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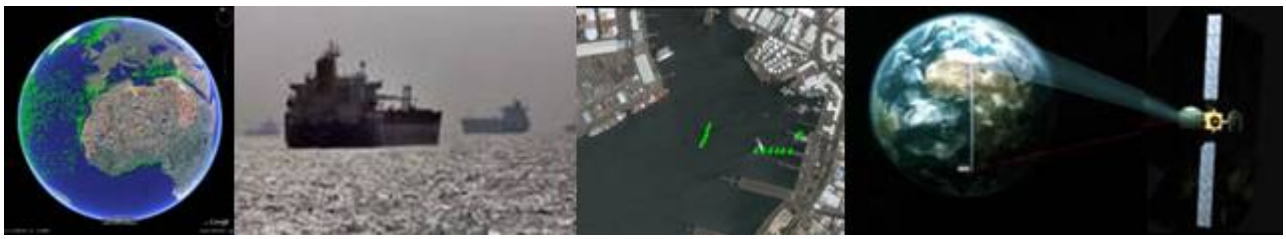
Institute of Space Systems

Flight Operations



Technical Note TN 4.2 PASTA MARE Interference Mapping

Issue 2 September 2010

Preparatory Action for Assessment of the Capacity of Spaceborne Automatic Identification System Receivers to Support EU Maritime Policy

DG MARE Service Contract MARE/2008/06 – SI2.517298

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1. SCOPE OF THE DOCUMENT

This Technical Note describes the identification of interference sources which may impact capturing of VHF AIS signals (161.975 MHz and 162.025 MHz) from space. In Section 1 the results of the investigation of the ITU frequency allocation files are presented. Section 2 addresses the initial plans of interference sampling by means of the COLAIS sampler which – for reasons outside the control of the consortiums had to be dorpped.

2. APPLICABLE AND REFERENCE DOCUMENTS

RD1	SpaceQuest (2008) : Technical eXchange on AIS via Satellite II, presentation to TEXAS II, September 3, 2008

3. DEFINITIONS AND ACRONYMS

AIS	Automatic Identification System
EMSA	European Maritime Safety Agency
ITU	International Telecommunication Union
LRIT	Long Range Identification and Tracking
PMR	Private Mobile Radiocommunications
RR	Radio Regulation
WRC-07	World Radiocommunication Conference in Geneva (2007)

4. INTRODUCTION

There are both legal and illegal terrestrial sources that can create interference with a space borne AIS. Due to the potential harmful impact of interferences which limits the overall performance of the system, a systematic analysis of the existence of interferences sources is essential. The identification of interference sources, their location and signal strength provides the foundation for:

- Delimitation of areas where space borne AIS services might be impacted, i.e. in the worst case might not be available and/or
- Need to improved receiver/antenna design as well as for an mission planning aiming at coping/mitigating the effect of the interference.

Figure 4.1 exemplifies different types of interference based on real sampled AIS data. The figure shows the signal power for the different frequencies. One can see the Gaussian shaped AIS signal in the middle which are the typical AIS messages. High narrow peaks correspond to narrowband interferences. Left and right of the AIS signal, the interferences from adjacent channels are visible.

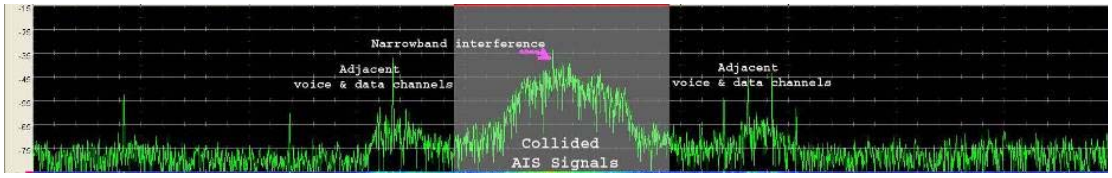

Figure 4.1: "narrowband" interference record, source [RD1]

