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Development of Solar Scintillometer

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Abstract. The index of scintillation measurement is a good parameter to compare different sites for image quality or 'seeing'. We have developed a scintillometer, which is deployed on the high resolution SPAR telescope in the island site of Udaipur Solar Observatory, for the site characterization to specify the proposed MAST (Multi Application Solar Telescope).

The scintillometer consists of a miniature telescope, termed as micro telescope (4 mm aperture, 15 mm focal length) mounted on a drive which tracks the Sun continuously, associated amplifiers and a data acquisition system. A photodiode is used as the detector. The telescope along with detector was obtained from National Solar Observatory (NSO), and is similar to the one used for Advanced Technology Solar Telescope (ATST) site survey. At USO we developed the amplifier and data acquisition system for the scintillometer. A 24-bit analog to digital converter based system was designed, assembled, tested and used as the data acquisition system (DAS). In this paper, we discuss the instrumentation and present the initial results.

Key words. Sun: scintillation, scintillometer, seeing.

1. Introduction

Atmospheric turbulence causes refractive index inhomogeneities in the air. Beams passing through the turbulent air are constantly being refracted. The net result of multiple deflections along the ray path results in blurring and scintillation. It is found that scintillation in the solar irradiance is closely related to image quality. Scintillometer measures the intensity variation in the incident beam caused by atmospheric turbulence. By measuring the scintillation it is possible to evaluate seeing for the site (Seykora 1993; Beckers 1998).

2. The scintillometer

The scintillometer which we developed can be basically divided into three parts.

- micro telescope
- signal processing unit and
- a data acquisition system.

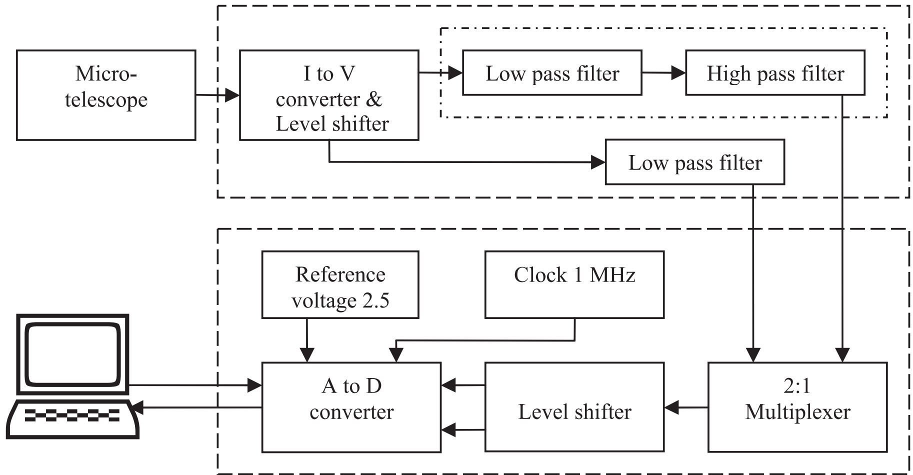

Figure 1. Schematic of scintillometer system.

The micro telescope collects the light from around 28 solar radii, including the Sun and feeds the collimated light into a photo-diode. The intensity of the collimated light consists of two components, a slowly varying (*dc*) component due to the diurnal variation of solar irradiance, and a superimposed rapidly changing (*ac*) component in Sun light intensity due to atmospheric effects, which is termed as scintillation. Since the amplitude of the *ac* component is relatively small, the measurement of scintillation involves extraction and amplification of the *ac* component from the total intensity signal. Two channels in the data acquisition system acquire both these components almost simultaneously with a sampling rate of 30 Hz. Figure 1 shows the schematic of the whole system and the complete circuit diagram is shown in Fig. A1. In the following sections, various components of the scintillometer are described in detail.

2.1 *Micro telescope*

The micro telescope is mounted on a tracking system. It consists of an objective lens of size 5 mm and effective focal length of 15 mm followed by two filters (blue and clear). A 2 mm field stop and a Fabry lens form an image of 4 mm diameter entrance aperture on a Silicon pin photodiode. The wavelength coverage is 220 nm centered around 510 nm. The pin photodiode output is connected to the signal processing unit using shielded cables and BNC connectors.

