Processing WVR3+ Tipping Curves

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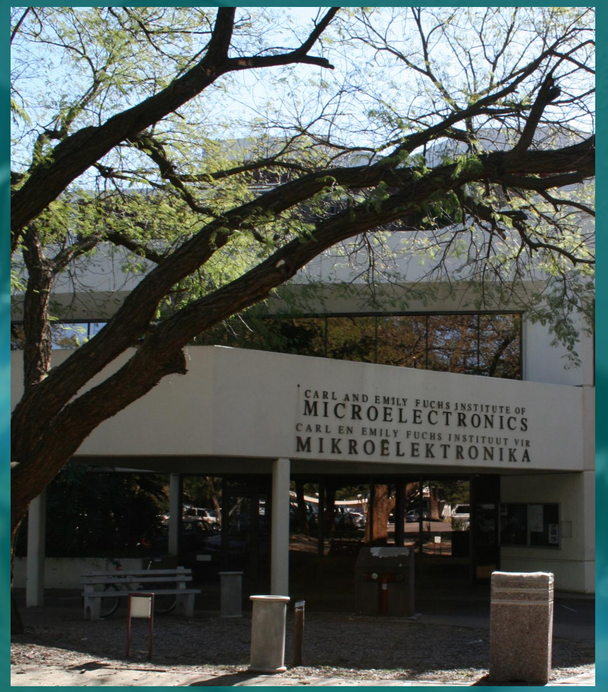
Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo



Why water vapour radiometry?

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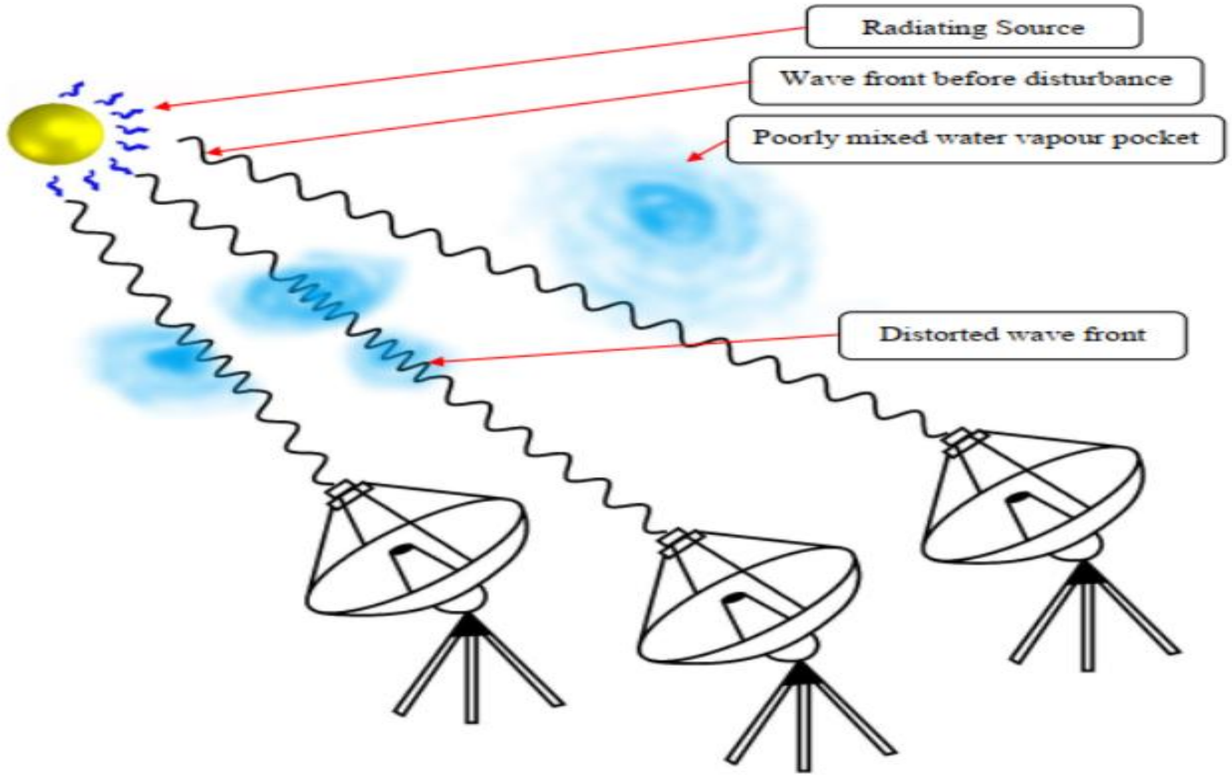
Water vapour affecting a VLBI system



Source: S. M. Walker, T. Stander, A. C. de Villiers, "Simulation approach to WVRs using an RF system simulator," Proc. SPIE 11450, Modeling, Systems Engineering, and Project Management for Astronomy IX, 1145004 (13 December 2020)

