GPS Jamming and its impact on maritime safety

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Introduction

The number of people using satellite navigation has grown dramatically over the past decade through the use of the US Global Positioning System (GPS) and will continue to grow with the repopulation of the Russian GLONASS system and the development of Galileo and COMPASS, the new European and Chinese systems. Growth in the use of these Global Navigation Satellite Systems (GNSS) has unfortunately increased the reliance on them too.

The General Lighthouse Authorities of the United Kingdom and Ireland (GLAs) provide marine aids-to-navigation (AtoNs) for the benefit and safety of all mariners using their waters. As such, the GLAs are keen to understand the effect of GNSS service denial and jamming on the safety of maritime navigation and have conducted two trials to date.

This article reports on the effect of GNSS jamming, its implications, and what mitigating actions should be considered to ensure the continued safe navigation of the mariner.

GPS jamming trials conducted by the GLA

The GLAs have conducted two GPS jamming trials: the first in 2008, off the coast of Flamborough Head; and the second, a series of demonstrations, held off the coast of Newcastle-Upon-Tyne last year. These trials have enabled the GLAs to gather important results as to what happens to their AtoNs and navigation equipment, communication systems and situational awareness, both on and off the ship.

The trials provided interesting results that the GLAs were able to publish openly for the first time. Knowing that GPS is being jammed and how to recognise the symptoms on AtoNs, vessel navigation equipment, or shore-based infrastructure is critical for the safety of the mariner.

For both trials, one of the GLA buoy-tender fleet was exposed to GPS jamming signals and the effects were observed. As expected, jamming resulted in a large number of audible alarms on the bridge, as the many GPS-fed systems failed, or reverted to a non GPS state. This in itself is unusual and can cause confusion.

It was observed that GPS fed equipment could be defined to be in one of three states, as detailed in Table 1.

TABLE 1: TABLE SHOWING THE EFFECTS OBSERVED FOR THE THREE STATES IDENTIFIED BY THE 2008 TRIALS

State	Ratio of signal strengths	Observed result
1	Jamming signal << GPS signals	Normal operation
2	Jamming signal ≈ GPS signals	GPS fed equipment provides erroneous data, some of which is hazardously misleading
3	Jamming signal >> GPS signals	GPS denied and equipment fails to provide any information

Figure 1. Google Earth™ Plot showing the reported positions from one of the typical marine grade receivers. The GPS position (red circle) is erroneously reported as being inland 22km west from the true eLoran position (green square). (Red lines indicate main lobe of the jamming unit and position marker colours indicate reported speed: blue <15knots, yellow< 50knots, orange <100knots and red >100knots).

These states can be observed in Figure 1, which shows the reported positions from a typical marine grade GPS receiver installed on the GLA vessel *Pole Star*, as she steamed between two waypoints through an area affected by the GPS jamming.

State 1 can be seen at either end of the path where the solid blue line occurs; this is where the jamming signal strength is much lower than the received signals from the GPS satellites, and the GPS-fed systems are operating normally.

As the vessel approaches the main lobe of the jamming signal, shown by the red lines, it reaches an area where the jamming signal is comparable with the received GPS signals – State 2 – and erroneous data can be observed, reporting wandering positions at high speeds.

As the vessel enters the main lobe of the jamming signal, State 3 is observed. This is where the GPS signals are swamped by the jamming signal, and the receiver fails to provide any positioning, navigation or timing (PNT) output.

Erroneous GPS positions generally appear during State 2 and the reported positions and speeds appear random. However, as Figure 1 demonstrates, while some errors are often several kilometres away reporting high speeds, others are only subtly different to the true position, reporting believable speeds, and the result is hazardously misleading information.

Ship-borne and shore-based systems that utilise GPS for PNT were all affected. The GLAs demonstrated this on the vessel's Electronic Chart Display and Information System (ECDIS), the Automatic Identification System (AIS), radar,

Figure 2. Two vessel traffic images. Left: Erroneous positions reported for the trial vessel Pole Star under jamming conditions (first GLA jamming trial). Right: No erroneous positions were reported from the trial vessel Galatea under jamming conditions (second GLA jamming trial).

