

## **4G Technologies and Maritime Radar Coexistence - Shoeburyness Trials Results**

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## Executive summary

**Recent trials evidence indicates that the imminent proliferation of 4G mobile phone networks in the 2.50–2.69 GHz band is unlikely to affect the performance of S band civil marine navigation radar systems.**

Early theoretical studies of the potential for interference from 4G mobile phone networks (using signals conforming to the WiMax or LTE standards) to affect radar systems operating in S band, initially led to concerns that there could be a reduction in the quality of civil marine navigation radar services. However, later theoretical work using improved methods and mounting anecdotal evidence have indicated that there is only a low risk of direct impact.

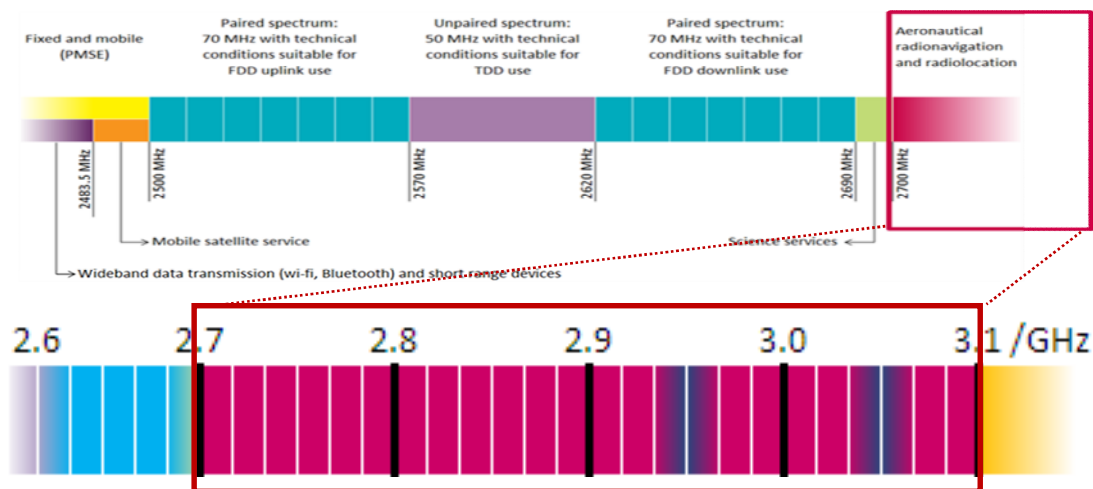
This report presents a high level description of a trial at the MOD Shoeburyness radar range that aimed to provide further real world evidence on the issue of interference. The trial used Ofcom's 4G high power base station simulator and confirmed that the latest version of Kelvin Hughes' Sharpeye radar and Sperry's Bridgemaster radar do not exhibit any signs of interference when illuminated by worst case 4G LTE signals in the 2.5 to 2.69GHz band. Other manufacturers will presumably need to convince their customers that their systems are also resilient to this interference, but the indications are that the technologies used by the civil marine navigation radar industry are not inherently susceptible to 4G interference from the 2.5 to 2.69GHz band.

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## 1 Introduction

The electromagnetic spectrum has become a significant resource for provision of wireless communication technologies. The next generation of mobile broadband services is termed 4G (following on from the mature 2G and 3G services already deployed throughout the world) and uses the LTE or WiMax standards to pass data between base stations and mobile equipment (phones, laptops etc). World and European agreements have opened up a 190MHz band of spectrum from 2.5GHz to 2.69GHz for 4G communications services<sup>1</sup>. The '2.6GHz' 4G band is adjacent to an important band used for radar which runs from 2.7 to 3.4GHz and is usually referred to as S band (or less commonly E/F band depending on the band convention being used). S band civil marine navigation radar systems can use the 2.9 to 3.1GHz portion of the band but are usually fixed at frequencies of 2.95 or 3.05GHz. The layout of the spectrum is shown in *Figure 1-1*.



