Official sponsor IGS Workshop 2017

septentrio

designs, manufactures and sells

highly accurate GNSS receivers

for demanding applications

MADE IN BELGIUM

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Data Quality: from Tracking to Archiving with no Gaps

F. Clemente, S. Dean, J.M. Sleewaegen, W. De Wilde

GNSS RFI vulnerability: interference is everywhere

GNSS signals as received on the ground : very low power

Sharing of radio spectrum with other services, some operating at high power (Ligado/Docomo LTE , DME, Iridium, Inmarsat)

Narrowband
Wideband

Pulsed
Continuous

Unintentional
Intentional (jamming)

In-band
Out of band

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Interference impact on applications

Depends on frequency and duration of the offending transmissions

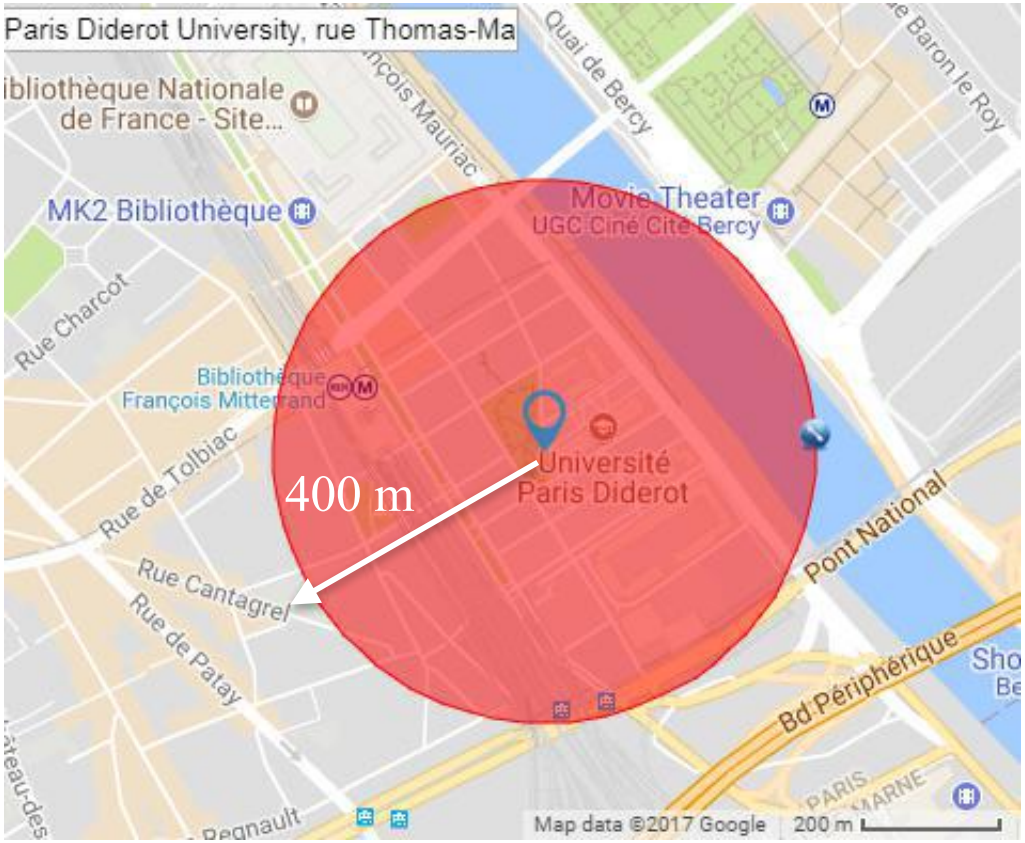
Daily processing: data editing → remove arcs with less than a specified amount of continuous slip free observations.

Accuracy effected.

Kinematic processing: most impacted is real-time PPP (re-convergence), risk of missing out on events.

Ambiguity resolutions difficult to impossible depending on interruptions.

What if a 10mW jammer was on the roof of the this building?



With no mitigation

Reference station → no supply of differential corrections
→ Gaps in RINEX files

Rover → No RTK in a radius of 400 m from the emitter

Old school troubleshooting

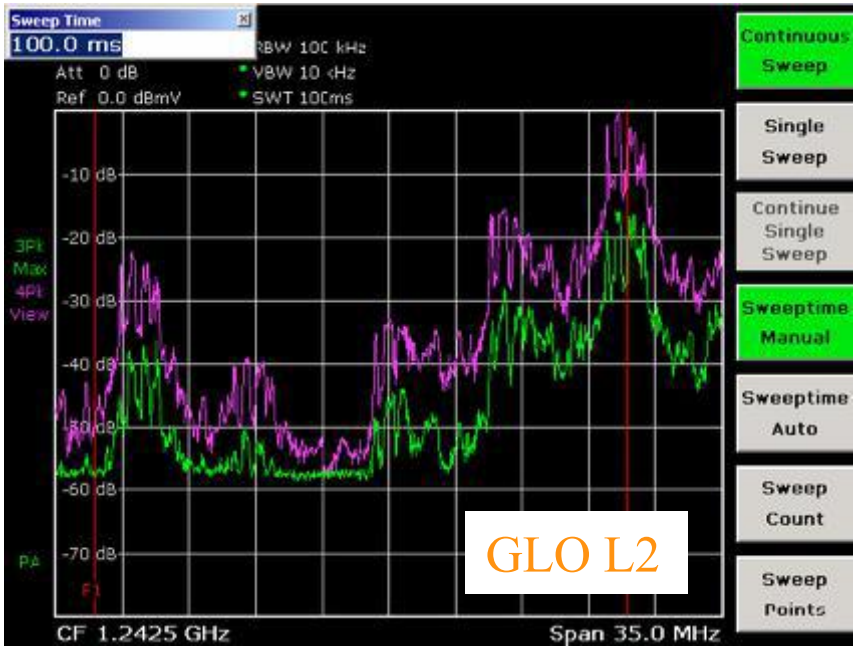
Specialized personnel & dedicated hardware (spectrum analyzer)