Digital Selective Calling (DSC), amongst other ship systems, but also on some AtoNs and shore-based infrastructure. Any system that takes information from a GPS receiver should sound an audible alarm and will potentially provide erroneous data or no data at all while affected by GPS jamming. The implications can be severe, for example the DSC reports the vessel's GPS position in an emergency, and so could potentially send Search and Rescue (SAR) to the wrong location. (For a full account of the GLA trials, please refer to other GLA publications [1, 2].)

Raising awareness

The GLAs have been increasing awareness that GPS jamming can and does occur, and what the impact can be. The demonstrations held by the GLAs in 2009 were to show the importance of resilient PNT to a selected audience of key decision-makers from European and UK Governments, maritime industry, mariners and other AtoN service providers; and enabled them to observe the effects of GPS jamming first hand. The outcome was very positive and should support the effort to develop resilient PNT systems.

The GLAs were also invited to present at a recent GPS jamming conference jointly organised by the UK Digital Systems Knowledge Transfer Network and the Royal Institute of Navigation titled 'GPS Jamming & Interference – A Clear and Present Danger'. The aim of this conference was to discuss not only what GPS jamming can do, but also the efforts being undertaken to prevent jamming from occurring, and to discuss what can be done when it does.

It covered the technical aspects of GNSS jamming, including how GPS signals are the equivalent of a 100-watt light bulb shining down from 20,000km away and discussed how, unfortunately, jamming units are becoming more available and are commonly being used by the criminal fraternity, increasing the likelihood of exposure.

Implications for ports and harbours

The effect of jamming on the mariner is clear; however, the effect is not limited to the vessel. Shore-based infrastructure, such as vessel traffic services (VTS) rely on AIS to some extent and can also be affected both directly and indirectly.

It has been noted that different vessels react differently when subjected to GPS jamming. It is thought that this is due to the use of different equipment from different manufacturers, and also how the equipment is integrated. For example, Figure 2 shows two traffic images. The left image was provided by the Maritime and Coastguard Agency (MCA) and shows an image of the traffic off Flamborough Head present during the first trial. One can clearly see the erroneous positions reported for the GLA vessel *Pole Star*. However, other vessels in the vicinity show signs of being affected too, such as the *Dutch Progress*, which is reported inland and travelling at high speeds. At first glance, the other vessels appear to be unaffected.

If we now consider the right-hand figure, this time the traffic image shows the reported AIS positions of *Galatea*, during the demonstrations in 2009. This time, the AIS unit fails safe and does not provide any erroneous data, opting not to provide any information at all during the jamming period. If we look back at the vessels that appear valid in the left-hand figure, such as the one circled, we are left with the query as to whether they truly are unaffected. It could be that this is the last known position of the vessels and they are not really where they say they are. Integrity in the traffic image is therefore compromised.

Although radar itself is not affected directly, it too can add to the confusion. Many radar displays can overlay the reported AIS positions. Figure 3 shows a photograph taken during the first trial, and shows the reported AIS position and radar return for the same vessel as two locations. It could be that this is the last known position of the vessel and it is not really where it says it is. Integrity in the traffic image is therefore compromised.

In general, if a port was subject to GPS jamming, then the Port authorities, VTSs and vessel crews could all experience unusual working conditions, multiple alarms and a loss of situational awareness.

Mitigating actions

Mitigating actions can help reduce the impact of GPS jamming. Such actions might include using a resilient mix of systems to provide PNT and ensuring that traditional means of navigation are available and can be skilfully utilised. Other mitigating actions may be available depending on the systems affected and the processes involved.

The GLAs strongly advocate the use of multiple systems, and are working hard to develop eLoran as a complimentary system to satellite navigation. eLoran has dissimilar failure modes to GNSS, while providing comparable accuracy and timing functionality – meaning that, should one system fail, the other can take over seamlessly. A resilient PNT solution can be applied to any system, whether an AtoN, a ship-based unit, or the port VTS.