*Figure 1-1: Representations of the S band frequency spectrum. The top plot shows light blue 4G LTE band sitting adjacent to the bottom of the radar band, shown in red. The bottom plot shows a close up of the radar band, again in red, with the major frequencies of marine radar systems, 2.95 and 3.05GHz shown as navy blue.*

Radar system manufacturers and Government bodies such as the MCA are increasingly under pressure to assure existing radar services in the presence of greater spectrum congestion in neighbouring bands. Ultimately a radar manufacturer may suffer from a loss of sales unless it can demonstrate that its systems are unaffected by this new constraint. Unfortunately, legacy radar receiver design has relied on the relative emptiness of the surrounding spectrum to deliver low cost technology solutions. Some designs could therefore be susceptible to interference from RF signals using frequencies that are outside of the radar band, which includes 2.6GHz 4G as shown in *Figure 1-2*. This out of band (OOB) interference can affect radar receivers in two ways: Firstly, if the interference is strong enough, the low noise amplifier can be overloaded leading to 'blocking' which is a loss of amplification of in-band signals. Secondly, at lower interference powers, the OOB interference will cause the receiver to operate non-linearly meaning that intermodulation products inside the band will rise. Both these effects can lead to an effective increase in the background noise in the radar receiver and a consequent loss of detection performance when the radar antenna is pointing in the direction of the interference source.

<sup>1</sup> 4G will also be deployed in other frequency bands but this report is only examining interference effects from the 2.6GHz band

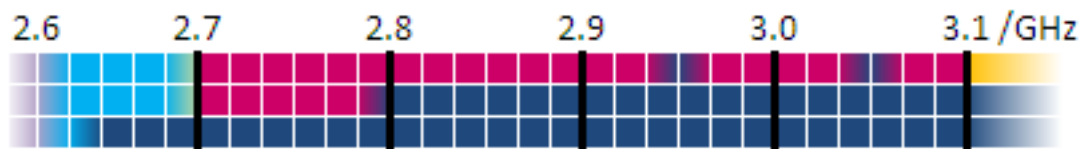


Figure 1-2: Three pictorial representations of S band spectrum based on the colours in Figure 1-1. The top row shows the simplified theoretical band with marine radar systems represented by thin navy blue bands. The second row represents how typical marine radar receivers are actually sensitive well outside of their frequency of operation. The third row represents a receiver with a wideband of sensitivity that extends past the 2.7GHz boundary and so would be affected by OOB interference from the 2.6GHz band.

Radar systems are designed to deal with some interference. The effect of interference from existing sources, such as that from other radar systems in S band, is limited by both the directionality of radar antennas and their low duty cycles (less than 0.1%) leaving plenty of clear intervening time and space to detect targets. However 4G base stations present a potentially more serious interference challenge as they will become a common feature across large areas of coastline all over the world and will transmit with a high duty cycle (perhaps transmitting up to 80% of the time). Therefore, if civil marine radar receivers were affected by interference from 4G, important real targets could be masked by interference over large sectors of radar coverage.

Marine radar navigation systems used on ships and coastal stations use frequencies centred around 2.95 and 3.05GHz and so there is a large frequency gap between the radar and the 4G edge at 2.69GHz of more than 250MHz. Previous studies sponsored by the MCA and Ofcom ([4], [5]) have indicated that, unlike S band air traffic control radar systems, many existing civil marine radar systems are inherently resistant to 4G interference due to this wide frequency separation. Also ships using S band civil marine radar systems near the coastlines of countries already fielding 2.6 GHz 4G networks (such as Sweden) have not reported decreased performance.

## 2 Shoeburyness Radar Trial

### 2.1 Overview

In June 2012, the MCA coordinated a new trial to examine the interference rejection performance of navigation radar systems using an external simulator system, provided by Ofcom, sited close to two radar systems. The simulator (see reference [1] for more details) was set up to transmit a worst case arrangement of the LTE channels at varying power levels to represent a 4G base station operating at peak duty cycle at varying ranges from the radar. This aimed to simulate severe interference conditions, enabling a number of worst case assumptions that had been studied theoretically previously, to be validated in real radar systems.

Methods to test two radar systems using this simulator were agreed between the trial stakeholders (MCA, Ofcom, QinetiQ Ltd, Kelvin Hughes and Sperry) [6].

