Preliminary Design of S-AIS Payload for KOMPSAT-6

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***Abstract*— Space-based Automatic Identification System (AIS) payload was preliminarily designed for KOMPSAT-6 satellite. The AIS payload is to be a secondary payload of the KOMPSAT-6 satellite. The AIS payload receives and provides the AIS signal data for ship collision avoidance and traffic management by means of on-board processing (OBP) and on-ground processing (OGP). This paper focuses on the preliminary design of AIS payload for KOMPSAT-6 satellite from the point of view of electrical and mechanical interfaces.**

Keywords - S-AIS; on-board processing; on-ground processing; KOMPSAT-6.

I. INTRODUCTION

Automatic Identification System (AIS) is basically a short range coastal traffic system used for Ship-to-Ship and Ship-to-Shore (4S) communications. AIS is required to be fitted on every seagoing vessel of 300 gross tons or more. Its purpose is to help ship crews avoid collision with other vessels as well as to allow maritime authorities to track and monitor ship movements [1]. Today's AIS allows ships to communicate with other ships and land based base stations through Very High Frequency (VHF) signals. This means that it is not possible to communicate outside the field of vision.

An AIS receiver in a satellite will extend the range considerably and make it easier to monitor ship traffic and fishing. The altitude of the satellite gives the AIS receiver a long range and the satellite can therefore make observations over large sea areas. The signals are strong enough to be received by a satellite in low Earth orbit by performing the analysis described in [2].

Korea Multi-Purpose Satellite-6 (KOMPSAT-6) is going to be launched for two main missions and one of them is to handle the expected volume of AIS messages around Korean peninsula. A preliminary design of AIS payload has been proposed with emphasis on the interfaces between Integrated Bus Management Unit (IBMU) and AIS receiver, including deployable AIS antennas.

The rest of this paper is structured as follows. In Section II, we present the S-AIS system overview. In Section III, we introduce the preliminary design and we discuss it from the point of view of electrical and mechanical interfaces. Section IV concludes the paper.

II. S-AIS SYSTEM FOR KOMPSAT-6

The main mission objectives of KOMPSAT-6 system are to expedite the provision of the space-borne Synthetic Aperture Radar (SAR) standard images with sub-meter resolution required for the national demand in Geographical Information Systems (GIS), Ocean & Land management, Disaster monitoring, and Environment monitoring.

The mission applications ("**GOLDEN**") are described as follows:

- **G**IS: Acquisition of independent high resolution images
- **O**cean & **L**and Management: Survey of natural resources
- **D**isaster & **En**vironment Monitoring: Surveillance of large scale disasters and its countermeasure

The KOMPSAT-6 satellite will be delivered to low Earth orbit in 2020 not only for all-weather day-night monitoring of Korean peninsula, but also for monitoring the ships around Korean peninsula. After achieving mission orbit and implementing In-Orbit Test (IOT), repetitive SAR and S-AIS observations for Earth's land and ocean will be conducted by Korea Aerospace Research Institute (KARI) for 5 years.

The overall operational concept of the S-AIS system is shown in Figure 1.

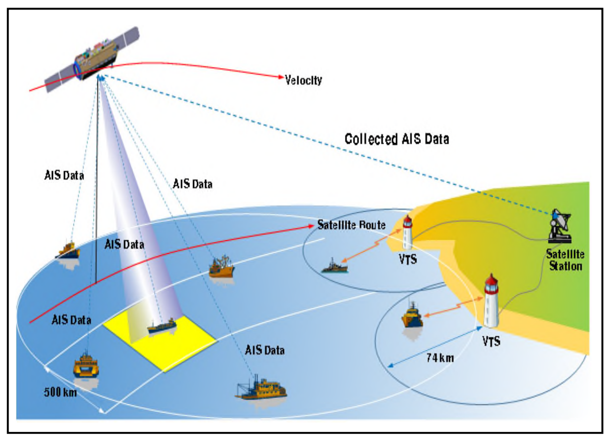

Figure 1. Operational Concept of S-AIS System for KOMPSAT-6

The AIS payload is to be placed in KOMPSAT-6 platform and the mission objectives of AIS payload are as follows:

- AIS signal collection from vessels on sea

- Raw data sampling for OGP (On Ground Processing) mode
- Demodulation of AIS burst signals for OBP (On Board Processing) mode

III. PRELIMINARY DESIGN

Space-based AIS payload has its own challenges due to the fact that AIS is primarily intended for sea-level reception and therefore leads to performance degradation when observed over large areas from space.

