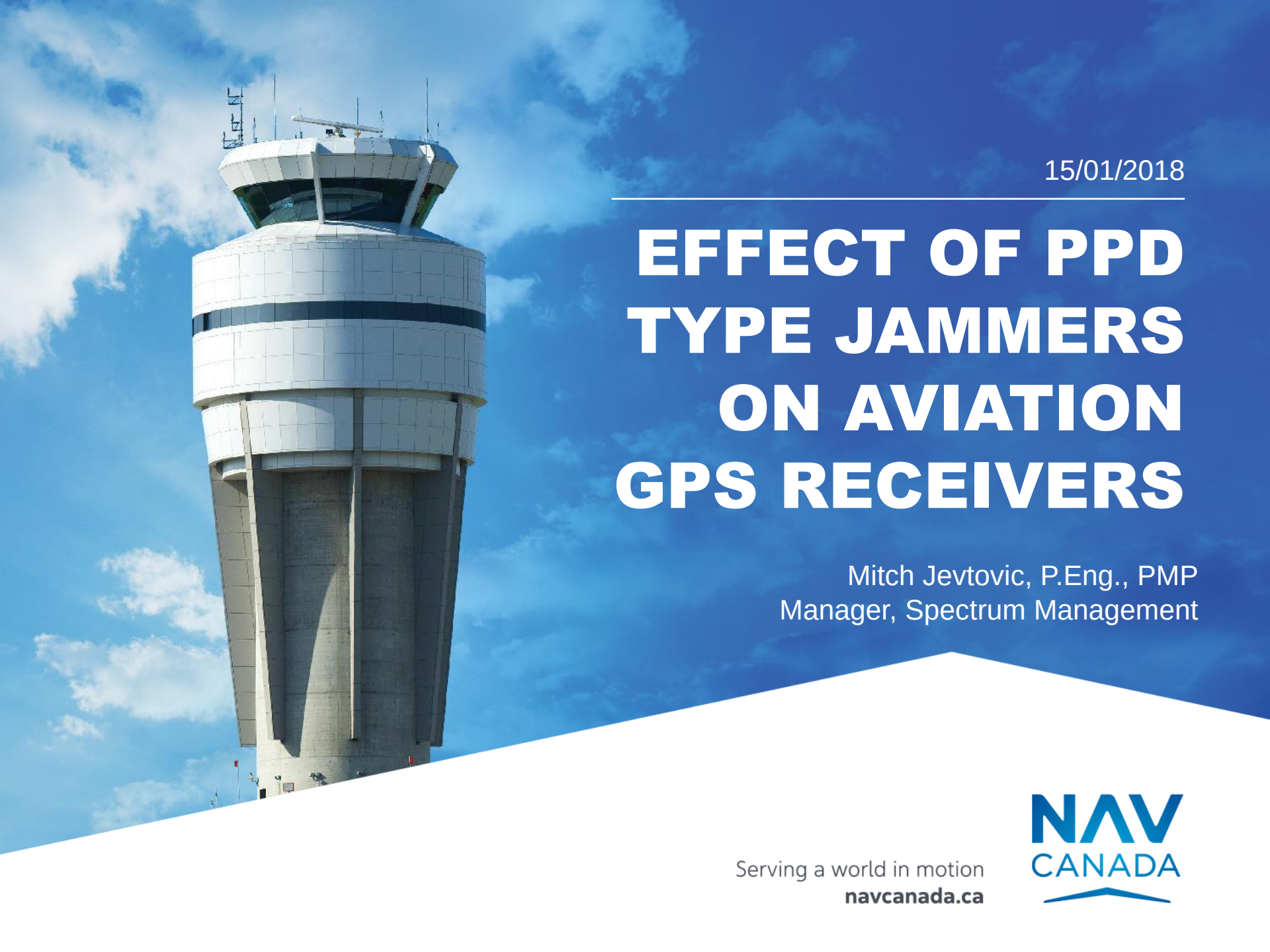

15/01/2018

EFFECT OF PPD TYPE JAMMERS ON AVIATION GPS RECEIVERS

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Manager, Spectrum Management

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NAV CANADA

CONTENT OF THE PRESENTATION

1) Ground testing: effect of GPS jammers on some GPS receivers used by NAV CANADA
2) Flight testing: effect of a low power GPS jammer on airborne GPS receivers
3) Summary from the Ground and the Flight tests
4) Long term monitoring: presence and effect of PPD type jammers in the vicinity of a busy airport
5) Way forward: what should an ANS provider do about GPS jammers

1) GROUND TESTING

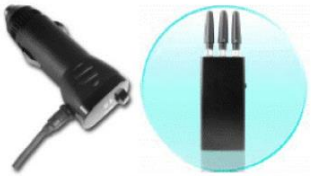
GPS Jammers

- PPD jammers: miliwatts to hundreds of miliwatts to watts; illegal

$110 Ebay

$335 Ebay

$92 Ebay

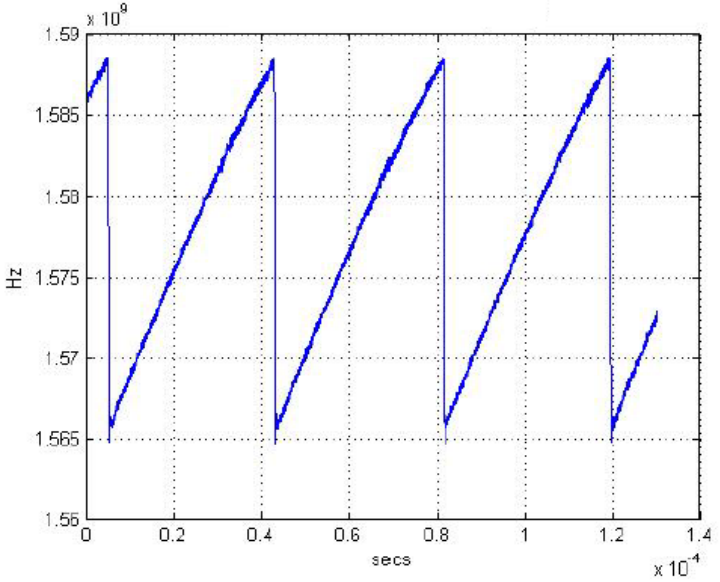


$40 GPS&GSM
www.chinavasion.com

$55 Ebay

$83 GPS&GSM
www.Tayx.co.uk

$152 Ebay

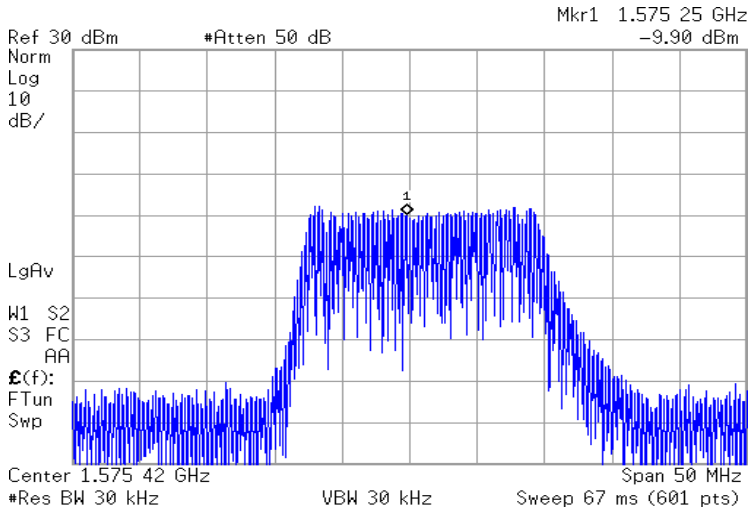


- Not considered:
  - Military – high power jammers
  - Intentional jamming

GPS Receivers Under Test

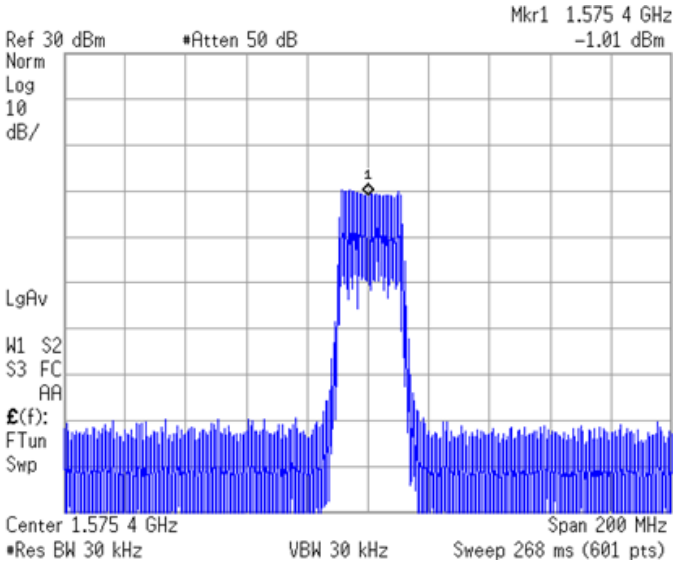
1) Ashtech SkyNav GG12W aircraft GPS receiver (TSO-C145/146 compliant);
2) Squid - Vehicle Location ADS-B transponder (GPS receiver built-in), manufactured by ERA (used by Nav Canada for ground vehicle tracking);
3) Hemisphere DGPS Receiver (used by Nav Canada to verify the exact location of the MLAT Sensors/Remote Units).