### 2.2 Trial layout

The trial was carried out on 07 Jun 2012 at the MOD range at Shoeburyness which is run by QinetiQ Ltd. Radar manufacturers use this range for navigation radar type approval. Two of these manufacturers volunteered to provide their systems and engineers to support the trial. Kelvin Hughes offered the latest model of their SharpEye solid state radar system [2] which includes a receiver designed to exclude 2.6 GHz 4G interference. Sperry offered their latest Bridgemaster magnetron based system [3] which included no special modifications to filter out the 4G interference but was understood to have inherent protection due to its existing receiver design. These two radar systems represent the state of the art for S band navigation radar systems.

The Ofcom simulator was positioned about 70m due west of the radar antennas as shown in Figure 2. The simulator directional transmitter dish antenna was pointed directly at the radar antennas and measurements were made to calibrate the output power levels at the radar antenna.

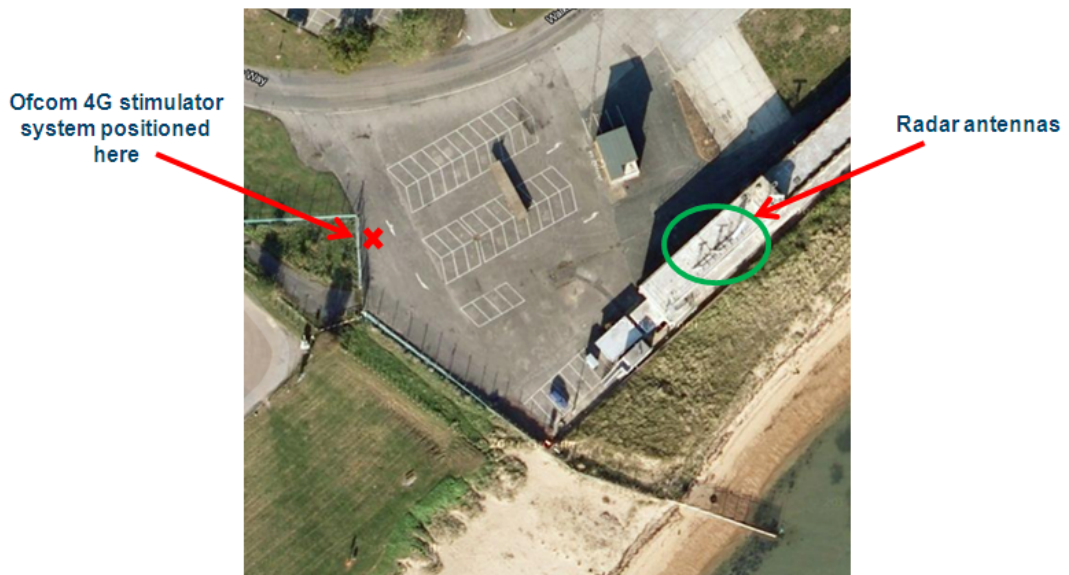


Figure 2-1: Trials set up with the Ofcom 4G simulator placed at around 70m from the radar antennas



Figure 2-2: The Ofcom simulator equipment set up for the trial of an ATC radar. The system is housed in the dark blue trailer next to the mast in the left hand photo and outputs through a horn antenna at the top of the thin mast. (Images courtesy of Ofcom).



Figure 2-3: Kelvin Hughes (left) and Sperry (right) S band radar antennas. (Images courtesy of the radar manufacturers)

## 2.3 Results and Observations

During setup and calibration the simulator was briefly set to provide LTE waveforms inside the radar band (rather than in the 2.6GHz band). The unprocessed raw data shown on the radar plan position indicator (PPI) screen (as shown in *Figure 2-4*) during this setup phase demonstrated obvious effects of interference in the beamwidth around the azimuth looking towards the simulator. The background level was clearly raised over the whole sector which would drastically reduce target detection.