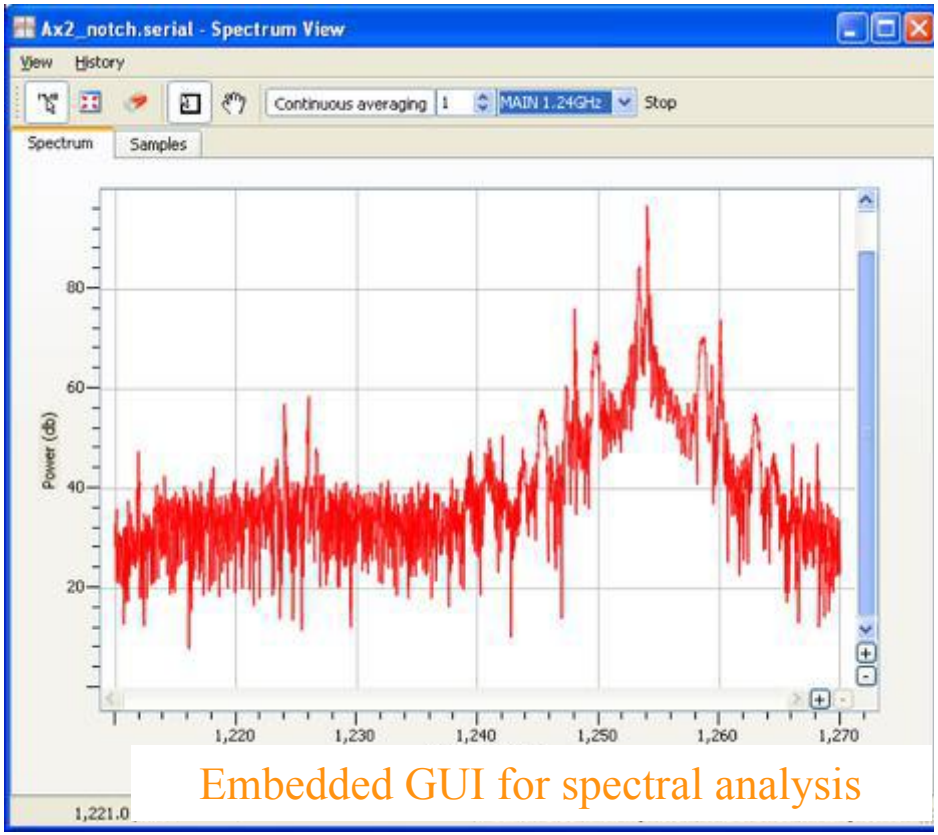
Long field campaign

Intermittent interference hardest to detect

Septentrio
GNSS receiver

SBF
Protocol



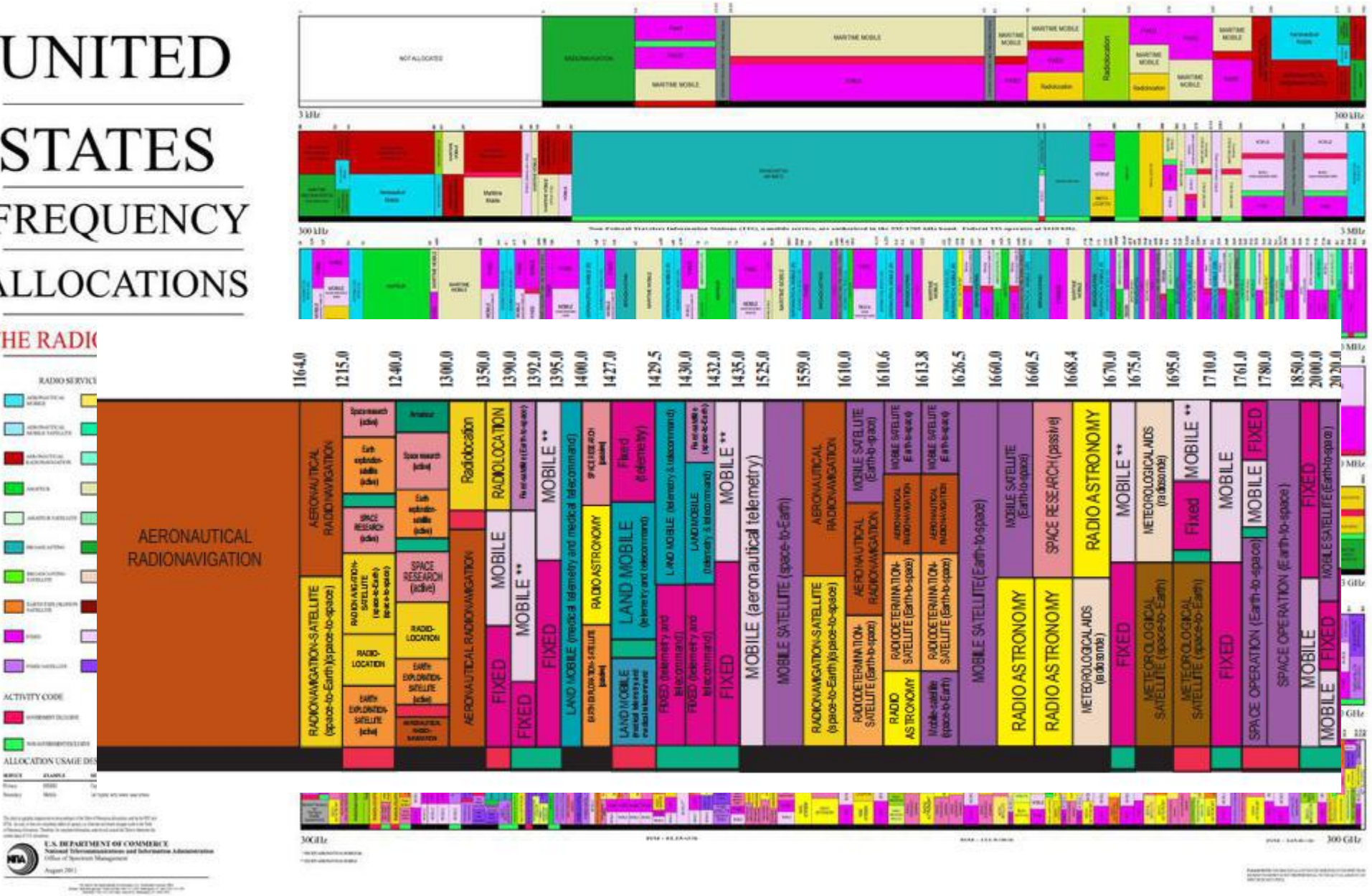


Analog
Video
Transmission
@ 1254 MHz

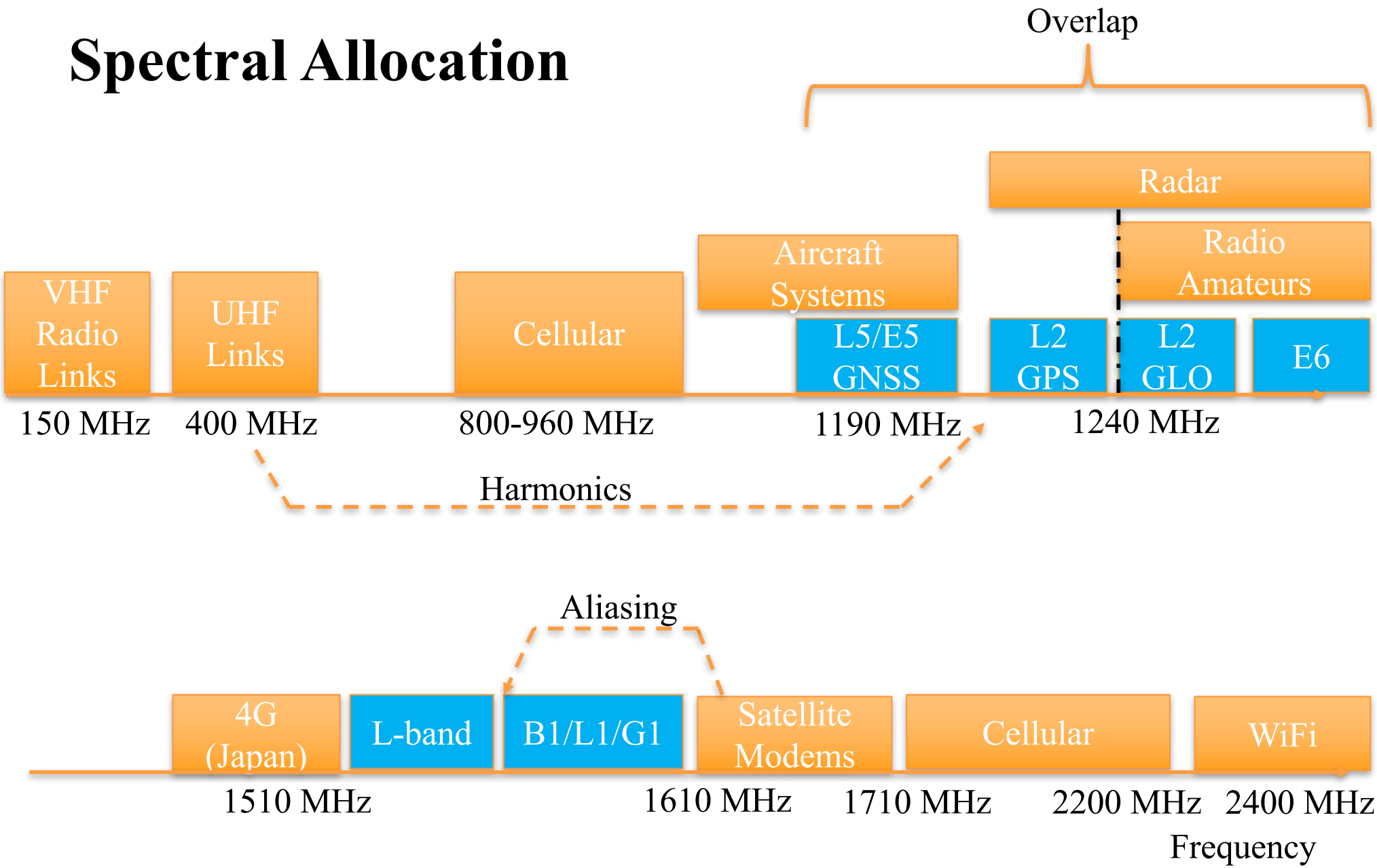
Much more than detection

AIM+ @ interference

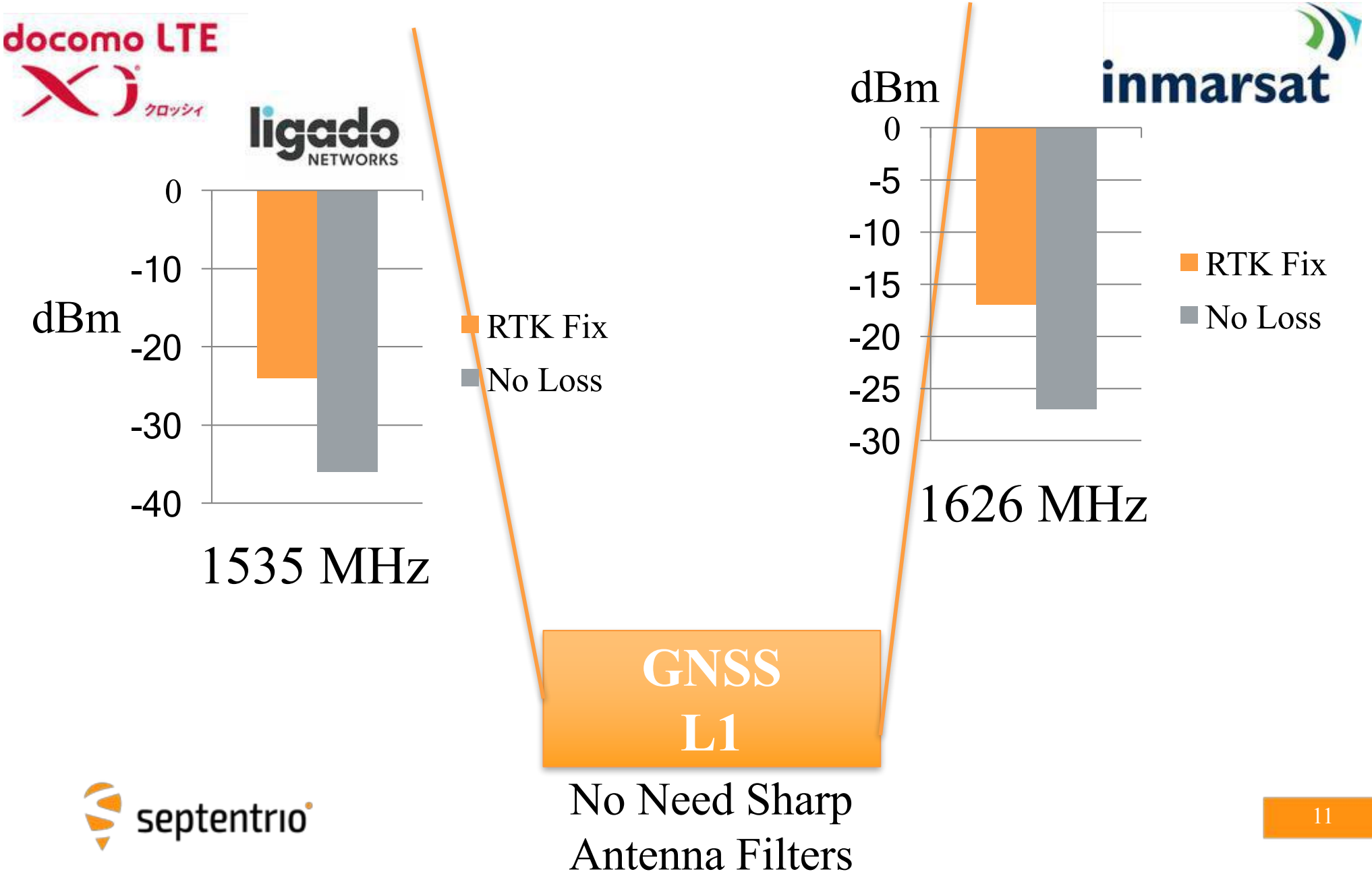
UNITED STATES FREQUENCY ALLOCATIONS



Spectral Allocation