Two interference sources can be distinguished: legal and illegal interferences

Legal interference sources are those which use the dedicated AIS frequency over land areas for mobile or fixed services or specific sources that create strong VHF sources like electronic warfare equipment (large antenna stations). Legal interference sources are operated in accordance with the national regulations of the country they are located in. Those national regulations adhere to the international framework created by International Telecommunication Union (ITU)

There might be also illegal interference sources, created by countries or entities interested in hiding specific areas. In addition, there might be voluntary “jammers” of the signal, who are interested to blank out the view of the space based AIS receivers over certain areas. Those

interference sources can be detected through a space based AIS sampling device. Those are mounted on the upcoming AIS experiments and satellites embarked during the project. The sampling devices allow the creation of snapshots of the whole AIS frequency and ground processing is able to localize the sources of interference and jamming with a precision of several kilometers.

5. ANALYSIS OF THE ITU REGULATIONS

5.1 ITU REGULATIONS AND FREQUENCY NOTIFICATION

The International Telecommunication Union (ITU) is the leading UN agency for information and communication technology issues, and the global focal point for governments and the private sector in developing radio communication networks and services. ITU's radiocommunication sector (ITU-R) is coordinating the shared global use of the radio spectrum, i.e. managing the international radio-frequency spectrum and satellite orbit resources. ITU is in charge to allocate spectrum and register frequency assignments, orbital positions and other parameters of satellites, "in order to avoid harmful interference between radio stations of different countries". The international spectrum management system is based on regulatory procedures for frequency notification, coordination and registration.

5.2 ITU REGUALTORY STATUS OF AIS

The ITU publishes a series of reports which informs about spectrum allocation. With regards to AIS signal interferences the Radio Regulation (RR) and the International Frequency Information Circular (BR IFIC) – terrestrial services are of relevance.

5.2.1 THE RADIO REGULATIONS (RR)

The Radio Regulations contains the complete text of the Radio Regulations as adopted by the World Radiocommunication Conference and subsequently revised and adopted by the following World Radiocommunication Conferences. It includes all legal binding regulations, appendices, resolutions and recommendations. The latest revision was approved at the World Radiocommunication Conference in Geneva (2007) (WRC-07).

The ITU regulatory status of AIS VHF frequencies is defined in Article 5 of the Radio Regulation (RR), its corresponding footnotes as well as in Annex 18:

According to Article 5 (5.226: 3rd paragraph):

"*... the bands 156 – 156.4875 MHz, 156.5625 – 156,7625MHz, 156,8375-156,45, 160,6 – 160,975MHz and 161.475-162.05 MHz, each administration shall give priority to the maritime mobile service on only such frequencies as are assigned to stations of the maritime mobile service.*

Any use of frequencies in these bands by stations of other services to which they are allocated should be avoided in areas in where such use might cause harmful interference to the mobile VHF radiocommunication service. "

Footnote 5.227A states that

"... additional allocations: the bands 161,9625 – 161,9875 MHz and 162,0125 – 162,0375 MHz are also allocated to the mobile-satellite service (Earth to space) on a secondary basis for the reception of automatic identification system (AIS) emissions from stations operating in the maritime mobile service (see Appendix 18)"

In annex 18 of the WCR-07, it is further outlined that:

" f) The frequencies ...161,975 MHz (AIS 1) and 162.025 MHz(AIS 2) may also used by aircraft stations for the purpose of search and rescue operations and other safety related communication.

" *l) These channels (AIS 1 and AIS 2) are used for an automatic identification system (AIS) capable of providing worldwide operation, unless other frequencies are designated on a regional basis for this purpose. Such use should be in accordance with the most recent version of Recommendation ITU-R-M1371".*

p) Additionally, AIS 1 and AIS 2 may be used by the mobile satellite service (Earth to space) for the reception of AIS transmissions from ships

o) These channels may be used to provide bands for new technologies, subject to coordination with affected administrations. Stations using these channels or bands shall not cause harmful interferences, and shall not claim protection from, other stations operating in accordance with Article 5. The design of such systems shall be such as to preclude the possibility of interferences to the detection of AIS signals on 161,975 MHz or 161,025 MHz."

