Thermal Validation Testing of an Automatic Identification System (AIS) Receiver for Low Earth Orbit (LEO) CubeSat

Emir Husni, Nazmi Febrian
School of Electrical Engineering and Informatics, Institut Teknologi Bandung, Bandung 40132, Indonesia

Corresponding author’s e-mail address: ehusni@lskk.ee.itb.ac.id

Abstract. The advancements in electronics technology make nanosatellite missions more varied. One of its missions is to retrieve Automatic Identification System (AIS) data from vessels on the ground. The type of nanosatellite made in this study is a CubeSat with a size of 1.5U. The AIS receiver is created using RFIC Si4362 and MSP430G2553 Microcontrollers to control the device. The main mission of AIS Receivers is to receive and decode AIS signals at the frequency of 161.975 MHz and 162.025 MHz into the AIVDM NMEA0183 standard format. The decoded AIS data is sent to a Raspberry Pi Compute Module as On-Board Data Handling (OBDH) CubeSat before it is sent to the ground station. All of the CubeSat’s subsystems must be able to pass thermal testing before being launched into orbit. Thermal testing is performed to observe the performance of subsystems in extreme conditions similar to CubeSat conditions in space. Thermal testing is carried out at the Satellite Technology Center (Pusteksat) of the National Aeronautics and Space Agency (LAPAN) facility. The thermal test is done by running the device at temperatures of -20°C - 60°C for 3 hours and 56 minutes. The thermal testing indicates that the AIS Receiver can work in the orbital temperature range. After testing, the data reception success rate is 36.76% with a minimum RSSI value of -96dBm.

1. Introduction
An AIS Receiver is a device that is designed to receive AIS signals from vessels and decode the signals into the AIS AIVDM data format. AIS Receivers achieve better reception results located at 650km altitude. Many satellites in various sizes have been launched with an AIS receiver as their payload [1].

CubeSat was chosen because it is one of the satellite platforms developed at lower cost and shorter development time than other large satellites. Various universities worldwide and in ASEAN, in particular, have developed CubeSat for a variety of useful missions [2].

CubeSat has several subsystems such as an Electrical Power System (EPS); Communications (COM); an Attitude Determination and Control System (ADCS); Sensors and GPS; On-Board Data Handling (OBDH); and payload [3]. This study focuses on the development of a space-based AIS receiver as the CubeSat payload.

The main challenge in designing a CubeSat is the use of COTS components that can work in satellite orbit conditions [4]. In order to be classified as a space-based AIS receiver, it is required to pass some environmental tests of the robustness of the device in conditions approaching the satellite conditions when orbiting in space.
Common environmental tests are vibration tests, vacuum tests, thermal tests, electromagnetic interference/compatibility (EMI/EMC) tests, total ionizing dose (TID) tests, etc. [5]. This paper focuses only on the test results of the thermal test.

2. AIS receiver design and implementation

In 2016, an AIS receiver has been designed using RFIC Si4362 from Silicon Labs. The AIS receiver prototype was built from COTS components. The components of the AIS receiver prototype are not thermal and vacuum qualified because the receiver was merely built to verify its functional specifications. The functional test is completed by running the device at Tanjung Priok, North Jakarta [6]. The functional test shows that the AIS receiver can receive AIS signals from vessels.

To complete the thermal test, the components of the AIS receiver prototype must be replaced by industrial-grade components that have working temperatures between -40°C and 85°C. Electrolytic capacitors need to be removed and replaced by ceramic capacitors. Every through-hole component, except the SMA socket antenna, was replaced by Surface Mount Device (SMD) components. Figure 1 shows the AIS receiver for thermal testing in this paper.

![Figure 1. AIS receiver](image)

AIS receivers require a microcontroller to function. MSP430G2552 is selected as the microcontroller and it communicates using I2C protocol. MSP430G2552 is set in a low power state if no data is received by the AIS receiver. The process of receiving and translating data into the AIVDM format is done during the interrupt process by the AIS receiver.

The AIVDM formatted AIS data translated by MSP430G2552 is delivered to CubeSat OBDH, a Raspberry Pi Compute Module (RPI CM) with working capability at -40°C - 85°C. MSP430G2552 is connected to RPI-CM via a USB connection to send AIS RAW data. RPI CM stores AIS data on a file in the internal memory to be further accessible via a Linux-based Raspbian OS.

3. Thermal testing design and implementation AIS

Thermal testing for satellite components must be completed in order to meet the space requirements. Orbit temperatures can reach -40°C at minimum and +85°C at maximum temperatures. For the thermal testing of this AIS receiver, the temperature was set at -20°C until 60°C for one cycle.