Out of band and adjecent bands rejection



AIM+ Interference Mitigation

Out-of-band

4 demodulators

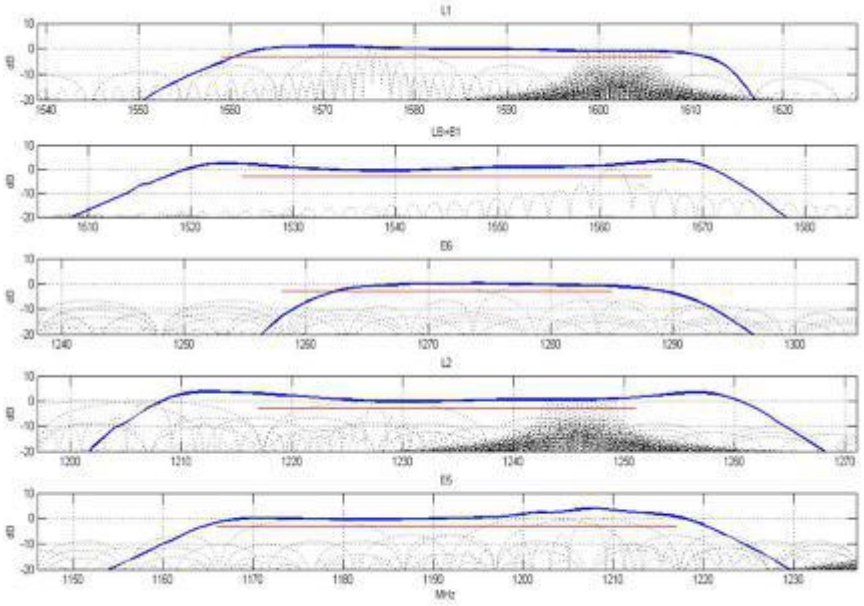
Separated filtering for all bands

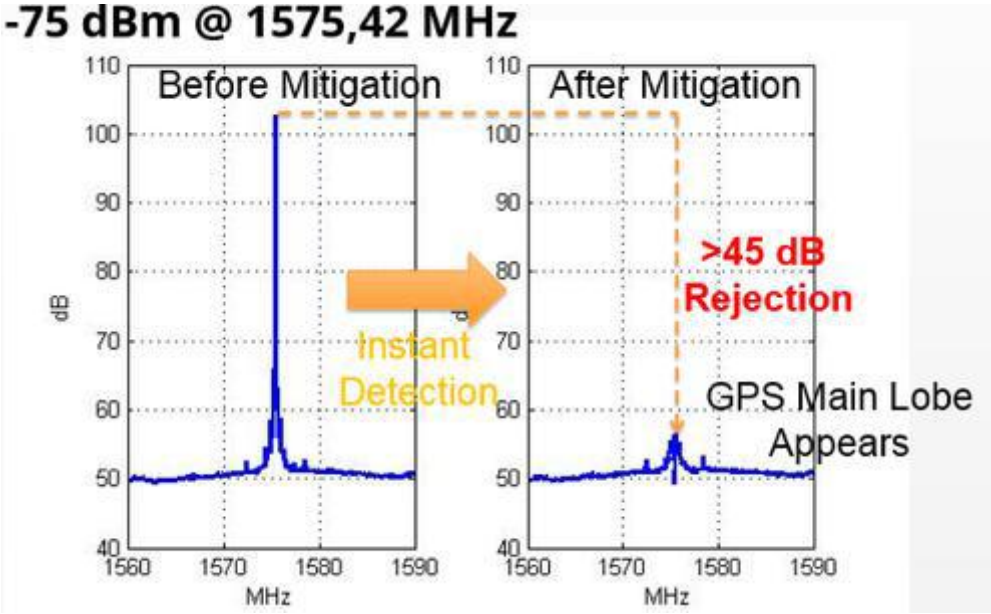
In-band

3 notch filters

Wide band mitigation unit

Pulse-blanking





Hilversum, The Netherlands

Radio Amateur digipeater

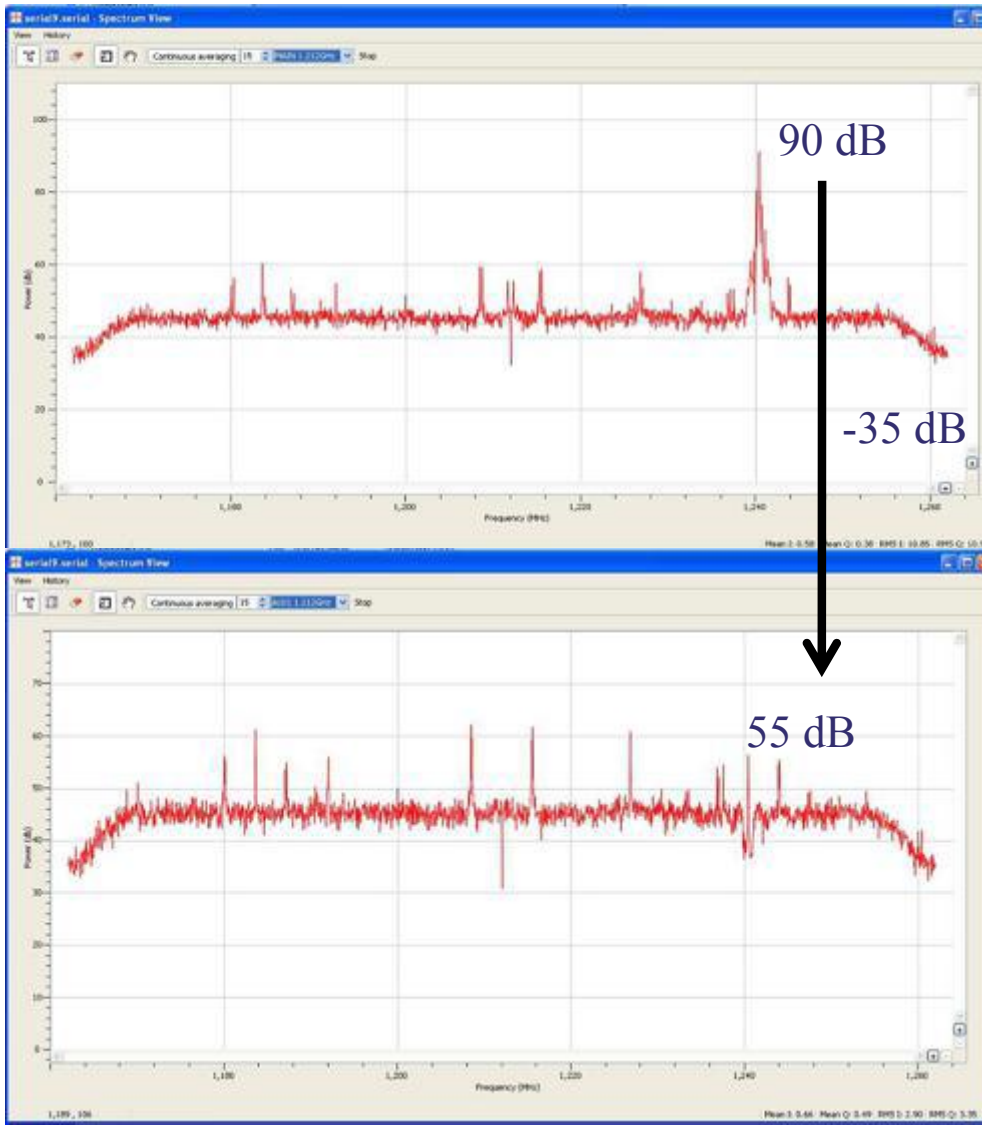
1240.4 MHz (GLO L2)

