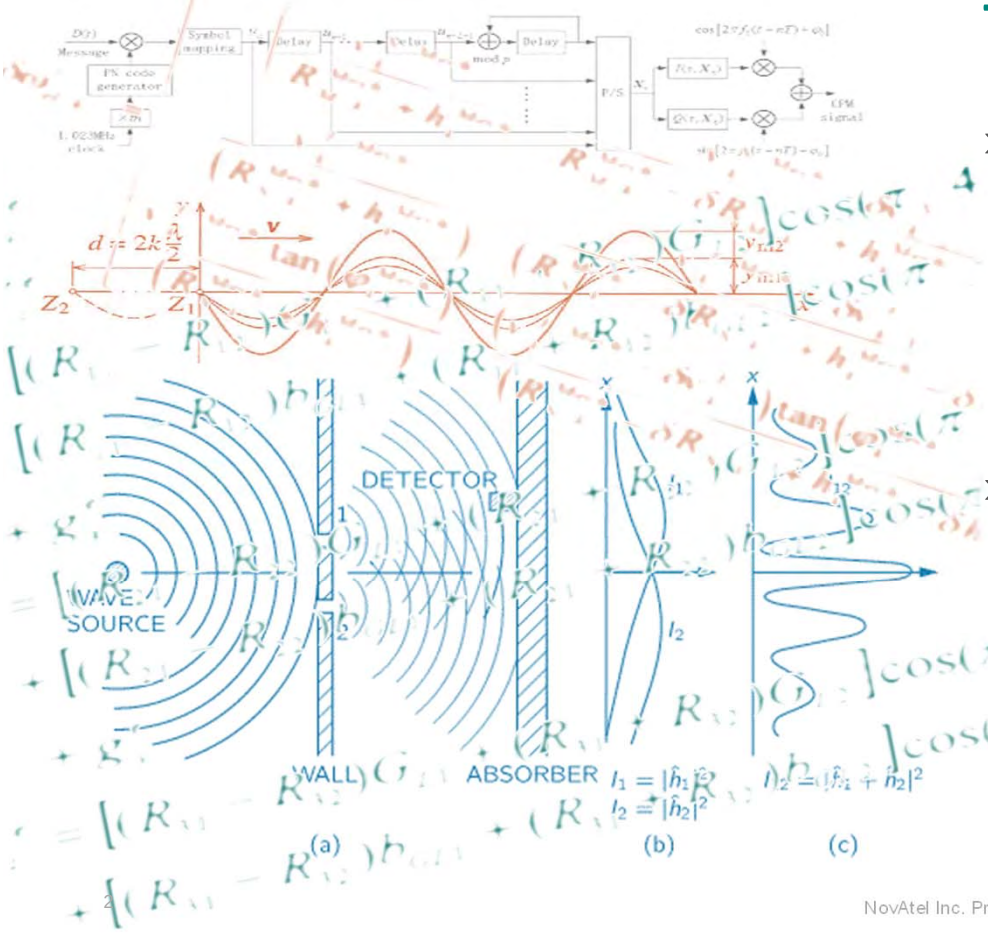
Interference Mitigation and Preserving Multi-GNSS Performance

Kirk Burnell, John Schleppe, Rod MacLeod

Background

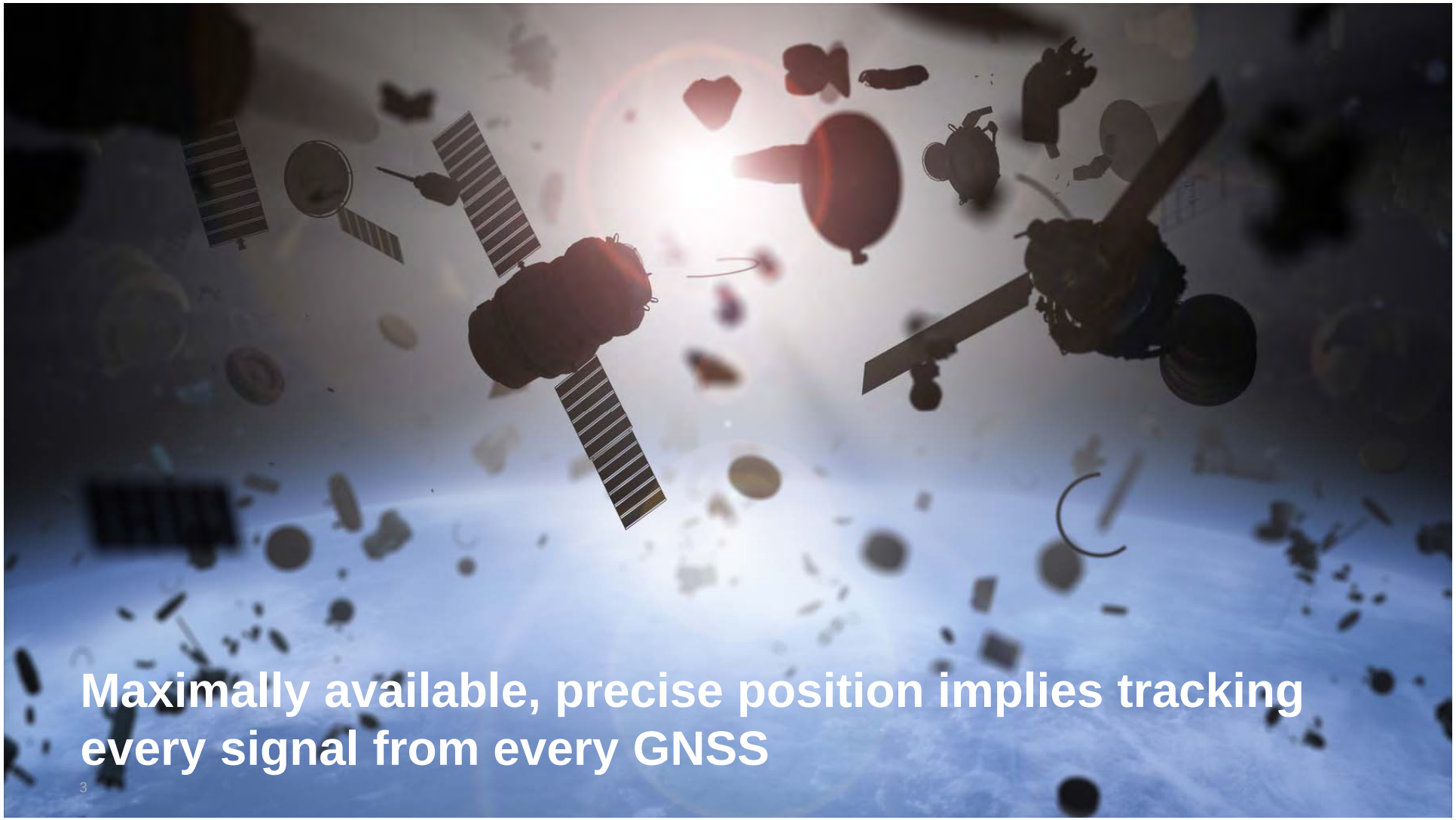


Types of Interferers

» Intentional transmitters
- Lab equipment
- Transmitting radios
- Jammers
- Spoofers

» Unintentional transmitters
- Electronics in general
- Malfunctioning electronics

$$\left(\frac{C_d}{N_0}\right)_{eff} = \frac{\frac{C_d}{N_0}}{1+\frac{C_i}{N_0}\int_{-\beta_r/2}^{\beta_r/2} G_i(f)\,G_d(f)\,df} \qquad (2)$$



