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Proposed microthermal measurements at Devasthal

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Abstract. For evaluating the optical quality of the Devasthal site, it is porposed to set-up a potentially viable instrument for detecting the microthermal fluctuations introducted by the atmospheric turbulence. The details of the instrument and the method of analysis have been described here.

Key words : site testing-microthermal fluctuations-astronomical seeing

1. Introduction

For characterizing the Devasthal site, an intensive site testing campaign has been started recently jointly by U.P.State Observatory, Nainital and Indian Institute of Astrophysics, Bangalore. It is proposed to use as many site testing instruments as possible to ensure the accurate seeing measurement, for evaluating the optical quality of the Devasthal site for high angular resolution astronomy. For achieving this aim, the Differential Image Motion Monitor (DIMM) has already been installed on 52 cm telescope at Devasthal. Another site testing instrument for the proposed site is related to the measurements of the microthermal fluctuations.

Local seeing effects due to small scale temperature gradient have variously been studied by using the temperature probes inside the telescope dome and in the immediate vicinity of the telescope site (Lynds 1963; Hall 1967; Coulman 1969, 1974). Lynds (1963) estimated the visual image quality with the 36 inch reflector telescope and compared these with the simultaneously taken temperature fluctuation traces. These observations showed that on the average the image size was correlated directly with size and frequency of occurence of temperature fluctuations. He has also concluded that seeing was never good when the thermal fluctuations were large and frequent. Likewise when the temperature fluctuations were small and infrequent the seeing was generally good. Thus, the detection of the local source of seeing degradation, which occurs within a few tenths of meters off the ground, is of great importance for evaluating the seeing condition of an astronomical observatory site.

It is an established fact that atmospheric turbulence with its associated random refractive index inhomogeneities disturbs a light beam passing through the turbulent atmosphere (Tatarski 1961;Hufnagel and Stanley 1964; Fried 1966) and in consequence, deteriorates the optical quality of the image. The correlation between the astronomical seeing and the atmospheric turbulence has been investigated recently by various authors (Barletti et al. 1974, 1976; Ken Knight et al 1977; Marks et al. 1996). Their investigations conclude that the parameter which gives a measure of the optical turbulence intensity related to the refractive index inhomogeneities is the refractive index structure coefficient. 'C_N^2' (Coulman 1969; Vernin and Munoz - Tunon 1994). The parameter C_N^2 is connected with the temperature structure co-efficient ' C_T^2 ' of the microthermal field variations, which produce fluctuations in the index of refraction at optical wavelength (Coulman 1969; Barletti et al. 1974) as

$$C_N^2(h) = \left(\frac{P(h)}{T^2(h)} \times 80 \times 10^{-6}\right)^2 C_T^2(h) \tag{1}$$

where, $P(h)$ and $T(h)$ are the pressure (millibars) and the absolute temperature (°K) respectively at height h (meter). Hence, knowledge of the $C_T^2\,(h)$ as a function of altitude (h) is prerequisite for the estimation of the astronomical seeing quality of any place. Following Barletti et al. (1974) and Marks et al. (1996) the method used to determine $C_T^2\,(h)$ involves the measurement of the temperature structure function $D_T\,(r,h)$ at points P_1 and P_2 at the same height, h, but horizontally separated by a distance r given by

$$D_T(r,h) = <[T(P_1) - T(P_2)]^2> \tag{2}$$

where, $T(P)$ is the temperature at point P and angle brackets denote ensemble average. As defined by Obukhov (1949) this is related to $C_T^2\,(h)$ by

$$D_T(r,h) = C_T^2\,(h)\; r^{2/3}. \tag{3}$$

The relationship between r_0, the Fried's parameter which represents the diameter of the telescope aperture for which the diffraction limited image resolution is equal to the full width at half maximum, ($f\,whm$) of the seeing limited image and C_N^2 as a function of height h through the atmosphere has been given by Fried (1996) as

$$r_0 = \left(16.7\,\lambda^{-2} \int_0^\infty C_N^2\;(h)\,dh\right)^{-3/5} \tag{4}$$