Narrowband interference

Transmits in bursts

2 second on / 8 seconds off

Mitigated with notch filter



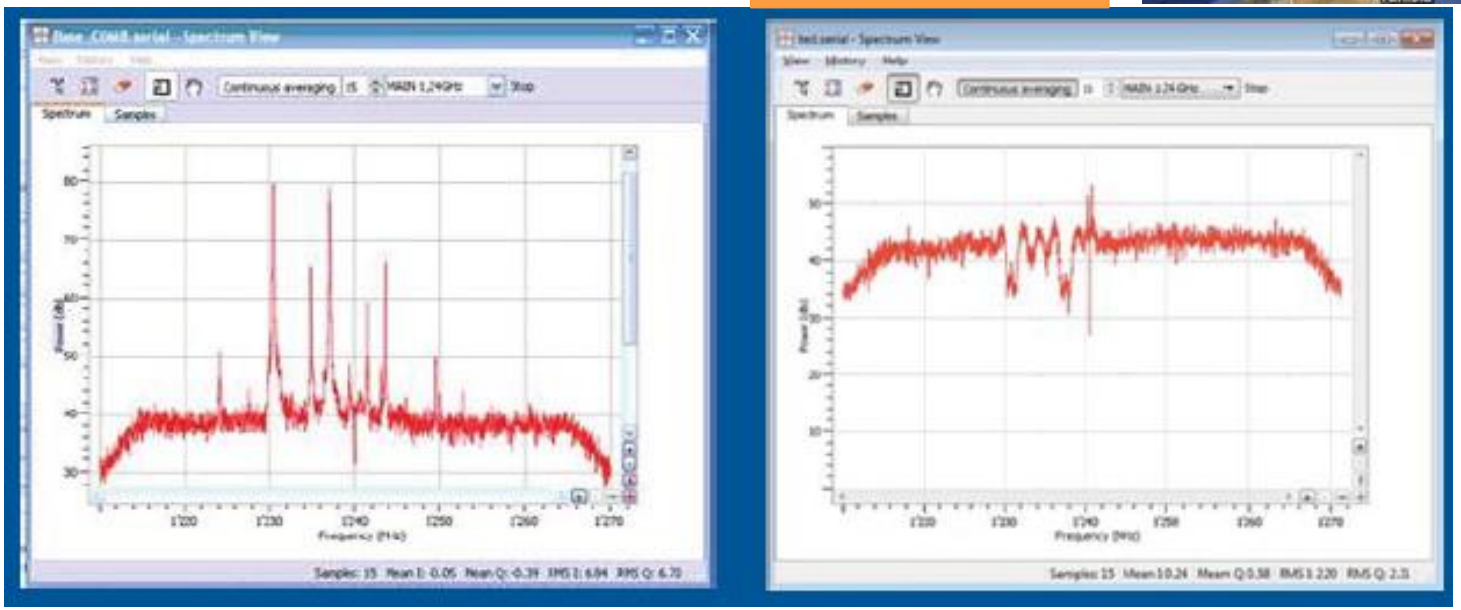
Tuymen, Russia

In-Band interference

Unknown source

GPS & GLO L2-Band

Mitigated with notch filter

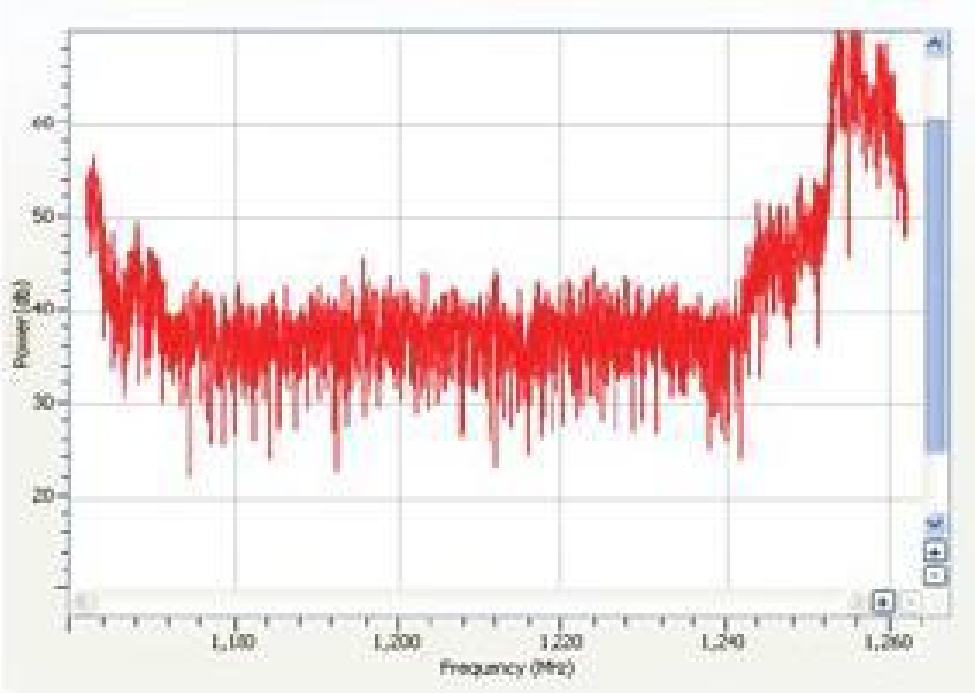


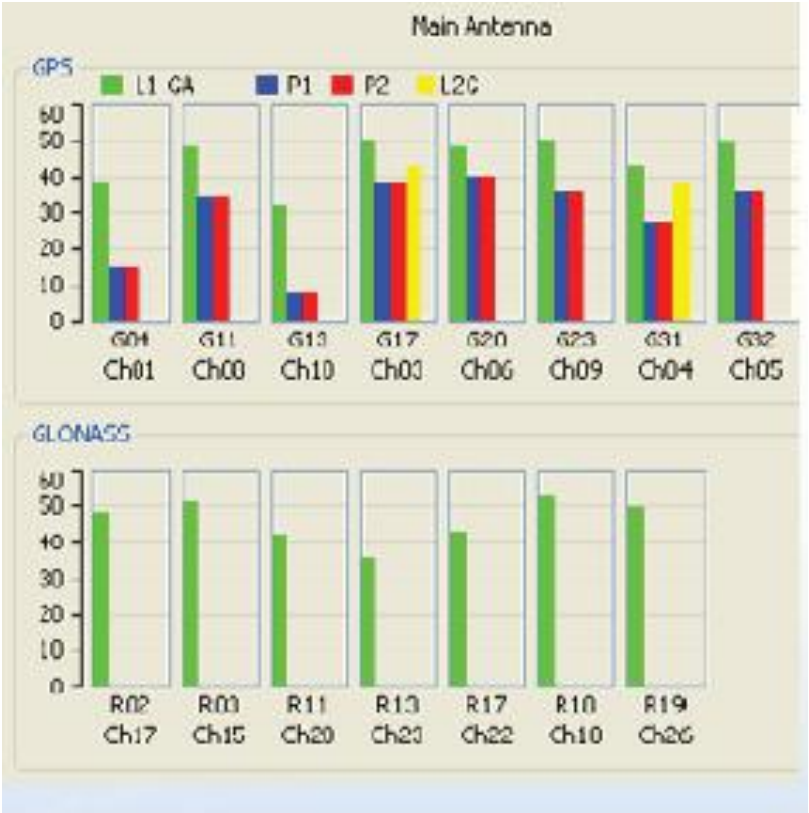
Ostende, Belgium

Broadband Amateur TV

1250MHz GLO L2

Spill over in GPS L2

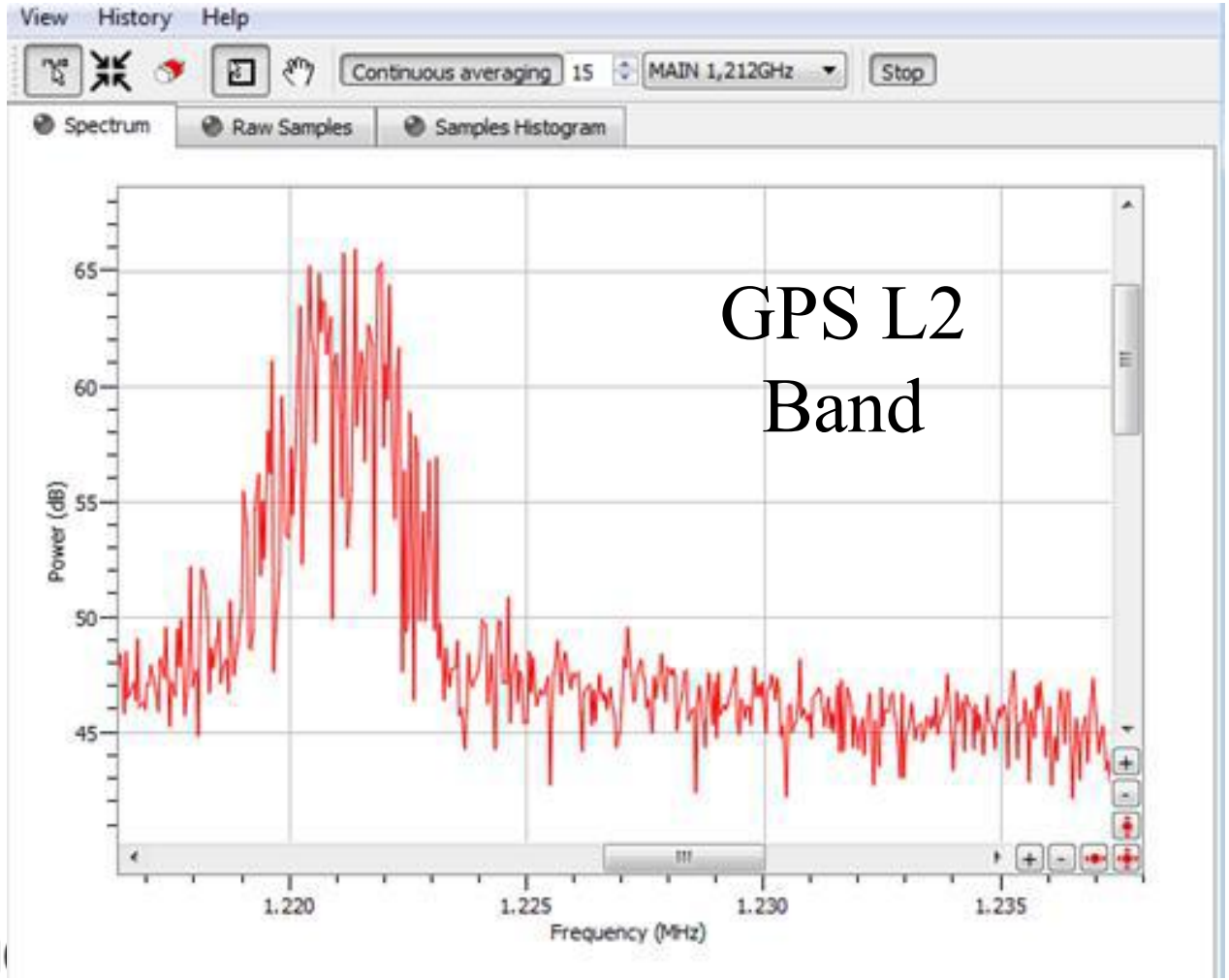




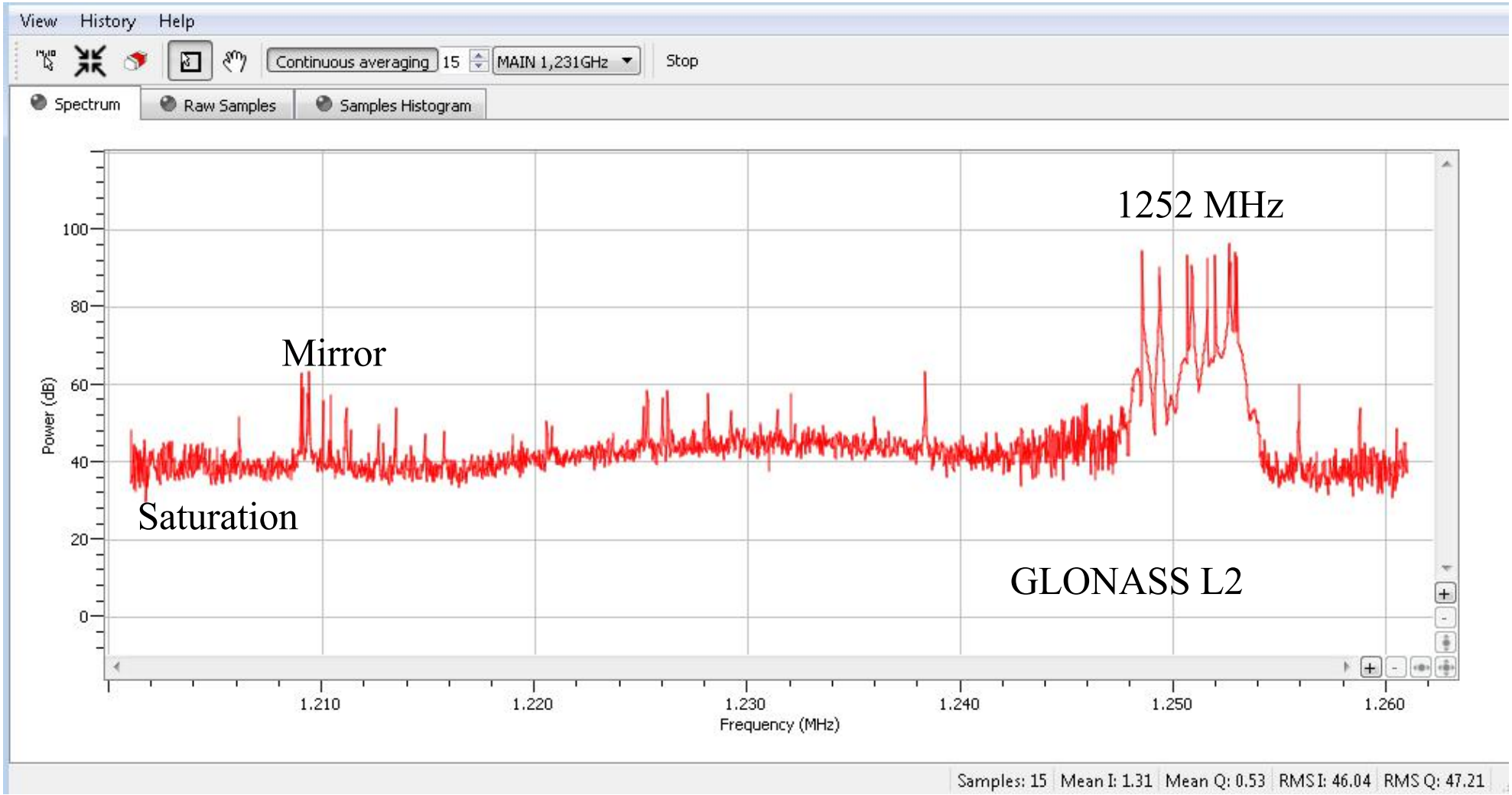
L2: Radiolocation Devices