Maximally available, precise position implies tracking every signal from every GNSS

We need to balance the user requirements

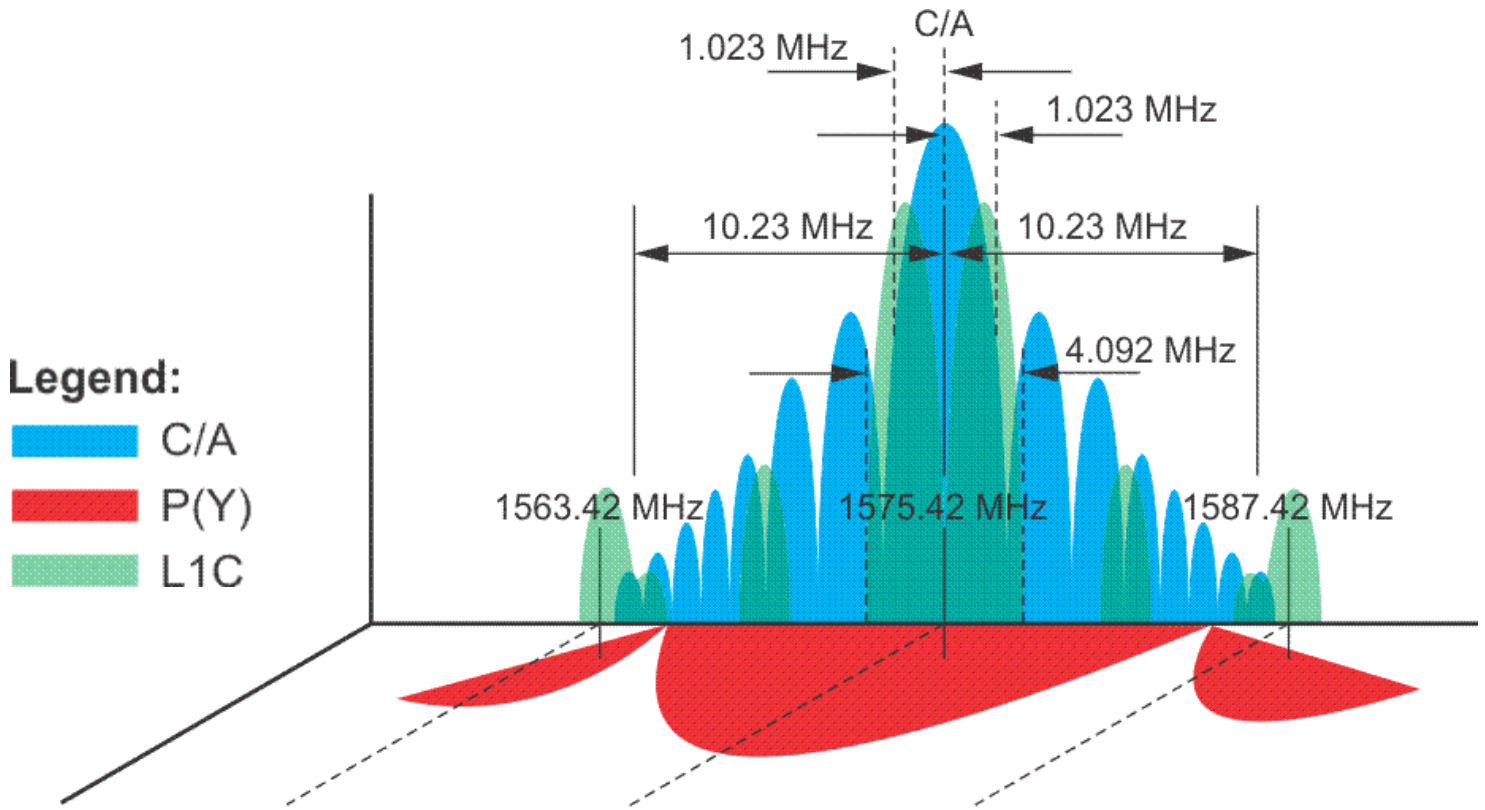
Narrowband receiver ‘good enough’ for many applications