In essence the Radio Regulation specifies that:

- the use of the VHF frequencies 161.975 MHz and 162.025 MHz for AIS satellite reception is on a secondary basis with regard to Mobile and Fixed services, i.e. satellite shall not claim protection from emissions of Mobile and Fixed stations.

- In the mobile service, apart from ships, the only specific applications mentioned in the RR that could use the same frequencies are aircraft stations involved in search and rescue operations/safety related communications in the Americas and Asia-Pacific
- Concerning the Fixed service, no specific application is mentioned in the RR. However, those applications have to protect VHF transmissions from ships.

5.2.2 BR INTERNATIONAL FREQUENCY INFORMATION CIRCULAR (BR IFIC) TERRESTRIAL SERVICES

Apart from the RR, the BR International Frequency Information Circular (BR IFIC) - Terrestrial Services is another potential source of information to identify any additional use of the AIS frequencies. The BR IFIC is a consolidated regulatory publication issued once every two weeks by the ITU Radiocommunication Bureau[1] and contains information on the frequency assignments/allotments submitted by the different countries to the Radiocommunication Bureau for recording in the Master International Frequency Register and in the various regional or worldwide Plans/Agreements.

The analysis of the BR-IFIC revealed that there is not any relevant information for the frequencies of interest. This is not surprising, since there is no obligation for national authorities to register all of their terrestrial stations and frequency assignments. Only if neighboring countries are impacted, coordination and notification to ITU is requested. ITU in that case is to ensure frequency coordination at the borders so no information on the stations inside a country is available.

5.3 CONLUSION:

The analysis of the RR revealed that AIS satellite reception is only on a secondary basis and thus cannot claim protection for other users.

The identification of interferences sources registered in the IFIC, respectively other users of the AIS frequencies did not show any result. The reason is that national authorities need to notify the frequency use to ITU only if causing cross-border interferences.

[1] • BR International Frequency Information Circular BR IFIC (Space Services) is another important source of information, but of no relevance for the AIS signal interference, because it contains information on the frequency assignments to space stations, earth stations or radioastronomy stations submitted by Administrations to the Radiocommunication Bureau for recording in the Master International Frequency Register.

The use of AIS frequencies by a specific country can also be identified when checking national frequency allocation tables. The AIS frequencies are primarily used for fixed service, notably Private Mobile Radiocommunications (PMR) used by police or fire brigades. Another example is the specific allocation in Morocco to terrestrial broadcasting services. The identification of potential interference sources via national frequency allocation tables is possible but would represent a huge task considering the number of countries to be consulted and the fact that national regulations are not always available in other languages that the national language. In addition, such a survey would only provide an indication on potential sources of interference but would not provide any quantitative information such as the number, location and characteristics of the interference sources. Such detailed information is indeed not publicly available as its only purpose is to be internally used by the national regulatory authorities.

The analysis of the international regulatory status of AIS frequency showed, that the foreseen frequency sampling becomes an important task to identify potential interference sources, impacting on the AIS signal detection from space.

6. AIS FREQUENCY SAMPLING USING COLAIS DATA

The LuxSpace AIS receiver (LUXAIS) is a highly sophisticated sensor completely designed and developed by LuxSpace.

Figure 5.1: LUXAIS receiver

Onboard the Columbus module of the ISS, the LUXAIS receiver will sample raw AIS data and environment data as well as provide demodulated AIS messages. During the in-orbit data acquisition and validation phase the LUXAIS receiver will be connected via the COLAIS RF AIS FILTER to an external VHF antenna of the Columbus module and controlled through the previously installed ERNObox computer payload provided by EADS Astrium.

Besides the AIS signal acquisition the LUXAIS receiver provides the possibility of sampling on three different center frequencies:

- 161.975 MHz
- 162.000 MHz

- 162.025 MHz

The signals are sampled with I and Q separately with 64000 samples per second and a resolution of 14 bits. This gives a high dynamic range from -60dBm to -128 dBm!