- **Sharing L2 band with GPS**

Singapore



Amateur Radio



In-Band interference – DME

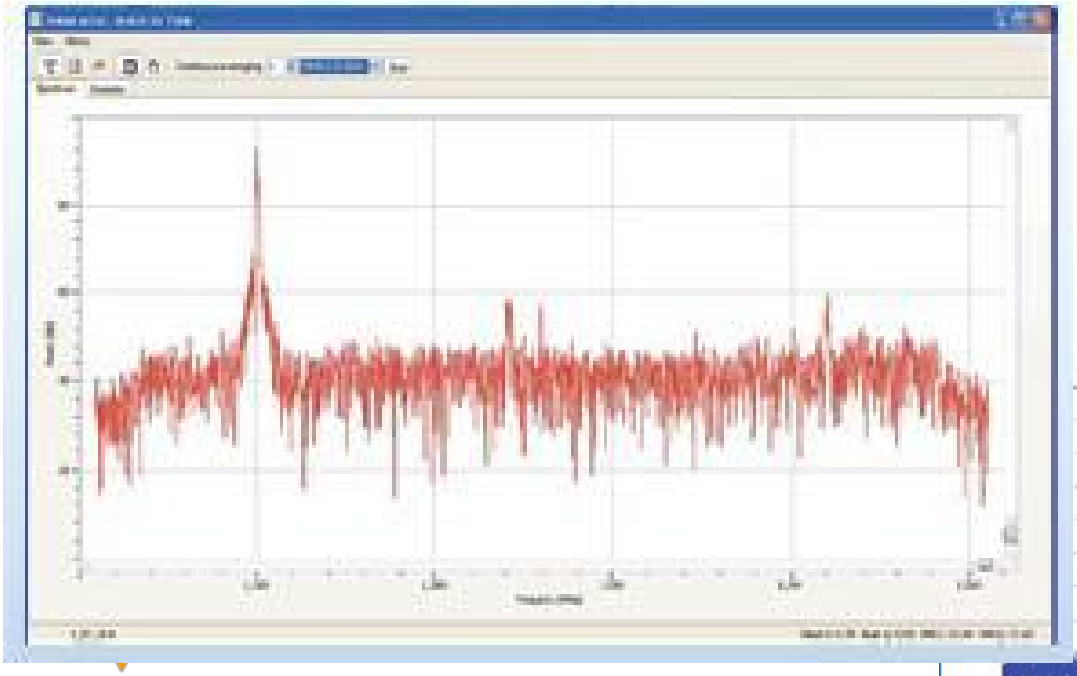
Distance Measurment Equipment (DME)

Tactical Air Navigation (TACAN)

Share band with GPS L5 and GALILEO E5

2700 high-power pulse pairs sent per second

Mitigated with notch filter
&
Pulse blanking



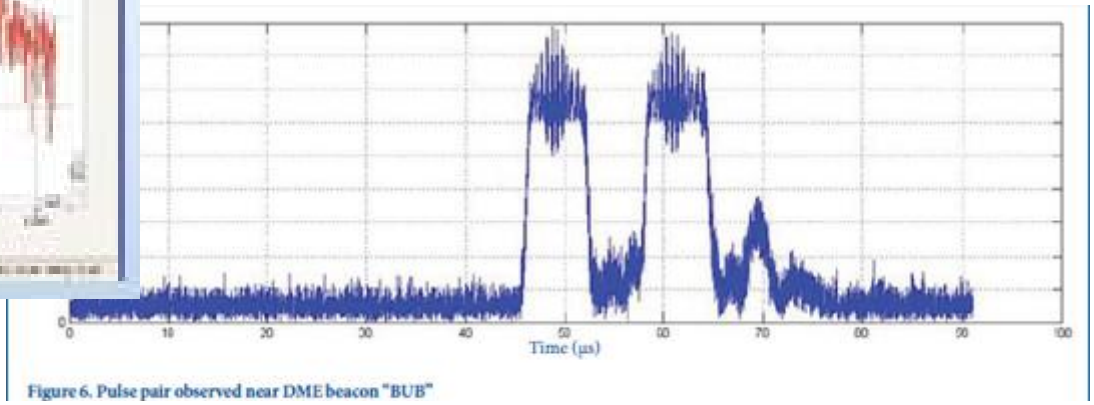
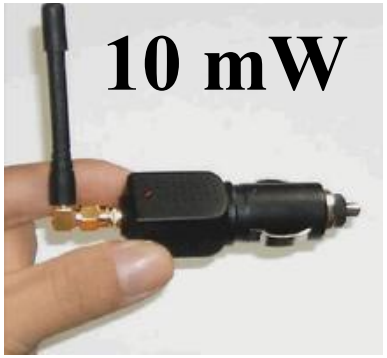


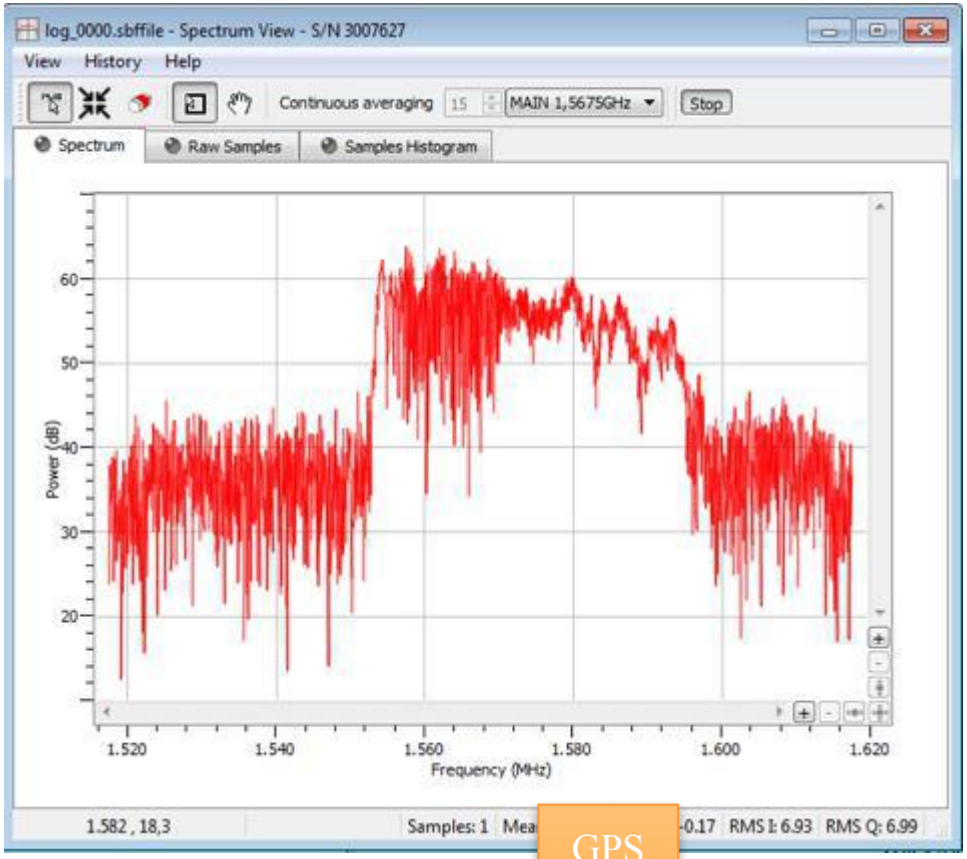
Figure 6. Pulse pair observed near DME beacon "BUB"

