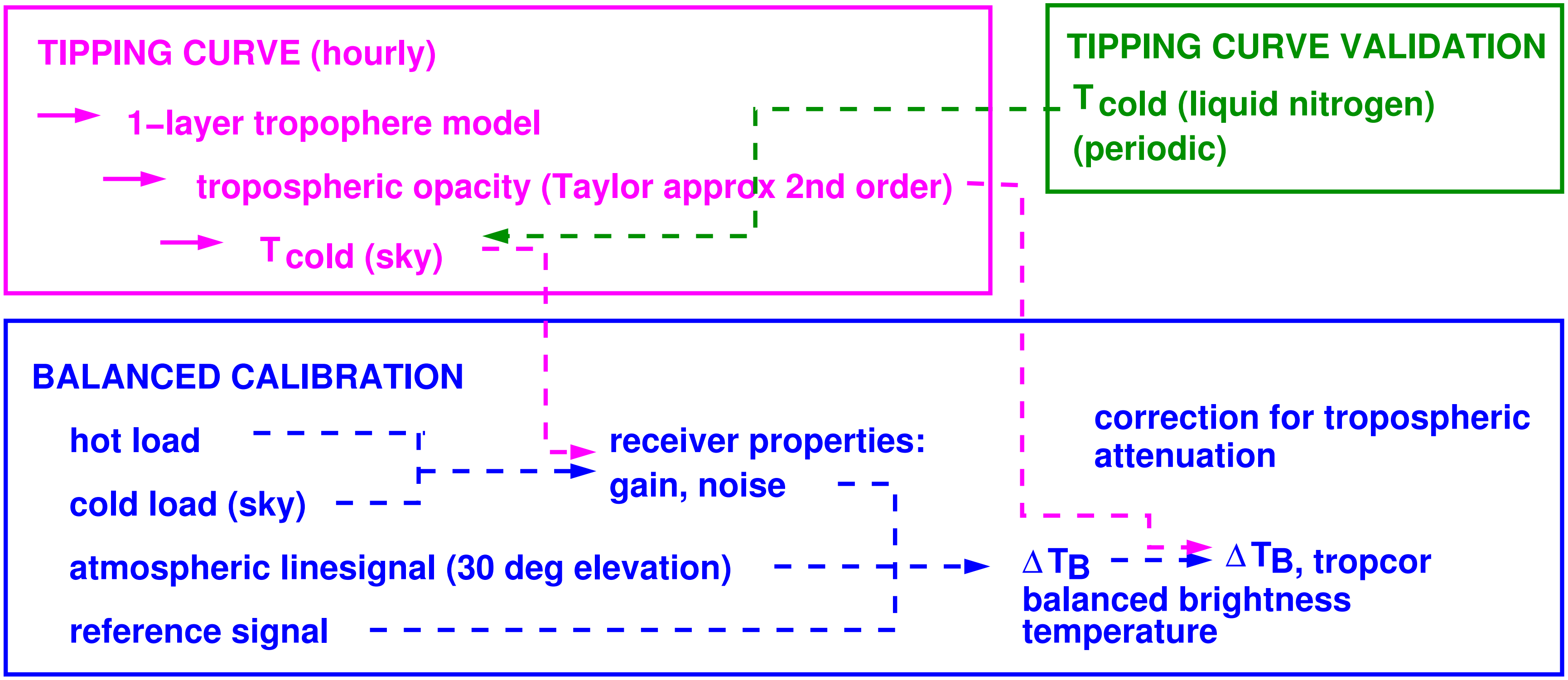
Instrumentation

Radio-frequency range	21.735 – 22.735 GHz
Operational mode	Single sideband (SSB) 50 dB sideband suppression
Mirror	Plane mirror (gauss beam optimised shape)
Antenna	Corrugated horn (HPBW 6 deg)
T_{rec}	133 K SSB
Broadband spectral analysis	Acousto-optical spectrometer (channels: 1725, f: 1.6–2.6 GHz, Δf_{FWHM}: 1.2 MHz)
Narrowband spectral analysis	Chirp transform spectrometer (channels: 4200, f: 390–430 MHz, Δf_{FWHM}: 14 kHz)
H_2O profile retrieval	Altitude range: 25 - 80 kilometres Measurement time per profile: 1-4 days

Blockscheme



Calibration Scheme



TIPPING CURVE (hourly)

→ 1–layer tropophere model

→ tropospheric opacity (Taylor approx 2nd order)

→ T_{cold} (sky)

TIPPING CURVE VALIDATION

T_{cold} (liquid nitrogen) (periodic)

BALANCED CALIBRATION

hot load

cold load (sky)

atmospheric linesignal (30 deg elevation)

reference signal

receiver properties: gain, noise

ΔT_B balanced brightness temperature

correction for tropospheric attenuation

$\Delta T_{B,\ tropcor}$

Calibration Scheme (Detail)

Calibration Loads:

- **Hot Load:** ECCOSORB CV3 absorber at ambient temperature.