Another issue is the message collision and the message loss. All exchanged messages which are transmitted from ships on the sea should be synchronized and guaranteed the functions of the system without any message loss. On the other hand, all AIS messages received by the satellite from lots of vessels at the same time with the same frequency cause a message collision and lead to message loss [3].

In order to resolve the expected concerns above, S-AIS was designed as a reconfigurable AIS payload which operates in both on-board processing mode and on-ground processing mode, depending on the shipping traffic conditions of the field-of-view. Furthermore, the enhanced de-collision algorithms have been applied to successfully decode the collided signals during preliminary design phase.

A. Electrical Interface Design

The IBMU primary (RCL, PPS and COM) is connected to the AIS receiver primary (hot), and the IBMU redundant is connected to the AIS receiver redundant (cold), as shown in Figure 2. The AIS payload has the following electrical interface characteristics.

- RS-422/RS-485: 115.2 kbps, 230.4 kbps, 460.8 kbps and 921.6 kbps (Baud rate is selectable)
- PPS input: RS-422/RS-485
- Redundancy control: RS-422/RS-485
- Connectors: Antennas: SMA 50 Ohm female,
- Power: High performance micro D-subminiature
- Serial: High performance micro D-subminiature

This configuration offers complete redundancy on all parts and quadruple redundancy on the decoder boards and most of interface board.

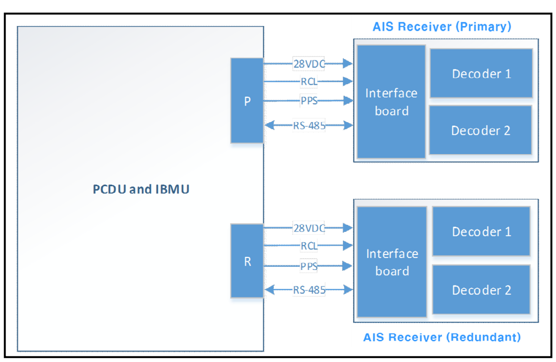

Figure 2. Electrical Interfaces between AIS Receiver between PCDU/IBMU

The Interface Board contains an RF front-end filter, one Low Noise Amplifiers (LNAs) for each antenna, external interface connectors, board connectors, power supply, and communication transceivers.

The RF front-end consists of a lumped RF filter followed by an LNA and switch. The redundancy control switch is used to route the output signal to the active Decoder Board. The 28VDC input supply is to be regulated to +5.0VDC (Volts of Direct Current) using two (one hot and one cold redundant) non-isolated DC/DC (Direct Current to Direct Current) converters. The DC/DC converters are enabled/disabled by the redundancy control signal, thus choosing which of the two Decoder Boards to be active. The regulators powering the RF front-end electronics are fed from the Decoder Board while the interface electronics are powered by regulators fed by the +5.0VDC. All transceiver circuits for the communication interfaces are also contained in the Interface Board and the interface transceivers are duplicated for redundancy purposes and the output enable pin is controlled by the redundancy control signal.

The Decoder Board contains the rest of the analogue receiver chains, analogue-to-digital converters and the digital platform for on-board processing and sample recording as shown in Figure 2. The digital hardware is based on a Field Programmable Gate Array (FPGA) and an anti-fuse FPGA is used to mitigate Single Event Upsets (SEUs) on the SRAM FPGA configuration data. A well proven watchdog functionality is implemented in the Anti-fuse FPGA as well.

The overall reliability value for AIS receiver is dependent on many factors. Primarily, it is the average lifetime ambient temperature and the average thermal cycles per orbit integrated over the lifetime that set the reliability figures. The temperature cycles per orbit integrated over lifetime is based on Coffin-Manson relationships, and is often not part of traditional reliability calculations. It is expected that the temperature cycles will only affect the board level soldering reliability. Table I shows the results of reliability calculations for the AIS receiver based on operating temperatures.