Chirp Jammers



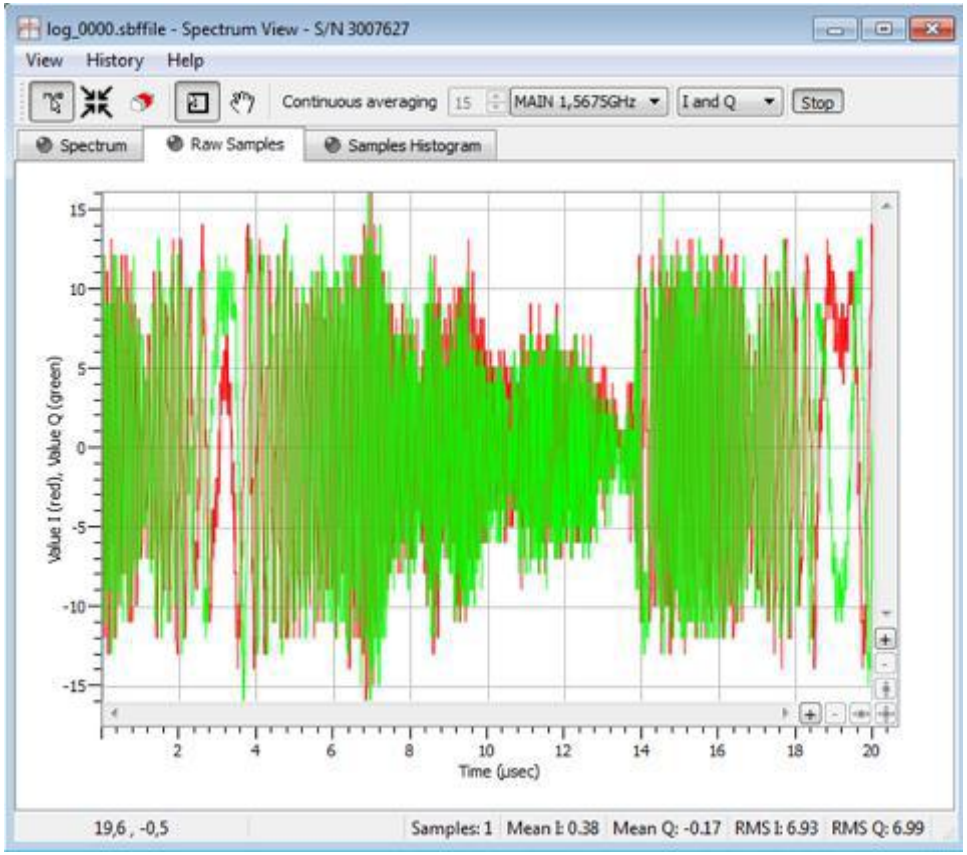
4x 300 mW

Spectrum:



GPS L1

Time:



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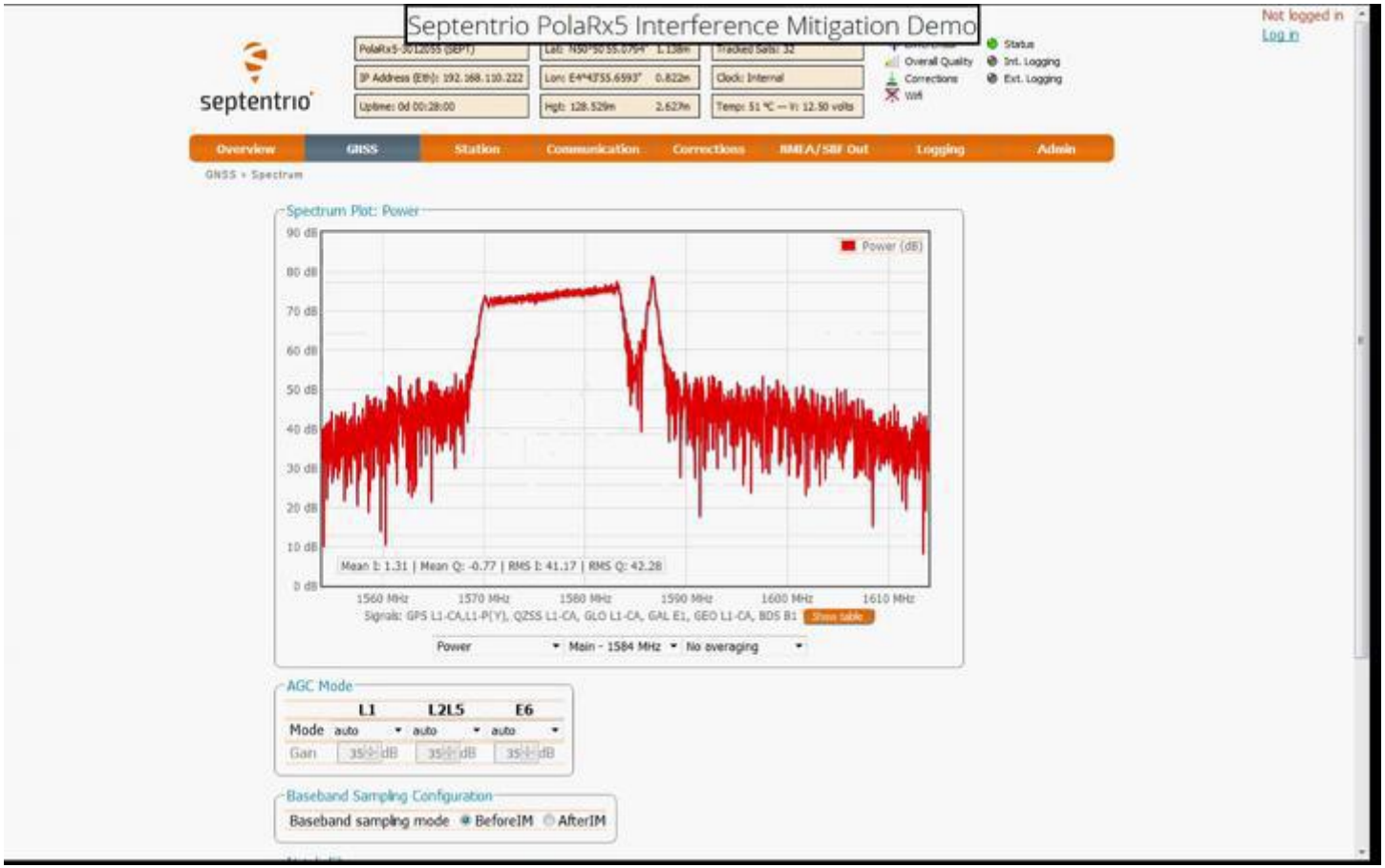
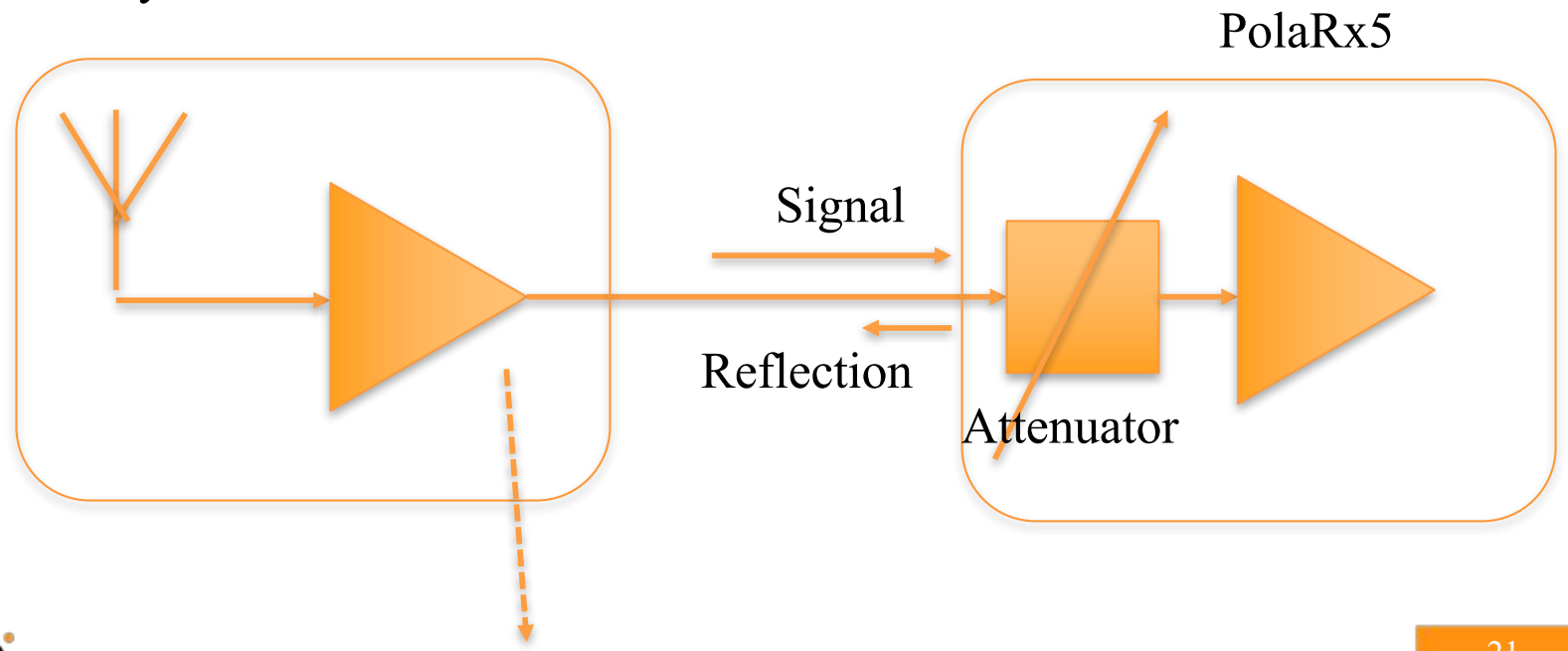