WVR3+

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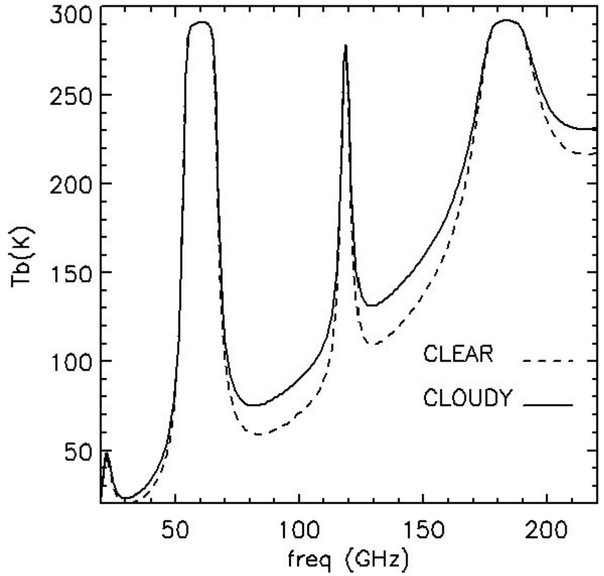
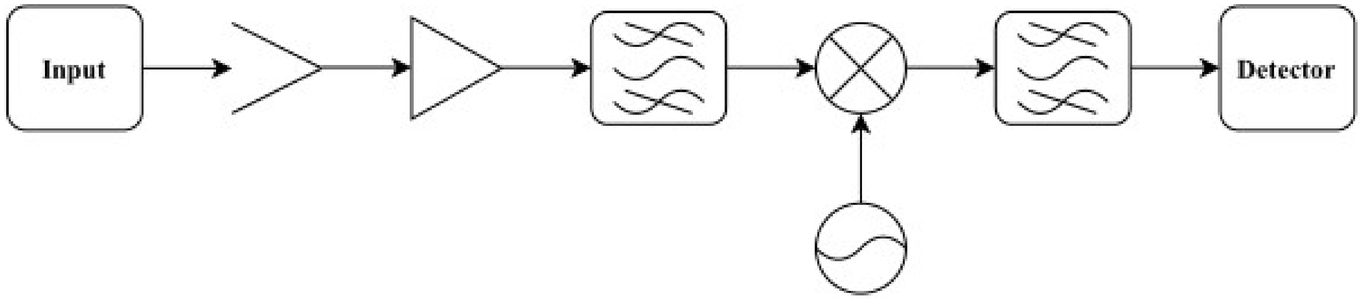
Water vapour radiometry

Water emission line at 22.235, 183.31, 380.197, 464,925, 547.676 and 556.936 GHz





Source: Westwater, E.R., Crewell, S. and Matzler, C., 2005. Surface-based microwave and millimeter wave radiometric remote sensing of the troposphere: A tutorial. *IEEE Geoscience and Remote Sensing Society Newsletter*, *134*, pp.16-33.