GPS Jammer 1 (FF-15)



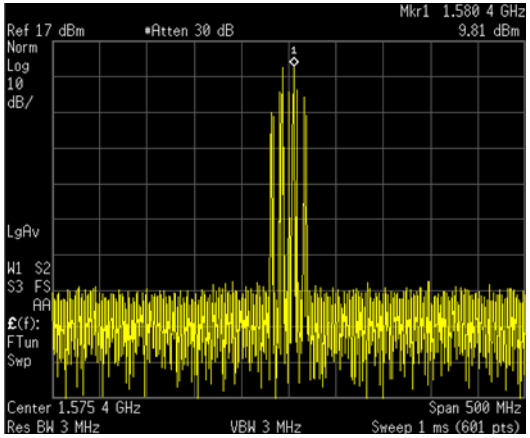
- Frequency: CDMA, GSM, DCS, 3G and GPS L1
- Jamming Range: up to 15 meters radius
- Output Power: Each band 300mW, total power is 1500mW

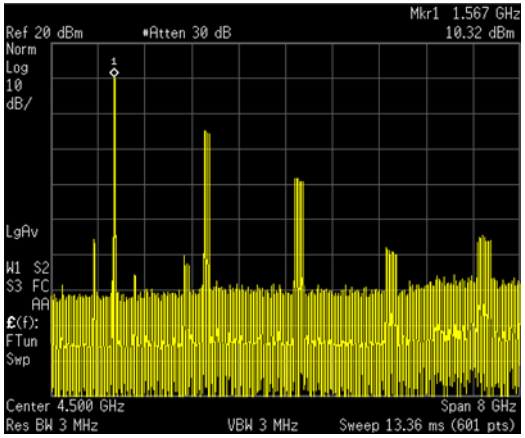
GPS Jammer 2 (GJ6)



- Frequency: GPS L1, L2 and L5
- Jamming Range: average 10 m radius
- Output Power: Each band 300 mW, total power is 450 mW

GPS Jammer 3 (L1/L2 Jammer)

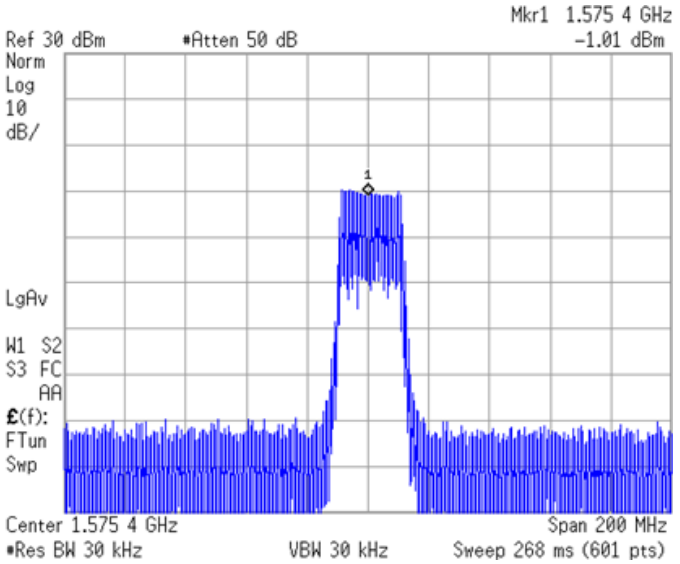




- Frequency: 1217-1237MHz / 1565-1575 MHz
- Jamming Range: radius 5-10 meters in car (with antenna)

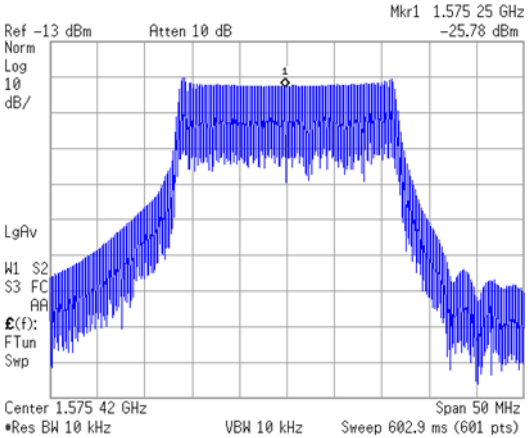
› Output Power: not specified, but limited with attenuators to 10 mW during test

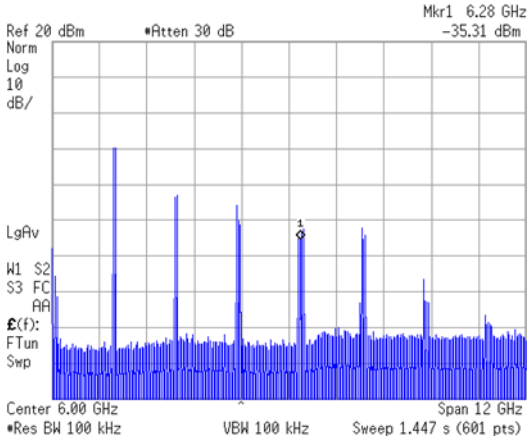
GPS Jammer 4 (GP4000)



- Frequency: 1450-1600 MHz
- Jamming Range: average 5 m radius
- Output Power: “7 dB” (integrated antenna, hard to estimate actual power)

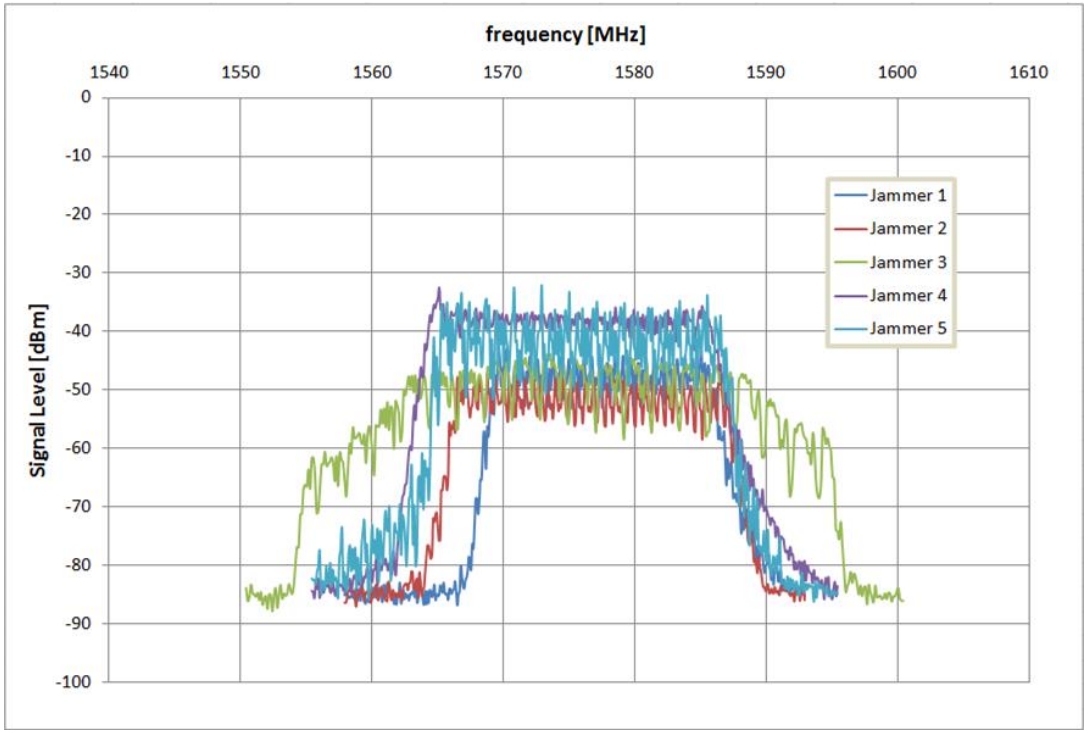
GPS Jammer 5 (GP5000)





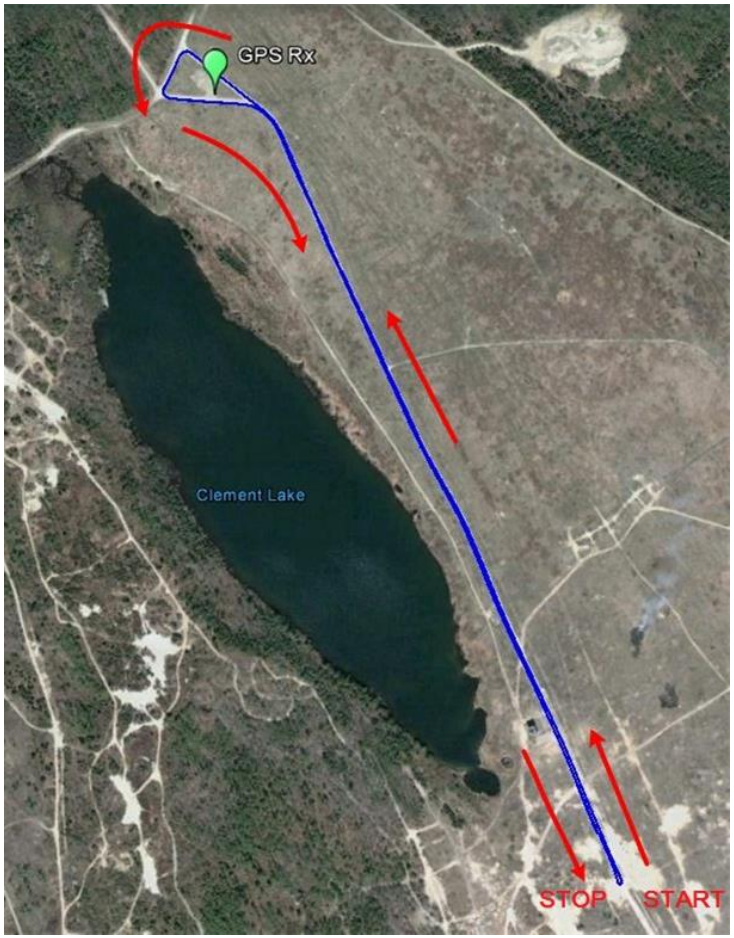
- Frequency: GPS L1
- Jamming Range: average 5 m radius
- Output Power: 200 mW