Personal navigation

GIS

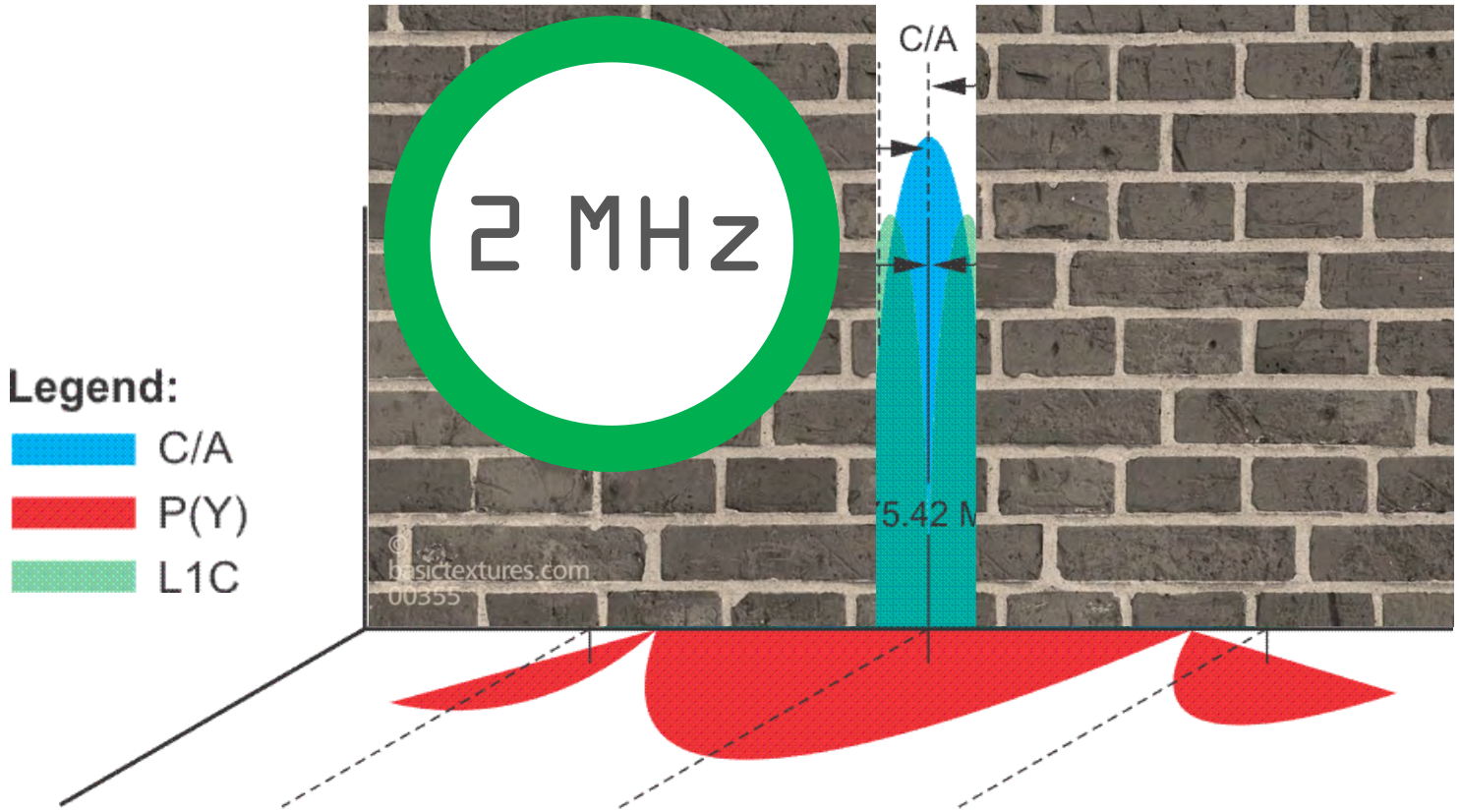
Mobile Apps

Narrowband receivers: good at filtering out interference



Source: GPS for Land Surveyors

Narrowband receivers: good at filtering out interference

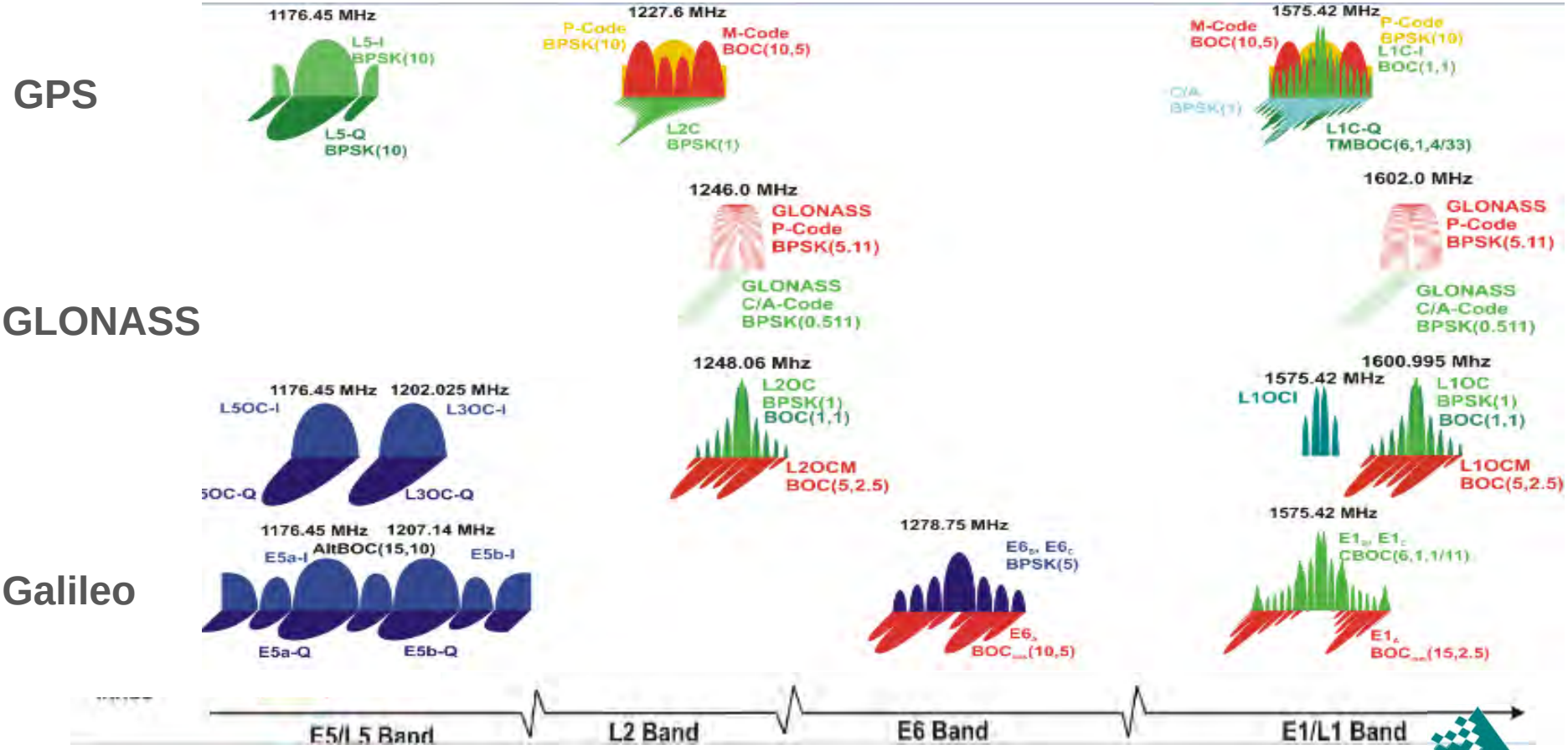


Source: GPS for Land Surveyors

Narrowband receivers: A Time-Tested Technique

Source: Neil Harris, helpmesortoutstpeters.blogspot.ca

Tracking all signals = more hardware + processing



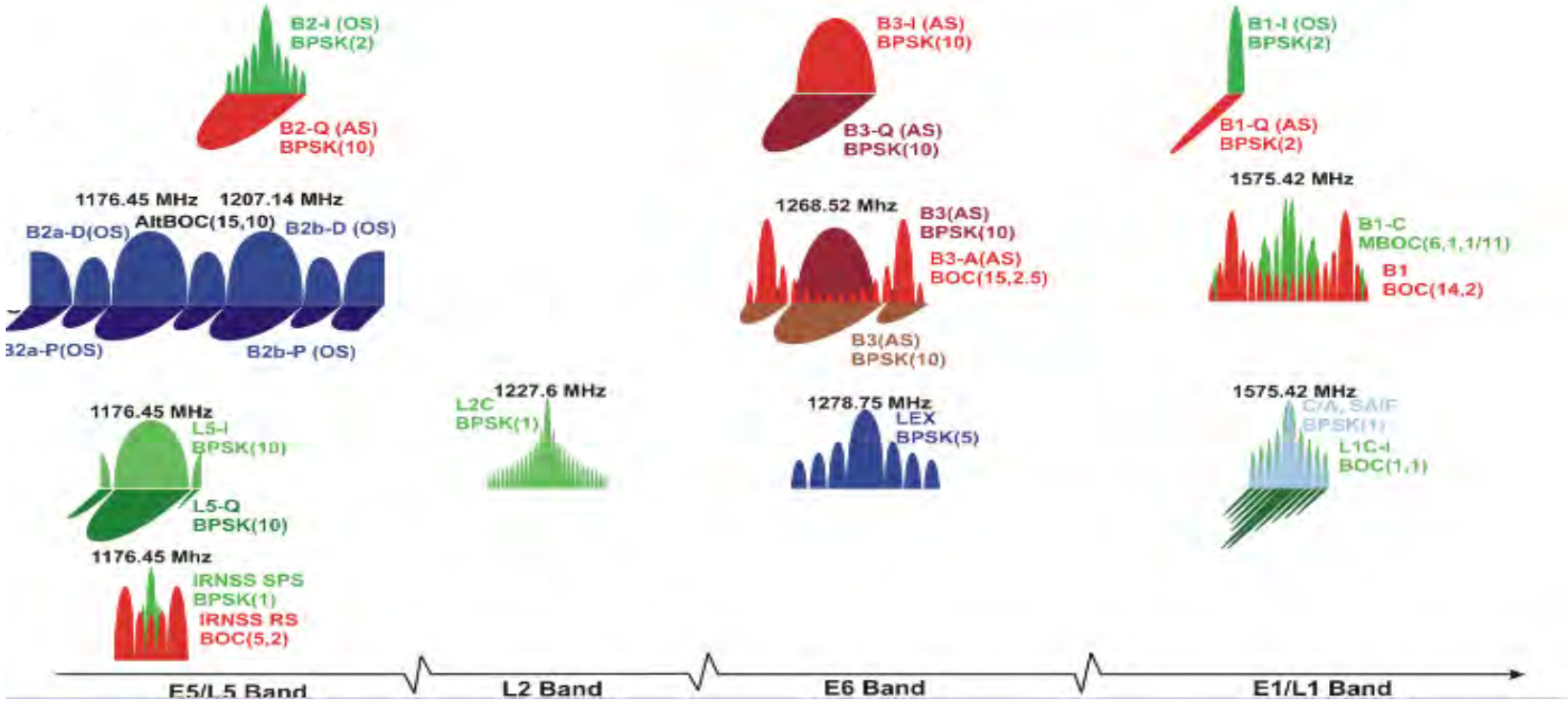
Source: Stefan Wallner

Tracking all signals = more hardware + processing

