Calibration of ASMUWARA (All-Sky MUlti WAvelength RAdiometer)

Lorenz MARTIN

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The ASMUWARA radiometers

band	f_0	B	S	T_{RM}	θ
21 GHz	18.75 GHz	300 MHz	14.8	222	9.5
	22.20 GHz	760 MHz	17.9	197	8.3
	23.60 GHz	900 MHz	17.8	211	7.9
31 GHz	31.50 GHz	1.1 GHz	17.6	243	8.6
52 GHz	52.50 GHz	590 MHz	5.8	1300	8.6
	53.94 GHz	120 MHz	5.6	1250	8.4
	55.26 GHz	520 MHz	4.1	2000	8.3
	57.20 GHz	1.3 GHz	5.8	1300	8.0
IR	11 μ	6 μ	100		4.0

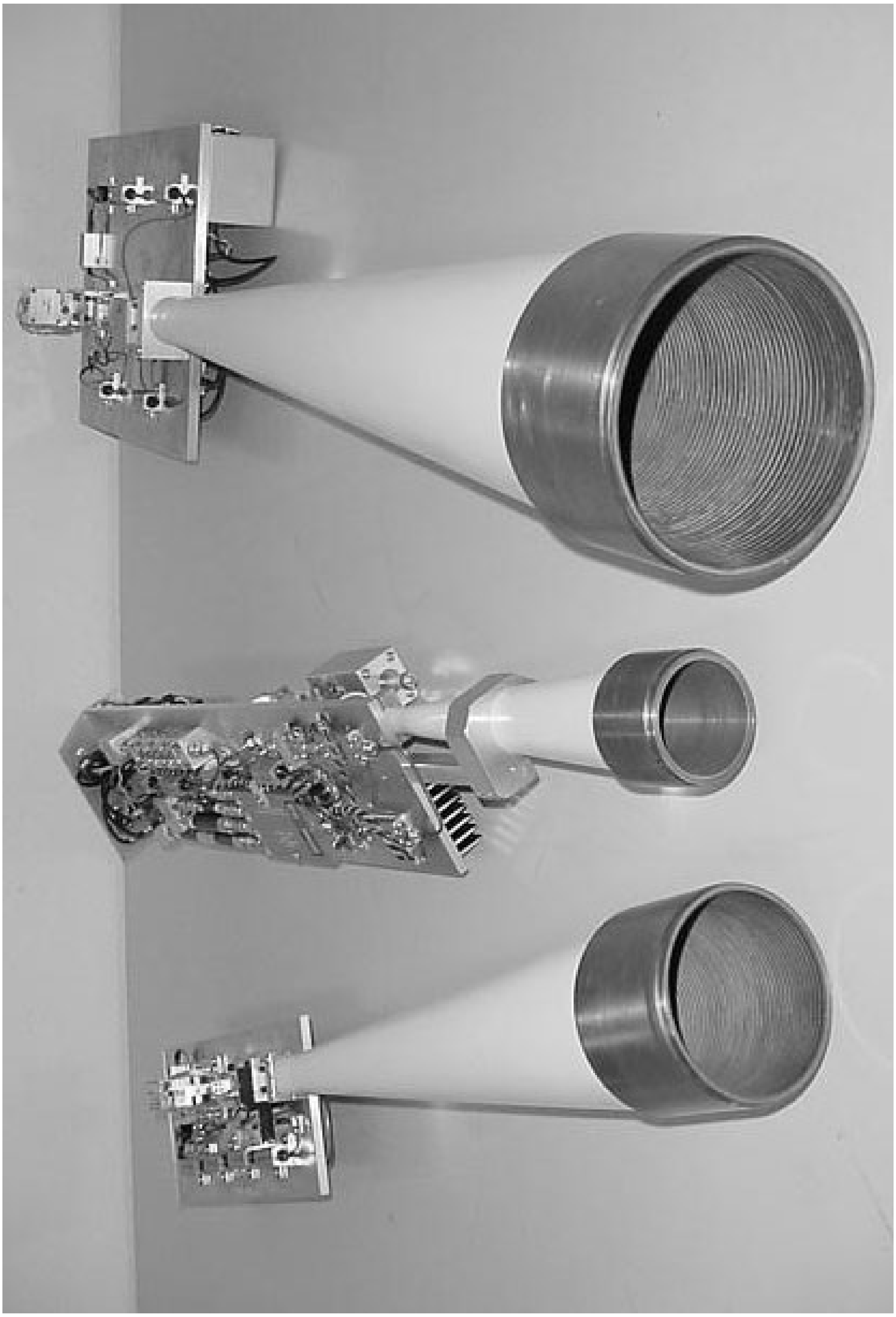
f_0: center frequency
B: bandwidth
S: typ. radiometer sensitivity [mVK^{-1}]
T_{RM}: typ. radiometer noise temperature [K]
θ: antenna half power full beam width [$^\circ$]

Calibration function for the microwave RM:

$$T_b = \frac{1}{S} U - T_{RM}$$

21 GHz and 31 GHz band RM: S and T_{RM} are determined with the measurement of the calibration load at ambient temperature and with tipping curves.

52 GHz band RM: S and T_{RM} are determined with measurements of the calibration loads at ambient and at a slightly higher temperature, respectively.

