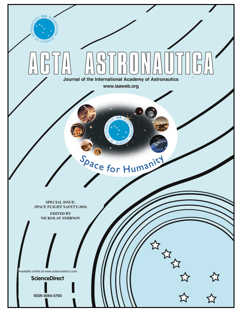
Accepted Manuscript



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PII: S0094-5765(17)30371-5

DOI: 10.1016/j.actaastro.2017.05.038

Reference: AA 6333

To appear in: *Acta Astronautica*

Received Date: 8 March 2017

Revised Date: 25 April 2017

Accepted Date: 29 May 2017

Please cite this article as: K. Zhou, X. Sun, H. Huang, X. Wang, G. Ren, Satellite single-axis attitude determination based on Automatic Dependent Surveillance - Broadcast signals, *Acta Astronautica* (2017), doi: 10.1016/j.actaastro.2017.05.038.

Satellite Single-Axis Attitude Determination Based on Automatic Dependent Surveillance - Broadcast Signals

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Abstract

The space-based Automatic Dependent Surveillance - Broadcast (ADS-B) is a new technology for air traffic management. The satellite equipped with spaceborne ADS-B system receives the broadcast signals from aircraft and transfers the message to ground stations, so as to extend the coverage area of terrestrial-based ADS-B. In this work, a novel satellite single-axis attitude determination solution based on the ADS-B receiving system is proposed. This solution utilizes the signal-to-noise ratio (SNR) measurement of the broadcast signals from aircraft to determine the boresight orientation of the ADS-B receiving antenna fixed on the satellite. The basic principle of this solution is described. The feasibility study of this new attitude determination solution is implemented, including the link budget and the access analysis. On this basis, the nonlinear least squares estimation based on the Levenberg-Marquardt method is applied to estimate the single-axis orientation. A full digital simulation has been carried out to verify the effectiveness and performance of this solution. Finally, the corresponding results are processed and presented minutely.

Keywords: Satellite, Attitude determination, Automatic dependent surveillance - broadcast, Signal-to-noise ratio

1. Introduction

Automatic Dependent Surveillance - Broadcast (ADS-B) is a surveillance technology in which an aircraft locates itself via satellite navigation system and periodically broadcasts the location information, enabling itself to be tracked [1]. ADS-B is primarily a terrestrial-based system which has been deployed as an add-on to radars or as an alternative in regions where a traditional air traffic management system based on radar stations is not cost effective [2]. The ADS-B signals are transmitted as the Mode-S Extended Squitter at low L-band frequencies (1090 MHz) with a typical sampling period of 1 second and a typical power of 125 Watts [3], in which the flight related information such as flight number, position, and velocity are included. This technology enhances the flight safety by making an aircraft visible to the air traffic control center and to other aircraft in real time. However, the terrestrial-based ADS-B system is not accessible for remote, polar, and oceanic areas, which account for roughly 71% of the Earth's surface. In order to cover this gap, a significant step forward is to transfer the broadcast message by the satellite in orbit, named space-based ADS-B.

As shown in Fig. 1, space-based ADS-B is an innovative technology that will provide significant benefits to commercial airlines by making use of satellites to perform a global coverage. Considering the link budget, it makes more sense to implement this technology on low Earth orbit (LEO) satellites. As a precursor to this technology, the team from International Space University accomplished an space-based ADS-B experiment by launching a scientific balloon to track the aircraft signals in 2010 [4]. At about the same time, the GomSpace team conducted a thorough research on the service quality of this technology [5]. GomX-1 is the first demonstration of space-based ADS-B by using a nanosatellite [6], and the followed GomX-3 achieved a more complete verification of this technology [7]. Another space-based ADS-B demonstration was conducted in the PROBA-V mission of ESA to validate the principle of detecting weak Mode-S signals from low Earth orbit [8]. To go a step further, the space-based ADS-B is being deployed as hosted payloads on Iridium NEXT, which is a constellation of 66 cross-linked LEO satellites [9]. The first 10 Iridium NEXT satellites have been launched into orbit by SpaceX at January 14, 2017. In the predictable future, more and more satellites will be launched into orbit carrying out space-based ADS-B technology.

In the light of this fact, it's attractive to explore additional applications of space-based ADS-B. One of the potential applications is satellite attitude determination utilizing the signal-to-noise ratio (SNR) measurement of the ADS-B signals. This idea derives from the experience of using GPS signals for attitude determination. Besides the solution utilizing the carrier-phase measurement of the GPS signals, the attitude determination solution utilizing the SNR measurement of the GPS signals has also been well studied [10–12].

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