- **Cold Load:** Sky at an elevation angle of 60^o. Calibrated with hourly tipping curves.
- **Reference Load:** Sky at 90^o elevation, Signal intensity adjusted with partly covering the beam with absorbing material (up to now: CV3).

Tipping Curve

- Tropospheric opacity τ is calculated from hourly tipping curves according to *[Jannsen, 1993]*.
- Brightness temperature of sky as cold load is calculated using ground surface temperatures *[Han and Westwater: 2001]*:

$$T_{cold,sky} = T_0 e^{\left(\frac{-\tau}{\cos\theta}\right)} + T_{Trop}\left(1 - e^{\left(\frac{-\tau}{\cos\theta}\right)}\right) \quad (1)$$

$$T_{Trop} = c_1(f)\Theta_{ground} + c_0(f) \quad (2)$$

T_{Trop}	mean tropospheric temperature [K]
Θ_{ground}	ambient temperature at ground [^{o}C]
c_0, c_1	linear regression coefficients

Balancing Calibration

- Balanced calibrated brightness temperature :

$$\Delta T_B = \frac{U_{line} - U_{ref}}{U_{hot} - U_{cold}} \left(T_{hot} - T_{cold,sky}\right) \qquad (3)$$

U	spectrometer output [counts]
T_{hot}	physical temperature CV3 hot load (AD490) [K]
$T_{cold,sky}$	brightness temperature of sky at 60^o elevation [K]

- ΔT_B is independent of spectrometer offset

- Tropospheric correction $\Delta T_{B,tropcorr}$ achieved by method described by *[Forkman et al. 2003]*

Validation of Tipping Curve Calibration: Concept

- Use of receiver noise temperature T_{rec} as a validation standard.
- Comparison of simultaneously measured T_{rec} using $T_{cold,sky}$ and T_{cold,LN_2}:

$$T_{rec,sky} = \frac{T_{hot} - y_{sky} \cdot T_{cold,sky}}{y_{sky} - 1} \quad (4)$$

$$T_{rec,LN_2} = \frac{T_{hot} - y_{LN_2} \cdot T_{cold,LN_2}}{y_{LN_2} - 1} \quad (5)$$

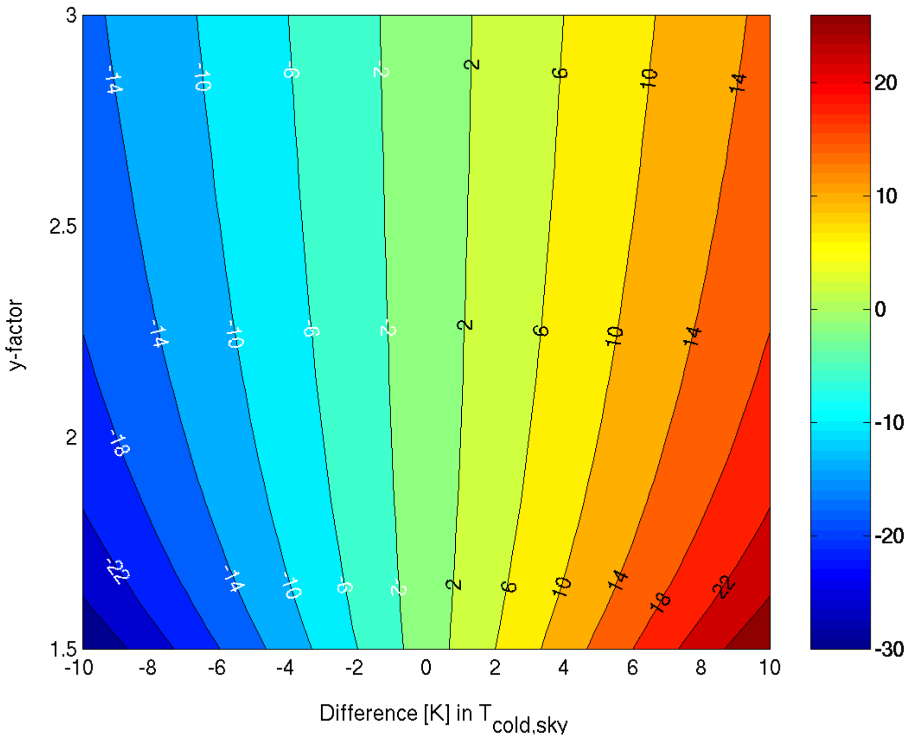
$$y_{sky} = \frac{U_{hot} - U_{offset}}{U_{cold,sky} - U_{offset}} \quad (6)$$

$$y_{LN_2} = \frac{U_{hot} - U_{offset}}{U_{cold,LN_2} - U_{offset}} \quad (7)$$

- Is T_{rec} sensitive to 'errors' in $T_{cold,sky}$?