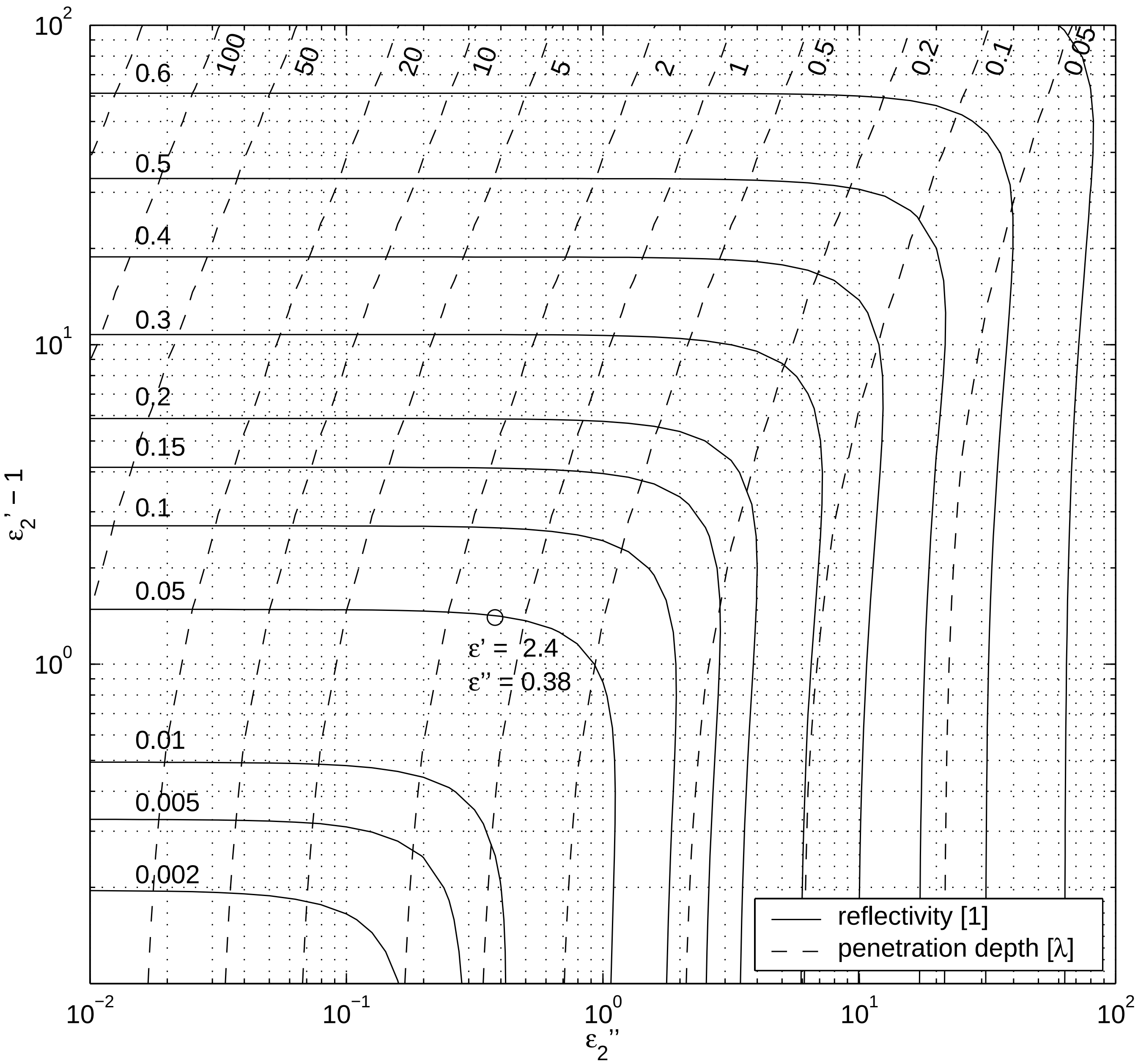


Calibration loads

Absorber qualities:

- low reflectivity
- high absorption coefficient
- large thermal capacity, high thermal conductivity

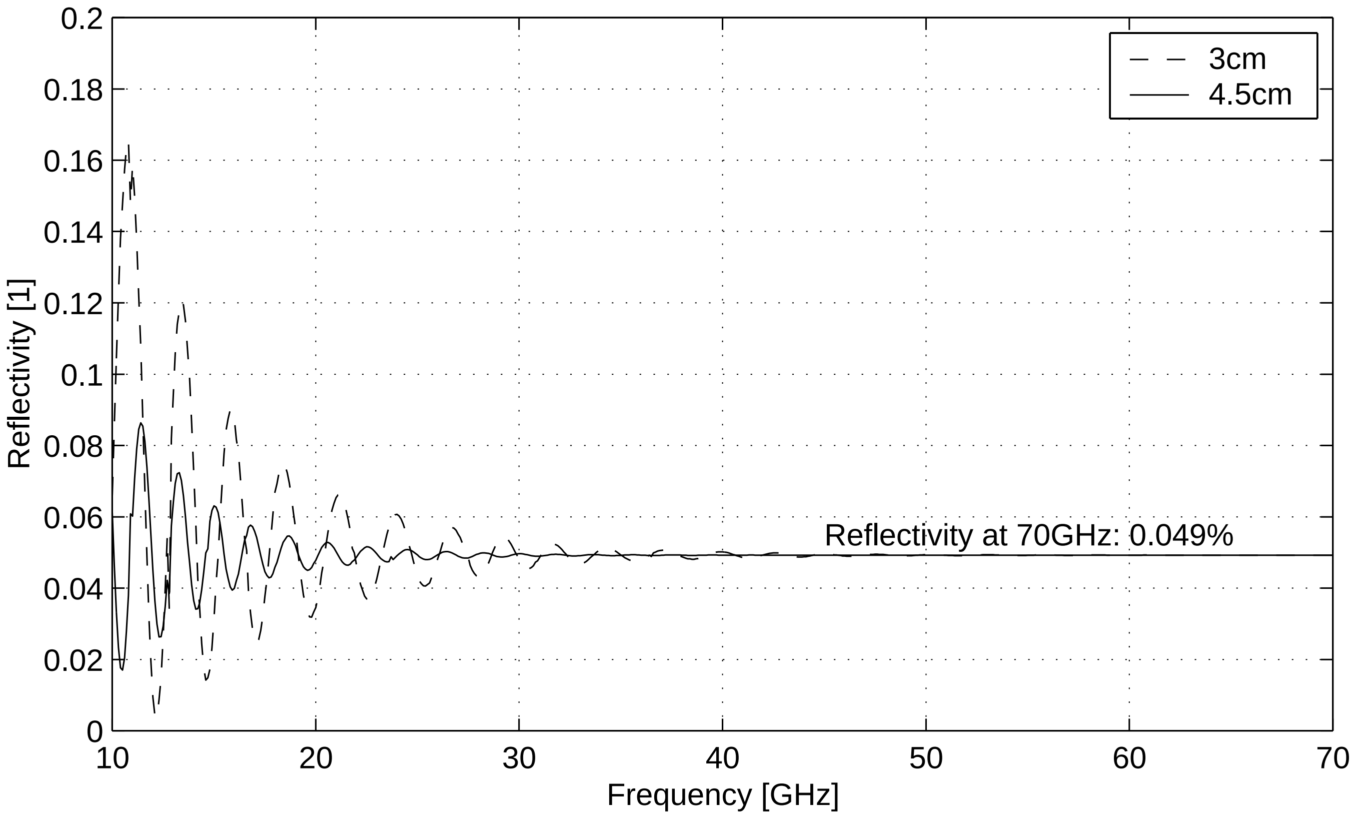
Reflectivity and penetration depth of a material with $\epsilon = \epsilon' + i\epsilon''$ (plain surface):