Comparison of Jammers' Spectral Signatures



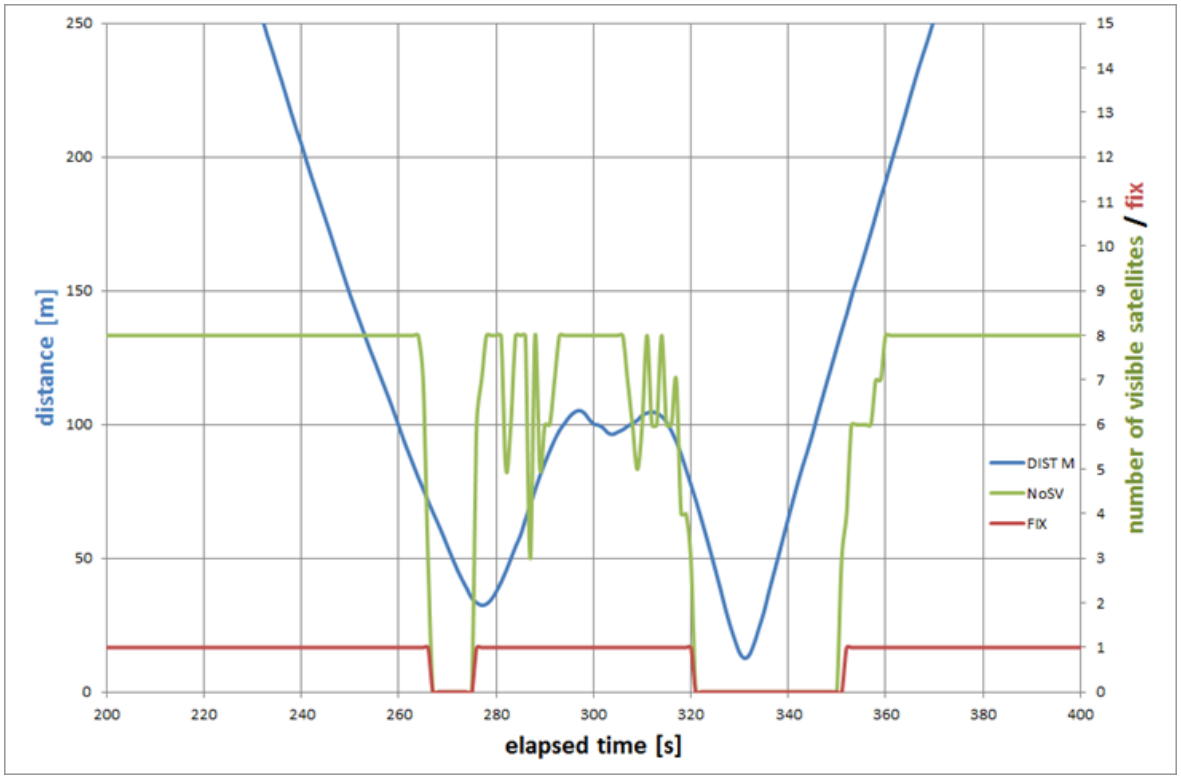
- Power was limited to 10 mW with attenuators (except for Jammer 4)
- Antennas for jammers 1, 2, 3 and 5 were on the roof of a vehicle
- Entire jammer 4 was on the roof of a vehicle

Relative Position of Jammers vs. Receivers



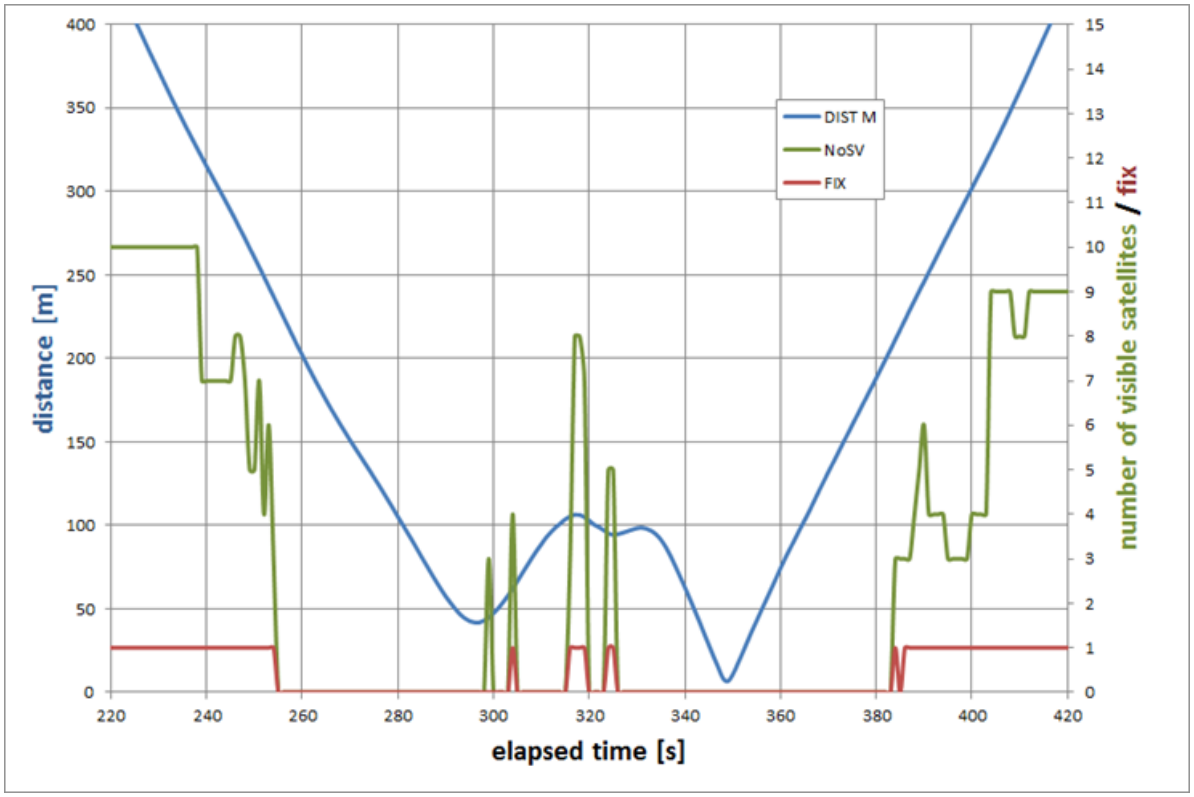
- The vehicle with the jammers was moving towards the receivers while logging time and location – relative distance to receivers calculated
- The receivers were stationary, logging time, Number of Satellites Visible (NoSV) (Range 0 to 12) and Fix/No Fix (0 = No fix/Invalid, 1 = Standard GPS, 2 = Differential GPS)

Same receiver is affected moderately by one jammer …



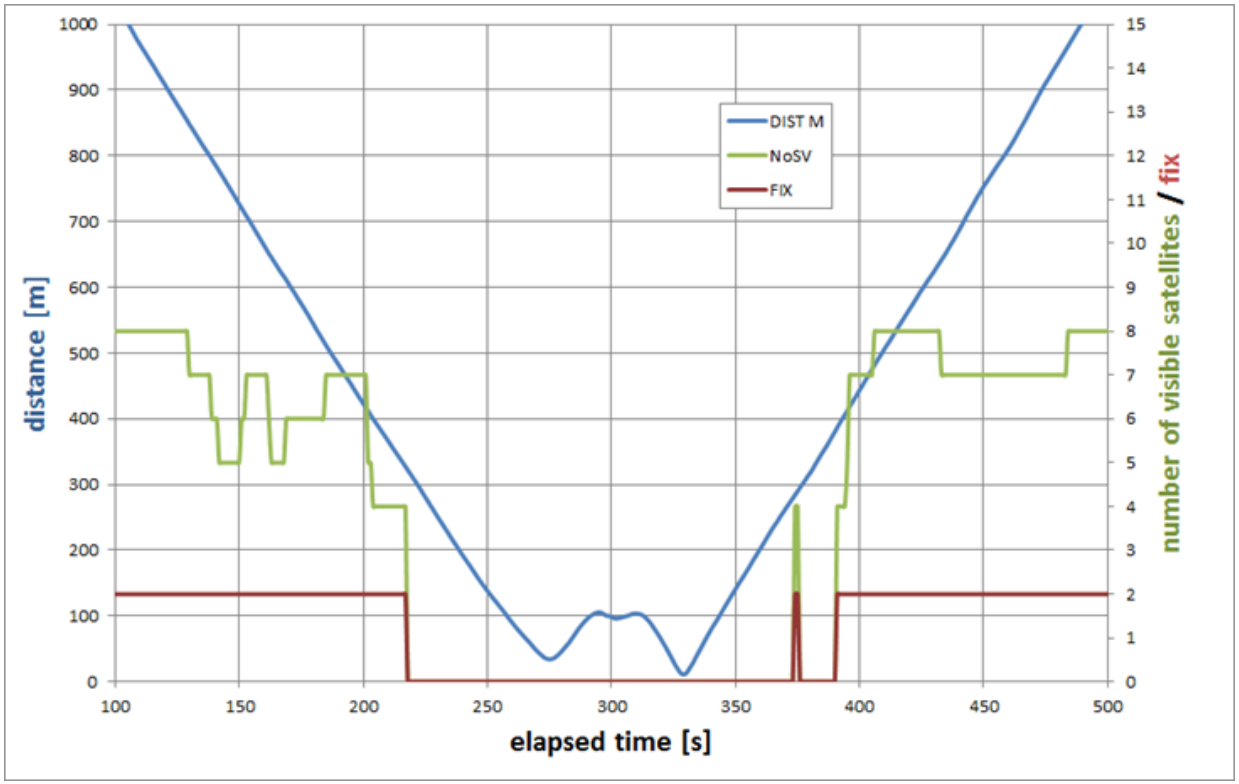
Effect of moving Jammer 2 on Squid/ERA receiver

