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Signal environment mapping of the Automatic Identification System frequencies from space

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Abstract

This paper presents received signal strength data recorded by the NORAIS Receiver on the four VHF channels allocated to the use of the Automatic Identification System (AIS). The NORAIS Receiver operated on-board the Columbus module of the International Space Station from June 2010 to February 2015. The data shows that a space-based AIS receiver must handle transient strong signals from land-based interference and that the effectiveness of the two long range AIS channels recently allocated is severely reduced in select areas due to land based interference.

Keywords: AIS; Vessel ID Sys; ISS; Columbus; Maritime VHF; NORAIS

1. Introduction

The Norwegian Defence Research Establishment (FFI) operated an Automatic Identification System (AIS) receiver, known as the NORAIS Receiver (Eriksen et al., 2010), on-board the Columbus module of the International Space Station (ISS) from June 2010 to February 2015. The official name for the operation of the AIS receiver on-board Columbus is Vessel ID Sys. In addition to receiving AIS messages and demonstrating space-based AIS as a security, safety and surveillance capability for European authorities, the NORAIS Receiver was designed to collect auxiliary data about the AIS signals and signal environment in space. The intention was to collect information that would contribute to the development of more advanced decoding algorithms, and investigate in-situ the challenges that space-based AIS receivers face. Among the auxiliary data is a received signal strength indicator (RSSI) value. The RSSI value is used in this paper to inform about the signal environment space-based AIS receiver systems will be subject to, both on the nominal AIS channels, 161.975 MHz and 162.025 MHz, and the channels intended for long range use, 156.775 MHz and 156.825 MHz. The long range frequencies were implemented, along with a long range AIS message, type 27, in the International Telecommunication Union recommendation ITU-R M.1371 (ITU, 2014). These long range frequencies are referred to as the space AIS frequencies in this paper.

This paper presents the signal levels experienced by the NORAIS Receiver on the standard AIS frequencies, the space AIS frequencies, and the temporal changes since the start of operations in June 2010 until June 2014. After a brief background in Sections 2 and 3 describes the methodology used collecting, processing and presenting the data and also discusses some important considerations for interpreting the results. Section 4 presents the results for the standard AIS frequencies while Section 5 presents the results for the space AIS frequencies. Section 6 presents

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a discussion of the results and their application. Finally, Section 7 concludes the results.

2. Background

For completeness, a high level introduction to the AIS system is appropriate: AIS is a ship-to-ship and ship-to-shore reporting system intended to increase the safety of life at sea and to improve control and monitoring of maritime traffic. AIS equipped ships broadcast their identity, position, speed, heading, cargo, destination, etc. to vessels and shore stations within range of the VHF transmission. The reporting interval depends on the message type and dynamic conditions of the vessel such as speed and rate of turn. The message types 1–3 with dynamic content such as position information are transmitted every 2–10 s depending on the dynamic conditions. If anchored or moored and moving slower than 3 knots the reporting interval is 3 min. The long range type 27 message reporting interval is every 3 min regardless of dynamic conditions. On ground level AIS stations on shore can typically receive AIS messages at distances about 40–50 nautical miles offshore. With a low noise, highly sensitive receiver capable of handling Doppler shifts up to ±4000 Hz (depending on altitude) an AIS receiver on a satellite can extend the range to global AIS message reception.

Simulations predicted, and in-orbit data verified, that in high density ship traffic areas, co-channel interference will degrade the performance of a space-based AIS system drastically (Eriksen et al., 2006; Helleren et al., 2008; Narheim et al., 2011). With an ever increasing AIS carrying fleet, a proposed solution for space-based AIS is the introduction of two channels dedicated to space-based AIS. Only the long range type 27 message shall be used on these new channels. The significantly longer transmission interval compared to the standard AIS reporting intervals and fewer bits in the message should increase the space-based AIS system capacity markedly because the co-channel interference is reduced (ITU, 2009).

2.1. The NORAIS Receiver

The NORAIS Receiver is installed in the Columbus module of the ISS connected to an external dipole antenna mounted on the forward facing side of the module. The NORAIS Receiver AIS payload was developed by Kongsberg Seatex AS and is a software defined radio that supports operation on any two channels within the maritime very high frequency (VHF) band from 156 MHz to 162.025 MHz. In addition to operating in the nominal mode decoding AIS messages, the payload also supports a sampling mode in which the raw signal, the in-phase and quadrature components, on a channel can be sampled for further processing on ground. The sampling frequency, number of bits and which bits to store is user configurable. The sampling frequency is however limited to integer fractions (0–9) of the 96 kHz internal intermediate frequency. The internal frequency itself is ten times the AIS message symbol frequency. The software defined radio also supports in-orbit upgrades, which have been performed several times during the 4.5 year operations period. The upgrades were developed based on data analysis of the collected AIS, auxiliary and sampling data.

The signal level measurements presented are calculated from a calibration curve measured at the antenna port input at the NORAIS Receiver, after any cable loss from the antenna mounted outside on the Columbus module. The signal level measurements presented herein may thus be considered to be on the lower end of what should be expected in orbit.

2.2. AISSat-1

The Norwegian AISSat-1 satellite is referenced later in the paper to demonstrate the effect different satellite orbit geometries have on the data analysis presented in this paper. AISSat-1 is a 6 kg nano-satellite built by the University of Toronto Space Flight Laboratory in Canada under contract from FFI (Helleren et al., 2012). The satellite was launched in July 2010 into a 635 km sun-synchronous orbit. AISSat-1 has a monopole antenna with full attitude control enabling the antenna to be pointed in any direction. The AIS payload is, for the purposes of this paper, identical to the NORAIS Receiver.

3. Methodology

Auxiliary measurement information such as time of reception, received signal strength and frequency shift relative to the receiver centre frequency is appended to every AIS message received. The received signal strength indicator (RSSI) value is calculated continuously by passing the amplitude of the signal samples (taken at a rate of 96 kHz) through an infinite impulse response (IIR) filter according to Eq. (1):

$$\mathrm{RSSI}(n) = \mathrm{RSSI}(n-1) + 0.1 \times (A(n) - \mathrm{RSSI}(n-1)) \tag{1}$$

where $A(n)$ is the signal amplitude of sample "n". Conversion from the RSSI value to dBm is done via a calibration curve from pre-launch calibration of the RSSI values.

If the receiver is not able to find a training sequence, indicating the presence of an AIS message, within ~20 ms into a timeslot, the receiver creates an "empty" timeslot measurement with time of reception, received signal strength and receiver centre frequency information only. The receiver may not be able to find an AIS message training sequence for a number of reasons. One possibility is that there is no AIS message in the timeslot, another that there are several AIS messages received at the same time in the same timeslot corrupting the training sequence, or some other source of interference overlapping with the AIS message training sequence. Only such "empty" timeslot