optimal material: beech wood

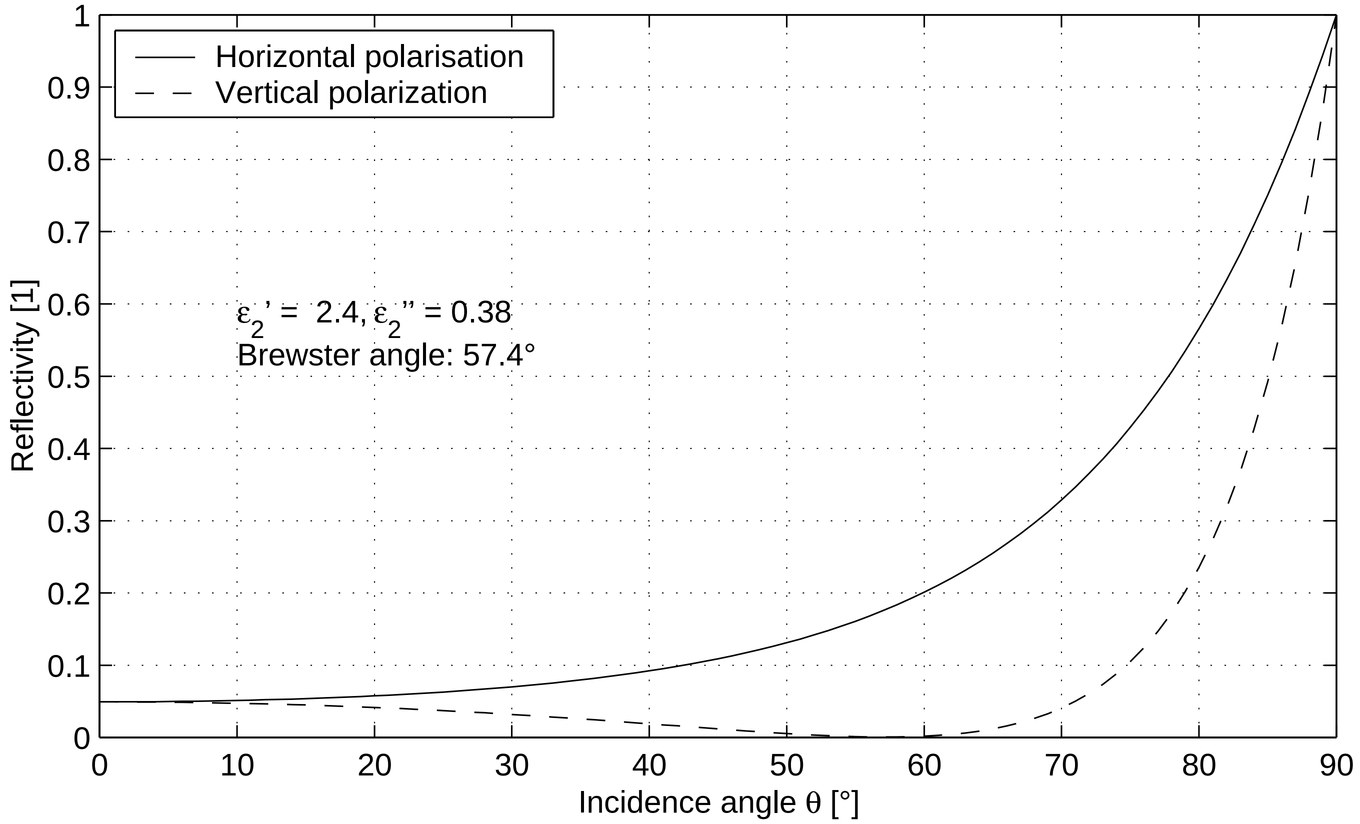
Layers of a typical absorber:

medium	thickness [mm]	permittivity ϵ [1]
air	∞	1
wood	30 and 45	2.4 + 0.38i
insulation	10	1
metal	1	100'000 + 0i
air	∞	1