… but quite strongly by another



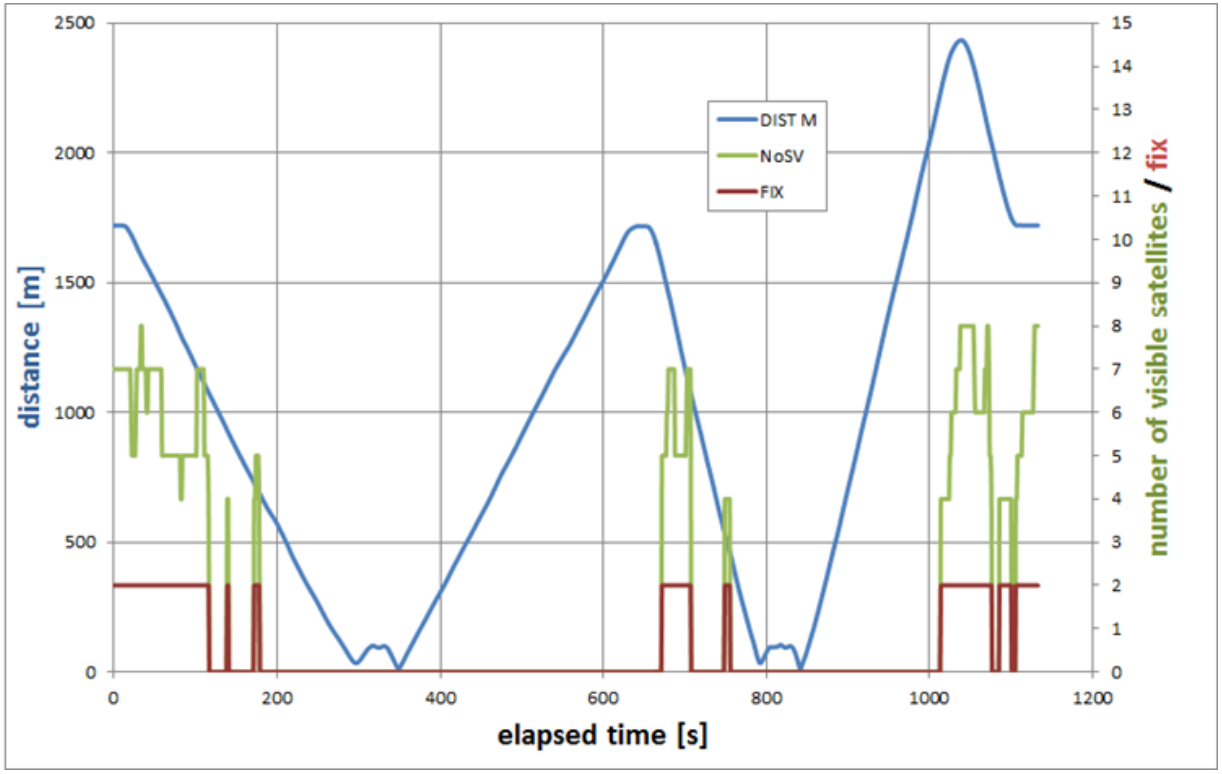
Effect of moving Jammer 4 on Squid/ERA receiver

Same jammer affects different receivers differently



Effect of moving Jammer 2 on Hemisphere DGPS receiver

Strongest jamming effect combination



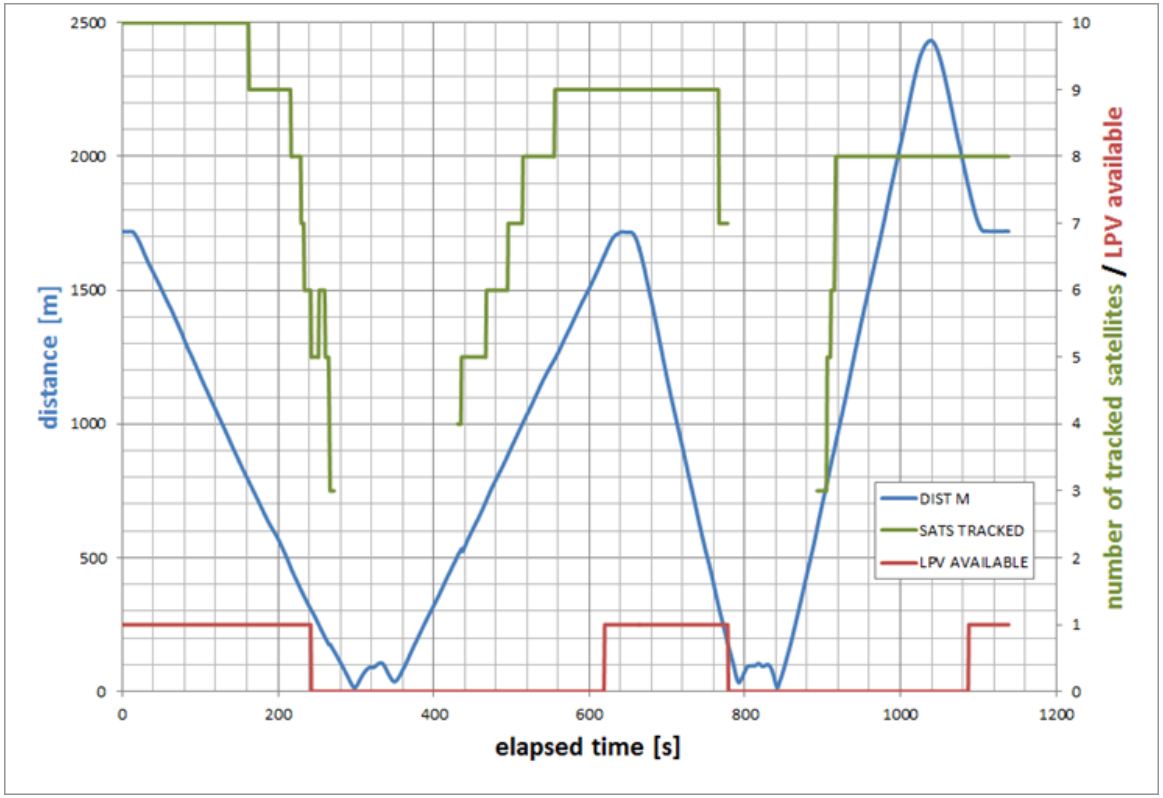
Effect of moving Jammer 4 on Hemisphere DGPS receiver

Ashtech SkyNav – the only aircraft GPS receiver tested

- Compliance:
  - RTCA DO-178B Level ‘B’ ((Software Considerations in Airborne Systems and Equipment Certification)
  - RTCA DO-208 (MOPS for Airborne Supplemental Navigation Equipment Using GPS)
  - RTCA DO-229D (MOPS for GPS/WAAS Airborne Equipment)

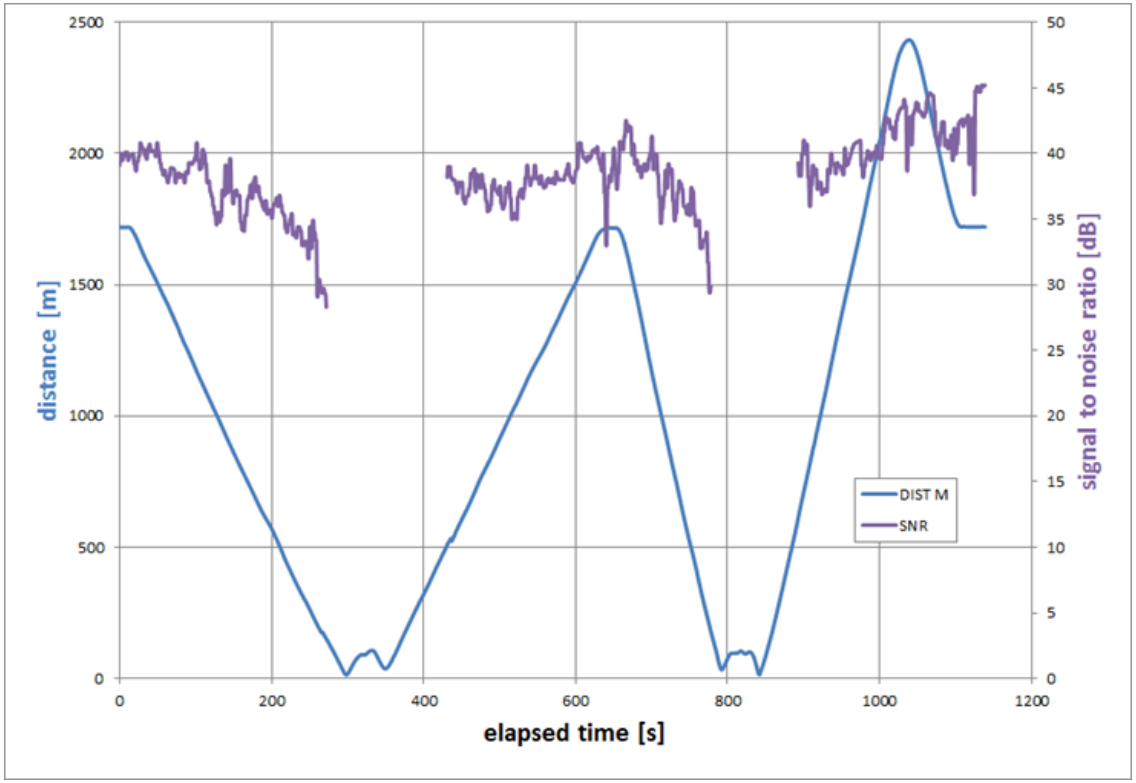
- “Features extensive anti-jam capabilities”:
  - RTCA DO-208 and DO-229D (WAAS MOPS) – meets CWI (continuous Wave Interference) specification
  - RE-ACQUISITION < 3 sec if blockage is less than 10 sec, <5 sec if blockage is 10–60 sec