where λ is the wavelength and C_N^2 is the refractive index structure constant, which gives a measure of the optical turbulence intensity related to the refractive index inhomogeneities in the atmosphere at height h. Vernin and Munoz-Tunon (1992) have mentioned that each turbulent layer at its altitude contributes to the degradation of the image according to the intensity of the turbulence. Thus C_N^2 represents the sum of the contribution from all turbulent layers in the atmosphere. The relation between seeing, ε_{fwhm} and r_0 is given by Dierickx (1992) as

$$\varepsilon_{fwhm} = 0.98\,\frac{\lambda}{r_0}\;. \tag{5}$$

Using the expression (4) and (5), it is possible to write seeing as a function of $C_N^2\ (h)$ as

$$\varepsilon_{fwhm} = 5.25\lambda^{-1/5}\left(\int_0^{\infty} C_N^2\ (h)\ dh\right)^{3/5}. \tag{6}$$

The refractive index structure constant in this case can be taken to represent the sum of the contribution from all turbulent layers in the atmosphere (Marks et al. 1996). Further, in order to assess the quality of an astronomical site, it is not sufficient to measure only the optical turbulence integrated over whole atmosphere but also to evaluate the relative contribution to the smearing of the image from each intervening slab.

2. Details of the instrument and results

The proposed technique for the microthermal fluctuation measurements is almost similar to that given by Marks et al. (1996). $D_T\ (r,h)$ measurements at Devasthal will be achieved by using pairs of microthermal sensors, horizontally separated by a distance of one meter and placed at three different levels on a mast. Since the resistance of the microthermal sensors varies in proportion

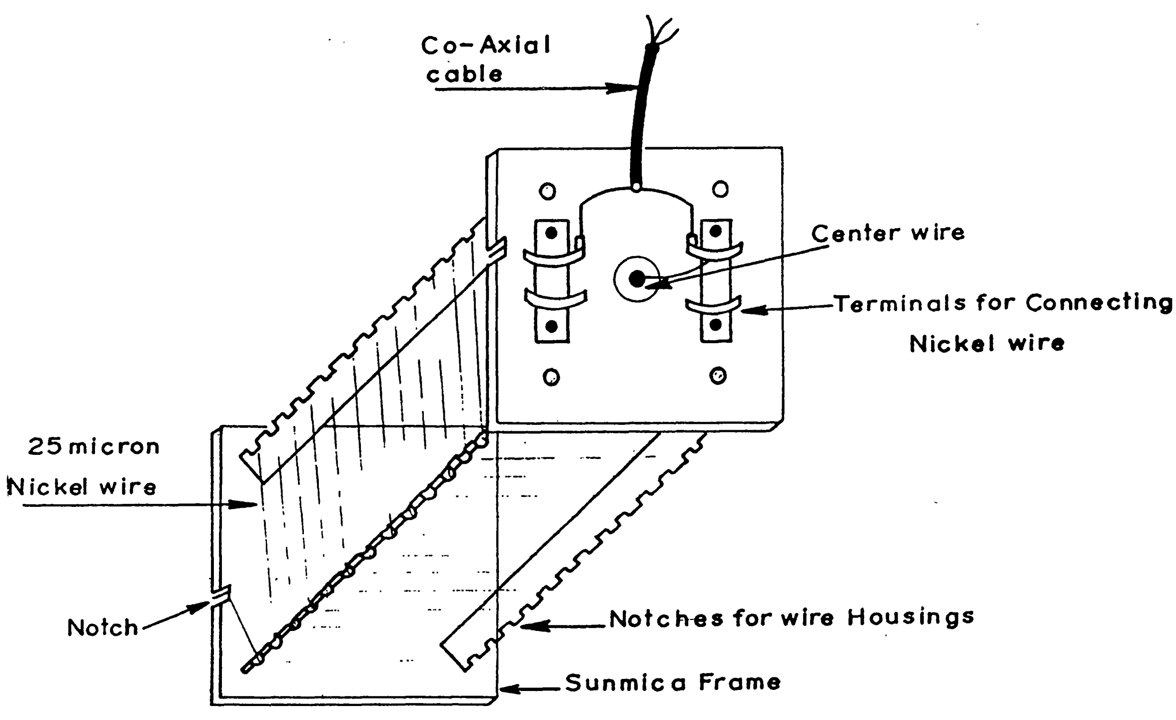

Figure 1. A microthermal sensor of the type used in the microthermal fluctuation measurements. The resistance element is shown as a spiral of 25 micron nickel wire.