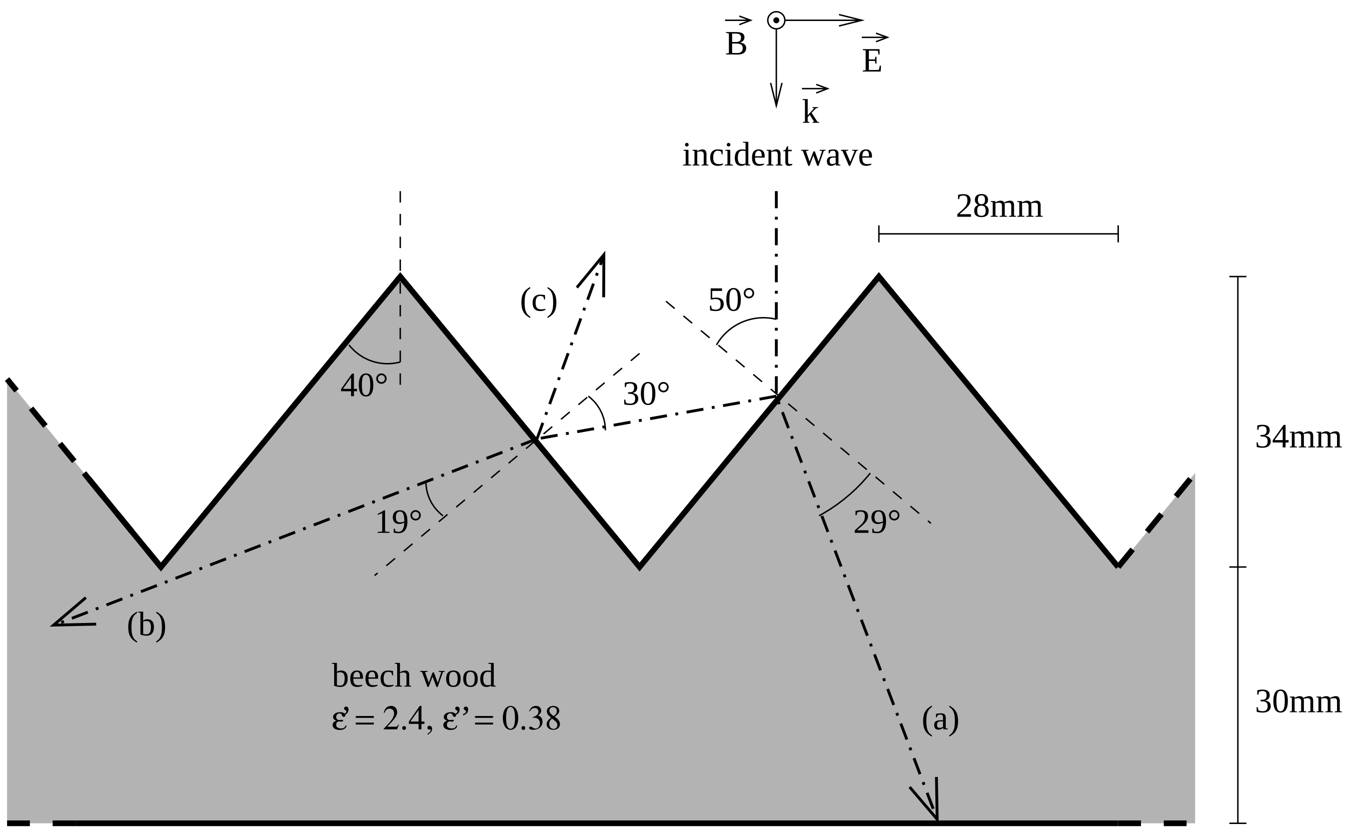
For a 3 cm thick wood plate, the reflectivity is less than 7% down to 18 GHz.

Angular dependence of reflectivity:

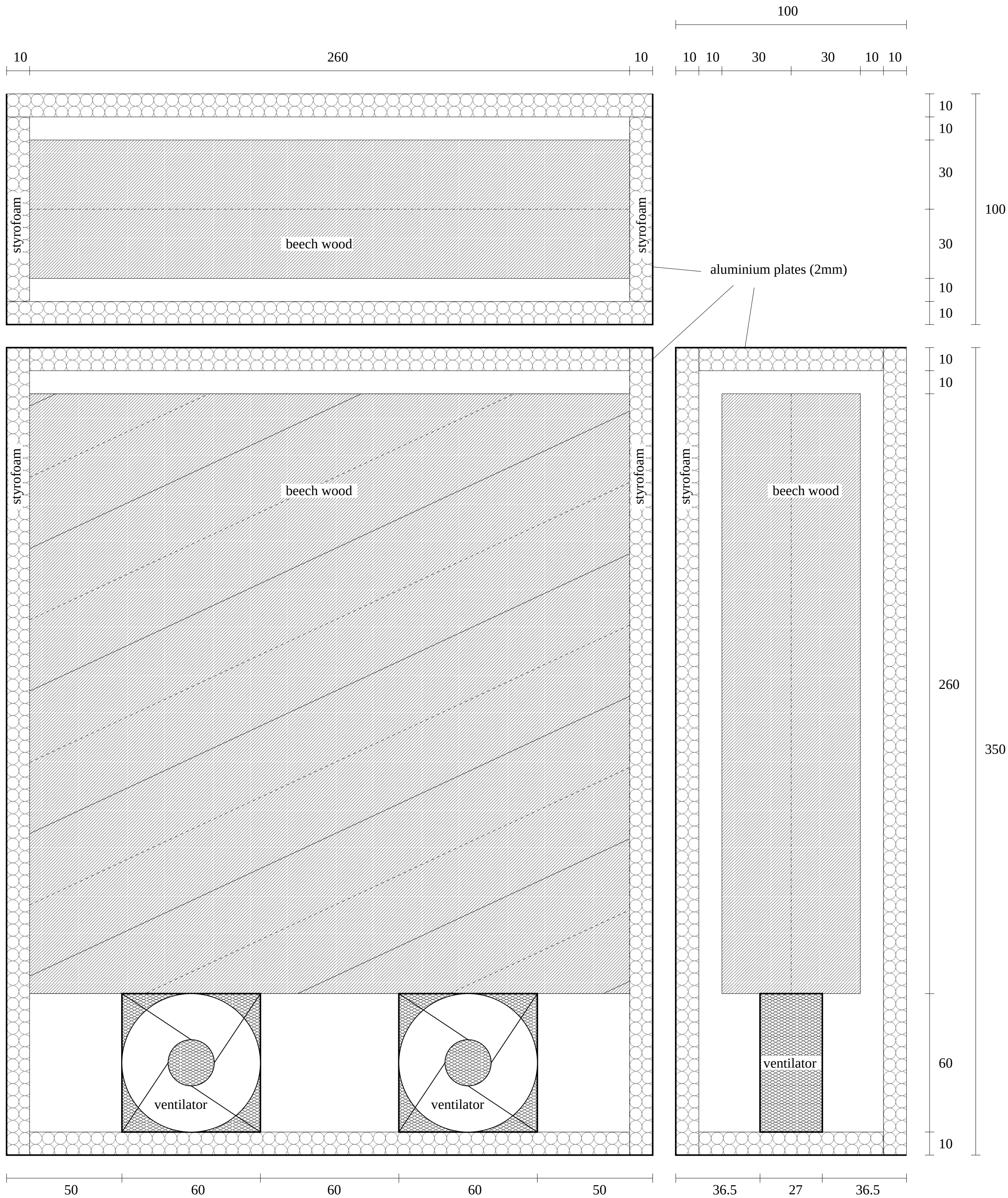


The inclination of the absorber surface to 50° reduces the reflectivity.

Surface geometry:



Construction:



Hot load

Calibration of the 52 GHz band radiometer

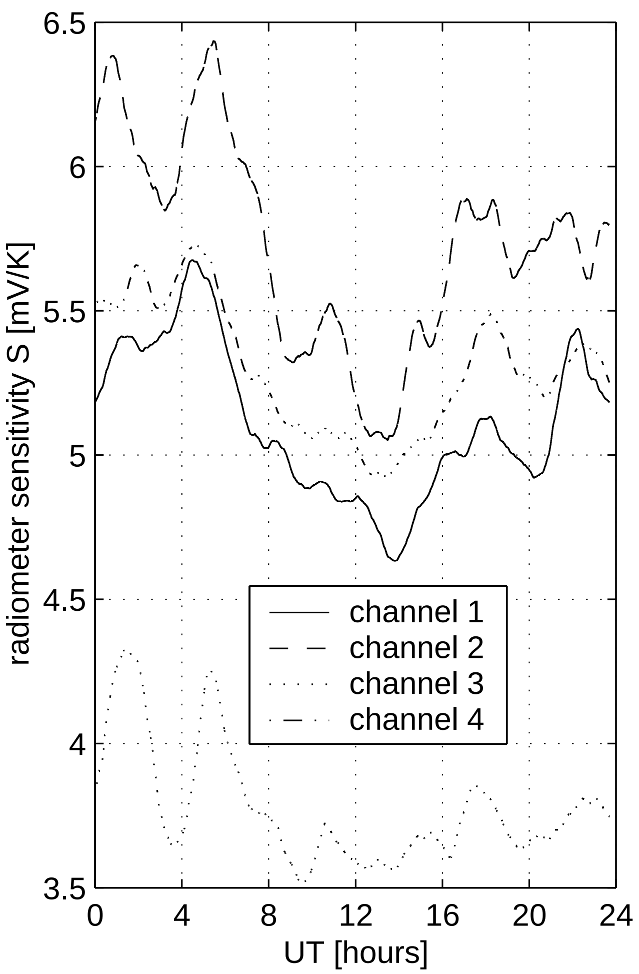
Radiometer calibration function:

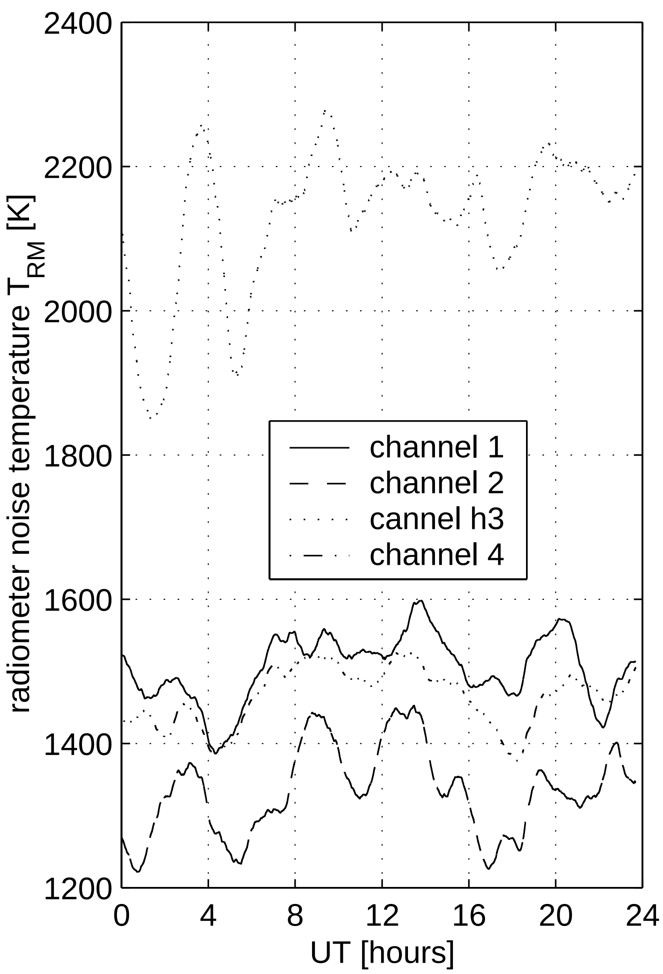
$$T_b = \frac{1}{S} U - T_{RM}$$

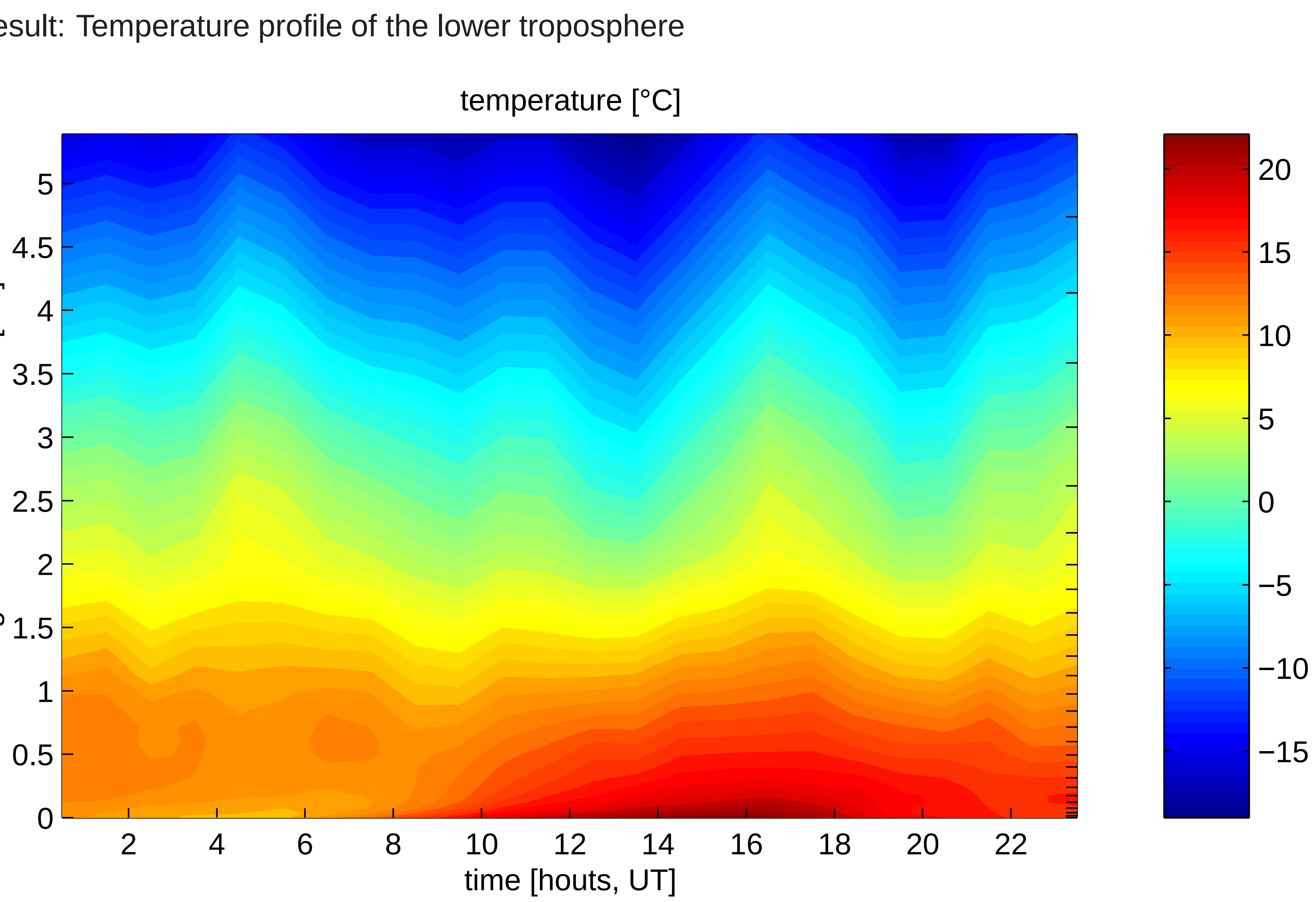
The measurement of T_{amb} and T_{hot} as well as the corresponding voltages, U_{amb} and U_{hot}, yields:

$$\begin{aligned} \frac{1}{S} &= \frac{T_{\mathrm{hot}} - T_{\mathrm{amb}}}{U_{\mathrm{hot}} - U_{\mathrm{amb}}} \\ T_{RM} &= T_{\mathrm{hot}} - U_{\mathrm{hot}} \frac{T_{\mathrm{hot}} - T_{\mathrm{amb}}}{U_{\mathrm{hot}} - U_{\mathrm{amb}}} \end{aligned}$$

S and T_{RM} during one day:







esult: Temperature profile of the lower troposphere
temperature [°C]
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
2
4
6
8
10
12
14
16
18
20
22
time [houts, UT]
20
15
10
5
0
−5
−10
−15