BeiDou

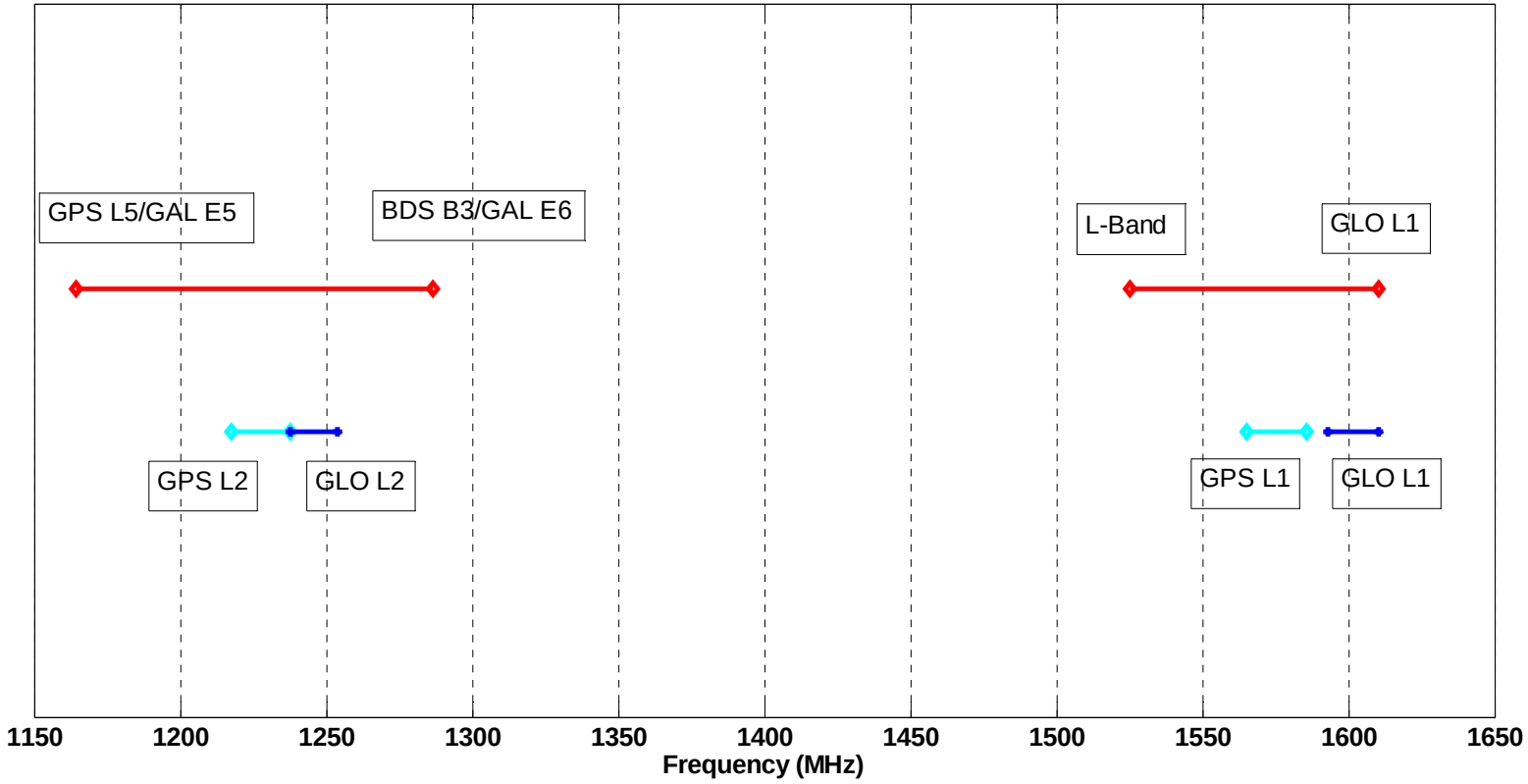
QZSS

IRNSS

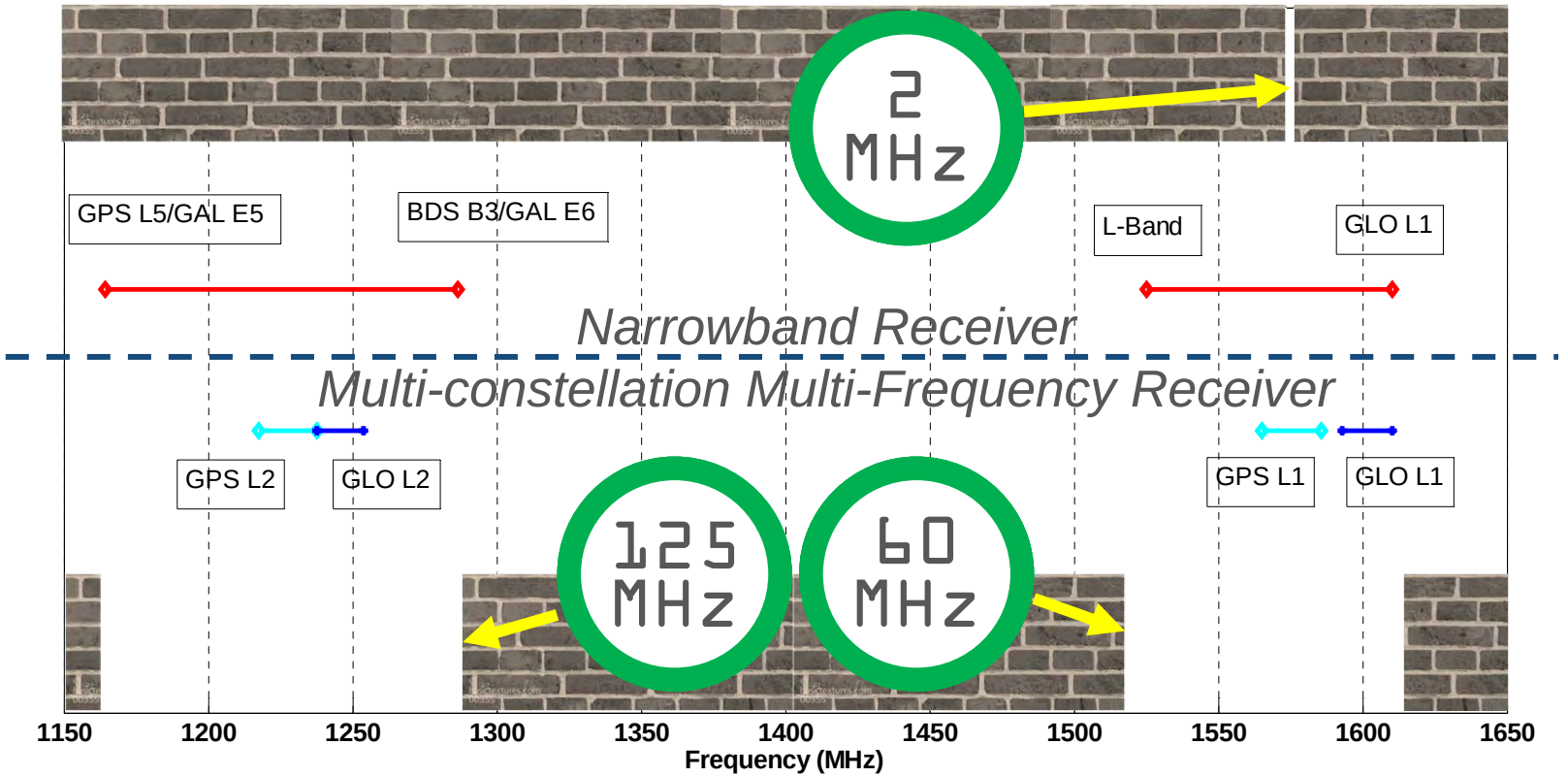


Source: Stefan Wallner

Tracking all GNSS signals ‘opens up’ the front end



Tracking all GNSS signals ‘opens up’ the front end



Wideband receivers: Need better mitigation techniques

Source: http://someordinarygamers.wikia.com/wiki/File:Ruined_castle.jpg

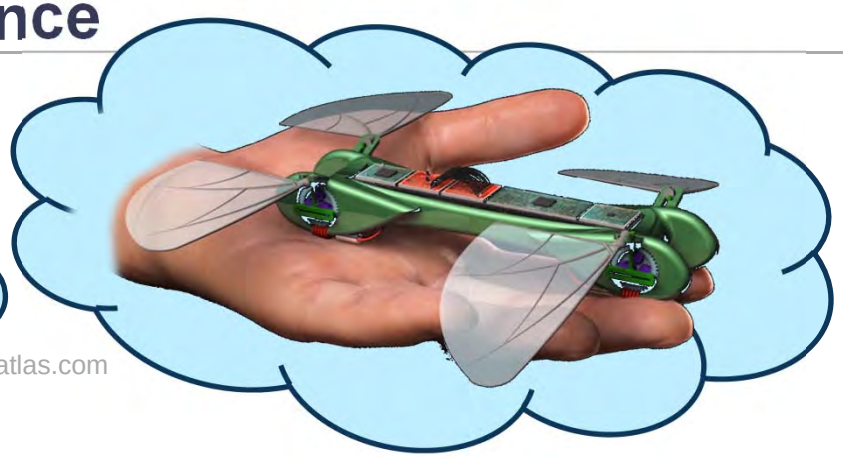
Which signals to choose to protect?

Which signals to choose?

Which signals to choose?

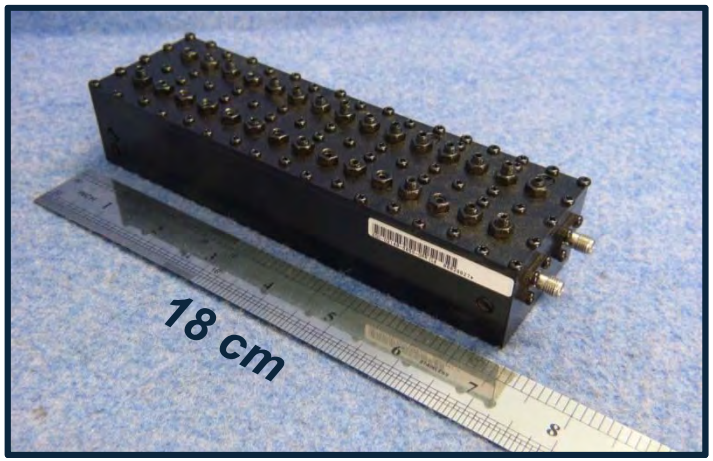