The AIS receiver was placed in the thermal chamber with only the antenna cable extending out of the chamber. The antenna cable needs to extend outside the chamber because the VHF antenna used in this test exceeds the size of the chamber. During the test, several data are sent simultaneously by the AIS receiver to the master PC via Bluetooth communication. The HC-05 Bluetooth module was
attached to the device using serial communication. Two HC-05 modules were used in this test. The first module was installed for the RPI CM and the second one for the power board.

The thermal chamber that was used in this test is a Votsch VC² 4018. The chamber is located at the Satellite Technology Center (Pusteksat) of Indonesia’s National Institute of Aeronautics and Space (LAPAN). The minimum temperature is set at -20°C and the maximum temperature at 60°C. The minimum and maximum temperatures are maintained for one hour.

**Figure 2.** Data reception success rate

**Figure 3.** Voltage over time graph

4. **Experimental results**

The thermal test for the AIS receiver takes 3 hours and 56 minutes for a maximum temperature of 1 hour and a minimum temperature of 1 hour. The RPI-CM that acts as OBDH receives AIS data in AIVDM format and stores it in a file. The RPI-CM is controlled using the HC-05 Bluetooth module and can be monitored when receiving AIS data. The AIS receiver is installed into the chamber with RPI-CM, Power board, and CubeSat structure. Figure 6 shows the device placed into the chamber during the test. After testing, it was observed that no part of the DUT sustained any physical damage.

The success rate of data transmission at a certain temperature interval can be seen in Figure 2. Based on Figure 2, the success rate of the data transmission is influenced by the duration of the test. This happens because the process of sending AIS data static is only done every 3 minutes for AIS class B. AIS class B also has the disadvantage of the absence of a booking time slot after one transmitting signal is finished.

Through figure 2, it can be concluded that at maximum and minimum extreme temperatures, the AIS receiver can still work with data reception rates of 53.37% and 29.41% respectively. These numbers are quite good considering that the number of vessels within the orbiting CubeSat coverage could amount to thousands of ships in a single pass through certain ocean territories [1]. The success
of the data reception is seen after the AIS RAW data format has been received by the PC and it is decoded using online an AIS decoder. The correct data shows the data message ID, user ID and coordinate position of the correct AIS transponder.

Figure 3 shows that battery voltage decreases 0.13V in 3 hours and 56 minutes testing. At low temperature, battery voltage dropped below the final battery voltage. The lowest voltage detected was 3.60V at the low temperature. The battery voltage drop occurs due to the chemical characteristics of the battery. At low temperatures, the battery’s ohmic resistance increases, this reduces the battery capacity. The utilizing of a battery heater could solve the battery voltage drop at low temperature. The current consumption shows almost stable values and did not have a temperature.

5. Conclusion
This test proves that the AIS receiver can work in extreme temperatures between -20°C and 60°C. The thermal test design in this research could collect various data such as AIS signal, RSSI, humidity, temperature, voltage and current consumption by the device. The AIS receiver has an overall 37.5% success rate in receiving AIS data. At the highest temperature test, the AIS receiver can receive 53.57% and 29.41% at the lowest temperature. The receiver success rate could be enhanced if several transponders are used during the test to increase the AIS signal over time. Creating a customized AIS transmitter could be a perfect solution. It could be designed to transmit AIS signal every second and transmit in two channels of AIS simultaneously. During the test, the current consumption of the device was almost constant at 200mA.

References
[1] Hoye G K Eriksen T Meland B J and Narheim B T 2008 Space-based AIS for global maritime traffic monitoring Acta Astronautica 62 240-245.
[2] Zafrane M A Boudjemai A and Boughanmi N ALCUBESAT-1 2015 Proceeding of 7th International Conference on Recent Advances in Space Technologies (RAST) (Istanbul, IEEE) 807-812.
[3] Johl S Lightsey E G Horton S M and Anandayuvaraj G R 2014 Proceeding of IEEE Aerospace Conference (Big Sky, IEEE) 1-13.
[4] Sethi A Gajanur N Sadasivan K S Thakurta V Cheela B S and Hosangadi R 2017 Proceeding of IEEE Aerospace Conference (Big Sky, IEEE) 1-11.
[5] Kingsbury R Schmidt E Cahoy K Sklair D Blackwell W Osarentin I and Legge R 2013 Proceeding of Radiation Effects Data Workshop (REDW) (San Fransisco, IEEE).
[6] Husni E 2016 Design of automatic identification system (AIS) receiver for low earth orbit (LEO) satellite International Review on Modelling and Simulations (IREMOS) 9 435-441.