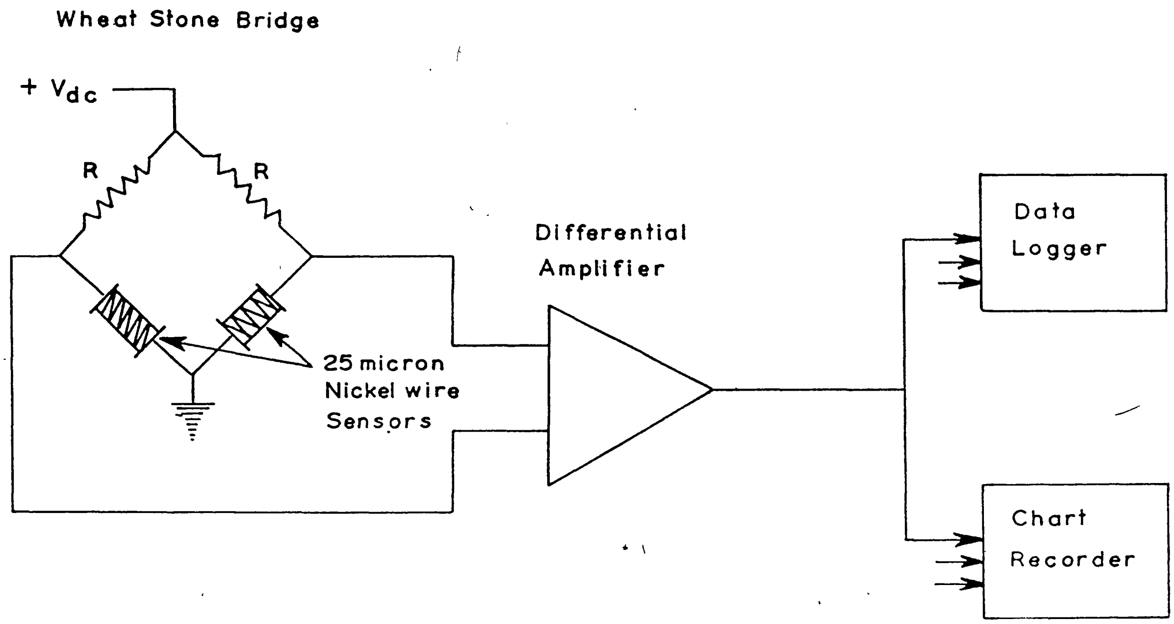

Figure 2. Block diagram of the microthermal fluctuation measurements system.

to very small and rapid temperature fluctuations associated with the atmospheric turbulence, hence the microthermal fluctuations in the turbulent atmosphere will be detected by means of thermal sensors made from Nickel wire of 25 micron in diameter, wrapped in a spiral on a supporting structure of sunmica frame (Dimensions: ~ 35 mm × 35 mm × 70 mm, Fig.1). These sensors are able to detect millidegree centigrade thermal gradients with a bandwidth of about 100 Hz. The temperature resolution of the system is the order of ~ $20 \times 10^{-3}\ °C$. This resolution can be achieved still better by increasing the gain of the amplifier if required.

The pairs of horizontally separated sensors are connected to the electronic circuit by co-axial cables. These two sensors constitute the two arms of a Wheat Stone bridge as shown in Fig.2. A DC current is fed through these sensors. The changes in the resistance of these sensors due to the temperature fluctuations produce a variable voltage signals for a differential amplifier. This out put voltage is proportional to the temperature difference between the two sensors, which are mounted one meter apart on a horizontal plane. Hence, any variations in the temperature encountered by the two sensors are reflected in the output of a very sensitive differential amplifier. Fig.3 shows a sample piece of the chart recording for the microthermal fluctuations measured at Manora Peak,