Classic solutions to interference

- Separate the GNSS antenna from interference sources
  - Not always possible



Source: Newatlas.com

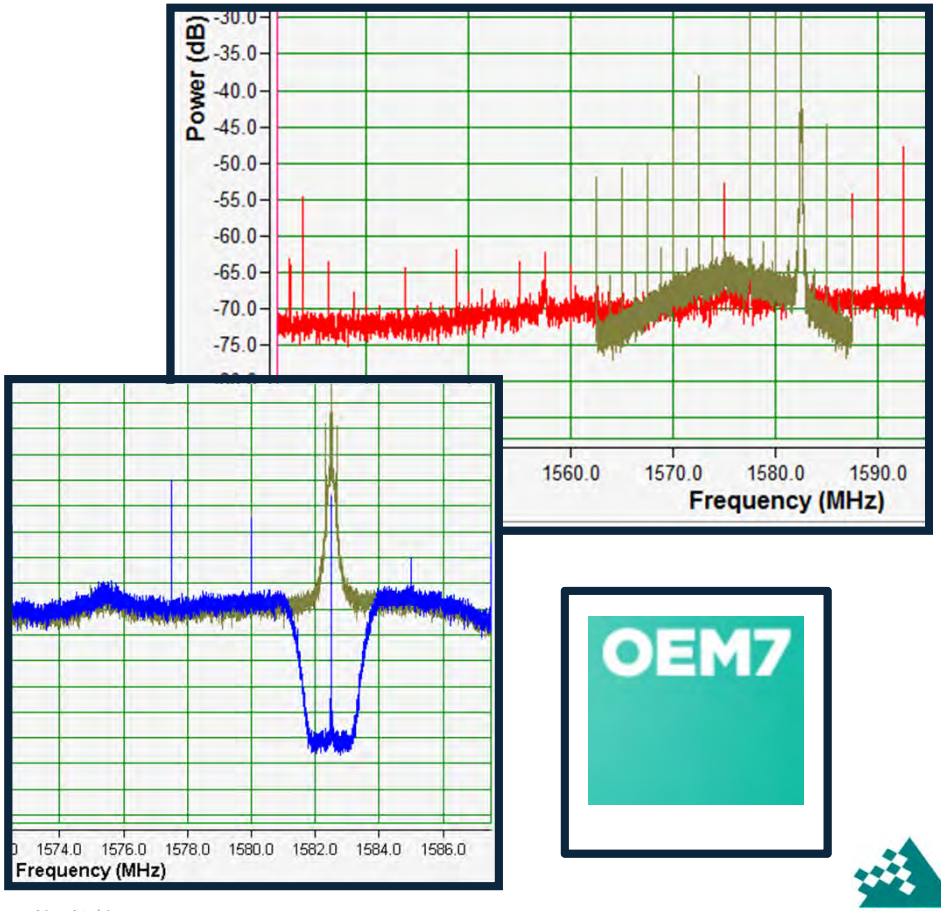
- Install a cavity filter between the GNSS antenna and receiver
  - Large
  - Heavy
  - Expensive



Source: ebay.com

New alternative to interference mitigation

- On-board filtering and signal processing with Interference Toolkit
  - See interference using spectral analysis
  - Mitigate using advanced signal processing and digital filtering
  - Part of every OEM7



