THE GEMNET PROJECT - GNSS THREAT QUANTIFICATION IN THE UNITED KINGDOM

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INTRODUCTION

• GEMNet was a collaborative project between Ordnance Survey the Satellite Applications Catapult.
• The Catapult is a not-for-profit, independent technology and innovation centre that connects businesses with the UK’s research and academic communities.
• There are many catapults for different areas of science, all of them overseen by Innovate UK which is the UK Government’s agency for innovation.
AREAS THAT COULD BE IMPACTED BY GNSS VULNERABILITY
Monitor the GNSS radio spectrum at a number of UK locations in order to quantify the occurrence of jammers in operational environments;

Capture “RF signatures” of jammers (both to understand the characteristics of threats, and to support aim 4 below);

Assess the impact of jammers and other interference on operational GNSS receivers;

Assess the impact that closer or more powerful jammers could have on GNSS receivers, i.e. different operational environments.
## DATA OUTPUTS

<table>
<thead>
<tr>
<th>Device</th>
<th>Outputs to GEMNet Database</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sensor-1</strong></td>
<td>12-bit In-phase (I) and Quadrature (Q) samples from the A/D Converter, Jammer-to-Noise (J/N) ratio estimation, Received Signal Strength Indicator (RSSI), Plots of the signal spectrum, spectrogram and histogram.</td>
</tr>
<tr>
<td><strong>Sensor-2</strong></td>
<td>Interference event reports, Interference classification, Normalised signal power, Plots of signal spectrum and spectrogram.</td>
</tr>
<tr>
<td><strong>Survey-Grade Receiver</strong></td>
<td>Carrier-phase positioning solution (L1/L2), Number of visible satellites, Cycle Slips, Geometric Dilution of Precision (GDOP).</td>
</tr>
<tr>
<td><strong>Mass-Market Receiver</strong></td>
<td>Code-phase positioning solution (L1 only), Number of visible satellites, Automatic Gain Control (AGC) voltage level, Jamming strength indicator.</td>
</tr>
</tbody>
</table>
## SENSOR 1 RESULTS

<table>
<thead>
<tr>
<th>Event Statistics</th>
<th>Impact on normal Receiver output parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average Change (compared to 90 seconds before the event)</td>
</tr>
<tr>
<td></td>
<td>C/N$_0$ [dB-Hz]</td>
</tr>
<tr>
<td></td>
<td>Mass-market Rx</td>
</tr>
<tr>
<td>≥5</td>
<td>10 [2 %]</td>
</tr>
<tr>
<td>2 to 5</td>
<td>169 [29 %]</td>
</tr>
<tr>
<td>1.76 to 2</td>
<td>406 [69 %]</td>
</tr>
<tr>
<td>Total</td>
<td>585</td>
</tr>
</tbody>
</table>
SENSOR 2 RESULTS

Event Duration

- More than 15s (43%)
- 5s to 15s (54%)
- Less than 5s (3%)

Event Priority

- Very Low (88%)
- Medium (3%)
- Low (2%)
- High (8%)

Graphs showing data distributions and results.
IMPACT OF HIGHER POWER INTERFERENCE ON GNSS RECEIVERS

RFIC Front-end
FPGA
(Upsampler)
USB Controller IC
RAM
Voltage Regulator
USB Microcontroller
(RF Tuning)
Sensor

RF GPS Constellation Simulator

Static Position

Captured I/Q Samples

GEMNet Dataset-1

Mass-Market Rx
Survey-Grade Rx

Spectrum Analyser

Channel

Rx
Tx

RF Splitter
RF Combiner

RF Combiner

Voltage Regulator

Software Tunable
- Transmit Gain (J/N Ratio)
- Centre Frequency
- Bandwidth
- Sampling Rate

Microcontroller (RF Tuning)

Microcontroller

USB

Microcontroller IC

USB Samples

GEMNet Dataset-1

Ordnance Survey
CONCLUSIONS

• Clear evidence of GNSS interference was collected
• Interference observed was of very low power
• Very occasional higher interference power
• Much of interference characteristic of deliberate low power jamming
• No discernible degradation in GNSS receivers
• HMI is possible
• Should operational jammers with 1000 times higher power than those operating today become common, then both mass market and survey grade GNSS receivers could often be compromised
• CNI sites may need better protection
RECOMMENDATIONS

• Strengthen and enforce legislation
• Standardise GNSS threat recording data parameters nationally and internationally, so that threat characteristics can be captured by platforms and detectors provided by multiple commercial vendors.
• Assess, and create a database of, the impact of identified interference threats on commercially available GNSS receivers

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