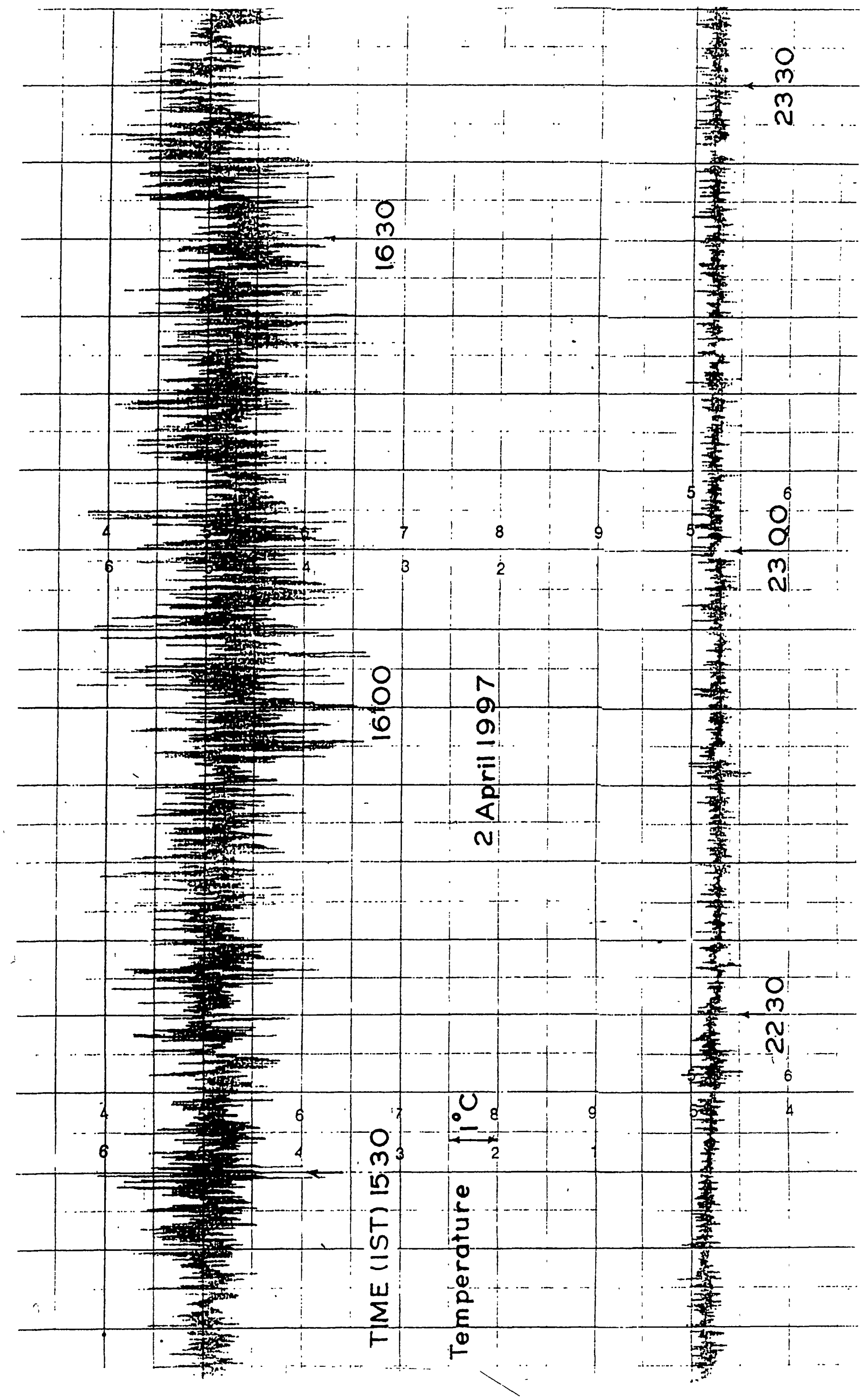

Figure 3. Response of microthermal sensor's pair to the microthermal fluctuations.

Nainital in the first week of April, 1997, which were taken for instrument testing. From these recorded data on 2 April 1997 we have evaluated the average value of C_N^2 at the height of 3 meters by using the relations (1), (2) and (3) as 1.24×10^{-12} m$^{-2/3}$ and 9.28×10^{-14}m$^{-2/3}$ for day and night respectively. Consequently, by using the relation (6) an average value of the optical seeing has been estimated to be as 2.7" and 0.57" for day and night respectively. To digitise the output signals of the differential amplifier, it is proposed to use the PC based data logger system for the recording, so that further analysis of the data could be achieved by using a PC.

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