POSITION CONTROL SYSTEM FOR THE NOTTE EXPERIMENT

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Abstract

During the total solar Eclipse in august 1999 in Romania, the NOTTE experiment, concerning the elementary particles physics was developed. It was an airborne experiment, to increase the duration of the measurement. An active control system was used to direct the measurement system to the Eclipse and to ensure the proper insulation against the angular perturbations induced by the flying aircraft. The measurement system and a digital TV camera are mounted on a large mass mobile platform with two angular degrees of freedom, driven by DC torque servomotors. Due to its large inertia, the platform's angular movements are very slow, giving to a computer the necessary time (0.16 s) to analyze the image from the TV camera and to find the angular position errors. These errors are used by a control algorithm that gives commands to the torque motors in order to correct the position of the platform. The admissible angular position errors are no larger than ±10 angular minutes.

1 INTRODUCTION

During the total Solar Eclipse in August 1999 in Romania, "Elie Carafoli" National Institute for Aerospace Research and ISS, both from Romania and Universita degli Studi di Bologna, Italy, carried out an experiment concerning the study of the solar neutrinos. The technical difficulties of the NOTTE Experiment (Neutrino Oscillations with Telescope during the Total Eclipse) came from the fact that the measurement system was mounted on a supersonic aircraft that pursued the Eclipse Shadow, to increase the duration of the experiment. The main problem was to direct the measuring device towards the Eclipse and to maintain its orientation with very low errors (less than ±10 angular minutes), despite the fact that the flying aircraft vibrates and executes small corrections of the trajectory. To fulfil this task, an active position control system was used.

2 DESCRIPTION OF THE POSITION CONTROL SYSTEM

Problem Setting

The main problem of this position control system was to get the position information. The two needed angular coordinates of the center of the eclipse are available by analyzing the image of the eclipse, given by a digital TV camera. Due to the large image processing time, a set of coordinates could be available only at every 0.16 s (a Pentium II/333 MHz was used). It is obvious that a control system, which uses only that information, would be very slow and unable to ensure the requested positioning precision. Therefor, it was necessary to use a supplementary stabilization method.

The adopted solution was to use a large mass mobile platform with a good static and dynamic equilibration sustained by a very low friction cardanic articulation. This solution offers a good mechanical insulation of the mobile platform on those two rotation axes. The mechanical system was mounted on the plane so that the direction versus the Eclipse would be approximately rectangular to the two axes of the cardanic articulation. This fact was possible because of the straight flight and the almost constant position of the Eclipse during the approximately 6 minutes of the experiment. The angular perturbations induced by the flying aircraft on this axis results only in the rotation of the image, which does not decrease the pointing precision. The perturbations on the rest of 3 degrees of freedom (3 translations) have no significant effect on the pointing precision, because of the very large distance to the Moon. However, due to the (low) friction torque of the bearings the orientation of the mobile platform is slowly modified, which results in angular position errors. To maintain these errors at an acceptable level, it is necessary to use a position control system, which, in these conditions, is able to ensure the requested precision.

2.2 The Position Control System

The position control system was called "Controlled Positioning Mobile Platform" (CPMP).

The angular position of the mobile platform MP is controlled on two rectangular axes, both approximately rectangular to the direction versus the Eclipse.

The scheme of the CPMP is presented in fig.1. The two angular coordinates of the center of the eclipse are available by analyzing the image of the eclipse, given by a digital TV camera. Based on this information, the algorithm implemented in the computer C gives commands to the DC torque servomotors M1 and M2 through the interface TMI, in order to correct the position errors.

The first pointing to the Eclipse is made by bringing the platform to a relative to the plane pre-determined position, with an initial positioning system IPS, driven by the computer through an interface.

The measuring system consists in a photon detector FD, mounted on the mobile platform and a data recorder DR (a second computer). The measuring system is independent to the position control system.

The power supply is ensured by a power source PS separate from the aircraft (batteries and a 12 V DC / 220 V AC inverter).

2.3. The electro-mechanical part of the system

The mobile platform is sustained by two DC torque servomotors. The axis of a motor is rectangular to the axis of the other motor. To reduce the friction torque, no gears are used. However, the torque developed by the motors directly to their axes is large enough to fulfil the demands of the control process.
The static equilibration was made by adjusting the position of a few counterweights attached to the platform and to the body of one of the motors. The static equilibration eliminates the effects of the linear accelerations (gravitational acceleration and the variable linear accelerations of the aircraft on 3 directions).
The angular movements of the plane on the direction which is rectangular to the axes of the motors gives effects such as torques as a result of the centrifugal forces and a dynamic coupling of the movements of the platform on its two axes. Both these effects were eliminated or strongly reduced by experimentally adjusting the position of some other counterweights. The operation was somehow similar to a dynamic equilibration.