2.2 *Signal processing unit*

The signal collected by the photodiode is fed to a signal processing unit. This signal processing unit consists of a current-to-voltage converter, filter circuits to separate out *dc* and *ac* components, and amplifiers to boost the signal level. The circuit is based on discrete components which include op-amps (TL082, TL084) and other passive parts. A low-pass filter with a cut-off frequency of 0.3 Hz is used to retrieve the slowly varying *dc* component while a band-pass filter with on and off frequencies of 0.1 Hz and 700 Hz respectively, is employed to separate out the scintillation signal. The output voltage

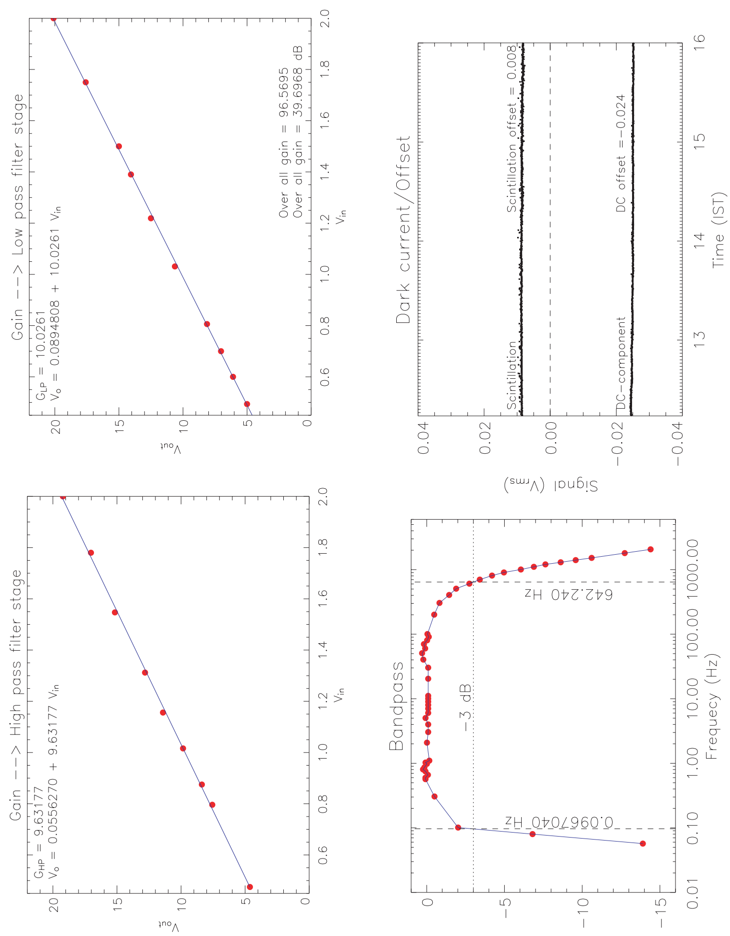

Figure 2. Calibration plots for signal processing unit and A/D converter. **Top:** Gain measurement for low-pass and high-pass filter stages. **Bottom:** (left) Frequency response of the band-pass filter, (right) dark current calibration for A/D converter.

from the *dc* part of the amplifier is adjusted such that, it does not exceed 8 volts during the entire day. The scintillation signal is amplified by a factor of 96 with respect to the *dc* signal, and for typical seeing conditions the value lies between ±2 volts. Figure 2 shows the gain for the *dc* and *ac* amplifier sections and frequency response/band pass of the *ac* section.

2.3 *Data acquisition system*

A 24-bit A/D converter based (Burr-Brown, ADS1252) data acquisition system is developed for digitizing the data. A 2.5 volts reference and auxiliary level shifting circuit makes the A/D converter capable of digitizing input voltages up to ±10 volts which is quite sufficient for our purpose. The A/D converter requires two separate clock signals CLK, SCLK for digitization and readout, respectively. A 1 MHz crystal oscillator circuit provides the CLK pulses, while readout clock pulses are generated by a computer and is applied through its parallel port to the A/D converter. The computer generates all other signals required for the A/D converter and also reads and stores the digitized data. The readout speed is limited to 70 Hz due to the slow response of the parallel port, and in our case it is carried out with a frequency of 30 Hz for each channel. A 2:1 multiplexer alternates the input signals (*dc* and *ac* components) to the A/D converter.