Tested aircraft GPS receiver also found vulnerable



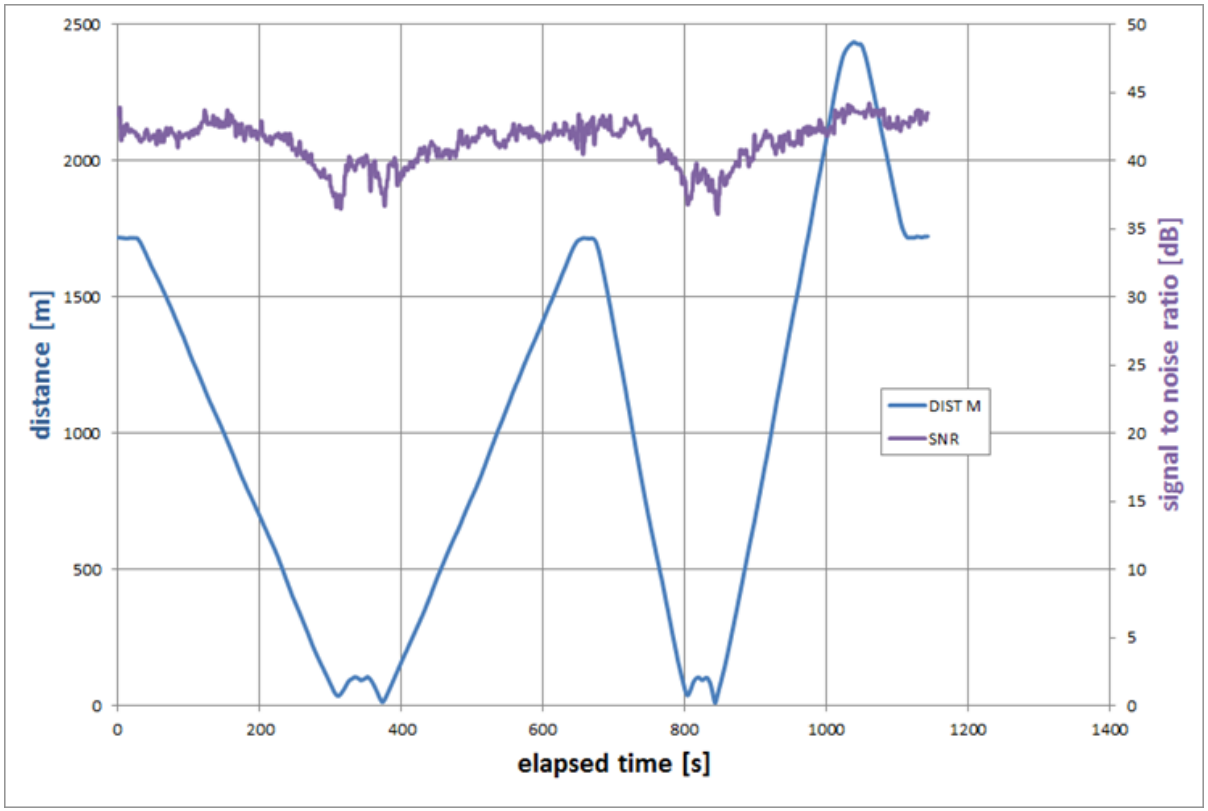
Effect of moving Jammer 4 on Ashtech aircraft GPS receiver – the longest loss of the LPV

Aircraft GPS receiver's S/N ratio during loss of fix



Effect of moving Jammer 4 on Ashtech aircraft GPS receiver's S/N ratio

Other jammers barely affect Aircraft GPS receiver



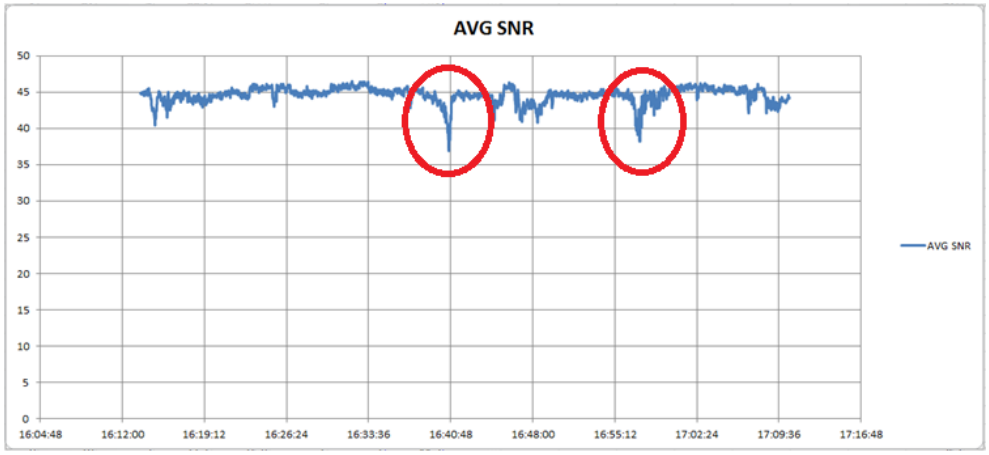
Effect of moving Jammer 3 on Ashtech aircraft GPS receiver's S/N ratio

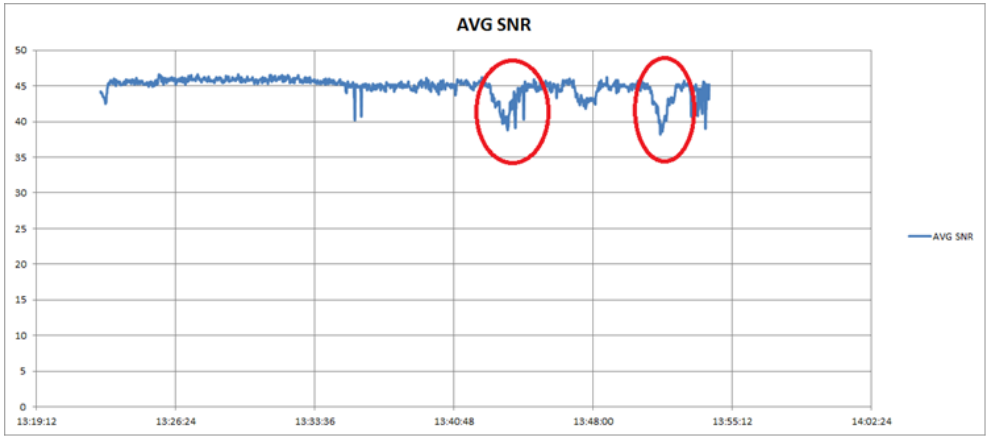
2) FLIGHT TESTING

NAV CANADA Flight Inspection Fleet

- 10 mW L1 chirp signal jammer on the ground; two GPS receivers in each A/C: cockpit and test receiver
- Bombardier DHC8 flew at 3500 feet ASL outbound and 3000 feet inbound directly over the jammer
- Bombardier CRJ2 flew 1500 feet both directions with 900 m offset

Minimum jamming effect on airborne GPS receivers





- In both cases test receivers logged minor drop in the S/N ratio
- No observable effects on the cockpit receivers

3) CONCLUSIONS FROM TESTING

- Exposure to GPS jamming by PPD type jammers is hard to predict:
  - Manufacturers' specifications re power and range cannot be trusted
  - Same receiver is affected by the different jammers differently
  - Same jammer affects different receivers differently
- Receivers on the ground are far more susceptible than airborne receivers:
  - Antenna radiation patterns, shielding by fuselage
  - Alternative ways of landing available where jammers are likely to be present
- Operations on the ground are at a higher risk:
  - Tracking systems for airport ground vehicles "drifting"
  - DGPS, GBAS
- Beware of stationary high-power jammers:

- $849 at www.jammer-store.com
- GSM, CDMA, 3G, 4G Wimax, 4G LTE, WIFI, GPS etc.
- 60 W
- Range: 60 m

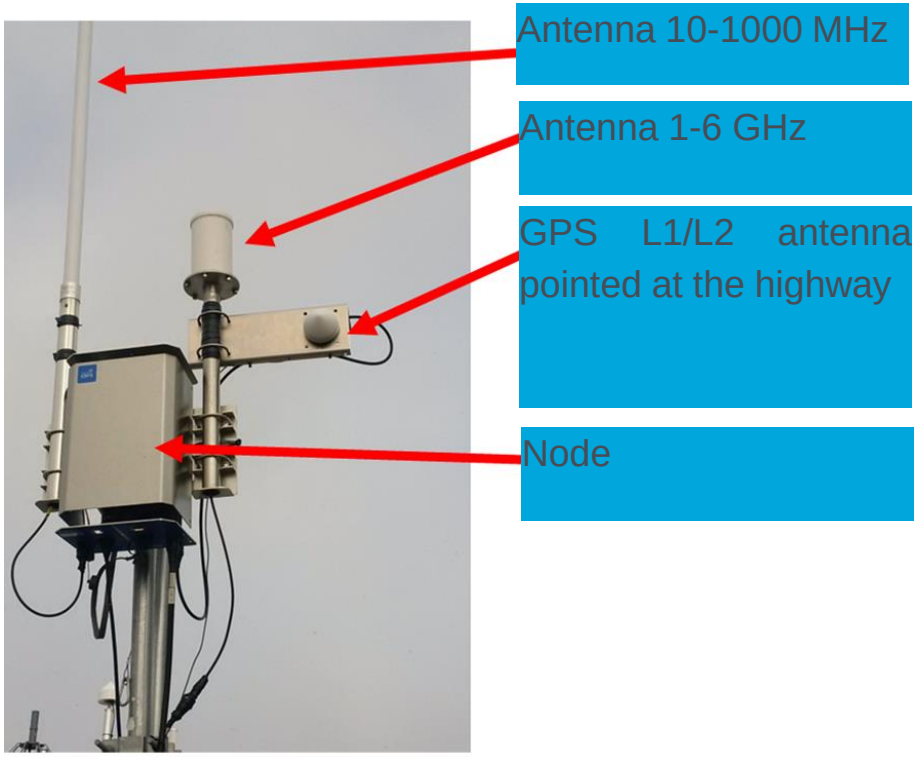
4) LONG TERM MONITORING

Objectives

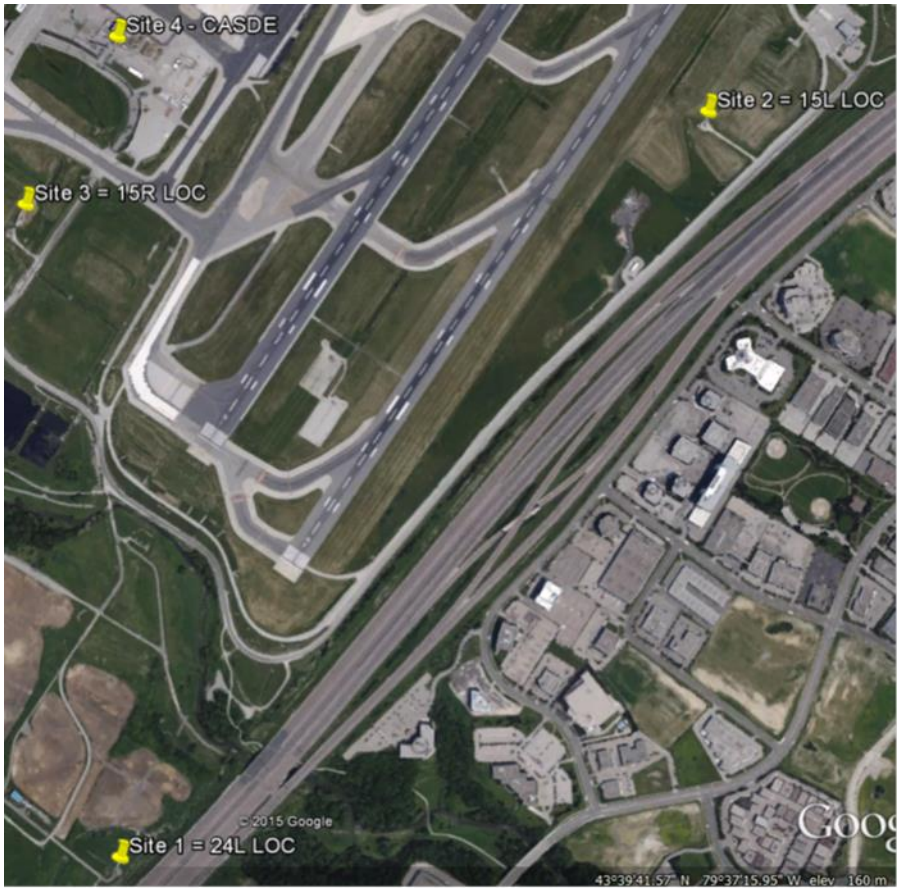
- Set up RF spectrum monitoring equipment capable of IDM of GPS jammers
- Learn about capabilities of the equipment
- Collect data and understand prevalence of jammers at the location (busy airport)
- Understand repercussions to aeronautical operation
- Propose operational workarounds, if any are deemed beneficial