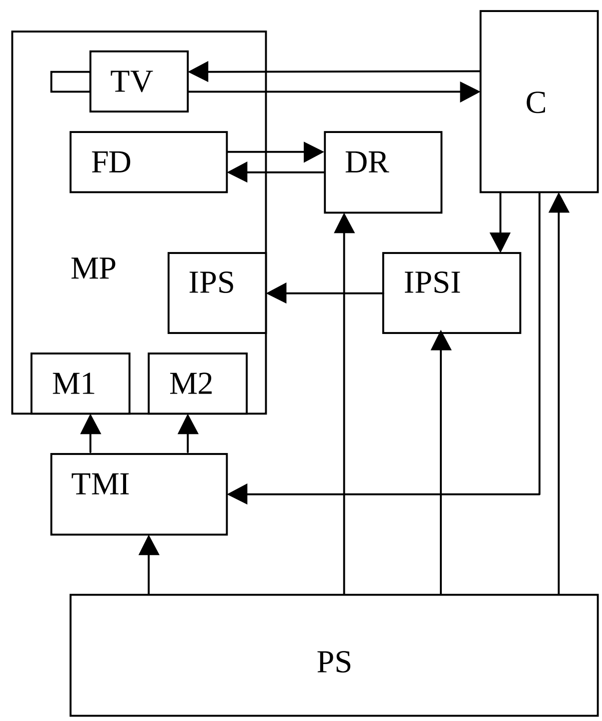

Fig. 1. The control system used in the NOTTE Experiment

The initial positioning system is simply electro-magnetical, with no control involved. Its task is to bring the platform to a pre-determined position (the position of the eclipse relative to the flying aircraft). The initial positioning system is used until the Eclipse image enters the TV camera field, than it is automatically disconnected. After that, the computer analyzes the image and gives commands to the torque motors in order to bring the Eclipse to the center of the TV camera field and maintain it there.
The optical axes of the photon detector and of the TV camera are set to be parallel, which ensures the pointing of the photon detector to the center of the Eclipse during the experiment.

3. THE NOTTE EXPERIMENT

The experimental model of the CPMP was built by ECNIAR and ISS from Romania (the position control system) and Universita di Bologna, Italy (the measuring system).
For the lab tests, an experimental device was especially conceived, which could simulate the angular perturbations, induced by the flying aircraft on two axes. After the successful passing of the lab tests (the obtained precision was approx. ± 7 angular minutes), all the parts of the CPMP were mounted on a MIG 29 chair, fig. 2.

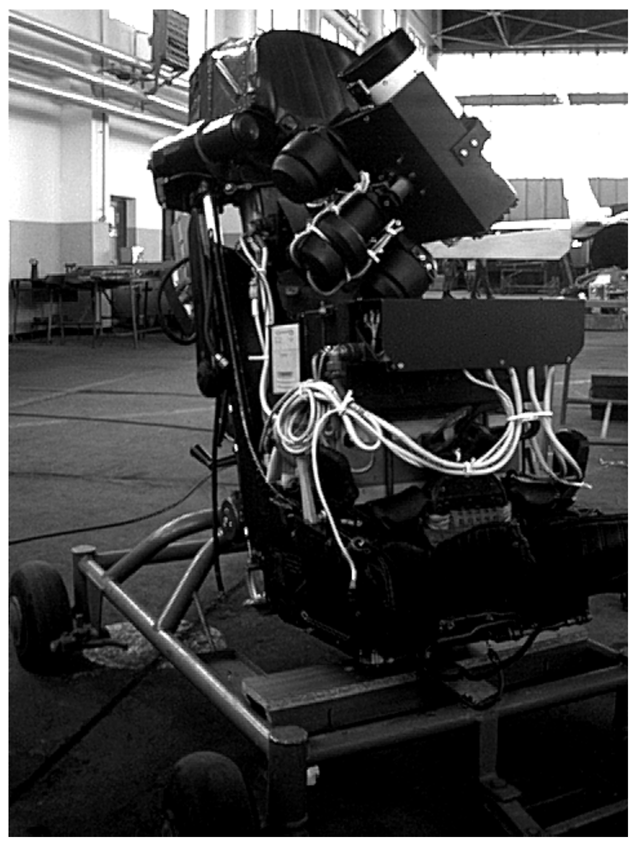

Fig. 2. The CPMP mounted on a MIG 29 chair

The chair equipped with the CPMP was mounted in the second cabin of a double command MIG 29.
After the ground tests, which proved that the system functioned well and did not electro-magnetically interfered with the systems of the plane, came the flight

tests. There were 11 flights, during which the performances of the CPMP were analyzed and improved. During the tests, both the TV camera and the photon detector were covered with optical filters, to prevent their deterioration when pointing them directly to the Sun.

4. CONCLUSIONS

The day before the total solar eclipse, a final test was made, simulating all the phases of the experiment. The CPMP functioned well.

Finally, the experiment during the total solar eclipse failed due to the extremely bad weather conditions, which made the taking off of the plane impossible.

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