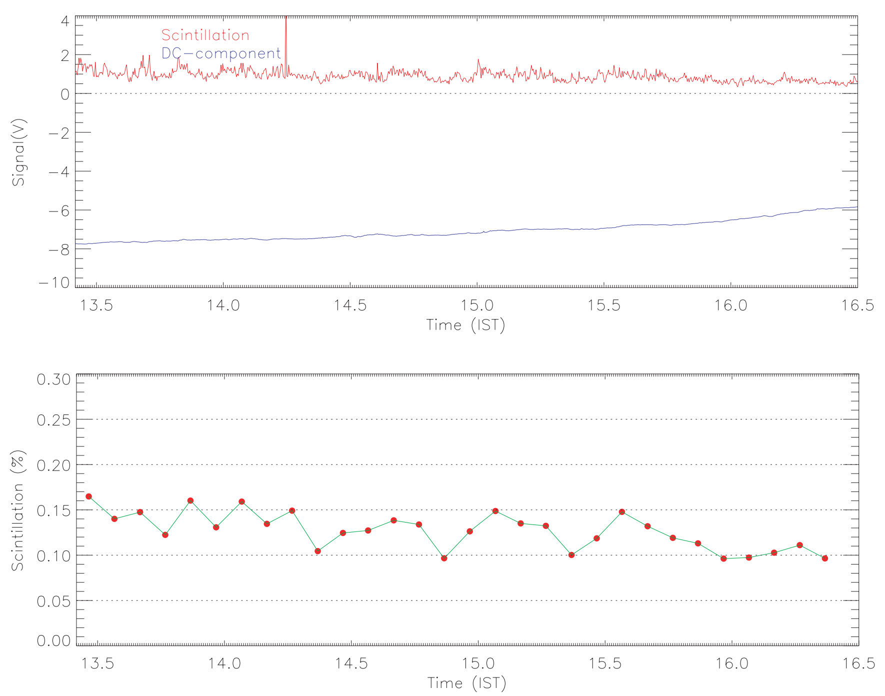

Figure 3. Scintillation recorded on March 31, 2005. **Top:** *rms* scintillation integrated over 10 seconds and the average *dc* component. **Bottom:** percentage scintillation averaged over 6 minutes.

