Preliminary Performance Analysis of Space-based AIS Payload for KOMPSAT-6

Yong-Min Lee, Byoung-Sun Lee
Satellite & Wireless Convergence Research Dept.
Electronics and Telecommunications Research Institute
Daejeon, Republic of Korea
ymlee01@etri.re.kr,

***Abstract*—Space-based automatic identification system (AIS) payload has been designed conceptually to provide a platform for AIS signal collection, down conversion, and demodulation of the AIS burst signals operating at VHF band. AIS receiver uses a reconfigurable Software Defined Radio (SDR) technology, which has digital filtering and cross-correlation functions within field programmable gate array (FPGA) device and demodulation of Gaussian minimum-shift keying (GMSK) waveform by a general purpose processor. AIS receiver is able to operate in either or both on-board processing (OBP) mode and on-ground-processing (OGP) mode depending on the availability of communications links, on-board resources and the user preference. In this paper, the link budget analysis and detection probability have carried out as a basic performance analysis of AIS payload for KOMPSAT-6.**

Keywords-space-based AIS; software defined radio; GMSK; on-board processing; on-ground processing; KOMPSAT-6.

I. INTRODUCTION

With greater emphasis being placed on global situational awareness, global asset monitoring, environmental monitoring, maritime and terrestrial sensor, and data acquisition systems are critical enabling capabilities that are becoming more ubiquitous [1].

A space-based AIS payload makes use of AIS system beyond the intended 4S (Ship-to-Ship and Ship-to-Shore) communications. A satellite even microsatellite equipped with an AIS receiver can provide reliable services in widely trafficked area.

The Korean government had started to develop a multi-purpose low earth orbit satellite named KOMPSAT-6. KOMPSAT-6 satellite will accommodate Synthetic Aperture Radar (SAR) as a primary payload and Automatic Identification System (AIS) as a secondary payload.

The focus on this paper is to develop a conceptual design for a space-based AIS payload for KOMPSAT-6 with special emphasis on the performance analysis of ship-to-satellite link budget and detection probability versus the number of ships.

II. SDR BASED AIS RECEIVER

AIS payload for KOMPSAT-6 was designed to collect, down-convert, detect and demodulate the AIS burst signals from vessels. AIS receiver processes two groups of AIS messages in terms of dynamic messages every 2~10 seconds and static messages every 6 minutes.

Software defined radio architecture for AIS receiver includes the digital filtering and cross-correlation function within a field programmable gate array (FPGA) device and demodulation of Gaussian minimum-shift keying (GMSK) waveform within a general purpose microprocessor. Store and forward architecture is also allowed for autonomous data collection and archiving from vessels. Figure 1 shows the operational concept of AIS payload for KOMPSAT-6.

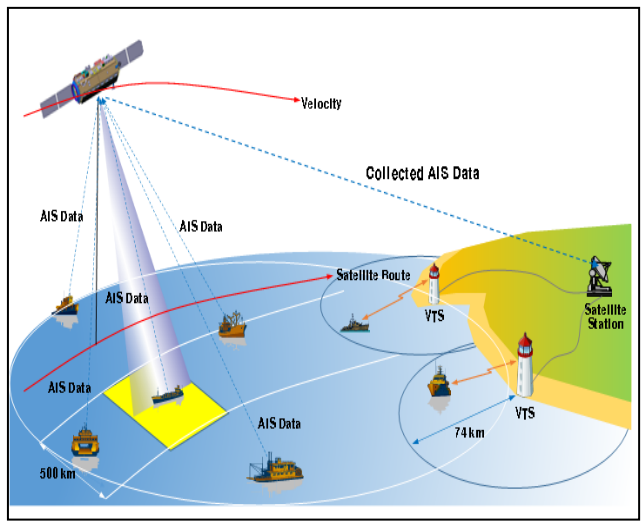

Figure 1. Operational Concept of AIS Payload for KOMPSAT-6

III. OPERATION MODES

The in-flight reconfigurable AIS payload is going to operate in either/both on-board processing mode or/and on-ground processing mode depending on the shipping traffic conditions of the field-of-view.

A. On-Board Procesing (OBP) Mode

The OBP mode leads to a reduced downlink bandwidth requirement but requires more powerful processing capability on-board AIS receiver. In areas with very high traffic density, it is not possible to successfully decode all AIS signals using this mode due to the high number of signal collisions. The OBP mode must not be confused with de-collision which is the process of applying de-collision algorithms to detangle the collided signals. Signal de-collision is only available with OGP.

B. On-Ground Processing (OGP) Mode

In OGP mode, the receivers take snapshot information of the RF environment and downlink the raw data to ground for processing by the very powerful ground processing equipment to apply the de-collision algorithms. This mode requires a lot of data handling and a larger downlink bandwidth to ground due to the amount of raw data generated (~20MB/s).