To adapt to different situations, several sampling modes are possible:

1. Two channels continuous (600s)
2. Two channels continuous (300s)
3. One channel sampling in four equally spaced periods in 9 minutes
4. One channel sampling for a user defined duration

Accurate time stamping in combination with the well observed orbital parameters of the ISS allows assignment of the sampled data to geographic positions. By examination of the sampled data, it will be possible to identify, quantify and even localize possible sources of interference.

Further, the LUXAIS receiver performs an ambient electromagnetic density measurement every 3 seconds. This will allow LuxSpace to create maps showing the electromagnetic density of the earth. These measurements will also give indications, where the AIS signal reception could be disturbed.

Interference sampling using the LuxSpace AIS receiver on the International Space Station (COLAIS) was scheduled to take place in Q2/2010 but had to be postponed several times due to technical difficulties of the on-board installation racks (so called “ERNO box”) of the International Space Stations. Both, the repair and the update of the time schedule for the operation of the LuxSpace AIS receiver is under the responsibility of NASA/ESA and thus outside the control of the consortium. According to latest information from ESA, the “switch-on” of the receiver is foreseen to take place in end of September/beginning of October 2010, thus unfortunately outside the time frame of PASTA MARE.

Here are typical examples of captured interference by LUSPACE’s PATHFINDER2 satellite during a sampling acquisition in 4 January 2010. The Acquisition started over Bering Sea, and stopped over Norway with the FoV covering North of Germany.

The first picture, and attached wave file shows interference produced by Russian Antibalistic missiles radars.