Septentrio PolaRx5 Interference Mitigation Demo
septentrio
Not logged in
Log in
Overview
GNSS
Station
Communication
Corrections
RMEA/SBF Out
Logging
Admin
GNSS » Spectrum
Spectrum Plot: Power
Power (dB)
Mean I: 1.31 | Mean Q: -0.77 | RMS I: 41.17 | RMS Q: 42.28
1560 MHz
1570 MHz
1580 MHz
1590 MHz
1600 MHz
1610 MHz
Power
Main - 1584 MHz
No averaging
AGC Mode
L1
L2L5
E6
Mode
auto
Baseband Sampling Configuration
Baseband sampling mode
BeforeIM
AfterIM

When it looks like Interference…but it is a broken LNA…

- Change in amplitude – T dependent
- Gradual and very significant frequency drift
- From one modus to another
- Loss on other frequency bands

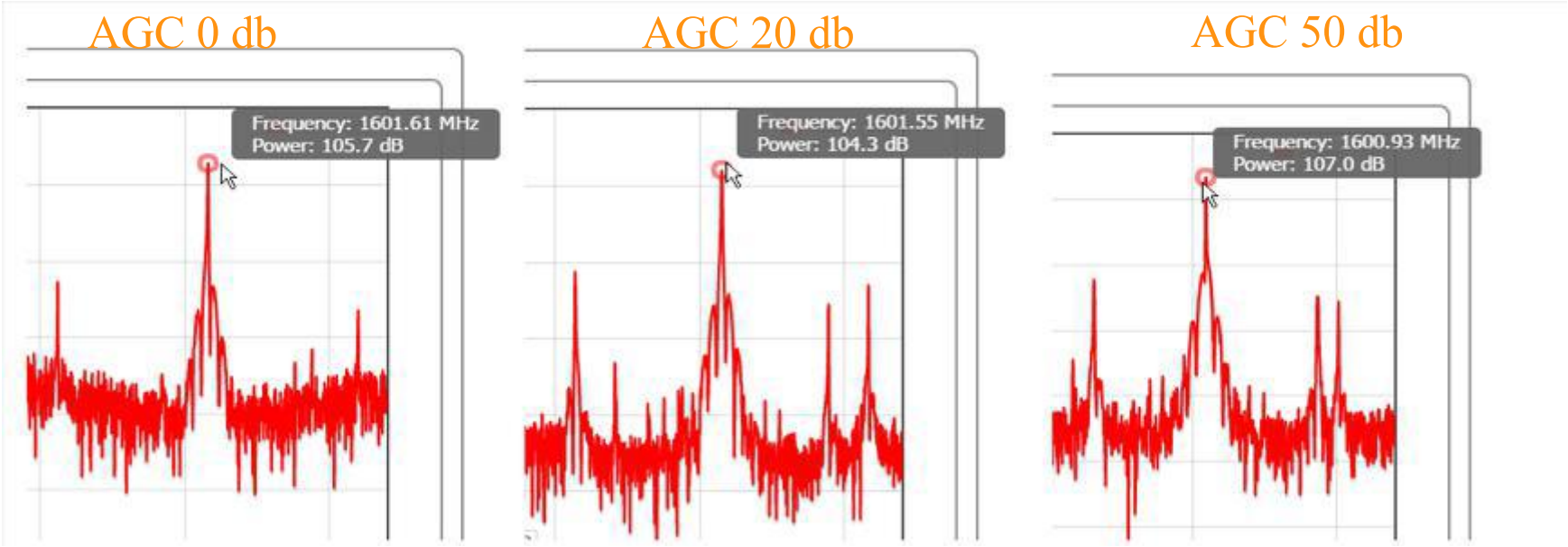
Conditional stability



Explanation on the impedance

If the interference is external/environmental → changing AGC = no impact on IF

Resonating antenna LNA → change AGC = IF frequency shift.



Data storage integrity

Storage integrity

Data collected by GNSS receivers are typically either streamed or FTP pushed to a server.

During telemetry it can happen that data packages are lost and that the files at the server side differ from what logged on the receiver.

So far, to recover the missing information, retransmitting the complete file was required.

Transmitting data can be expensive, especially when using Iridium telemetry and creates an unnecessary overhead.

Storage integrity

Fast differencing algorithm → delta encoding to minimize network usage

Only transfer the deltas
Reduce number of bytes
Lower the bill

Errors during transmission could be present →
Data gap in any part of the file

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Workflow

- Users configure data recording on an external computer
- Users configure the exact same recording on the internal disk of the receiver
- Synchronization scheduled on regular basis on the external computer to fetch data which would have been lost in the communication
- File names must be the same on both sides

3 take away

Septentrio is a Belgian manufacturer of high end GNSS receiver

Interference is a real threat and is widely diffused.

Septentrio has effective ways to monitor and mitigate it.

Optimize synchronization achieving data integrity by only transferring the deltas

Much more @ the booth

Laurent, Bruno and I will be happy

to answer more questions offline and talk further about Septentrio technology

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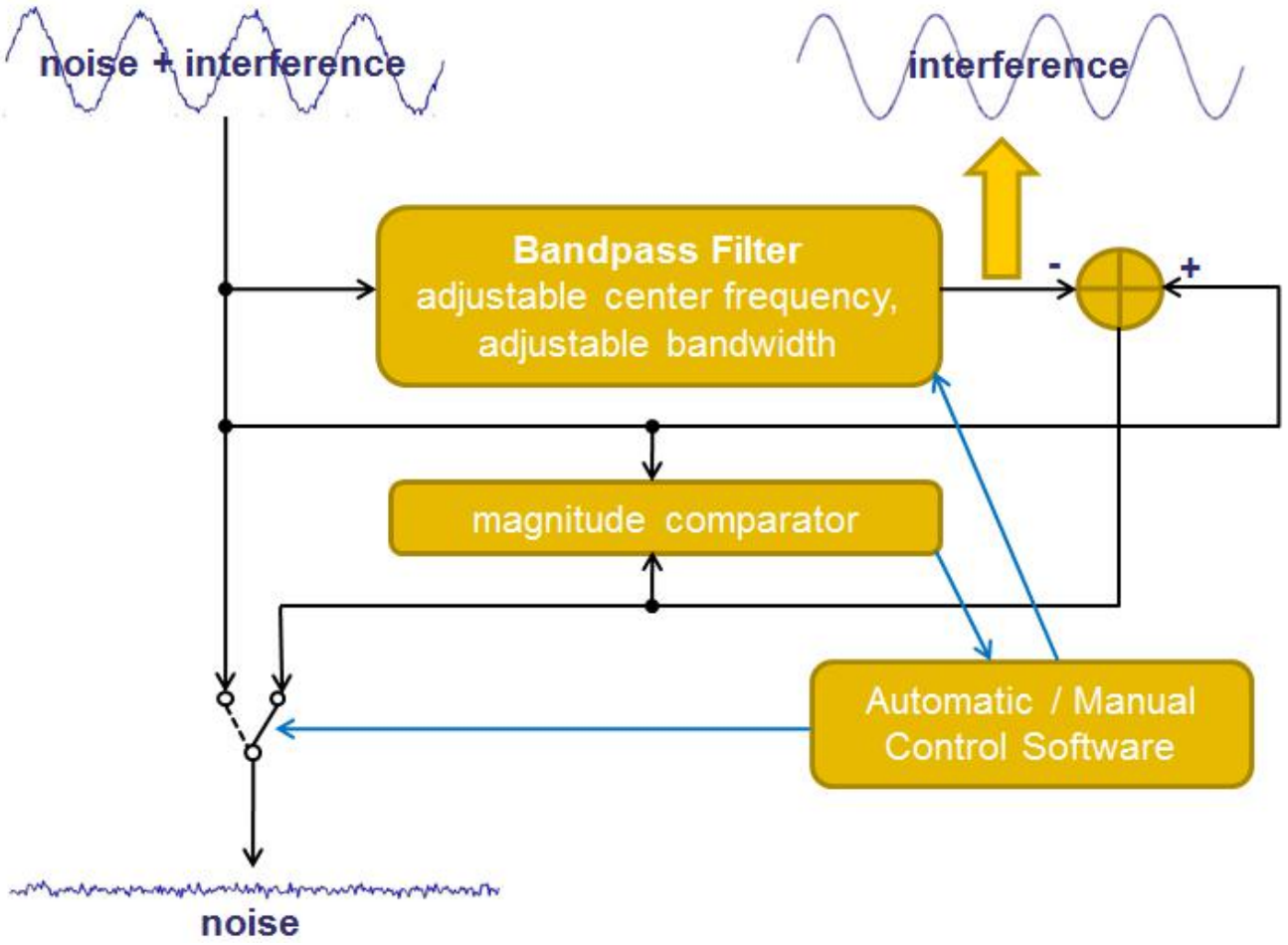
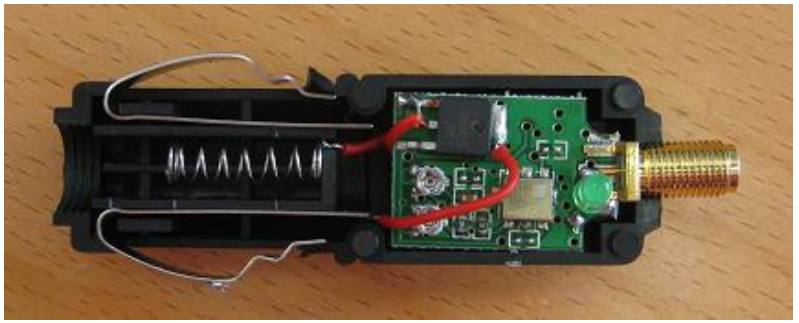
Back-up slides