Equipment

- Intelligent Networkable Spectrum Monitoring Node10MHz to 6GHz
- Embedded Linux System, Storage Limit: 512GB SSD



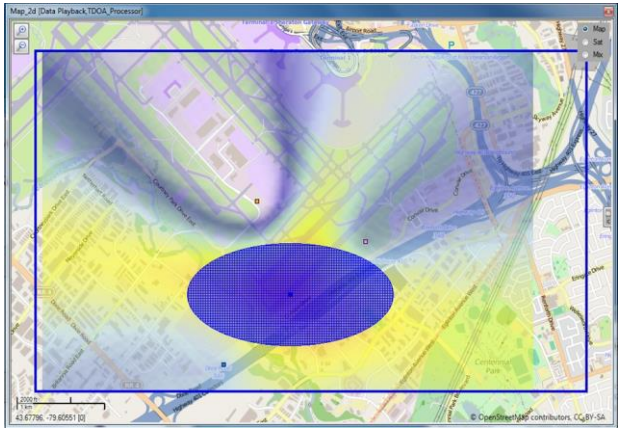
Network of 4 Nodes, storing and partially processing data

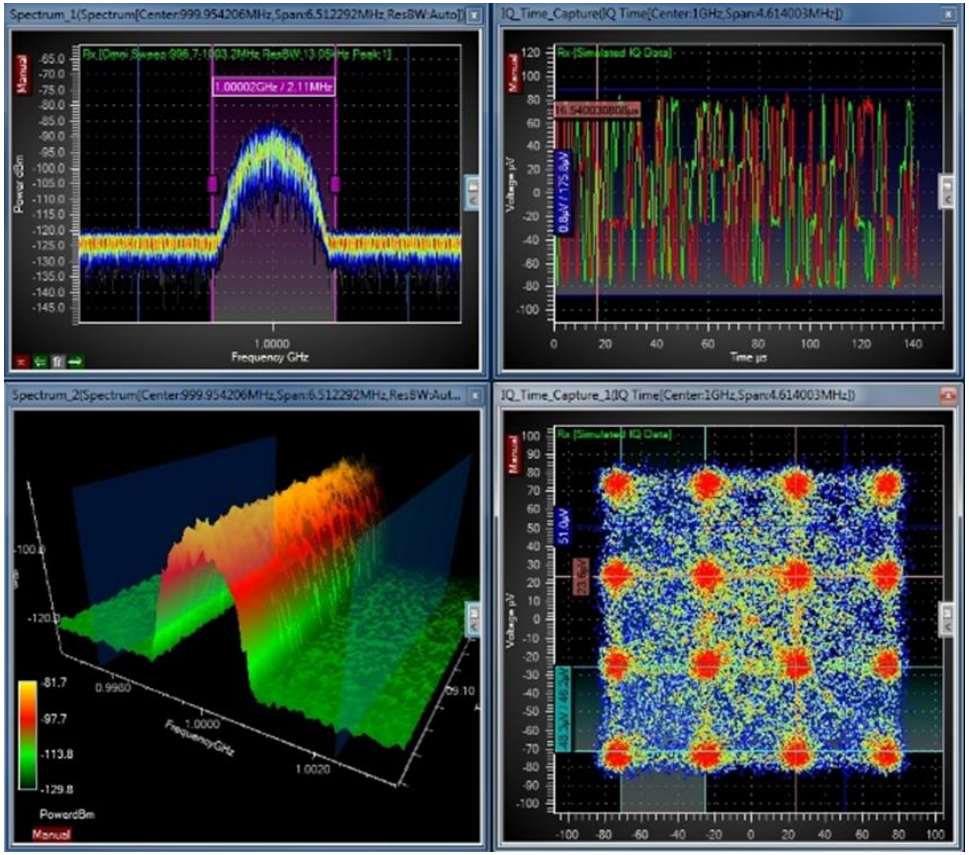


1) 24L LOC (50 m)
2) 15L LOC (250 m)
3) 15R LOC (1200 m)
4) CASDE (1250 m)

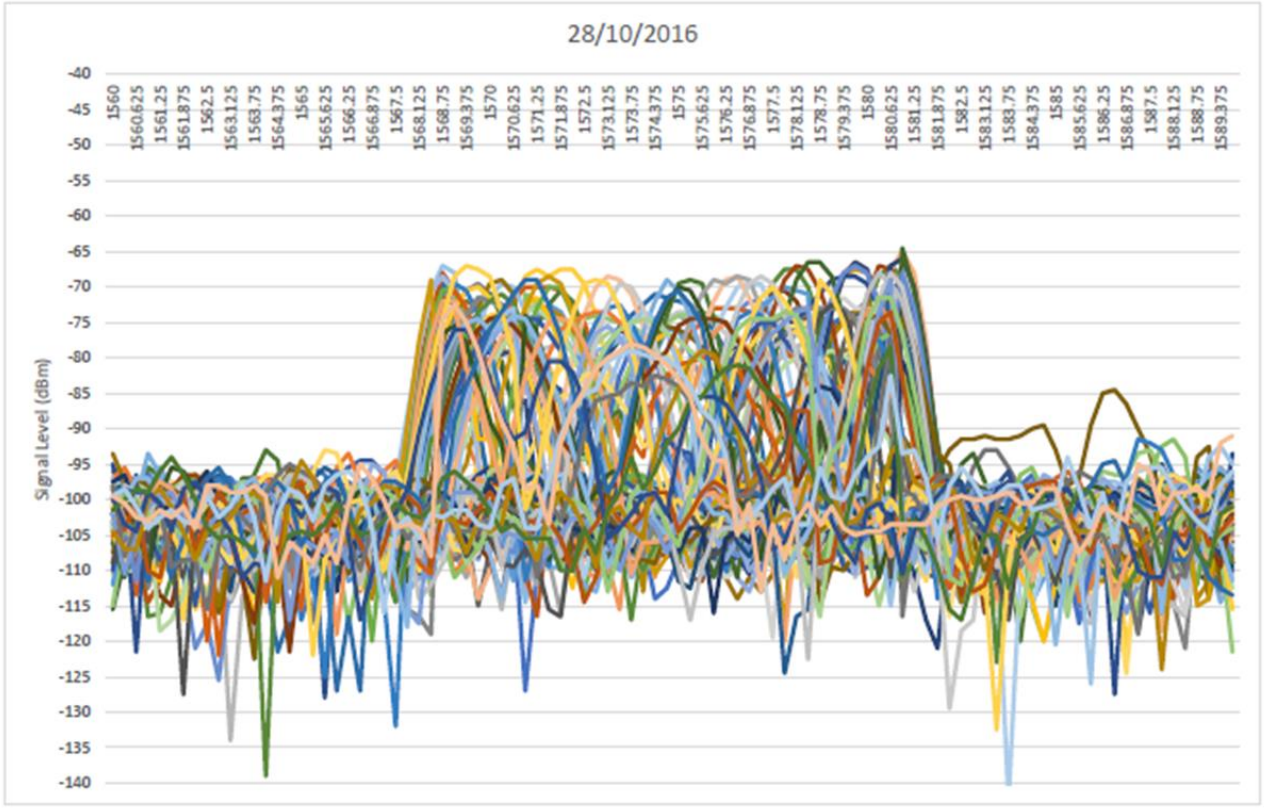
Processing software at remote location

- Real-time spectrum monitoring
- Monitors multiple nodes simultaneously
- TDOA/AOA Geo-Location