Water vapour radiometry

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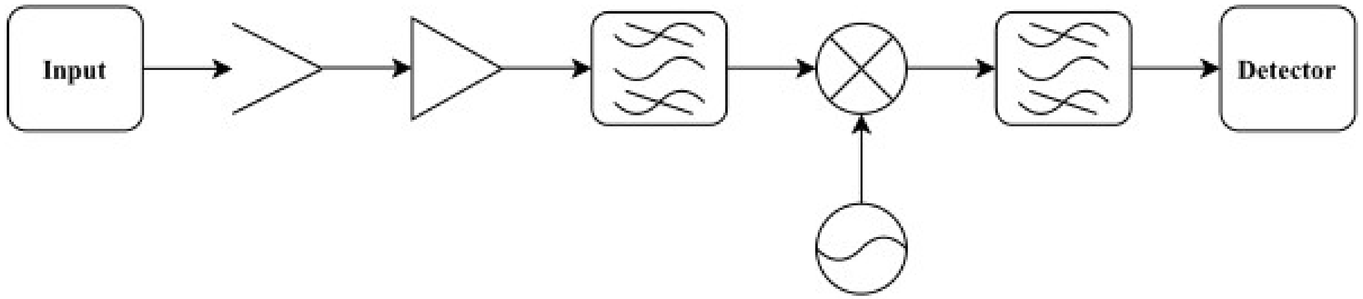
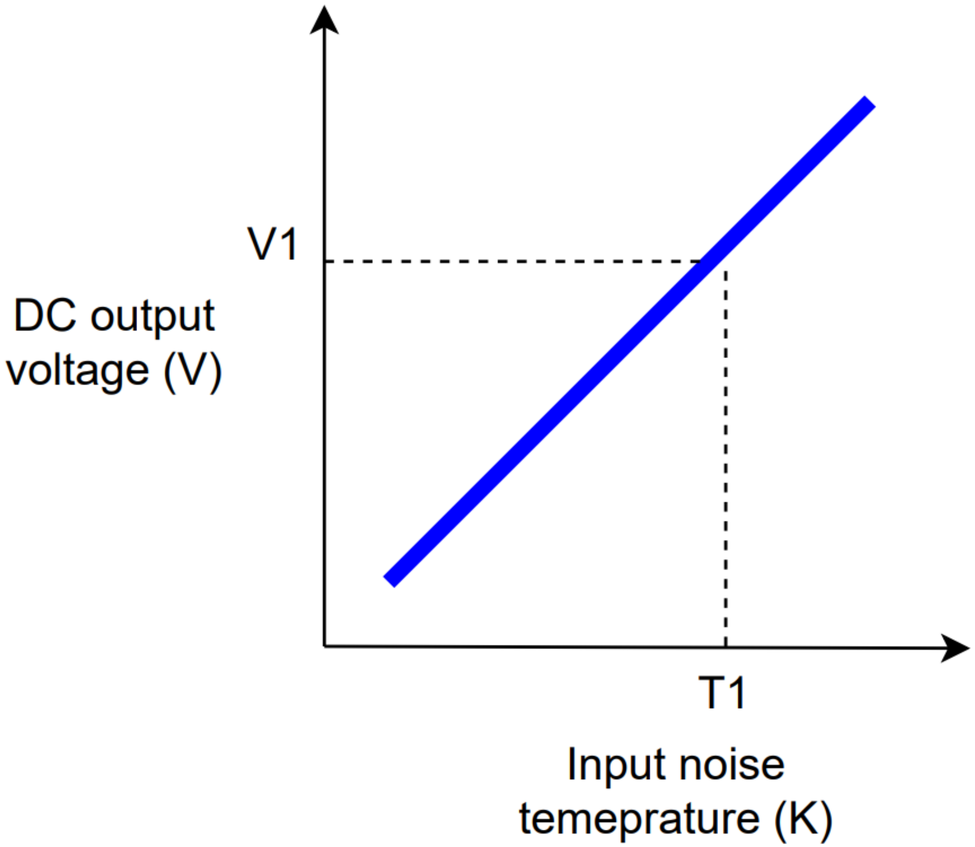
In the case of a total power radiometer, DC output voltage is proportional to input noise temperature