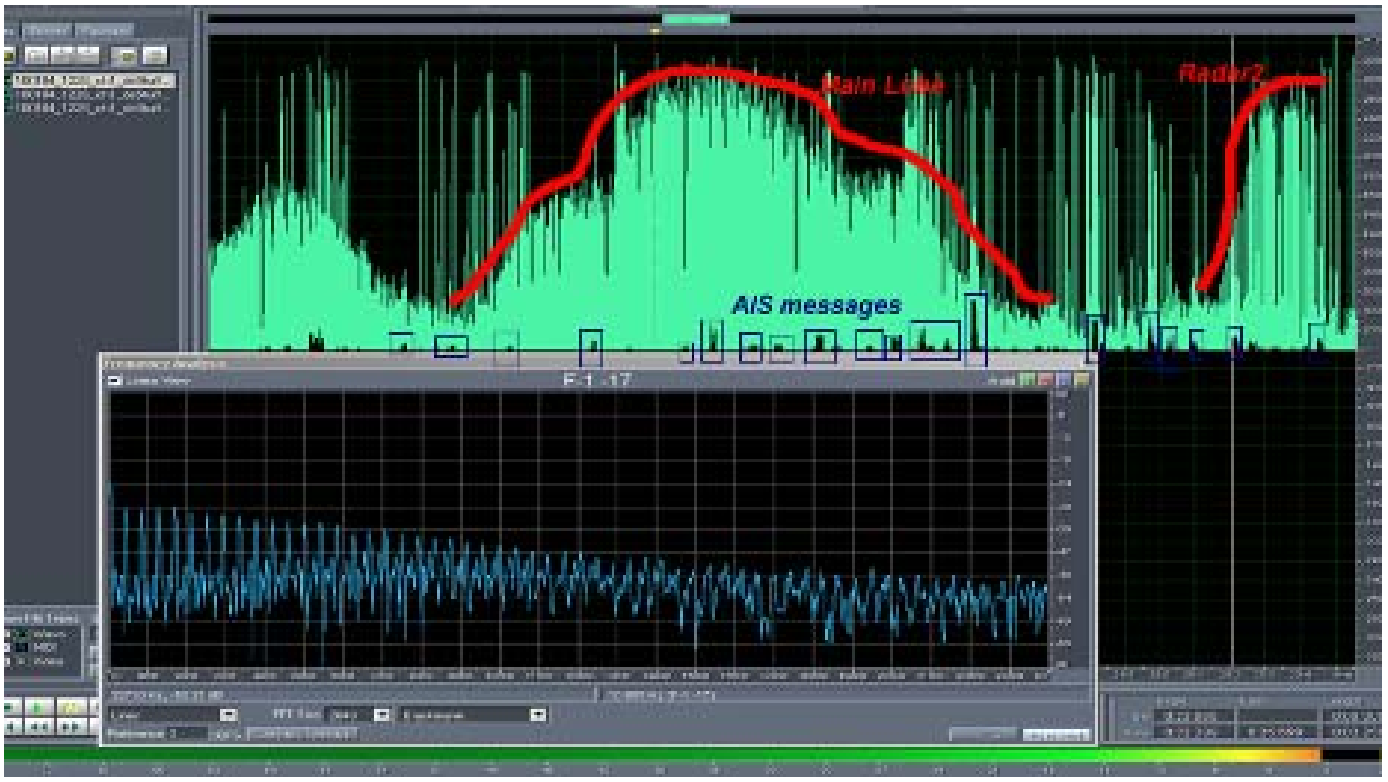

Figure 5.2 Screen shot of radar analysis, with spectral view of Pulse Repetition Frequency

The main lobe of the radar is shown in red (duration), along with the AIS messages marked in blue. It can be seen that the amplitude is quite challenging with respect to the one of the AIS messages.

The embedded .WAV files allow to easily distinguish between two different radars ('buzz slightly different)

Two deifferent Russian Radars over North pole 2010Jan04.wav

The following picture shows the position and FoV of the satellite at the time of interception.

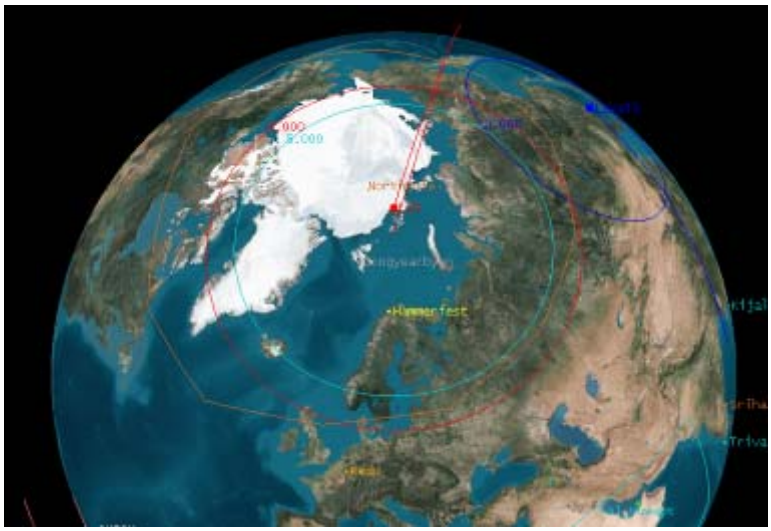

Figure 5.3 position an FoV of the satellite at the time of radar interception

The following (included) .WAV file allows to clearly hear voice speaking at the end of the record. This shows clearly the re allocation of the AIS frequencies to other use when, at Earth's level, there is no risk of interferences to the maritime service.

Voice over Danmark-Germany-2010Jan04wav.wav

Other examples follow, that have been recorded during the PASTA MARE flights in the area of Morocco and Gilbraltar. Some records are more than 1 minute long and precluded any demodulation of the AIS messages.

All in all, trying to sum up what can happen over Europe, from the sampling of PATHFINDER2 and the sampling of PASTAMARE flights, it is safe to assume that a satellite over Europe can have each AIS channel jammed for a period in the 5 minute duration, on average.

This obviously lowers considerably the detection rate of the messages, thus the PoD of ships.

As already pointed out by LUXSPACE in its final report of the PATHFINDER1A study (June 2008), it is clear that FoV Splitting (by onboard antenna patterns) will improve the performances of a space borne receiver.