Validation of Tipping Curve Calibration: Sensitivity Simulation

Changes in T_{rec} as a function of differences in $T_{cold,sky}$ from 30 K and the y-factor



Validation of Tipping Curve Calibration: Results

- T_{rec} is highly sensitive to changes in $T_{cold,sky}$ and can be used as a validation standard for $T_{cold,sky}$ calculated from the tipping curve measurements.
- **MIAWARA:** differences of simentaneously measured $T_{rec,sky}$ and T_{rec,LN_2} are smaller than 0.6 % or 0.85 K.
- **Conculsion:** Our tipping curve calibration is of good quality and the sky may be uses as cold calibration load.
- Validation is repeated periodically: $\approx$ 2-4 weeks.

Uncertainties Tippingcurve

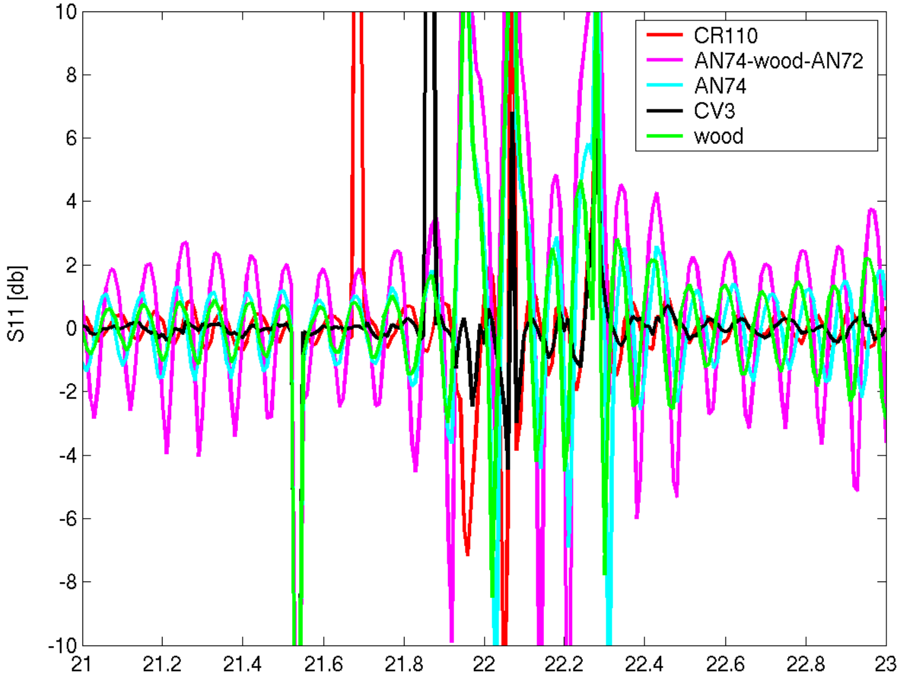
Variable	**Uncertainty s**
T_{hot}	$\pm$ 1 K
T_{Trop}	$\pm$ 3.5 K *[Han and Westwater, 2001]*
Elevation angle θ	0.5^o
T_0	0.5 K
$\longrightarrow$ **Tropospheric opacity** s_τ	10 %
$\longrightarrow$ **Cold sky temperature** $s_{T_{cold,sky}}$	2.5 K / 8.5 %