Noise temperature



DC Output voltage

Water vapour radiometry



$$V1 = A\big(G(T1 + Tsys)\big) + B$$

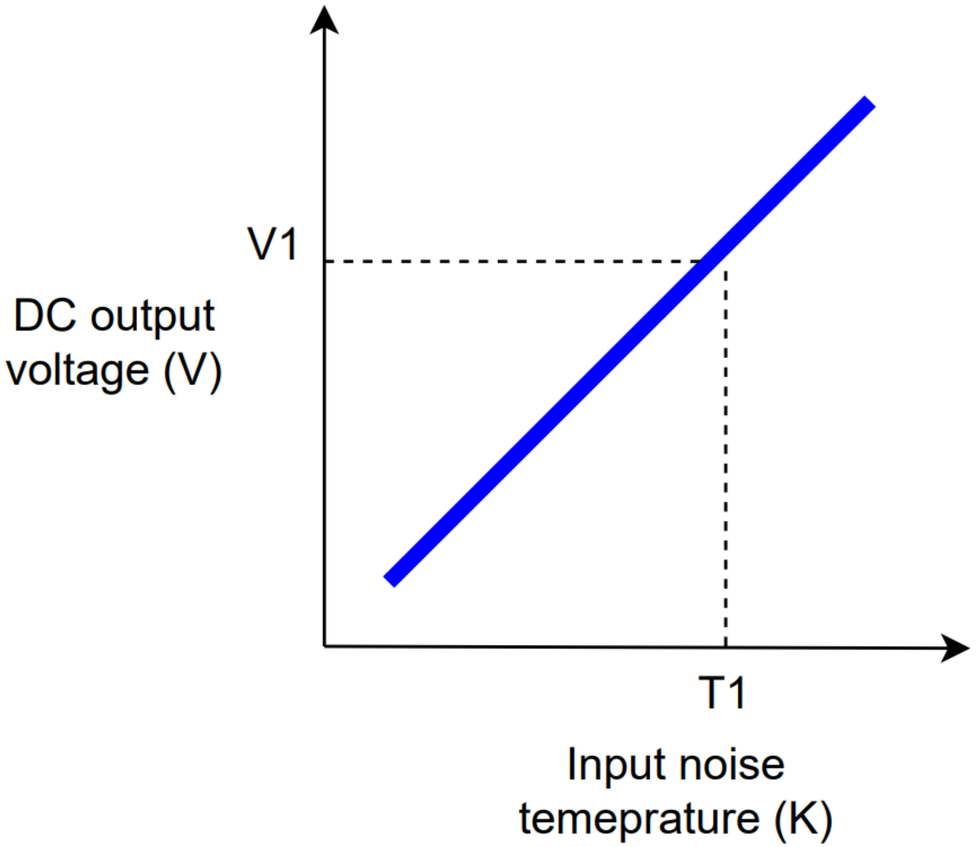
A: responsivity of the power detector

B: DC offset of the power detector

G: Gain of the receiver

$Tsys$: Noise temperature of the receiver

Water vapour radiometry

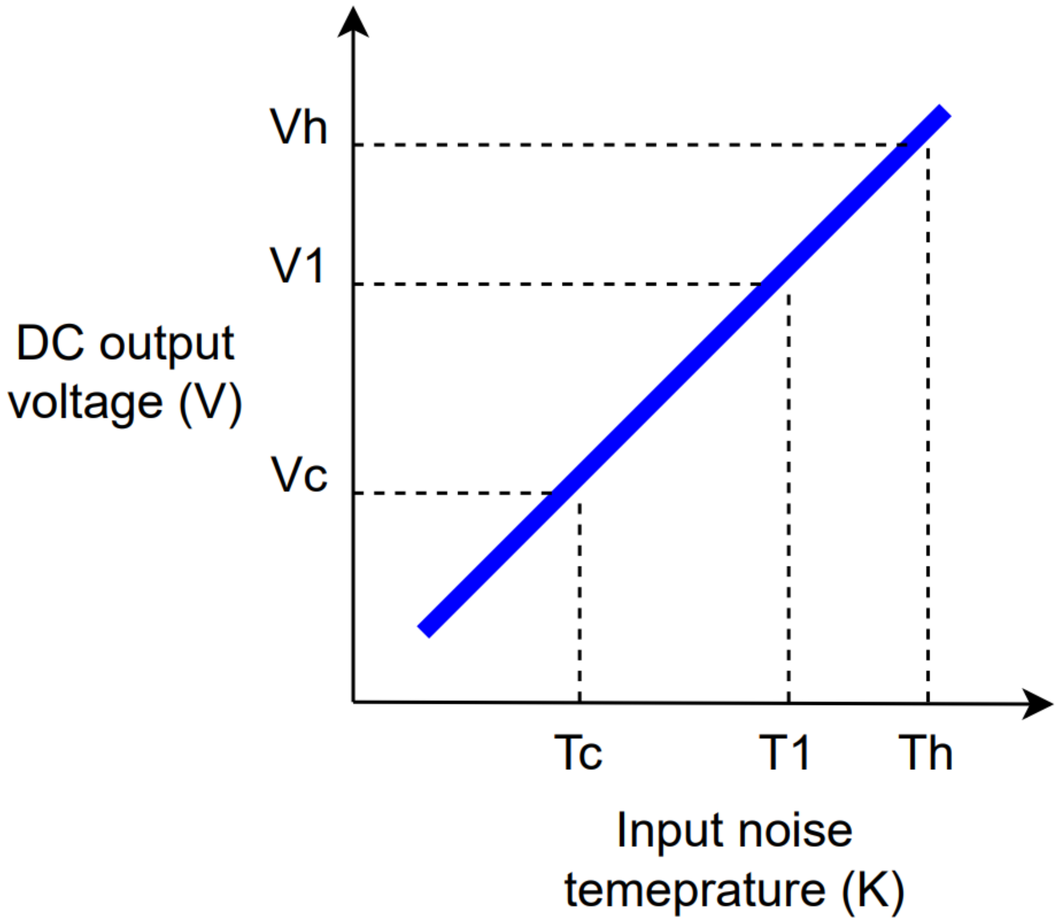


$$V1 = A\big(G(T1 + Tsys)\big) + B$$

A
B
G
$Tsys$

Temperature and device tolerance dependent

Water vapour radiometry

