Satellite Attitude Determination and Control

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Abstract

This Keynote paper describes a few key developments in satellite attitude determination and control that have occurred over the last 25 years. The topics are derived from the author's experiences in the design and implementation of attitude determination and control concepts for a number of actual satellite missions. This includes Geostationary Transfer Orbit (GTO) operations as performed on ESA's METEOSAT first-generation weather satellites (launched from 1978) and the ECS / MARECS communications satellites launched during the 1980's. All of these satellites made use of a spinning attitude stabilization mode, at least during their GTO phases. While this mode was also used by ESA's HIPPARCOS astrometry mission (launched in 1989) during its early GTO phase, the major design challenge came from its required three-axis attitude determination capabilities. In order to be able to perform its complex autonomous star observation strategy, with the satellite slowly scanning at about 1 revolution per 2 hr, the on-board computer needed real-time attitude knowledge at 1-arcsec (rms) accuracy level. This requirement was achieved by using gyros plus a unique star mapper configuration within the focal plane of the telescope together with stringent autonomous payload thermal control.

The well known and still widely used book on attitude determination and control by Wertz (Editor) presents a comprehensive overview on the state of the art at the time it was issued in 1978. During the last 25 years, however, satellite capabilities have evolved enormously in almost all respects. In particular, on-board computing power has expanded tremendously and powerful sensors can now be procured at a much lower cost than the less capable devices of some 25 years ago. For example, a star mapper that is capable of autonomously determining a satellite's attitude from any arbitrary 'lost in space' orientation within just a few seconds costs now about 100,000 $. Furthermore, during the last decade, the appearance of small low-cost satellites has lead to many new and unforeseen concepts. For instance, a low-cost concept for sensing as well as controlling a satellite's attitude is provided by utilizing the Earth's magnetic field by means of a magnetometer and magnetorquer, respectively.

The paper focuses on the issues mentioned above and addresses in particular:

- fast efficient methods for three-axis attitude determination (e.g., q-method and QUEST)
- arcsec-level on-board real-time attitude determination using Kalman filtering (HIPPARCOS)
- prediction of variation in spin axis attitude determination accuracy in GTO orbit (GIOTTO)
- accurate spin axis attitude determination including the reconstruction of biases (CONTOUR)
- accurate large spin axis attitude maneuvers using rhumb-lines and calibration techniques
- low-cost attitude determination and control by means of the Earth's magnetic field