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Aircraft monitoring by the fusion of satellite and ground ADS-B data

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ABSTRACT

The Automatic Dependent Surveillance- Broadcast (ADS-B) system is today a standard equipment on civil aircraft, transmitting periodically data packages containing information of key data such as aircraft ID, position, altitude and intention. It is designed for terrestrial based ground station to monitor air traffic flow in certain regions. Space based ADS-B is the idea to place sensitive receivers on board satellites in orbit, which can receive ADS-B packages and relay them the relevant ground stations. The terrestrial ADS-B receiver has been widely applied for airport information system, help monitor and control traffic flow, etc. However, its coverage is strongly limited by sea or mountain conditions. This paper first introduces the CubeSat mission, then discusses the integrated application of ADS-B data received from ground stations and from satellites, analyze their characteristics with statistical results of comparison, and explore the technologies to fuse these two different data resources for an integrated application. The satellite data is based on a Chinese CubeSat, STU-2C, being launched into space on Sept 25th 2015. The ADS-B data received from two different resources have shown a good complementary each other, such as to increase the coverage of space for air traffic, and to monitor the whole space in a better and complete way.

1. Introduction

Automatic dependent surveillance-broadcast, ADS-B, is a new generation of surveillance technique that allows aircraft to broadcast their own information such as position, velocity, flight number and other flight information via specific equipment. The equipment will become mandatory for civil aircraft from 2020. However, in these years a dedicated interest has arisen for aircraft monitoring from space to derive surveillance of traffic around the globe. The system is not originally designed for space-based receiving, which will raise big challenges for space usage, such as low signal levels, packet overlapping and delays, and large signal Doppler shifts. Several teams have launched satellites with ADS-B receiver, like Proba-V [1] from ESA and GOMX-1 from GOMSpace [2,3].

On 25thSept, 2015, SECM launched three CubeSats, called STU-2A (TW-1A), STU-2B (TW-1B) and STU-2C(TW-1C) respectively, for new-tech demonstration [4–6]. In this mission, A SDR ADS-B receiver is carried on on-board STU-2C intending to obtain in-orbit data for analysis and to explore further applications.

In this paper the implementation and integration of an ADS-B payload on-board STU-2C will be introduced and some experiment results in space will be compared with the ground ADS-B data. The system overview is introduced in Section 2. Section 3 discusses the implementation of integrating the ADS-B receiver into STU-2C CubeSat. Section 4 presents the in-orbit results of the ADS-B receiver on-board STU-2C. Section 5 elaborates the comparison and fusion analysis results of in-orbit data with ground ADS-B data. A summary is presented in Section 6.

2. System overview

A limiting factor for the a satellite based experiment is the wide line of sight range to any aircraft flying below the satellite. A radio link between ADS-B transmitter onboard an aircraft and the ADS-B receiver onboard the satellite should be considered and analyzed at the very beginning. Related calculations and assumptions are listed in Table 1 below.

The link budget is calculated based on the assumption that we have a receiver with higher sensitivity than the ground device. And the supposed maximum range is figured out to be quite sufficient for this mission with an orbit height of 481 km.

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Acronyms/Abbreviations

ADS-B	Automatic Dependent Surveillance-Broadcast
ASK	Amplitude Shift Keying
ATC	Air Traffic Control
BPPM	Binary Pulse Position Modulation
FOV	Field Of View
FPGA	Field-Programmable Gate Array
LOS	Line Of Sight
MCU	Micro-Controller Unit
RF	Radio Frequency
RHCP	Right-Handed Circular Polarization
SECM	Shanghai Engineering Center for Microsatellites
SDR	Software Defined Radio
TLE	Two Line Element

Table 1
Link budget for space-based ADS-B.

Parameter	Value	unit
TX power	24/250	dBW/W
TX antenna gain	1	dBi
Line Loss	2	dB
TX Bit rate	1.04	Mb/s
EIRP	23	dBW
Atmospheric gasses loss	2.5	dB
Polarization loss	6	dB
RX antenna gain	5	dBi
RX sensitivity	−103	dBm
Max Range	925	km

3. Implementation

3.1. ADS-B receiver and helical antenna

An SDR receiver with a helical antenna which can meet above system requirement is used for the mission. The diagram of the receiver is shown in Fig. 1. The signal from RF ends is fed into the FPGA to be decoded into ADS-B messages. And the decoded ADS-B messages are forwarded to the MCU, which is responsible for the plane position calculations and results storage.

A helical antenna which can be stowed to fit on the end of a standard CubeSat structure is used for space receiving, as illustrated in Fig. 2. Test in an antenna anechoic chamber shows that the RHCP antenna can obtain a peak gain of 8.8 dBi and a 3 dB beam width (half angle) of around 22° (shown in Fig. 3). The high directivity which can deliver high gain in a very tight envelope also pose a requirement for the attitude control system. In STU-2C, a pointing precision of 10° (3σ) with a stable of 0.5°/s is specified to ensure the success of the mission.

Fig. 2. Antenna for ADS-B (upper: stowed; lower: deployed).

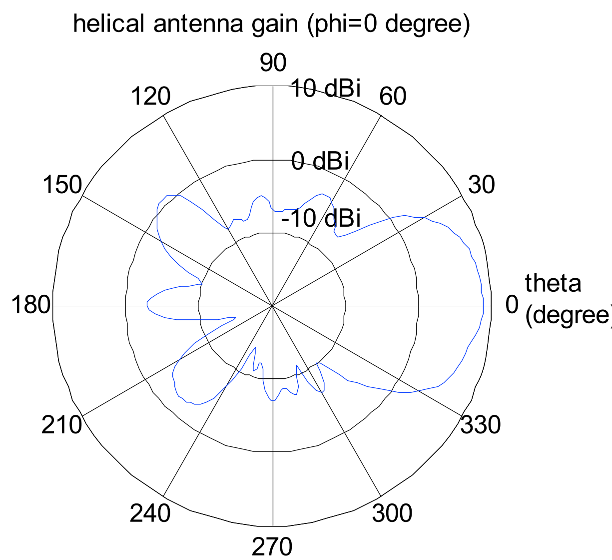

Fig. 3. Helical antenna gain (@ phi = 0°, f = 1090 MHz).

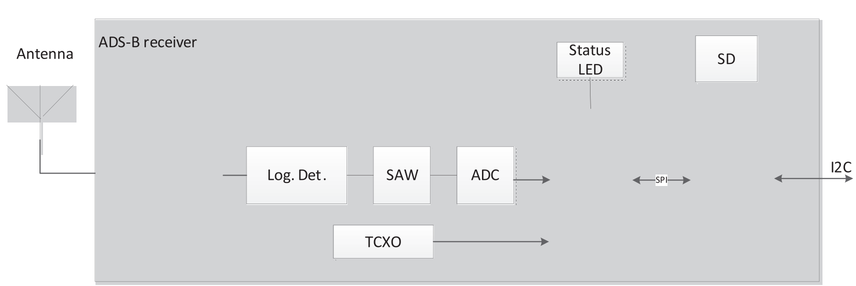

Fig. 1. Diagram of ADS-B receiver.