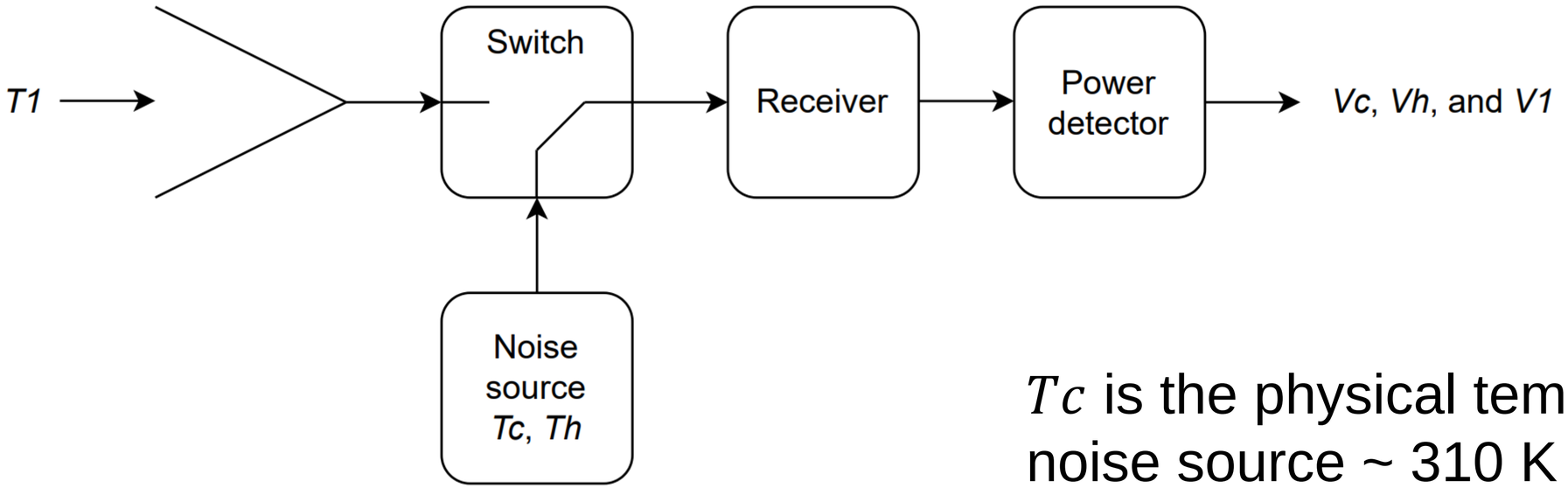


Tc and Th are known
Vc, Vh and $V1$ are measured

$$T1 = \left(\frac{V1 - Vc}{Vh - Vc}\right)(Th - Tc) + Tc$$

Calibration

Viewing black-body noise source of know noise temperature



Tc is the physical temperature of the noise source ~ 310 K

Th is not known exactly but ~ 700 k

Calibration

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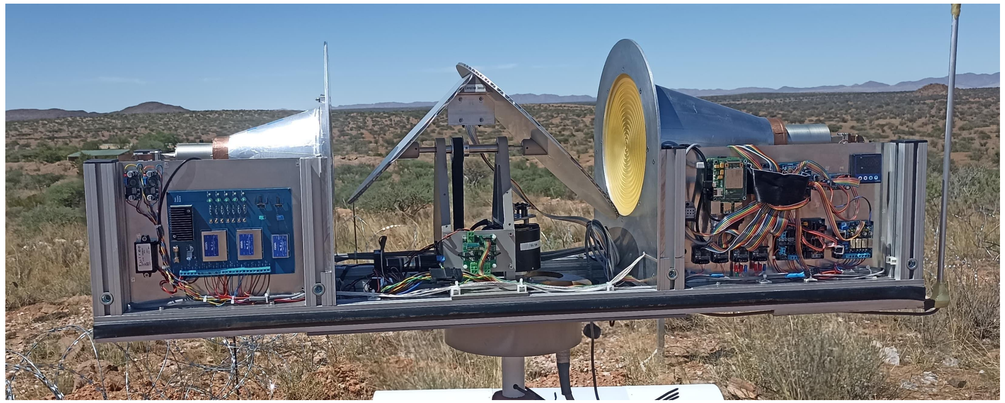
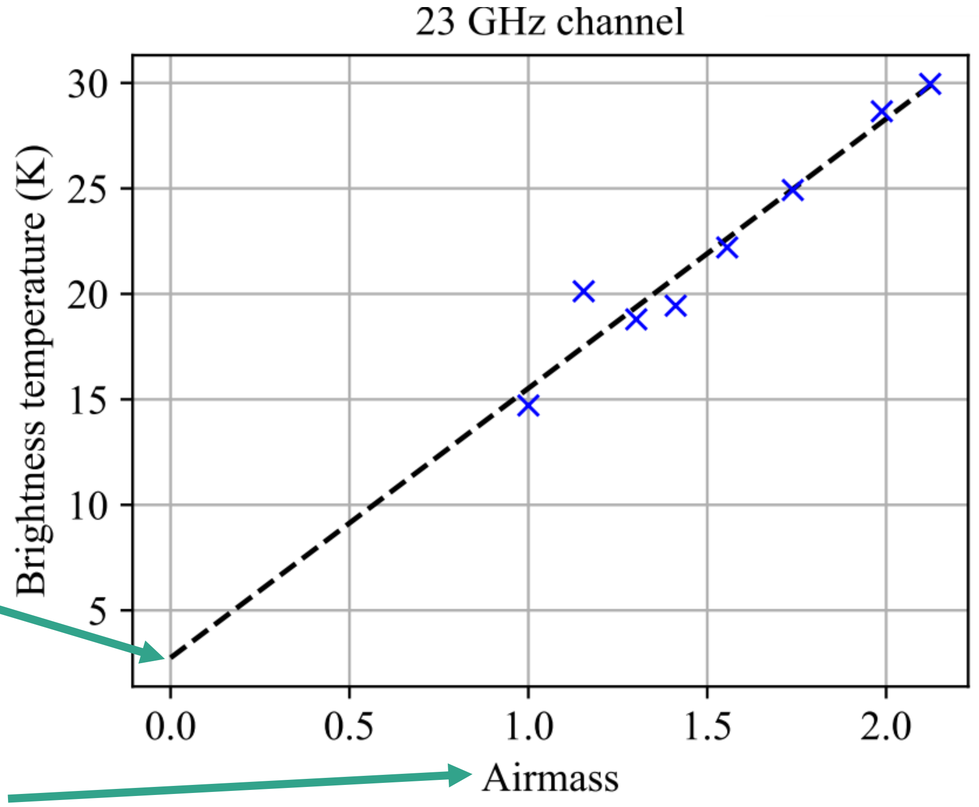
WVR3 is a tipping curve radiometer