Calibration of the 21 GHz and 31 GHz band radiometers

Radiometer calibration function:

$$T_b = \frac{1}{S} U - T_{RM}$$

Measured brightness temperature under zenith angle θ:

$$T_b(\theta) = T_{bg}\, e^{-\tau_\theta} + T_m \left[1 - e^{-\tau_\theta}\right] \qquad (1)$$

T_{bg}: background brightness temperature [K]
T_m: mean tropospheric temperature [K]
τ_θ: opacity under zenith angle θ

Iterative calibration:
1st step: estimation of the zenith opacity τ_0

$$\tau_0 = \frac{1}{\sec\theta - 1} \ln \frac{U(T_b(0)) - U(T_m)}{U(T_b(\theta)) - U(T_m)}$$

2nd step: calculate S and T_{RM}

$$\frac{1}{S} = \frac{(T_m - T_{bg})e^{-\tau_0}}{U(T_m) - U(T_b(0))}$$

$$T_{RM} = T_m - \frac{1}{S} U(T_m)$$

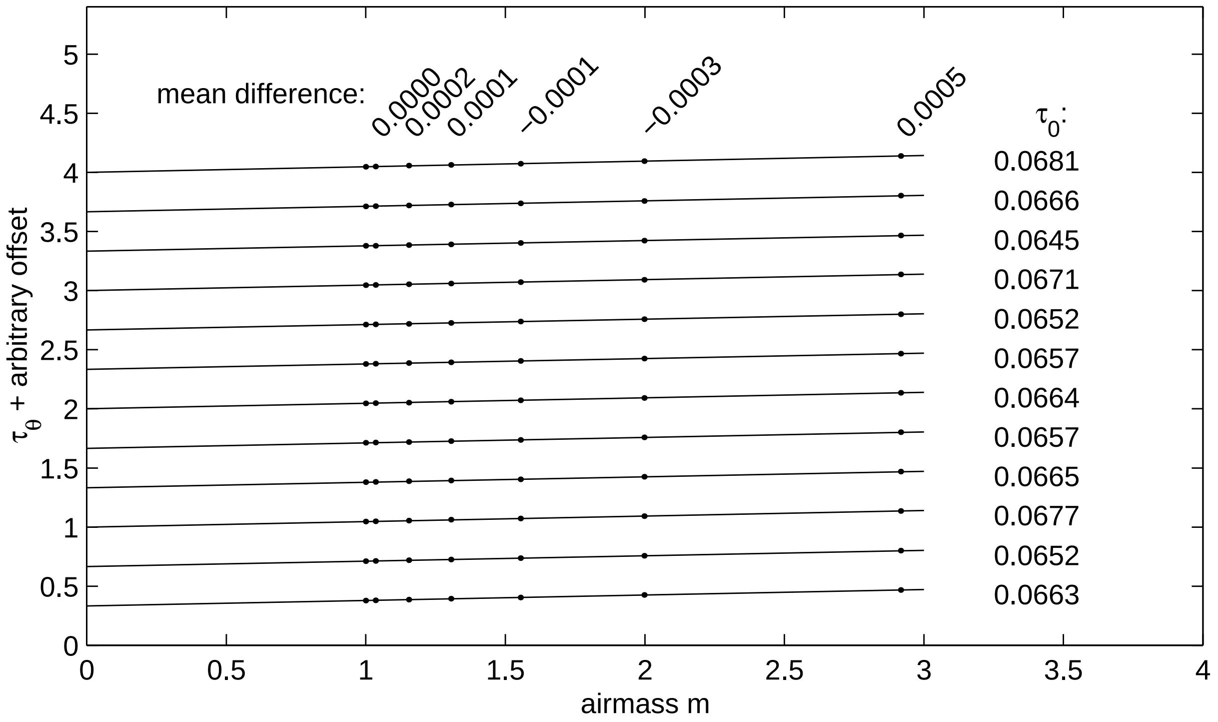
3rd step: calculate T_m with Eq. 1

Repeat 2nd and 3rd step until $U(T_m)$ converges.

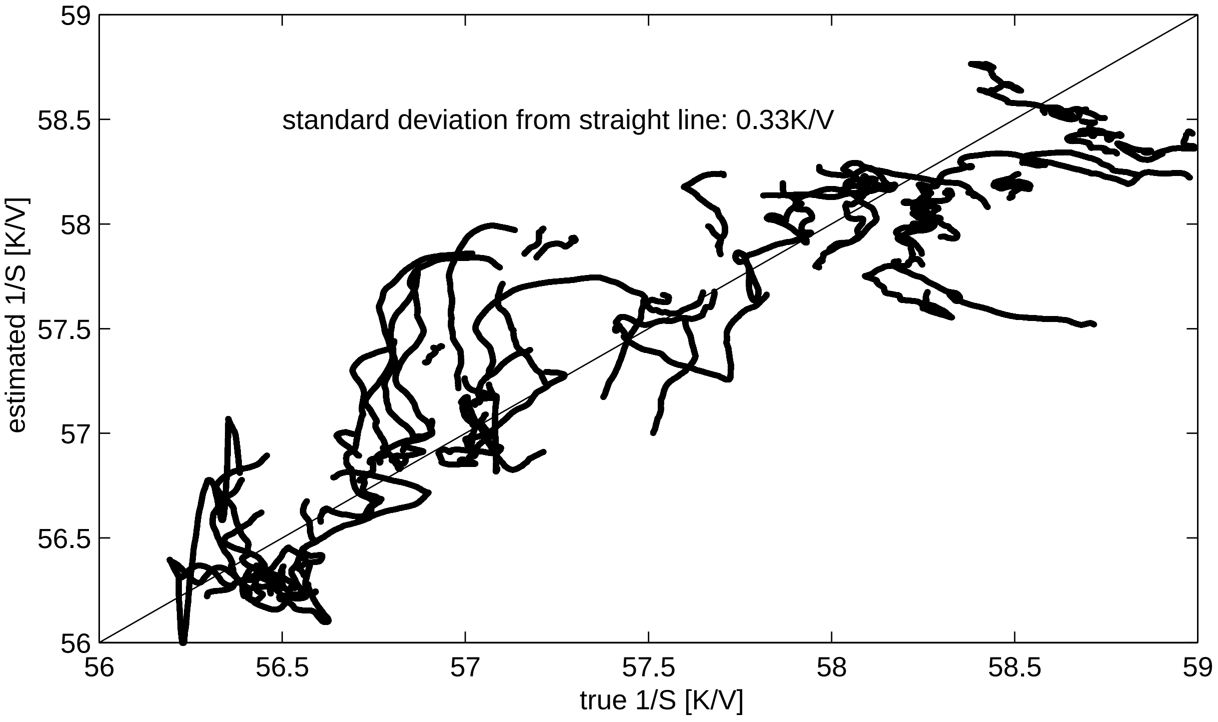
Further adjustments;