Conclusions

One can conclude that GPS jamming can significantly affect the safety of maritime navigation and situational awareness for both ship-based and shore-based systems.

The main effects observed from the two GLA jamming trials are:

- Random errors are presented, leading to hazardously misleading information that could, depending on the installation, lead a vessel off course.
- Erroneous and potentially misleading data are presented to other vessels and shore-based infrastructure.
- The sheer number of alarms on the bridge of the vessel could be disconcerting and distracting for the mariner.
- GPS-fed systems are lost, which can create an unfamiliar bridge situation and remove safety critical systems from operation.
- Situational awareness can be lost or made appreciably confusing.

The loss of GPS, or a lack of integrity in the reported information, leads to an unfamiliar situation on the bridge. The crews of the *Pole Star* and the *Galatea* were expecting to lose GPS and had primed other systems so that they could navigate safely. In real life, there would be no advance notice and the impact on the crew would be more severe.

The GLAs recommend that mariners use all available means to navigate safely and strongly support the need to create a resilient means of providing position, navigation and timing information.

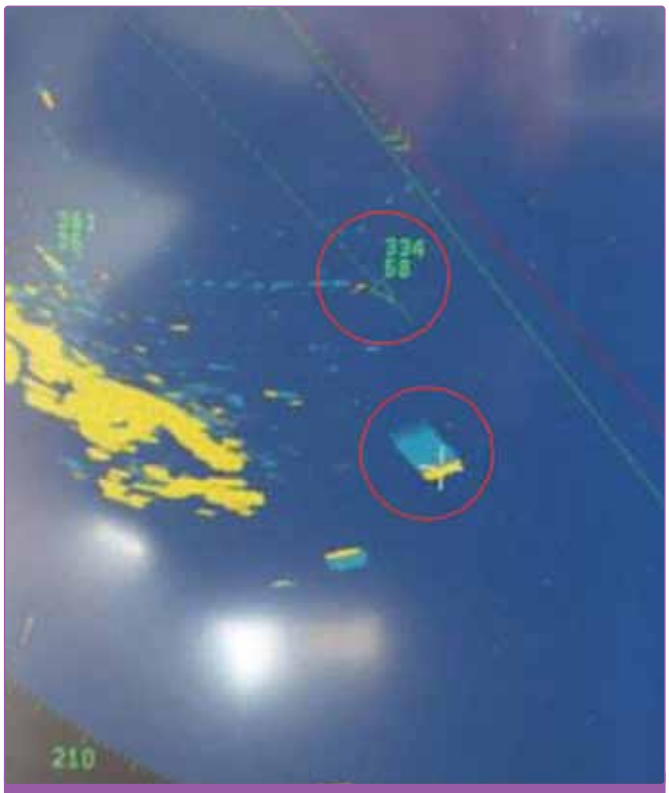

Figure 3. The vessel's radar display during GPS jamming trial. The two circles highlight the AIS and radar return, which correspond to the same vessel albeit some distance apart. Jamming has resulted in the vessel reporting an incorrect AIS position.

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REFERENCES

[1] Grant, A., Williams, P., Ward, N. & Basker, S., "GPS Jamming and the impact on maritime navigation", Journal of the Royal Institute of Navigation, 62, April 2009.

[2] A. Grant, "Observed impact of GPS Jamming and the benefits of eLoran", Royal Institute of Navigation and Knowledge Transfer Network jointly sponsored GPS Jamming & Interference conference, Teddington, February 2010.

Links to these publications are available from the GLA website: www.gla-rrnav.org

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ABOUT THE ORGANISATION

The **General Lighthouse Authorities of the United Kingdom and Ireland** (GLAs) comprise of Trinity House, the Northern Lighthouse Board and the Commissioners of Irish Lights. The Research and Radionavigation Directorate (R&RNAV) works on behalf of all three authorities undertaking research and development, system engineering and support operations.

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