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220 GHz tipping radiometer for monitoring atmospheric opacity at Hanle*

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Abstract. In this poster presentation, we describe the working principle, data acquisition method and data reduction scheme of a 220 GHz tipping radiometer. We also present the preliminary 220 GHz zenith optical depth results at Mt. Saraswati, Digpa Ratsa Ri, Hanle, Ladakh, India with some conclusions.

Key words : opacity, precipitable water vapour (pwv)

1. Introduction

The identification of a high altitude desert site, Hanle, in the Himalayan region of Ladakh for an Indian Astronomical Observatory (IAO) by IIA opens up the possibilities of future observing facilities in the sub-mm and lower wavelength bands. As the expected atmospheric opacity at sub-mm frequencies derived from the surface RH and air temperature measurements that are being recorded since the summer of 1996 is encouraging, a collaborative work to measure directly and continuously the 220 GHz transparency/opacity of the sky, at this site for about two years is underway. Atmospheric transparency, at this site at higher frequencies, can be extrapolated from the zenith opacity value at 220 GHz. The instrument was installed for continuous monitoring on December 23, 1999.

2. Description

This personal computer (PC) controlled instrument, consists of an off-axis parabolic mirror of focal length 150 mm, with a projected aperture of 80 mm, mounted at 45° to the rotation axis, and a 220 GHz prime-focus receiver also located on the rotation axis. With this simple arrangement, the system can look at the sky at all elevations or zenith angles (z) at a fixed azimuth position, with just one axis rotation and with no blockage.

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*Hanle : Lat. 32°46′46.3″ N, Long. 78°57′51.1″ E and Altitude - 4470 m

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The mirror with about 1° beam is driven by a step motor under PC control is rotated to look at every 0.72° on the sky for 90 msec, covering a zenith angle range of nearly – 90° to + 90°. The sky coverage through the radome window is limited to about 90° i.e., from –75° to + 15° in zenith angle. The window is covered with a low loss woven teflon membrane. A forward scan and a reverse scan are taken in about a minute. Towards the + 90° zenith angle position is a reference load, a black body at room temperature (T_{ref}). The averaged signal corresponding to these mirror positions is the reference for temperature calibration of the signal received from the sky emission.

The signal received from each sky position is down converted to 1450 MHz with 500 MHz bandwidth, detected, digitized and stored in the PC's hard disc. Scans are taken once every 10 minutes. System sensitivity or minimum detectable signal T_{rms} is 2 K.

3. Analysis

The basic equations relating the detected voltage and temperature are :

$$V_{sky} = C[T_{rx} + T_{medium}(1 - e^{-(\tau_o sec(z))}) + T_b e^{-(\tau_o sec(z))}] \tag{1}$$

$$V_{ref} = C[T_{rx} + T_{ref}] \tag{2}$$

where, C is proportionality constant or conversion factor, T_{rx} is receiver Noise Temperature and T_b is background source temperature. With the assumptions that system gain is constant or variation is corrected, system sensitivity is same at all zenith angles, sky is stable during the scans, no background source in the beam and $T_{medium} = T_{ambient} = T_{ref}$, the above equations can be reduced to single linear equation and zenith optical depth can be determined by a least square fit routine using the sec(z) dependency of the sky emission. Data up to air mass 2.4 is used in the fit to derive zenith opacity.

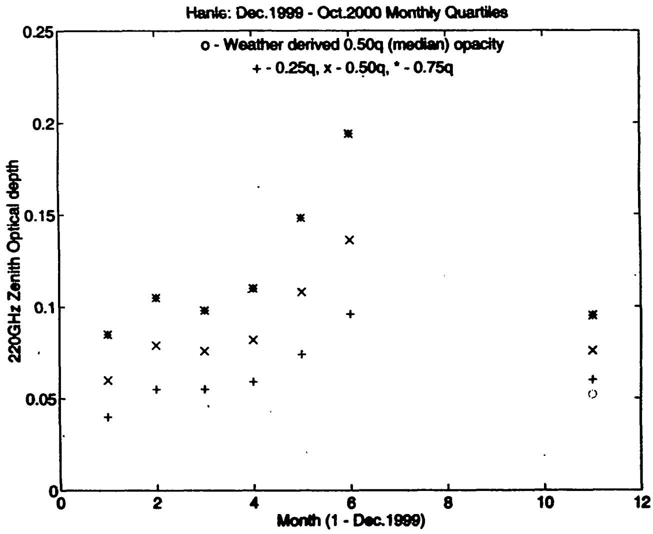

Figure 1. Monthly quartiles of opacity, errors +/– 0.03 and +/– 'o' 0.5q expected from weather-derived pwv assuming a 1.5 Km scale height.

