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A new automatic star tracker for balloon-borne astronomy instruments

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Abstract. The tracking of an astronomical object requires continuous updating of the look angles in azimuth and zenith. The mathematical calculation of these angles needs the position coordinates (latitude and longitude) of the place of observation as the input variables, apart from the celestial co-ordinates of the object. In the case of a balloon-borne platform, the position co-ordinates vary due to float winds both in latitude and longitudinal direction. An accurate pointing thus requires correction of the input position variables continuosuly. We have developed a new microprocessor controlled stand-alone star tracker with a built-in GPS receiver for use in the X-ray astronomy experiments using balloons. GPS receiver provides a highly accurate (~ *arcsec*) instant longitude and latitude of the balloon platform on continuous basis. Present hardware design is restricted to 12-bit resolution (~5′~). This paper presents some of the technical details of the new system.

1. Introduction

The target acquisition and tracking during astronomical observations is done by computing the Azimuth and Zenith co-ordinates of the object and updating these values on a continuous basis. For a narrow beam telescope, the inaccuracy in the target acquisition can lead to appreciable systematic errors due to off-axis shadow effect. The look angles θ and A at a given time and for a given platform position are calculated by using the coordinate transformations; $\cos\theta = \sin\phi \sin\delta + \cos\phi \cos\delta \cos t$, $\sin\theta \cos A = \cos\phi \cos\delta - \sin\phi \cos\delta \cos t$ and $\sin\theta \sin A = \cos\delta \cos t$. Where t, is the hour angle given by $t = V_0 - \alpha$, V_0, the sidereal time corresponding to the local observation time at the given longitude L and latitude ϕ, α and δ are the right ascension and declination of the source.

The real time source tracking for space borne instruments, can only be achieved by either uploading the new coordinates continuously by ground command, or computing the changed coordinates by an on-board system or by using pre-loaded look up tables for a given target. The on-board computation method requires the instantaneous values of variable parameters i.e. local time, latitude and longitude. The latitude and longitude are fixed parameters for a ground based telescope. For an orbiting platform, the latitude and longitude can be obtained by solving the equation of orbital motion. However, in the case of a balloon-borne platform the latitude and the longitude vary randomly both in the north-south and the east-west directions due to drift of the balloon caused by the ambient wind vector at the ceiling altitude. The accurate attitude control therefore, requires the instantaneous latitude and longitude of the platform either in-situ or loading the values into the on-board star tracker by ground command.

2. System description

The New star tracker is seen in figure 1. The system consists of a 8085 Microprocessor based computation unit with a stored algorithm and data (Source Directory and Observational plan). The time and calendar information is derived from an on-board clock. A GPS receiver (G 4250) is used to get instantaneous position (latitude and longitude) of the balloon payload and is linked to the central computing unit via 8032 micro-controller based hand-shake module. The processor computes the new cordinates and generates the error signal for achieving the new position. The error signal activates the motor drive circuits for azimuth and zenith control motors and drives in the required direction (clockwise or counter-clockwise). A command interface is available to override the automatic operation and provide the ground control. The computed parameters are also transmitted on telemetry channel from a ground check and in-flight control of different parameters.

A single PCB contains the central processor, real-time clock, communication ports with tri-state buffers, programmable memory modules for storing the mathematical code and the target directory and observation plan and scratch memory. A 2000 instructions mathematical code, is written in assembly language to implement the flow-chart routines and is stored in a 8k EPROM. The GPS unit is commercially obtained PCB, which receives the civilian access signal at L1 band from 2 or 3 satellites from the constellation of 24 satellites making up the Global Positioning System. Phase modulated data in Gold code (pseudorandom binary code) is processed using a Kalman filter and position of receiver is computed with respect to the reference satellites. The intrinsic position error is typically 15-30 meters. However due to 'SA error' (dithering of signal for selective availability), a 2-D fix gives a position error of 100 meters. Which translates to an accuracy of *fewarcsec* in the latitude and longitude of the balloon position.

3. Salient features of the automatic star tracker

1. A Real Time Clock Chip DS 12287 is used. The chip has a built in back-up power supply to retain the data for 10 years, except for crystal no external components are required. Apart from the real time (IST), the chip also provides the date and the month calendar.