Uncertainties Balancing Calibration

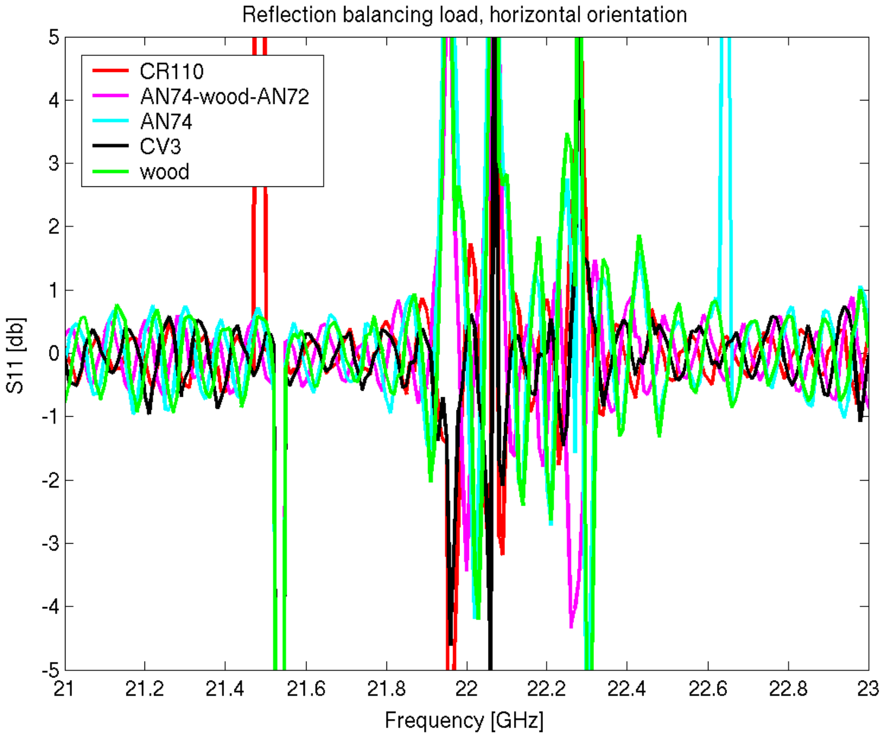
Variable	**Uncertainty s using** $T_{cold,sky}$	**Uncertainty s using** T_{cold,LN_2}
T_{hot}	± 1 K	± 1 K
$T_{cold,sky}$	± 2.5 K	
T_{cold,LN_2}		± 1 K
$\rightarrow$ **balanced brightness temperature** $s_{\Delta T_B}$	≈ 1 %	≈ 0.2 %

Which Balancing Load Causes Minimized Baseline Effects?

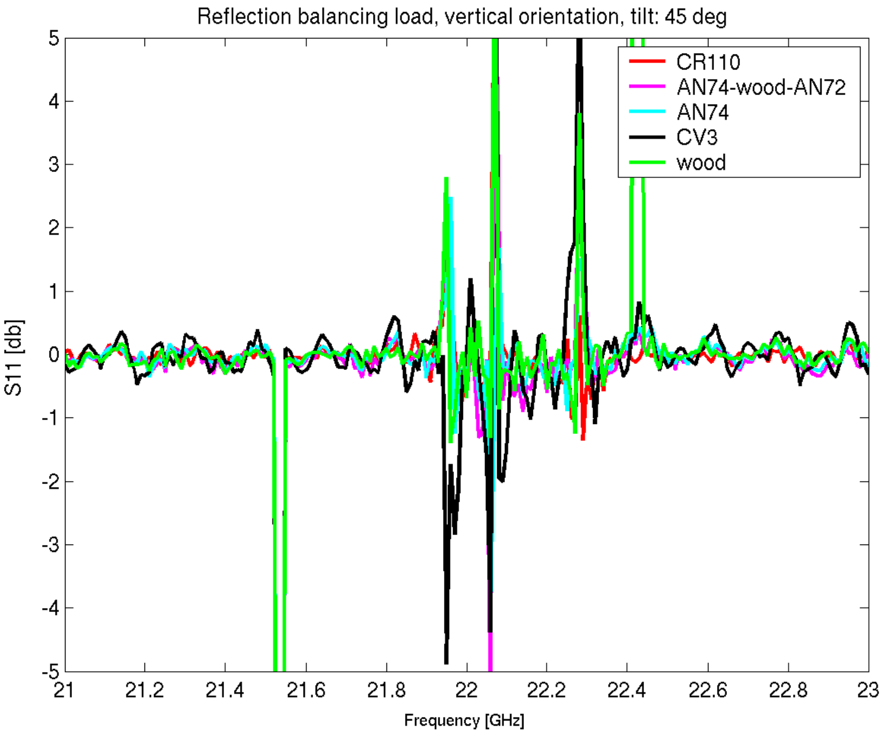
’Horizontal Orientation’



’Vertical Orientation’



’Vertical Orientation: tilt 45 deg’



Conclusion

- At 22 GHz the sky may be used as cold calibration load.
- $T_{cold,sky}$ can be estimated from tipping curve calibration and the ground surface temperature.
- T_{rec} is suitable for tipping curve validation purposes.
- Balancing load has substantial influence on baselines.
  For baseline issues, the material of the load is less critical than the orientation in the beam.