IV. PERFORMANCE ANALYSIS

The detection of AIS transmissions was recently improved by the introduction of satellite sensors, which enables the collection of AIS over wide areas in the open ocean. However, 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. It is therefore critical to understand how the performance of these new sensors, and to identify the condition under which the performance is acceptable for operational use.

Another issue is the message collision and the message loss. All exchanged messages transmitted from ships on the sea are synchronized and guaranteed the functions of the system without any message loss. On the other hand, AIS messages received at satellite from lots of vessels at the same time with the same frequency cause a message collision and lead to message loss [2].

In this paper, the link budget and detection probability analysis have carried out as the main factors impacting the performance.

A. Link Budget Anlysis

A substantial part of the AIS payload design is to evaluate the received power from the ships compared to the noise power in term of carrier-to-noise (C/N) ratio.

Table I shows a rough link budget calculated for ships near the edge of the satellite swath. The received power at satellite is -107.1 dBm and the link margin is about 4.8 dB. If we take into account some potential losses due to Doppler shift and ionosphere effects, the margin may go down a few but more sensitive receiver will help to increase the margin.

B. Dectection Probability

Basically AIS is designed as a ship collision avoidance system for terrestrial use and used a multiple access scheme called self-organized time domain multiple access (SOTDMA) that assigns approximately 2,000 time slots, automatically and dynamically, to ships in local "cells", that is, ships within VHF range of each other [3]. This communication protocols make sure that interferences cannot occur with normal traffic density.

However, a space-based AIS payload receives signals from a number of cells over the antenna footprint and a time slot is not coordinated properly. It means that signal collisions occur from other ships outside its self-organizing cell.

TABLE I. RESULTS OF AIS LINK BUDGET ANLAYSIS

AIS Transmission Parameter	Value
AIS-1 Frequency (MHz)	161.975
AIS-2 Frequency (MHz)	162.025
Data Rate (bits/sec)	9600
Line code	NRZI
Modulation	GMSK
Number of Training Bits	24
Transmit Bandwidth Time Product	0.4
Receive Bandwidth Time Product	0.5
Class A Transmit Power (W)	12.5
Channel Bandwidth (kHz)	25
Geometry	
Range (km)	530
MinTransmit Elevation Angle (Deg)	0
Satellite Antenna Off-axis Angle (Deg)	67.5
Maximum Slant Range (km)	2183
Maximum Surface Range (km)	2018
Power	
AIS Transmit Power (dBm)	41.0
Ship Antenna Gain (dBi)	2.0
Transmit Cable & Other Loss (dB)	3.0
Free Space Loss at Max Range (dB)	143.2
Polarization Mismatch Loss (dB)	3.0
Satellite Antenna Gain at Horizon (dBi)	1.6
Satellite RF Cable & Filter Loss (dB)	2.4
Satellite Received Power (dBm)	-107.1
Receiver Sensitivity (dBm) @ 20% PER	-112.0
Link Margin (dB)	4.8

The probability of detection of an uncorrupted ship's AIS message for KOMPSAT-6 has calculated with the different observation time shown in Figure 2 [4].

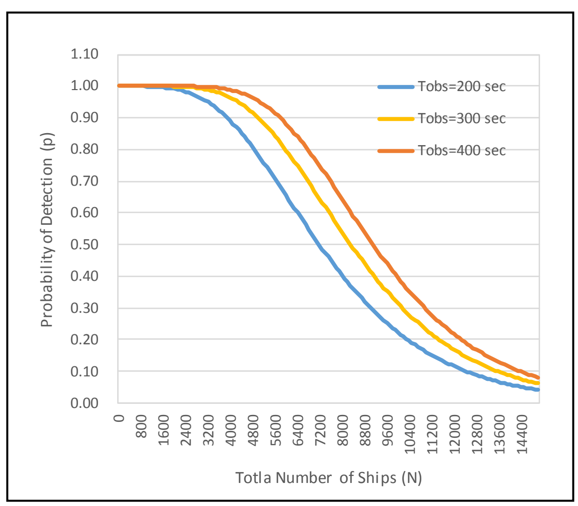

Figure 2. Probability of detection vursus total number of ships

V. CONCLUSIONS

In this paper, we have looked at general considerations around AIS payload and evaluated the feasibility for a space-based AIS receiver for KOMPSAT-6 conceptual design with respect to a basic link budget and detection probability. It can be concluded that there is sufficient margin about 4.8 dB to receive messages from ships and interferences between AIS messages will depend upon the number of vessels in the field-of-view. In order to improve the performances of AIS payload, there are ways to implement the interference cancellation schemes by using antenna diversity methods and de-collision algorithms on the ground.

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