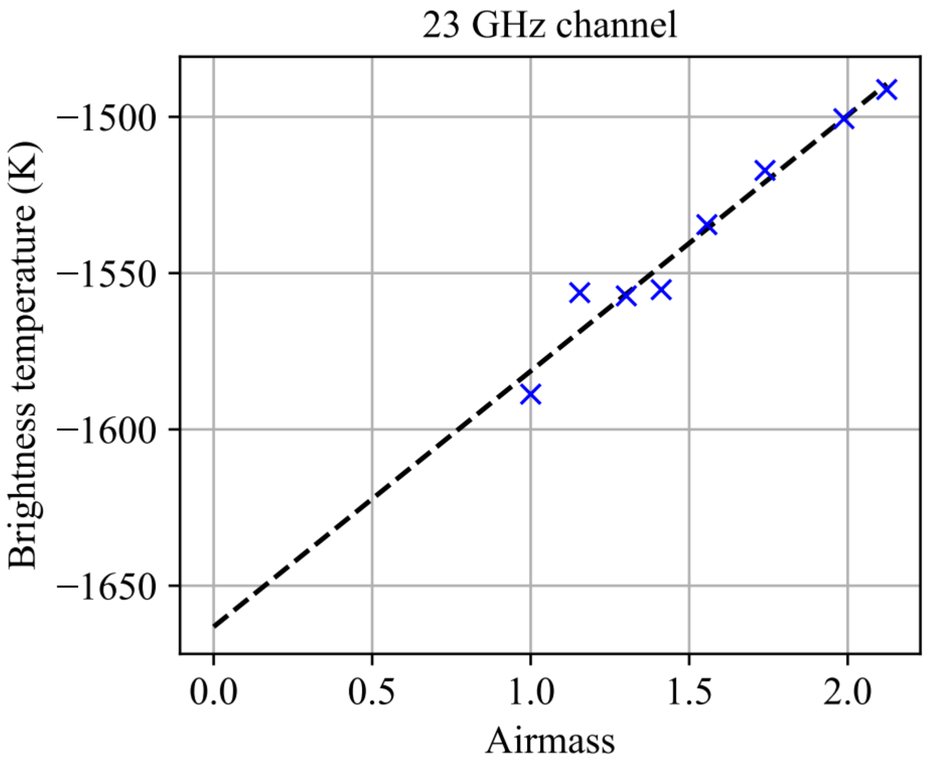
Cosmic background $Tc = 2{,}7\ K$

Airmass = $\frac{1}{\sin(\theta)}$ where θ is the elevation angle

Calibration

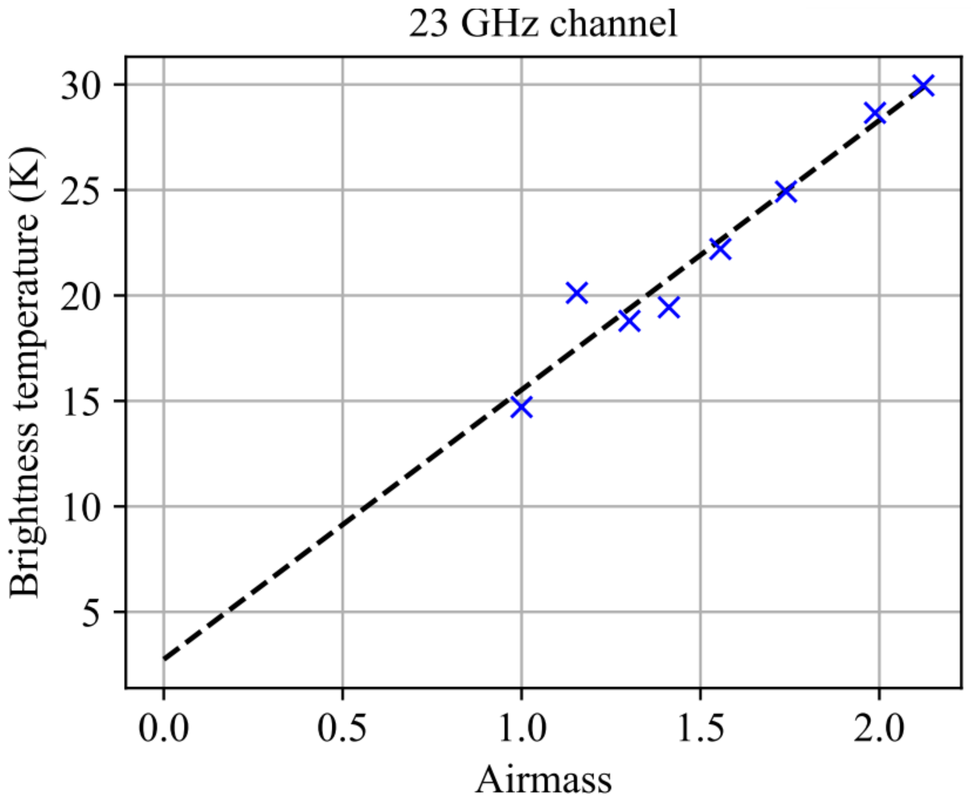
Uncalibrated

$Th = 700\ K$

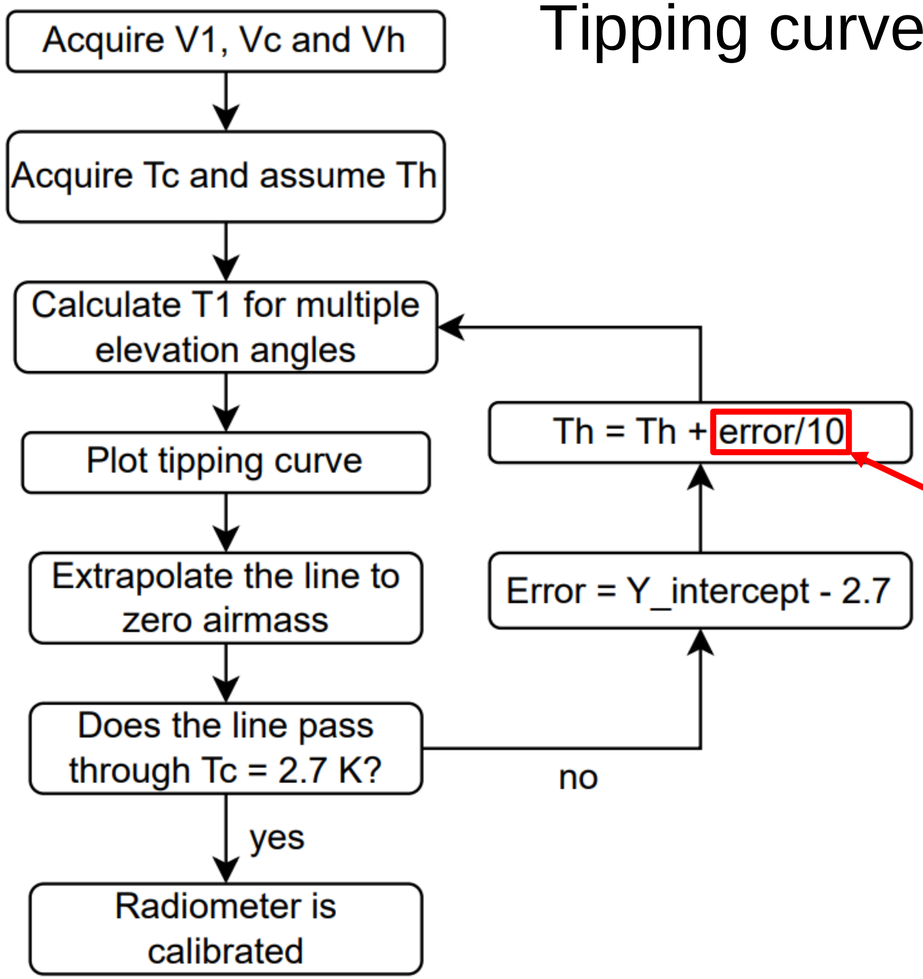


Calibrated

$Th = 372\ \ K$



Calibration



Tipping curve calibration algorithm

Divide by 10 to prevent over correction and possibly an infinite loop

Data format

The data is stored in a csv file called “T240312.csv”, which is data taken on 12 March 2024 at the H.E.S.S in Namibia