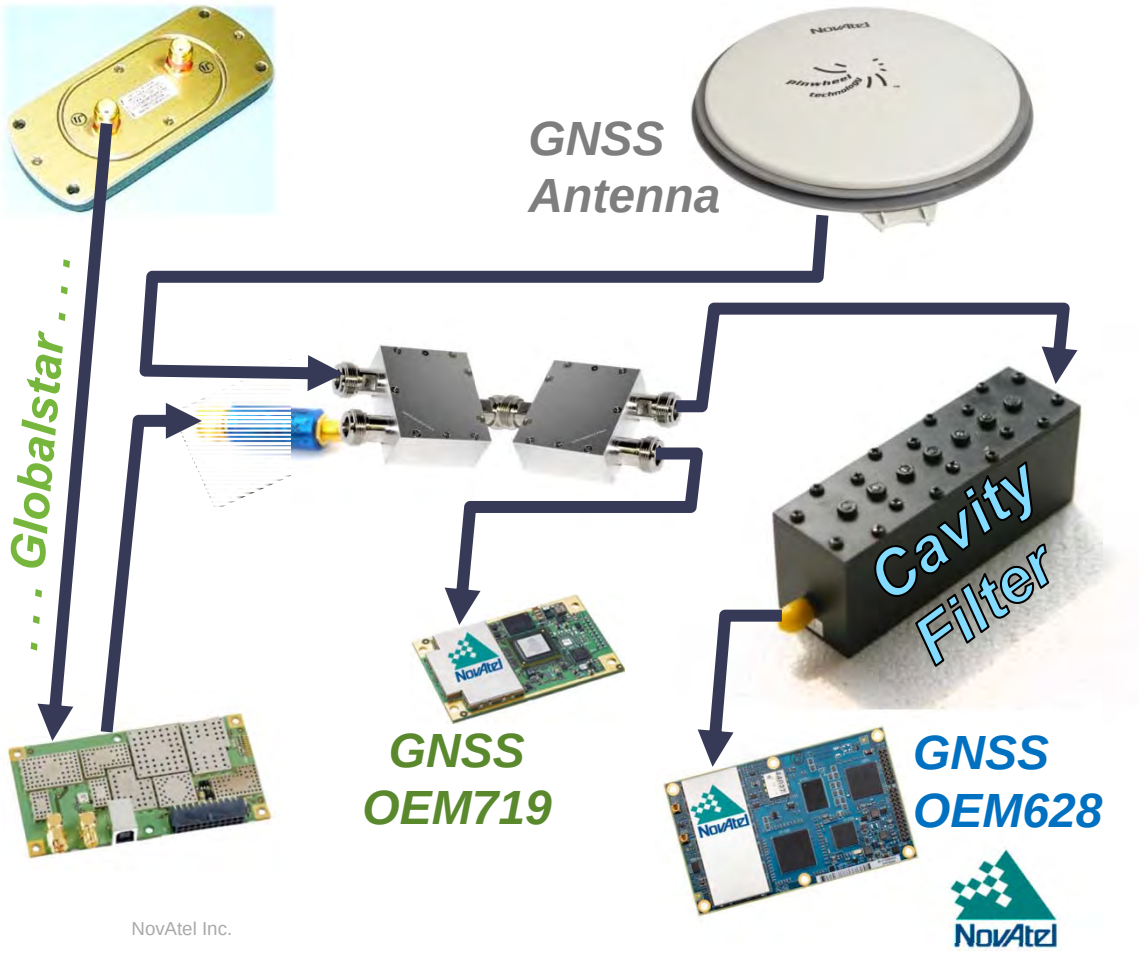
So can our alternative mitigation save the castle?

OR

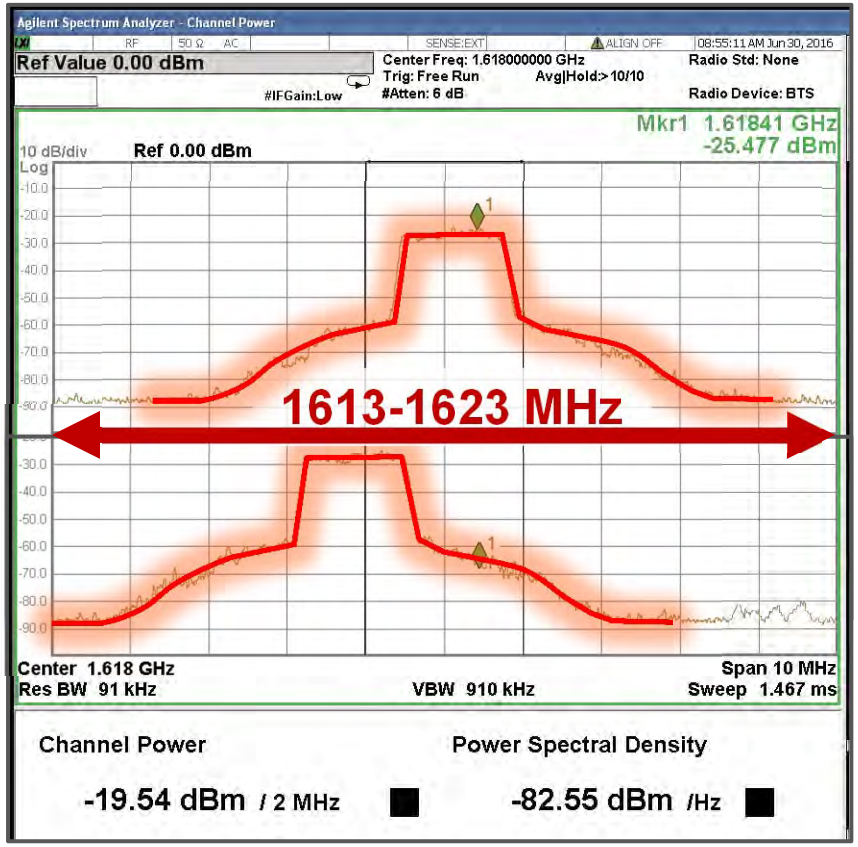
LET’S DO SOME TESTS

Test setup

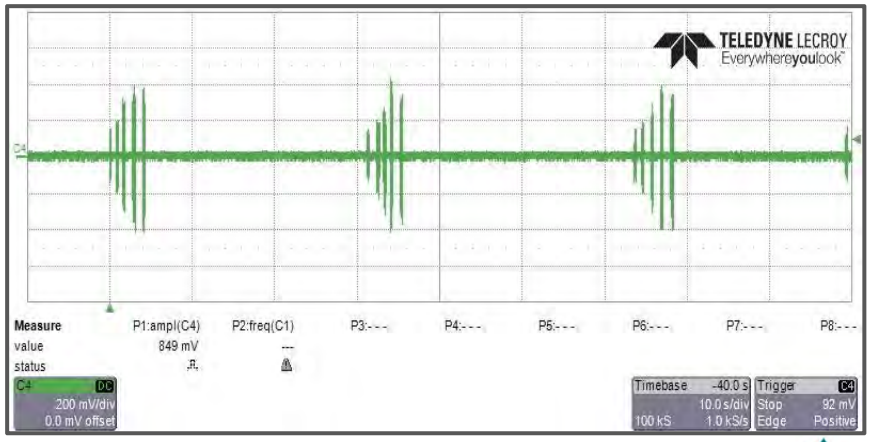
- Live satellite tracking on the roof
- Injected interference signal at receiver input from Globalstar modem
- OEM628 will use a cavity filter
- OEM719 will use the Interference Toolkit