- correction for antenna beam width
- dependence of T_m on θ

Opacity τ_θ vs. airmass $\sec\theta$ at 22.20 GHz:

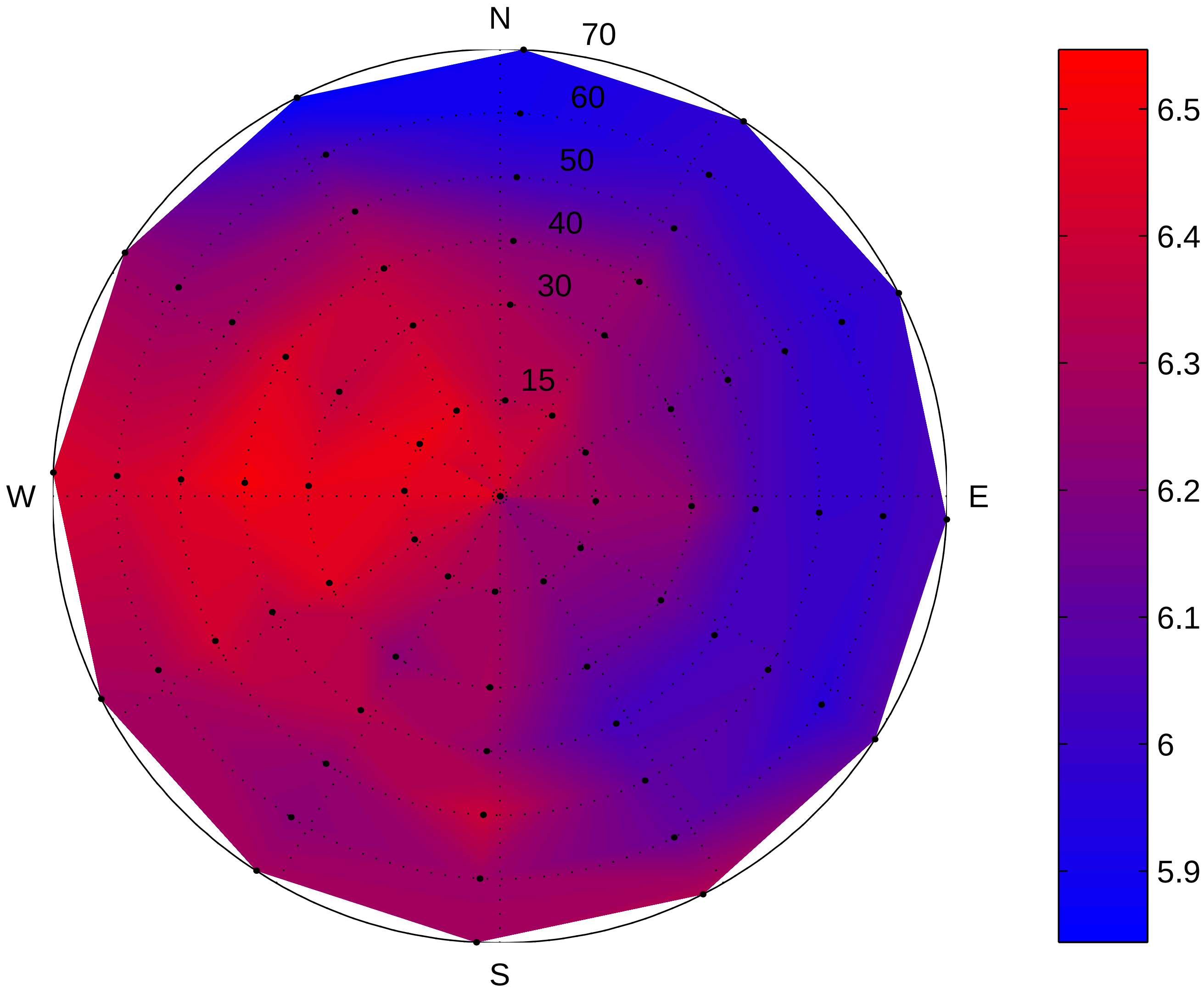


Simplified calibration: Estimation of S from the physical temperature of the radiometer:



Result:
Maps of the atmospheric water vapour and liquid water distribution

Integrated water vapour content [mm], 2003−03−18, 05:23 UT



Visit ASMUWARA in the internet:
http://www.iapmw.unibe.ch/research/projects/ASMUWARA/