1	2024-03-11 23:59:45	89.80	6.7436	7.7150	5.3073	7.3999	7.8509	5.1249	311.698	312.038	312.649	312.785	295.08	52.44	826.54
2	2024-03-12 00:00:04	60.20	6.7439	7.7137	5.2989	7.3981	7.8491	5.1411	311.834	311.902	312.581	312.751	295.10	52.35	826.52
3	2024-03-12 00:00:22	50.20	6.7446	7.7119	5.2776	7.4003	7.8518	5.1730	311.766	311.936	312.513	312.717	295.12	52.01	826.53
4	2024-03-12 00:00:40	45.20	6.7446	7.7110	5.2841	7.4015	7.8520	5.1783	311.868	312.105	312.513	312.683	295.14	52.17	826.51
5	2024-03-12 00:00:59	40.20	6.7435	7.7101	5.3183	7.3989	7.8488	5.1875	311.800	311.902	312.581	312.717	295.18	51.79	826.54
6	2024-03-12 00:01:17	35.20	6.7443	7.7128	5.3342	7.3999	7.8526	5.1952	311.834	311.936	312.581	312.717	295.19	51.91	826.56
7	2024-03-12 00:01:35	30.20	6.7458	7.7153	5.3238	7.4003	7.8534	5.2242	311.834	311.970	312.615	312.785	295.19	51.41	826.53
8	2024-03-12 00:01:53	28.10	6.7458	7.7140	5.3317	7.4003	7.8528	5.2440	311.834	311.902	312.615	312.683	295.18	51.55	826.56
9	2024-03-12 00:02:28	89.90	6.7443	7.7137	5.3103	7.4045	7.8552	5.1273	311.800	311.766	312.615	312.615	295.18	51.32	826.54
10	2024-03-12 00:02:47	60.20	6.7470	7.7195	5.3039	7.4009	7.8555	5.1463	311.732	311.902	312.683	312.649	295.21	51.10	826.48
11	2024-03-12 00:03:05	50.20	6.7461	7.7199	5.2709	7.4027	7.8563	5.1677	311.732	311.800	312.479	312.547	295.26	50.90	826.51

Each tipping curve consists of 8 different elevation angles

Data format

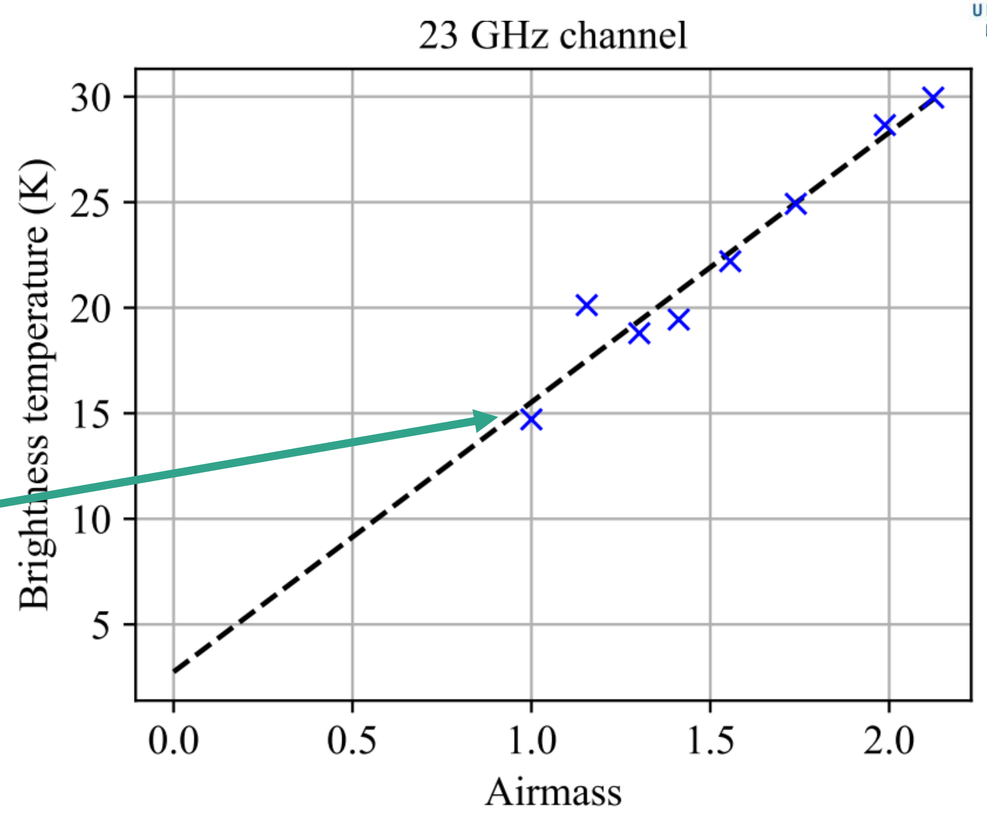
1. Index
2. Date - Time [YYYY-MM-DD hh:mm:ss]
3. ELV (Elevation angle [deg]) ← θ
4. VRF31 (Cold [V])
5. VRF31 (Hot [V])
6. VRF31 (Antenna [V])
7. VRF23 (Cold [V]) ← Vc
8. VRF23 (Hot [V]) ← Vh
9. VRF23 (Antenna [V]) ← $V1$
10. TN23 (Noise Source [K]) ← Tc
11. TA23 (Plate [K])
12. TN31 (Noise Source [K])
13. TA31 (Plate [K])
14. TWS (Ambient Temperature [K])
15. HWS (Relative Humidity [%])
16. PWS (Barometric pressure [mbar])

Note that 'Date - Time' are merged into a single column.

Note that there are two channels, 23 GHz and 31 GHz. Both can be processed independently using tipping curves.

Activity

Using the supplied data files, T240312.csv, process the data to produce the 23 GHz sky brightness temperature at Zenith, 90 degrees elevation angle



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