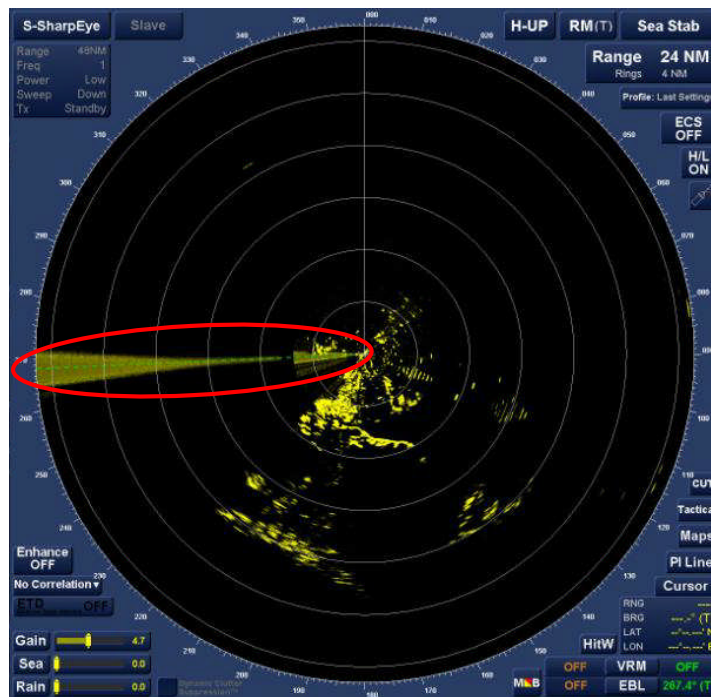


Figure 2-4: PPI showing in-band interference test. Obvious interference effects can be seen in the beamwidth in the direction of the simulator system (as highlighted by the red oval)

The radar test method was broadly the same for both radar systems [6]. Each radar was in turn switched on and then the Ofcom system was switched on and off in order to highlight any change in interference effects. The Ofcom transmission power was stepped up incrementally to simulate a full power 2.6GHz 4G base station at decreasing separation ranges.

At the highest power tested, the mean signal strength at the radar antenna was at 11dBm/m<sup>2</sup> which is equivalent to a fully populated, full power, 4G base station at less than 400m from the radar.

The two radar systems were assessed by their respective engineers using similar methods. The trials and their results were observed by a team from the MCA and Ofcom.

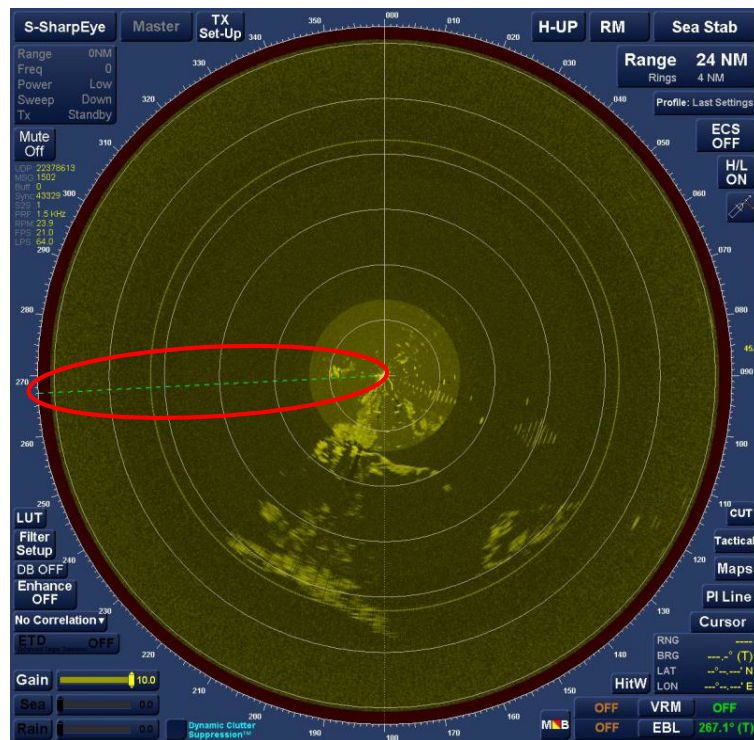


Figure 2-5: Kelvin Hughes SharpEye PPI set up to show background noise. No interference effects are visible in the direction of the 4G simulator highlighted by the red oval. The fixed range test target is visible just outside the 4<sup>th</sup> range ring from the centre.