Interference



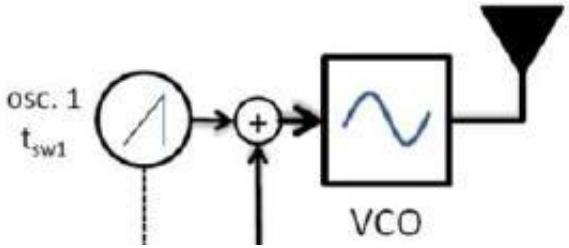
Jammer Operating Principles

Cheap circuit

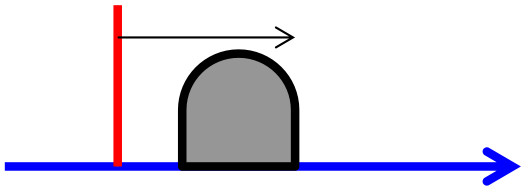


Two types:

- Pure sine-wave (CW)
  - VCO + manual tuning
  - Significant drift over temperature
  - Effective for narrowband
  - Can be mitigated by AIM+



- Chirp type
  - Frequency sweep sine wave
  - Sweep makes sure to hit L1
  - Less impact on narrowband
  - Septentrio has technology available to mitigate



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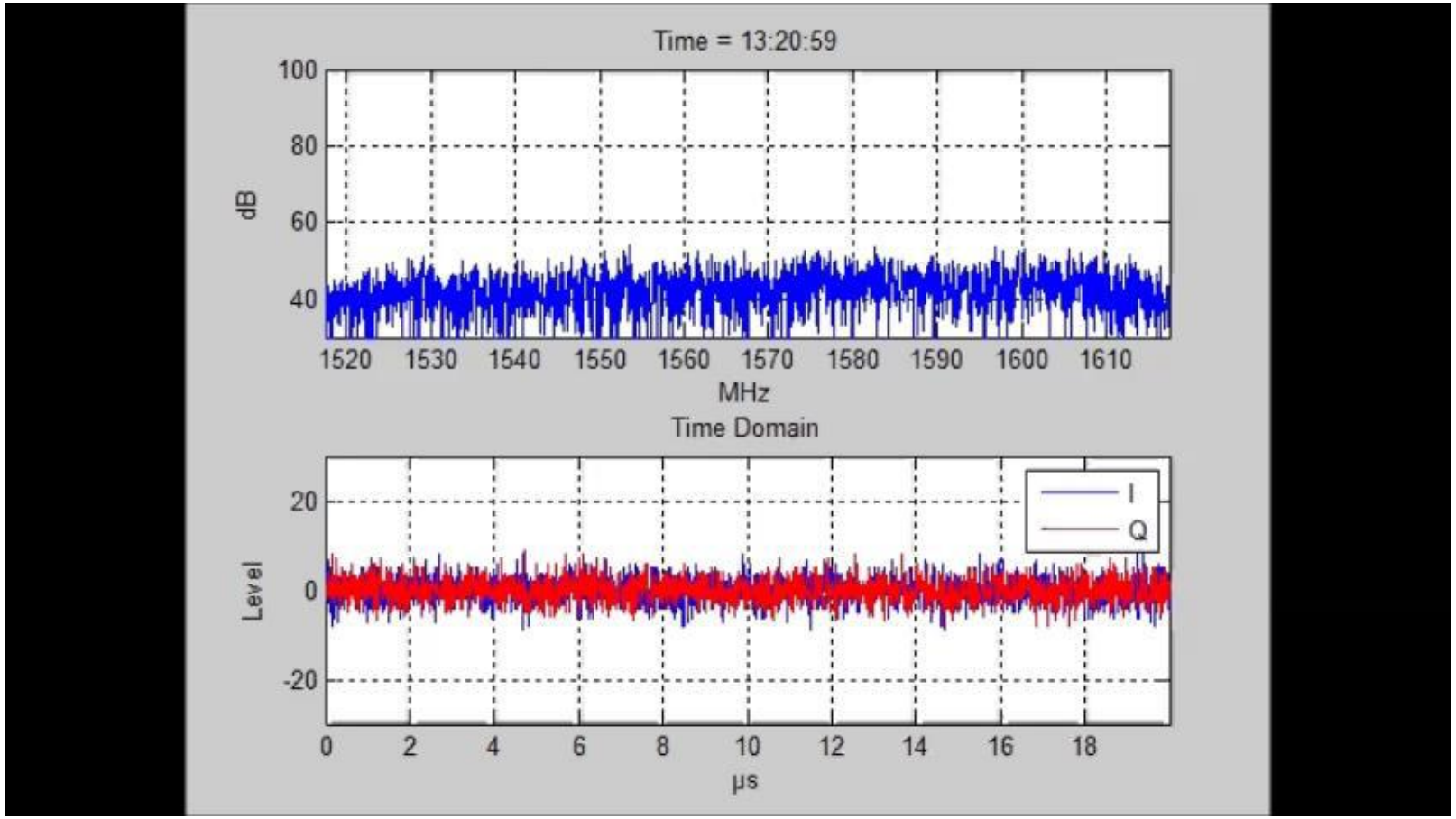
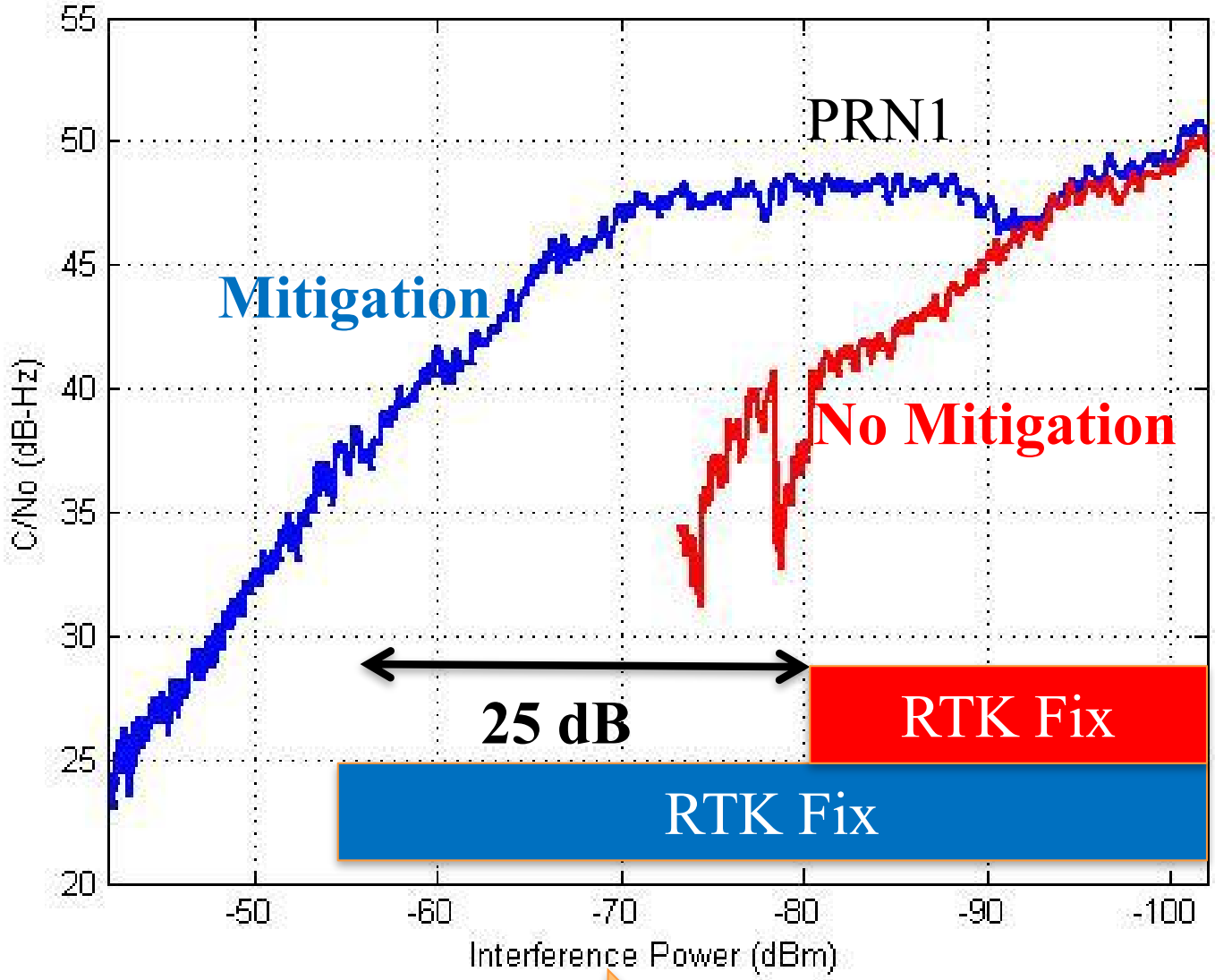
Chirp jammer in action



With AIM...Rejection



Decreasing Power

Jammer Detection

C/No

- One band much worse than others

Histogram

- Normal signal (noise): Gaussian distribution
- Jammer: sine-wave distribution