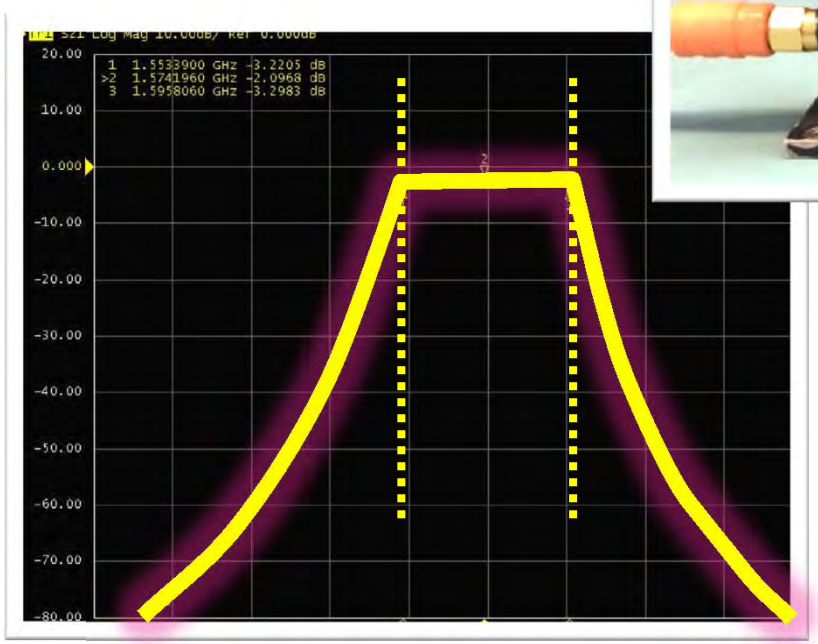
Interference source: Globalstar satellite modem



- Globalstar signal transmits between 1610 and 1619 MHz
  - Transmit signal can shift, as shown on the left
- Attempts to uplink every 30 sec.



Cavity Filter connected to OEM6

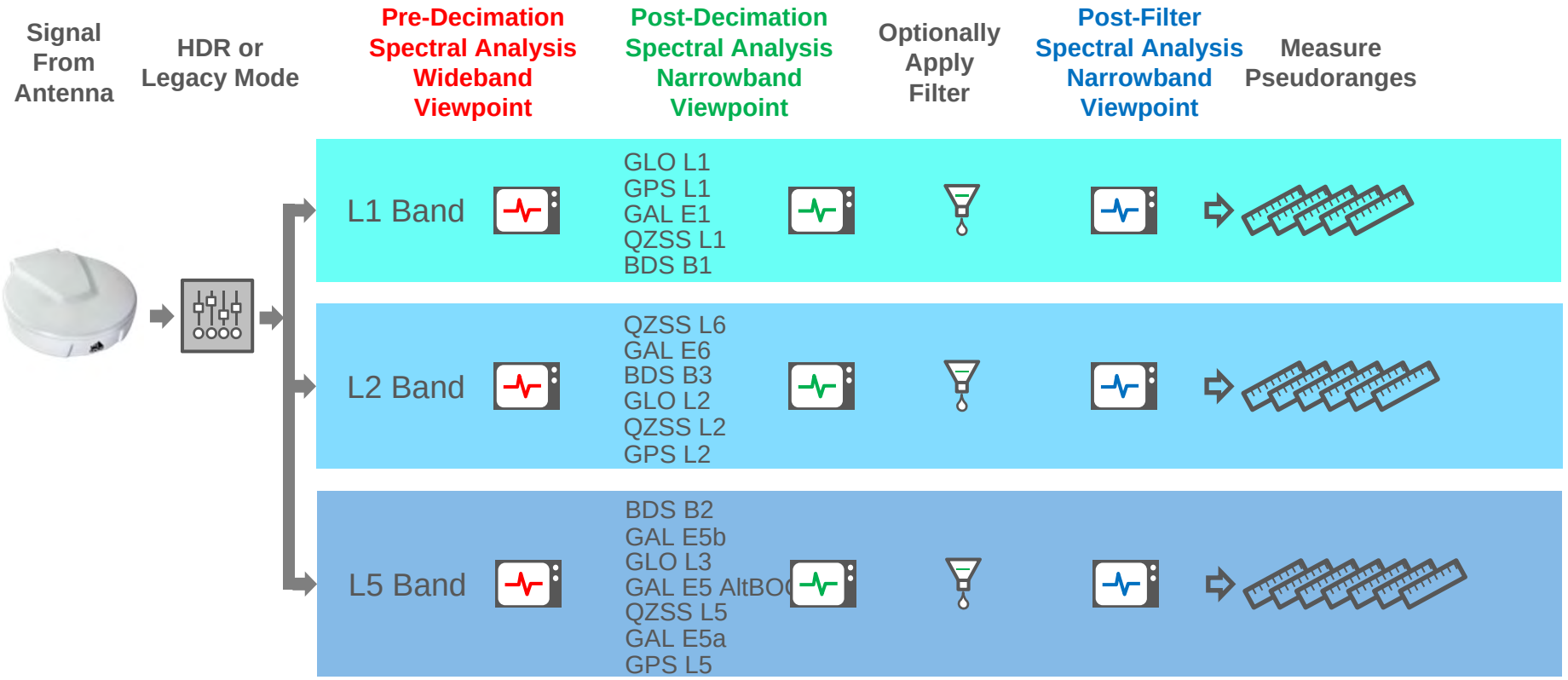


1553 - 1595 MHz

Passes:
- GPS L1
- Galileo E1
- BeiDou B1

Blocks:
- L-band
- GLONASS L1
- Globalstar

Interference Toolkit in operation on OEM7



Spectral Analysis – Signal Selection

Easy to use

Step 1: Select where in the signal RF path to view the spectrum

- Pre-decimation shows the widest spectrum viewpoint (up to 100 MHz wide)
  - Provides an excellent overview
- Post-decimation shows the signal entering the GNSS path (25 MHz wide)
  - Shows what normally is turned into pseudorange measurements
- Post-Filter shows the signal after applying mitigation filters (25 MHz wide)
  - Shows how well the filter is removing interference

Step 2: Select which part of the RF spectrum to analyze

- Select GNSS frequency of interest
  - Examples: Galileo E5b
    GPS L1, etc.