The Kelvin Hughes radar was assessed during the trial through examination of an injected high power test target and the background PPI noise levels. The built-in interference suppression and other signal processing algorithms were switched off to ensure that any interference would be visible on the PPI screen. The absence of any degradation of the injected target also indicated the absence of degradation to the receiver through saturation. Digital radar data sets were also recorded for offline analysis. The system was tested over several frequency channels and in some channels radar to radar interference was clearly visible from ships in the vicinity. However no interference was visible in the direction of the 4G transmitter (as shown on the PPI in Figure 2-5) and there was no discernable change visible on the PPI when the 4G was switched on and off. Off-line analysis carried out by the manufacturer after the trial gave further confirmation that there was no increase in background receiver noise due to the 4G. The results are detailed in a trials report provided to the MCA by Kelvin Hughes [7].



Figure 2-6: Sperry Bridgemaster PPI setup to show background receiver noise. No increase in noise is visible in the direction of the 4G simulator (shown by the red oval)

The Sperry radar was also set up so that the background radar noise was visible on the PPI. The PPI showed no extra noise when the 4G signal was switched on (as shown in Figure 2-6). Efforts were also made to inject a small target into the receiver for analysis of interference effects on target detection. The small target analysis was not wholly conclusive due to problems getting a consistent trigger during the test set up. However, overall indications were that there was no interference impact on target detection. Sperry has provided a short trial report to the MCA that summarises their conclusions from the trial [8].

### 3 Conclusions

Neither radar system showed any observable increase of background noise levels despite very high 4G powers representing a worst case channel transmission arrangement. This indicates that target detection and therefore navigation service is unlikely to be unaffected by 4G network signals operating within the 2.6 GHz band.

It must be concluded that neither radar system will be affected by realistic levels of 4G interference from future mobile phone networks operating in the 2.6 GHz band. The systems tested represent two very different technology solutions used for civil marine radars. The majority of other navigation radar manufacturers will be based on magnetron technology and should be broadly similar to the Sperry system although it is possible that more systems will move over to solid state technology in the future. The results from this trial for these two radars should be applicable to other manufacturer's products as well.

#### 3.1 Remaining risks and issues

- The Kelvin and Hughes solid state radar receiver used in this trial is the current commercially available receiver which has been upgraded to limit out of band interference from below 2.7 GHz and above 3.4GHz to meet the challenge of high 4G signal strengths. There remains a question mark over whether older solid state radar systems not fitted with this filtering arrangement will be affected by realistic 4G power levels [5]. Fortunately this is a new technology and so the total number of systems affected is likely to be low and there is the potential for developing a suitable upgrade kit.
- Although the systems tested are likely to be representative of the state of the art, other radar systems from other manufacturers have not been tested. It is possible that other radar systems might still be affected by 4G.
- There remains the potential for an indirect increase in interference due to the frequency movements of air traffic control (ATC) S band radar systems that have been modified to deal with 4G. This could lead to some increased radar to radar interference for marine radars. However there are relatively few ATC radar systems near to the coast, radar to radar interference is less of a problem for marine radar systems (relative to 4G) and any impact could be managed by further modification to ATC frequency channel usage.
- These tests only addressed LTE transmissions from the 2.6 GHz band. They did not address potential transmission sources either within other future 4G bands 2.7 – 2.9GHz or 3.4 – 3.6 GHz. Further work would be needed in this area to establish limits of interference.

#### 3.2 Acknowledgements

The author thanks the teams from Ofcom, Kelvin Hughes, Sperry, and QinetiQ Ltd for their contributions to this important trial.

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## **Glossary**

### **S band**

The region of the microwave electromagnetic spectrum between 2 and 4 GHz

## **List of abbreviations**

|       |  |
|-------|--|
| 4G    | Fourth generation mobile telephony                       |
| ATC   | Air traffic control                                      |
| Dstl  | Defence Science and Technology Laboratory                |
| GHz   | Gigahertz  |
| LTE   | Long term evolution                                      |
| MCA   | Maritime Coastguard Agency                               |
| OOB   | Out of band  |
| PPI   | Plan position indicator (the standard radar screen view) |
| WiMax | Worldwide Interoperability for Microwave Access          |

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## Report documentation page

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