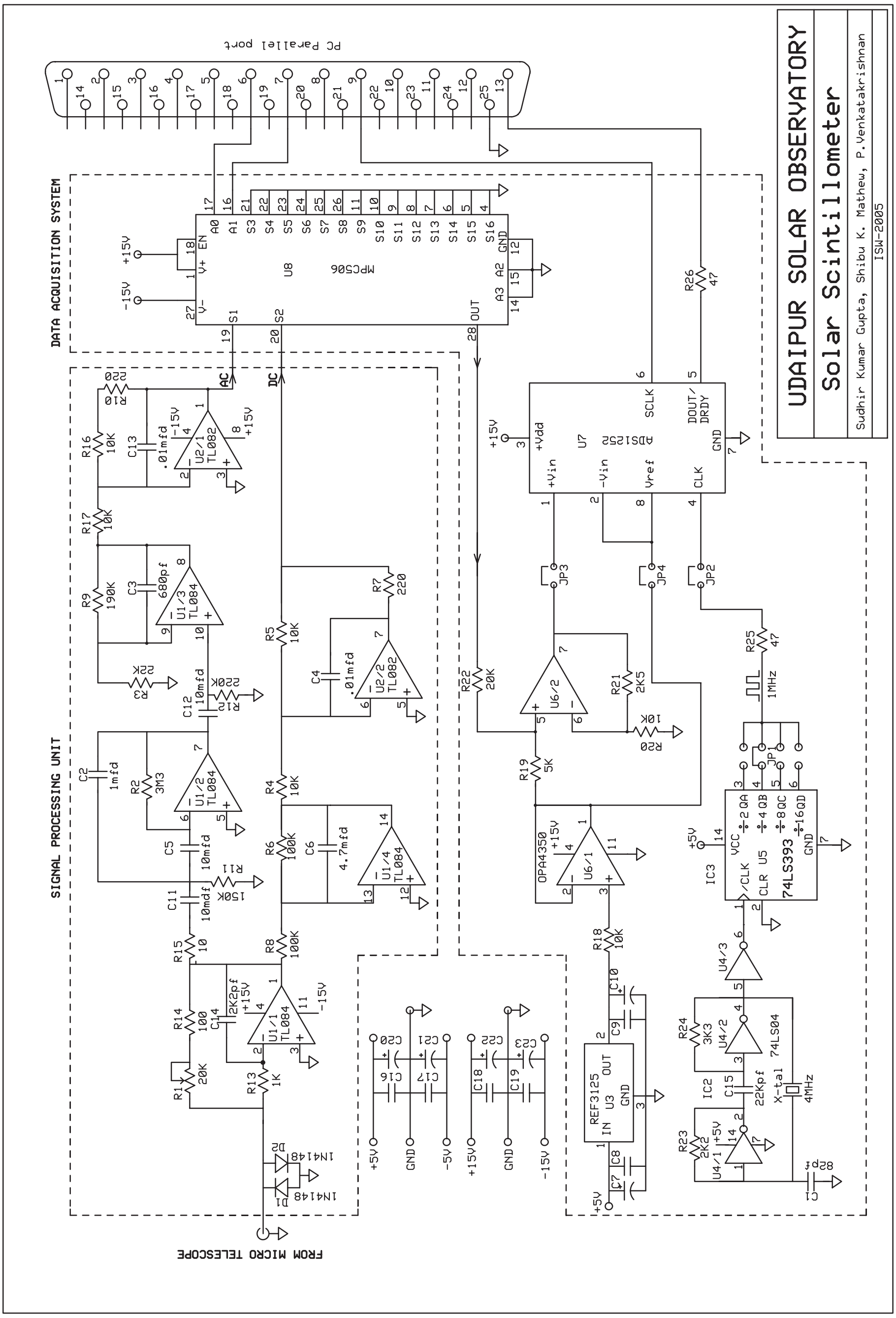

Figure A1. Scintillometer circuit including the signal processing unit and data acquisition system.

Programs are developed in C++ and IDL for operating the data acquisition system from the computer. The C++ program produces all required clock pulses and carries out the digitized data readout. A Graphical User Interface (GUI) is developed in IDL which collects all user inputs such as readout frequency, integration time, etc. and passes on these parameters to the C++ program. The free parameters which can be adjusted are, the start and end time for data recording, channel selection, readout frequency and integration time. The GUI creates a data file for each integration segment and also calculates and stores the rms value of scintillation for the entire observing period.

3. Preliminary results

Figure 3 shows the preliminary result of scintillation measurements. These measurements were carried out on March 31, 2005 from 13:30 to 16:30 IST. The top panel shows *rms* scintillation integrated for 10 seconds and the *dc* component. In the bottom panel we display the percentage scintillation averaged over 6 minutes for the same time period. The percentage scintillation is computed by taking the ratio of *ac* and *dc* components after normalizing the *ac* component with the amplification factor. Percentage scintillation is the parameter which is normally used for inferring the r_0 values. In order to carry out the calibration of percentage scintillation we are in the process of obtaining simultaneous measurements for r_0 using high resolution H_α observations (Goode *et al.* 2000; Sridharan *et al.* 2004). r_0 values can be obtained by *spectral ratio* technique from a series of short exposure H_α observations. We did an initial comparison of our results with already existing calibration plots found in the literature (Beckers 2001). According to these plots corresponding values of r_0 plotted in Fig. 3 ranges from 2.5 to 4.4 for percentage scintillation of 0.165 to 0.095, respectively.

Our future plans include continuous scintillation measurements of MAST site, cross calibration of percentage scintillation with our own r_0 measurements, and deployment of identical calibrated scintillometer in other sites.

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References

Beckers, J. M. 1998, *ASP Conf. Series*, **155**, 255.
Beckers, J. M. 2001, *Exp. Astronomy*, **12**, 1.
Goode, P. R., Wang, H., Marquette, W. H., Denker, C. 2000, *Solar Phys.*, **195**, 421.
Seykora, E. J. 1993, *Solar Phys.*, **145**, 389.
Sridharan, R., Dashora, N., Venkatakrishnan, P. 2004, *Solar Phys.*, **222**, 35.