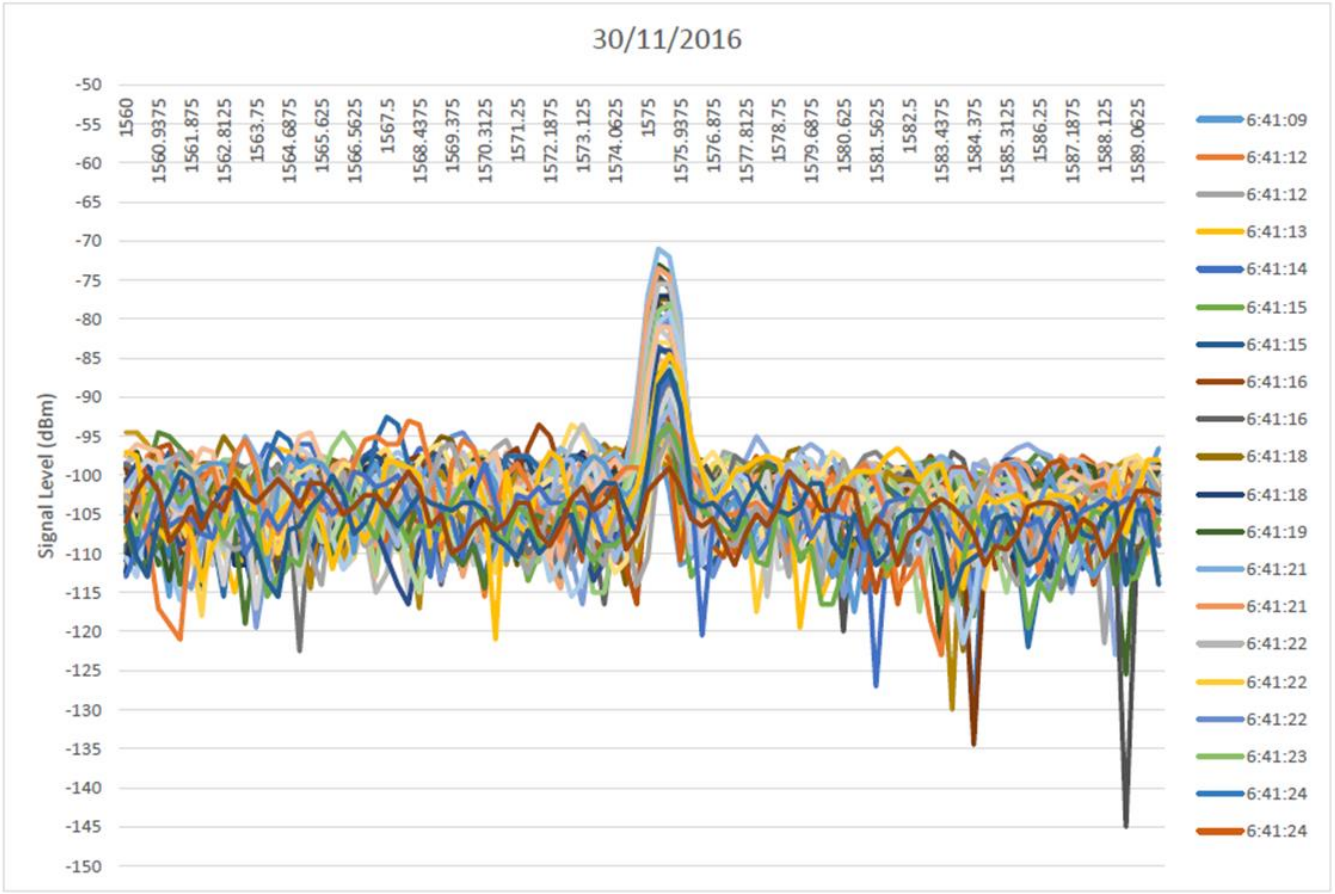




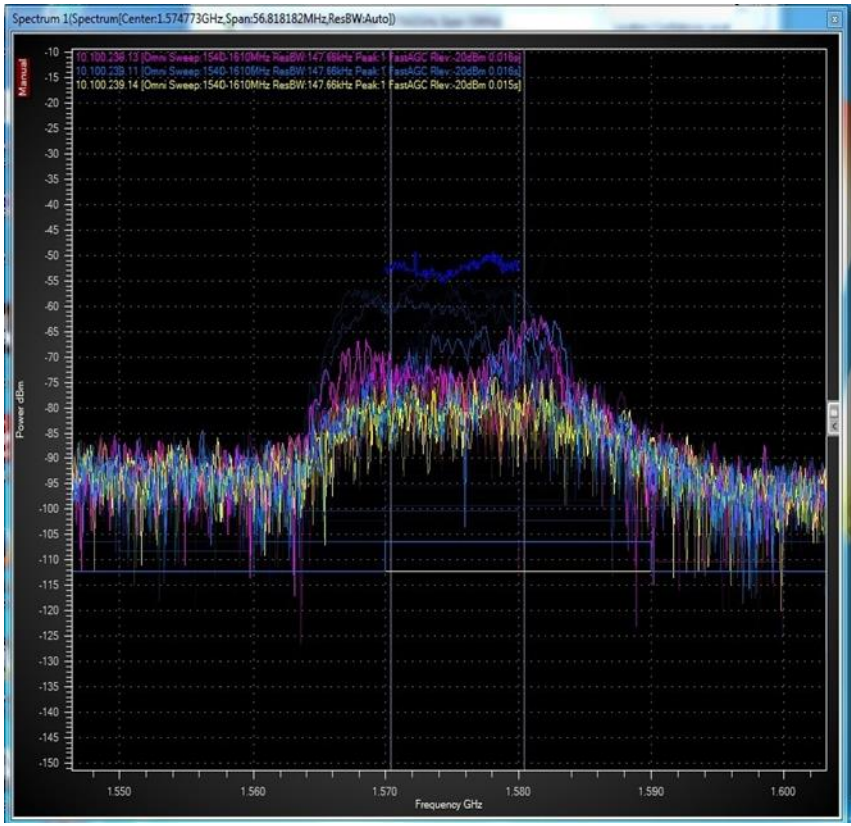
Some detected jammers

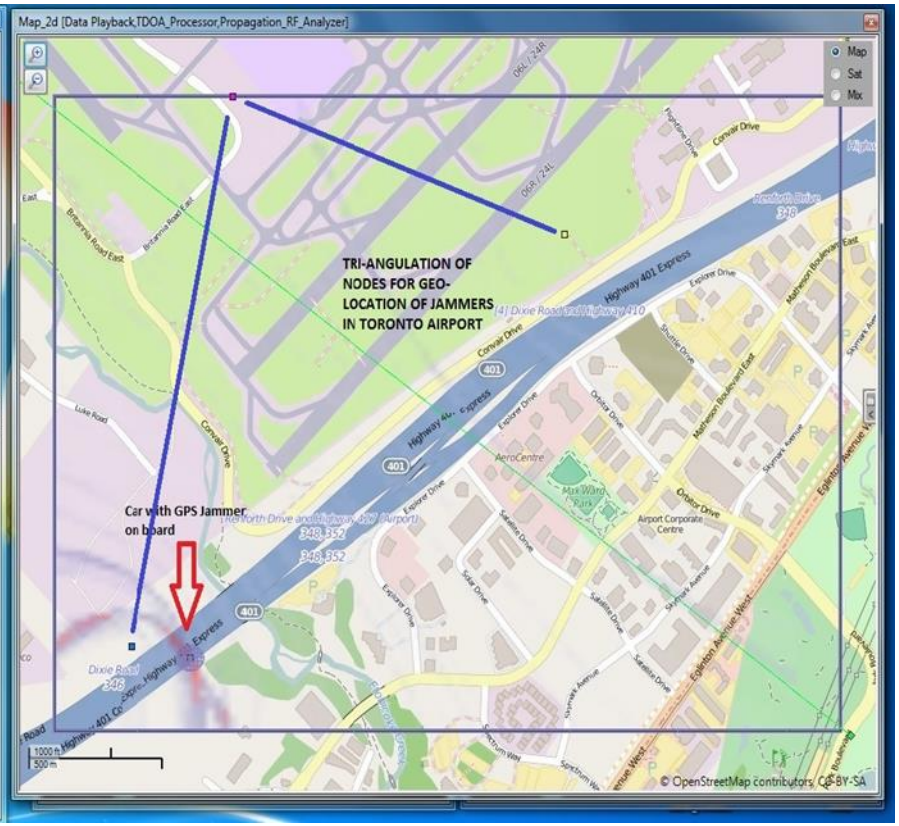


Some detected jammers

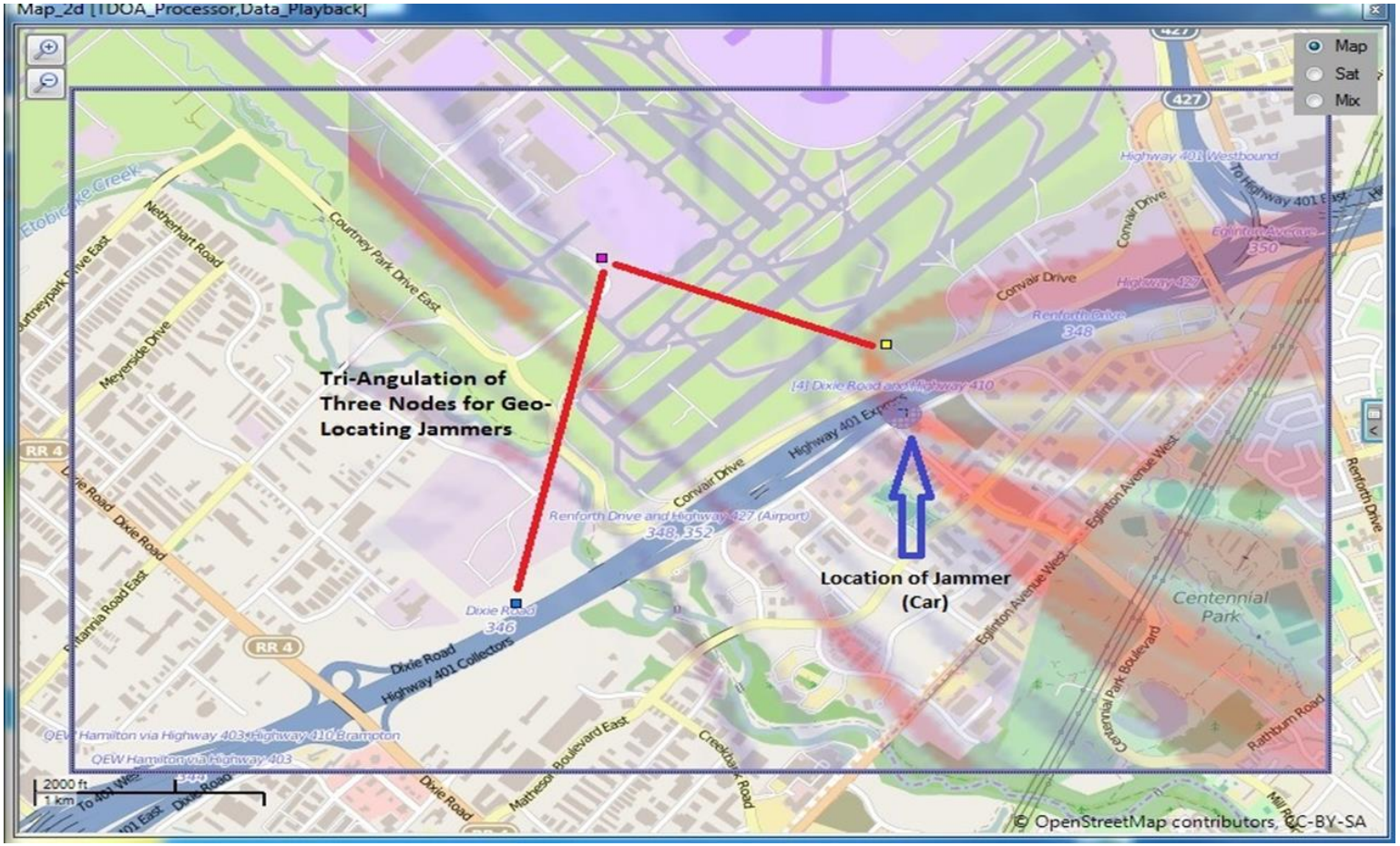


Some geolocated jammers





Some geolocated jammers



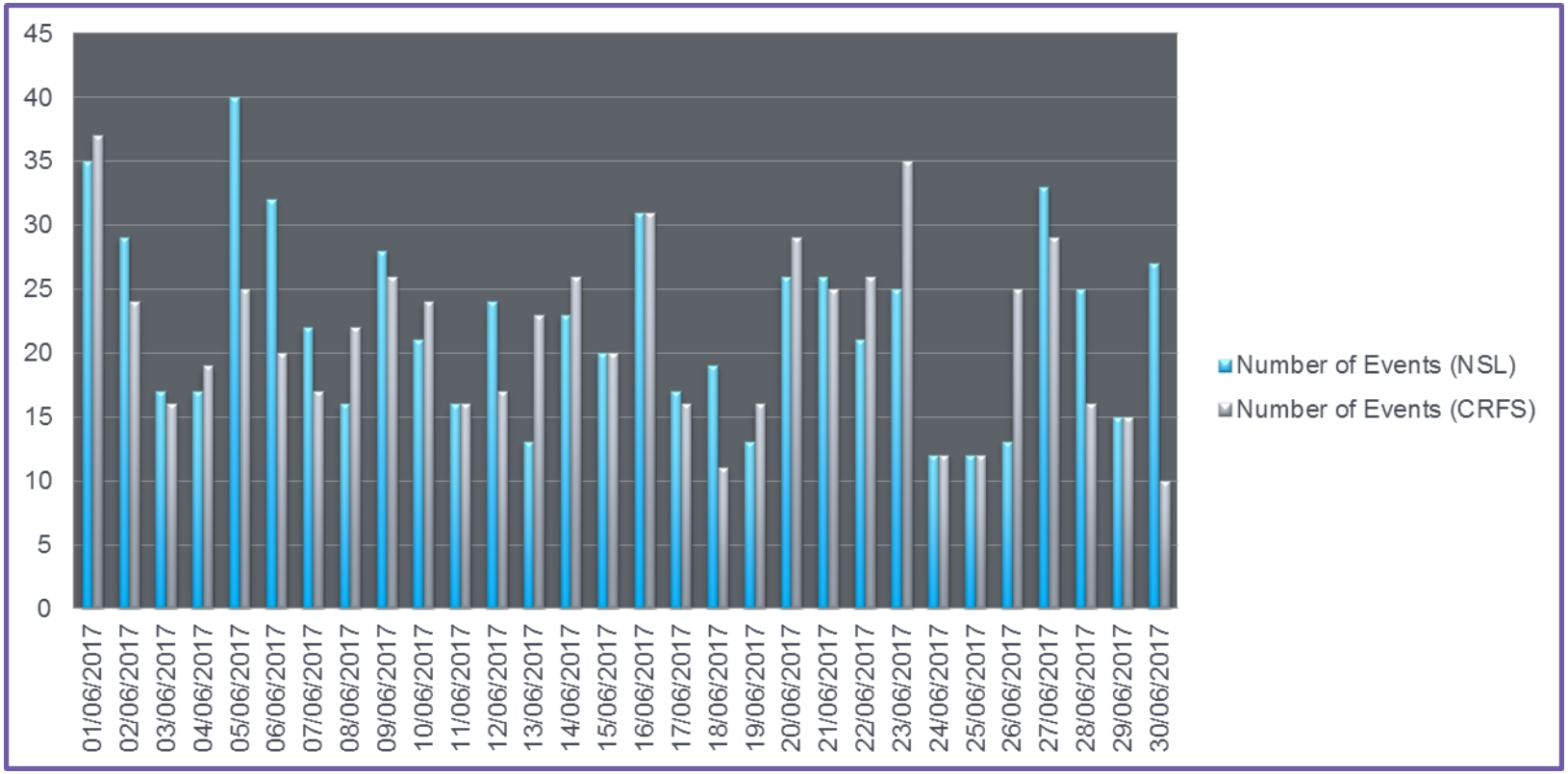
Monthly Events Statistics

Time	July	August	September	October	November	December	
1							13
2							7
3							10
4							13
5							11
6							34
7							18
8							15
9							17
10							36
11							42
12							50
13							31
14							36
15							61
16							30
17							33
18							35
19							29
20							17
21							22
22							22
23							15
24							7
No. of Events	38	98	134	105	122	107	

Total No. of Events for six months
604

- No significant consequences to airport operation: one complaint from pilot

Monthly Events Statistics (improved node antennas)



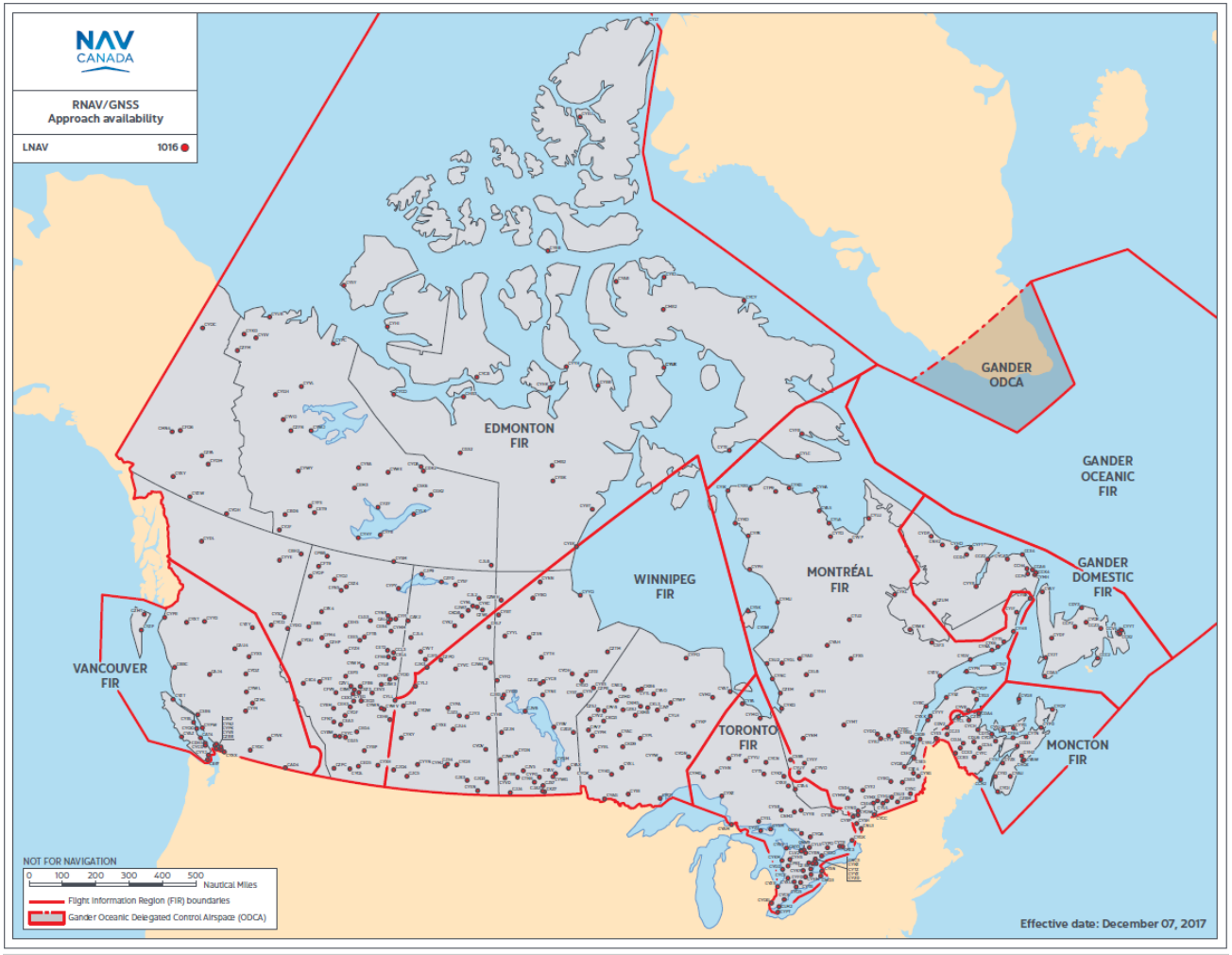
NAV CANADA's shift to Performance Based Navigation

- NAV CANADA published 1578 PBN approach procedures using chart title 'RNAV (GNSS)' as of December 2017:
  - 1016 with LNAV lines of minima
  - 178 with LNAV/VNAV lines of minima
  - 355 with LPV lines of minima
  - 29 with RNP AR lines of minima

- GNSS approach often the only instrument assisted approach to remote airports; luckily, there are usually no GPS jammers there

- Many GPS jammers around major airports; luckily, there are usually alternate ground based facilities to assist landing

RNAV/GNSS approach availability in Canada



5) WHAT TO DO ABOUT GPS JAMMERS

- Should ANS providers invest in GPS jammers IDM equipment and training?
- Should procedures be introduced to address jamming, e.g. jamming events alarms, rapid reaction and location efforts, reporting to authorities?
- Should dealing with GPS jammers be entirely left to the regulators and/or low enforcement authorities?
- Should ANS providers lobby regulators and enforcers for preferential treatment in protection against GPS jammers?

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