2. A built-in command interface to allow changes to all the stored parameters, including adjustments to the real-time clock, during the baloon flight.

3. Capacity to store precessed co-ordinates for a large number of target sources for easy selection during the flight.

4. With a 12 bit shaft encoders used in the present system, the angular resolution is ~ 0.09°, both in azimuth and zenith.

5. A de-mountable alphanumeric LCD display is provided in the unit for displaying all parameters like time, date, calculated co-ordinates, command status and the target being tracked. It is vital for carrying out ground checks and field adjustments.

6. A single chip motor driver (L298) for the elevation and azimuth motors is included in the unit. It is digitally compatible chip and does not require any additional logic circuit. This reduces the component count and thereby the servicing and maintenance.

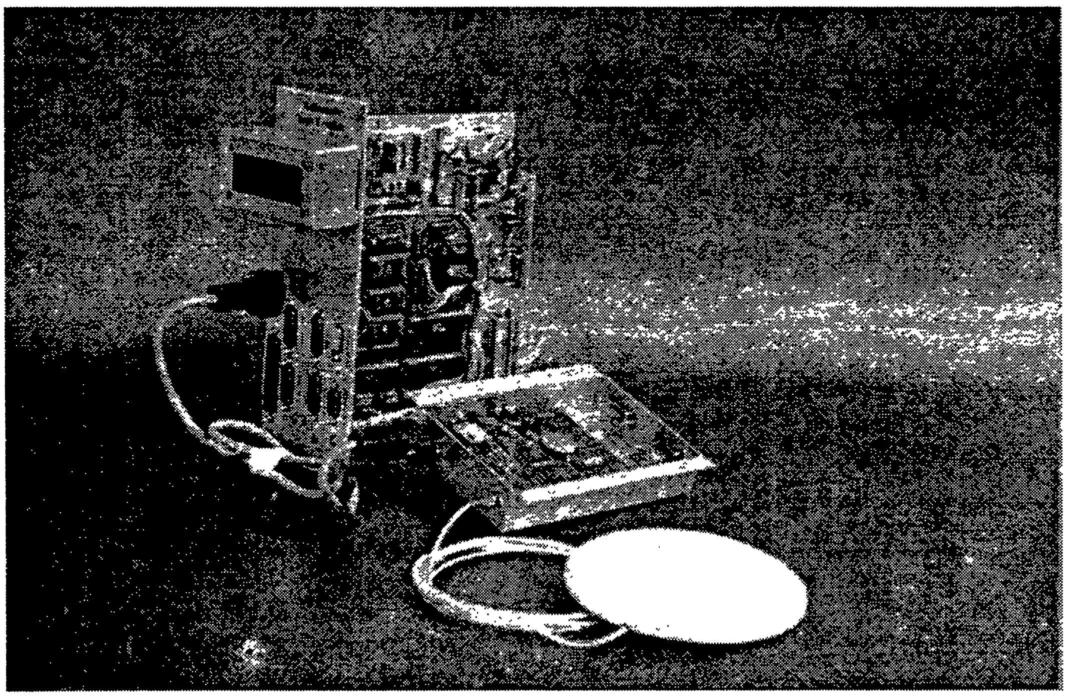

Figure 1. A photograph of the entire unit

For fail-safe operation of the star tracker we have added few additional features; (i) The μP based circuits have tendency to hang-up when faced with situation of say infinite do-loop or transient pick-up. Such condition can only be corrected by giving a power reset. A supervisory circuit known as watchdog circuit (WDC) is built into the system to minotor the functioning of the microprocessor. In case of abnormal hang-up of the microprocessor, WDC forces a power reset to the μP after a waiting period of 1.5 sec.

(ii) As a further redundancy to the above, a Master Reset to the μP is also provided through the ground link.

(iii) In case of failure in the GPS segment (corrupted data or no lock) the Star Tracker by-passes the data from the GPS and carries out computations using the fixed position coordinates stored in the on-board memory along with the flight plan data. These values can however, be changed via ground command.

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