TABLE I. RELIABILTY CALCURATION FOR AIS RECEIVER BASED ON OPERATING TEMPERATURES

Ambient Temperature (T_a)	Temperature Cycles (ΔT)	Failure in Time (FIT)	Reliability R(t)
20 °C	±0 °C	182,5	0,9920
	±2.5 °C	222,2	0,9903
	±5 °C	278,2	0,9879
	±10 °C	507,1	0,9780
	±15 °C	917,3	0,9606
30 °C	±0 °C	391,8	0,9830
	±2.5 °C	414,3	0,9820
	±5 °C	479,6	0,9792
	±10 °C	846,2	0,9636
	±15 °C	1311,1	0,9442
40 °C	±0 °C	769,9	0,9668
	±2.5 °C	796,3	0,9657
	±5 °C	871,2	0,9626
	±10 °C	1175,7	0,9498
	±15 °C	1682,1	0,9290

B. *Mechanical Interface Design*

The mechanical interfaces design has been carried out for the AIS receiver and the AIS antennas mounting on the spacecraft. The unit accommodation design for KOMPSAT-6 is in a preliminary design phase so far. Mounting configurations of AIS receiver [4] and locations of antennas on the spacecraft are shown in Figure 3 for AIS receiver and Figure 4 for AIS antennas, respectively.

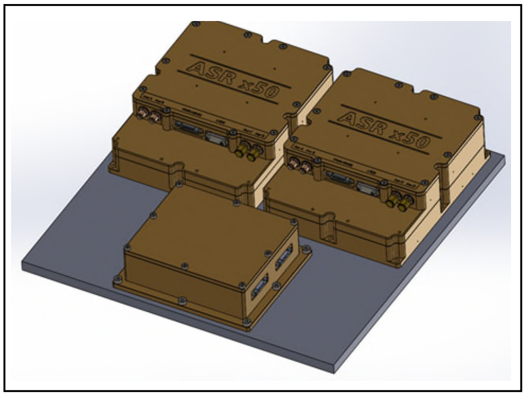

Figure 3. AIS Receiver Mechanical Configuration for Accommodation

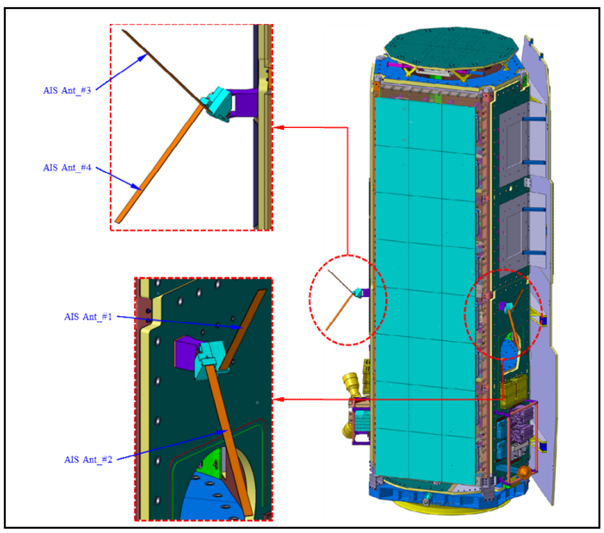

Figure 4. AIS Antennas Accommodation Design on Spacecraft

The AIS receiver consists of three inter-connected boards in a housing with all external connectors mounted at a recessed top front. The mounting points to the satellite structure are placed on a single plane at the bottom of the receiver. The enclosure is made as a non-magnetic metallic case which forms an all-enclosing electromagnetic and radiation shield. The mechanical design assumes a spacecraft manufacturing tolerance of +/-0.1mm.

IV. CONCLUSIONS

ETRI is now aiming to design and develop the S-AIS system for KOMPSAT-6 using the experiences and well trained engineers from previous project, development of Communication, Ocean and Meteorological Satellite (COMS). S-AIS is a system for AIS signal collection, down conversion, and demodulation of the AIS burst signals from vessels on the sea operating at VHF band.

In this paper, we have looked at electrical and mechanical interfaces of S-AIS system as a part of the preliminary design of AIS payload for KOMPSAT-6 satellite.

It is expected that the critical design and analysis will be performed in order to fix the S-AIS payload design as part of short term activities and future work.

REFERENCES

[1] Guidelines for the Onboard Operational Use of Shipborne Automatic Identification Systems (AIS), IMO Resolution A.917(22).

[2] Y. M. Lee and B. S. Lee, “Preliminary Performance Analysis of Space-based AIS Payload for KOMPSAT-6”, SPACOMM 2015, April 19 - 24, 2015.

[3] R. Goldsmith, “Preparatory Action for Assessment of the Capacity of Spaceborne Automatic Identification System Receivers to Support EU Maritime Policy : The PASTA MARE Project”, Maritime forum, October 2010.

[4] Design Definition File Summary Report, Issue 1A, ASRx50-KSX-DDF-014, Kongsberg Seatex AS, 2015.