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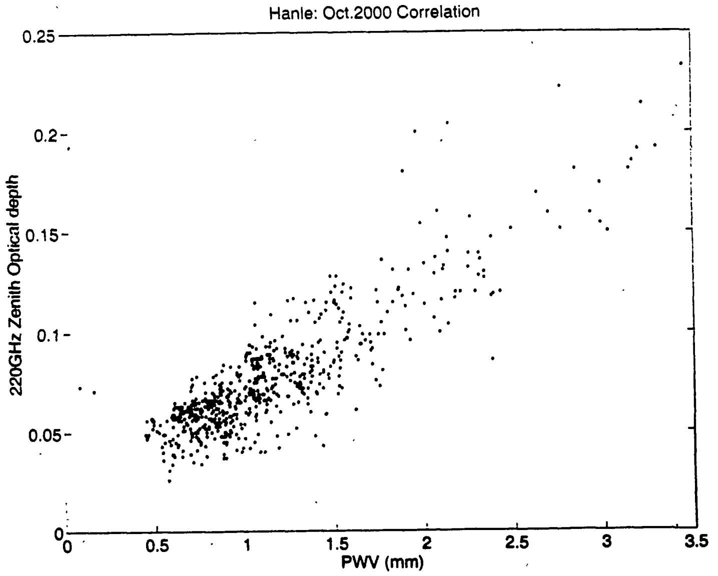

Figure 2. Correlation between 220 GHz opacity and weather-derived-precipitable water vapour for data from 6th to 31st Oct. 2000.

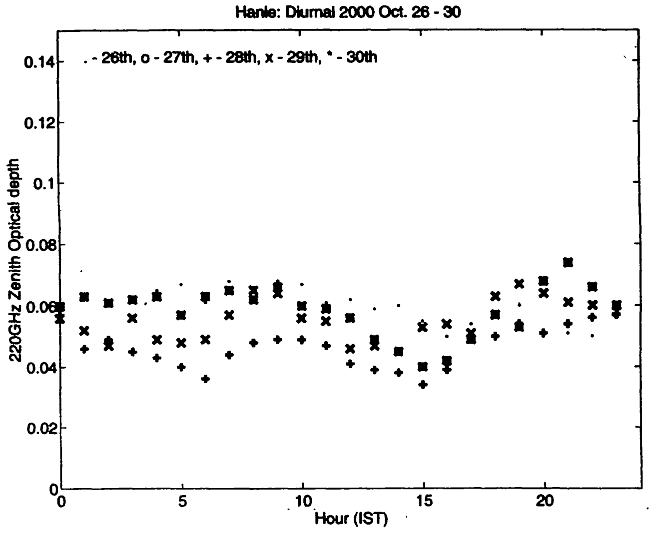

Figure 3. Diurnal variation of opacity for 5 days in Oct. 2000.

4. Results and Conclusions

1. The opacity values from 23 Dec. 99 to 12 May, 2000 has errors due to imperfect gain cancellation between the two scans in a 10 minute run. The system was also unstable, intermittently from April to August, and was fully not functioning during September.

2. For the Oct. 2000 opacity values, there is good correlation with the pwv derived from surface RH and air temperature measurements assuming a 1.5 Km scale height (Fig. 2).

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3. The measured opacities are higher compared to surface-weather-derived opacities. The expression from ALMA Memo No. 271 was used to derive opacities from surface weather parameters (Fig. 1).

4. The radiometer data is being reanalysed to identify possible systematic errors such as in the identification of correct zenith position. Together with further data being collected, it should be possible to make a comparison with other good sites in the world.

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