GPS	L1
GLONASS	L1
Galileo	E1
BeiDou	B1
QZSS	L1

L-Band	L

GPS	L2
GLONASS	L2
Galileo	E5b
	E5 AltBOC
	E6
BeiDou	B2
	B3
QZSS	L6

GPS	L5
GLONASS	L3
Galileo	E5a
QZSS	L5

Step 3: Done

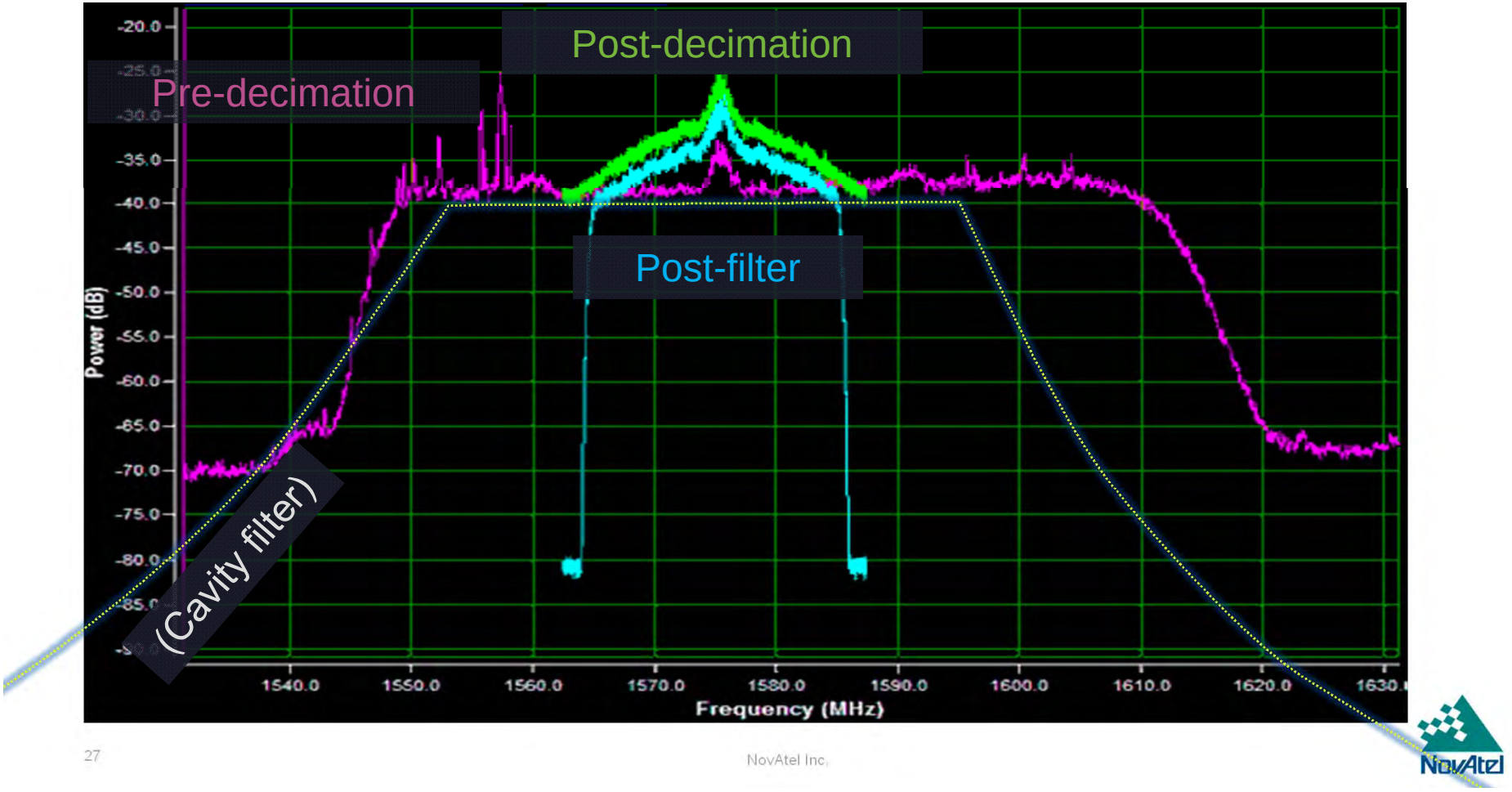
Interference Mitigation: HDR Mode

- User must decide to initiate wideband mitigation (HDR mode) or not (Legacy mode, default)
  - **High Dynamic Range** (HDR) mode turns on special signal processing, and draws slightly more power
  - **Legacy** mode is the normal signal filtering, designed for minimal power draw and normal RF environments
- HDR mode works by sharpening the band filter and actively adjusting signal levels within the RF band
  - Improves linearity and optimizes the AGC to withstand strong interferers
- HDR mode can be combined with notch and/or bandpass filters
- New user command to select and manage HDR mode

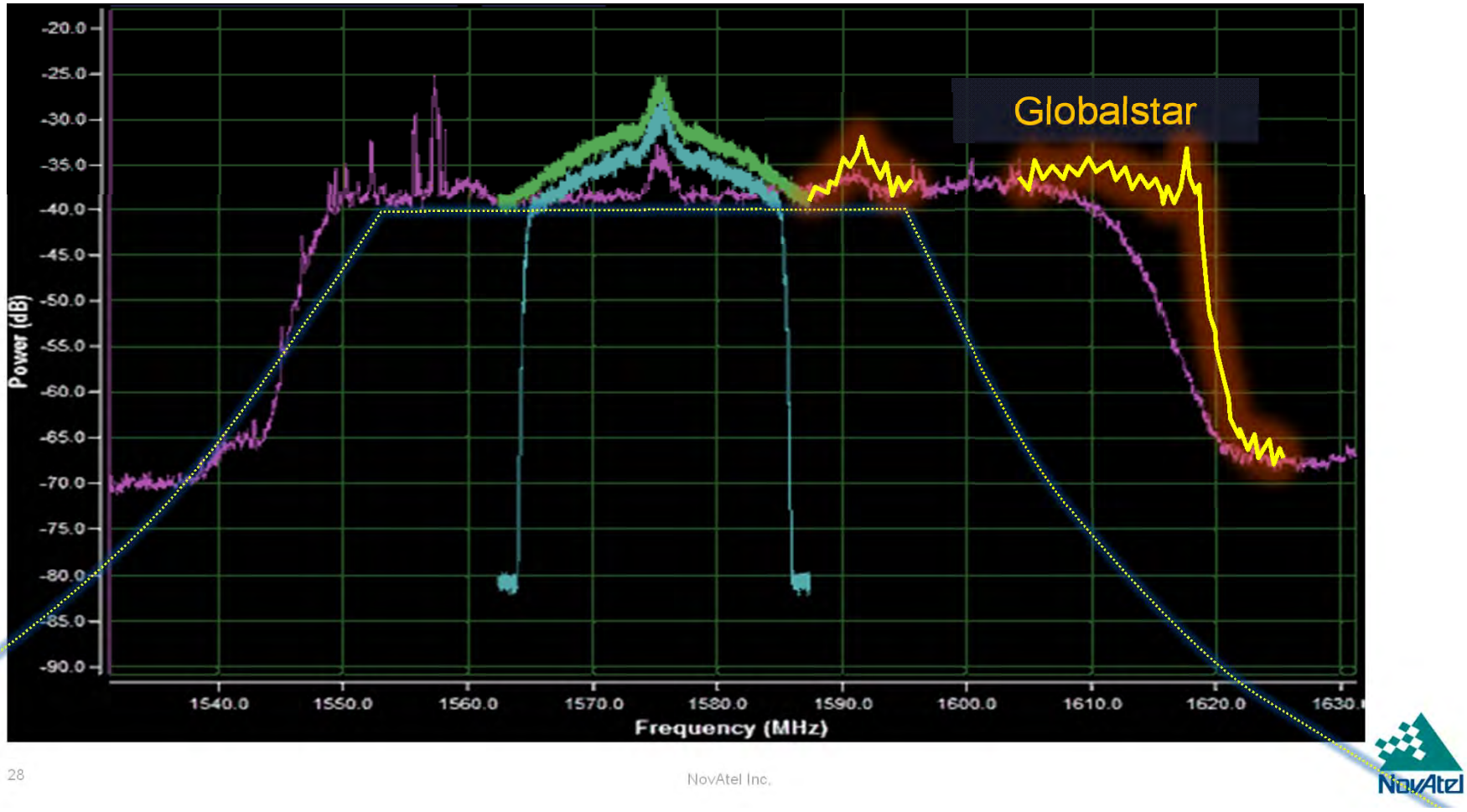
Interference Mitigation: Filters

- Currently the user must initiate mitigation (filters) if desired, later it will be auto
- Filter mitigation works by pushing the interferer below the noise floor of the RF band
- Filters are configurable to adjust rejection bands
- Two mitigation options:
  - **Bandpass** filter
  - **Programmable** filter, configure as:
    - Notch filter
    - Bandpass filter
- Multiple filters can be chained together on a single RF path
- OEM7 filters are symmetrical around a band's central frequency
- New user commands added to select and manage filters

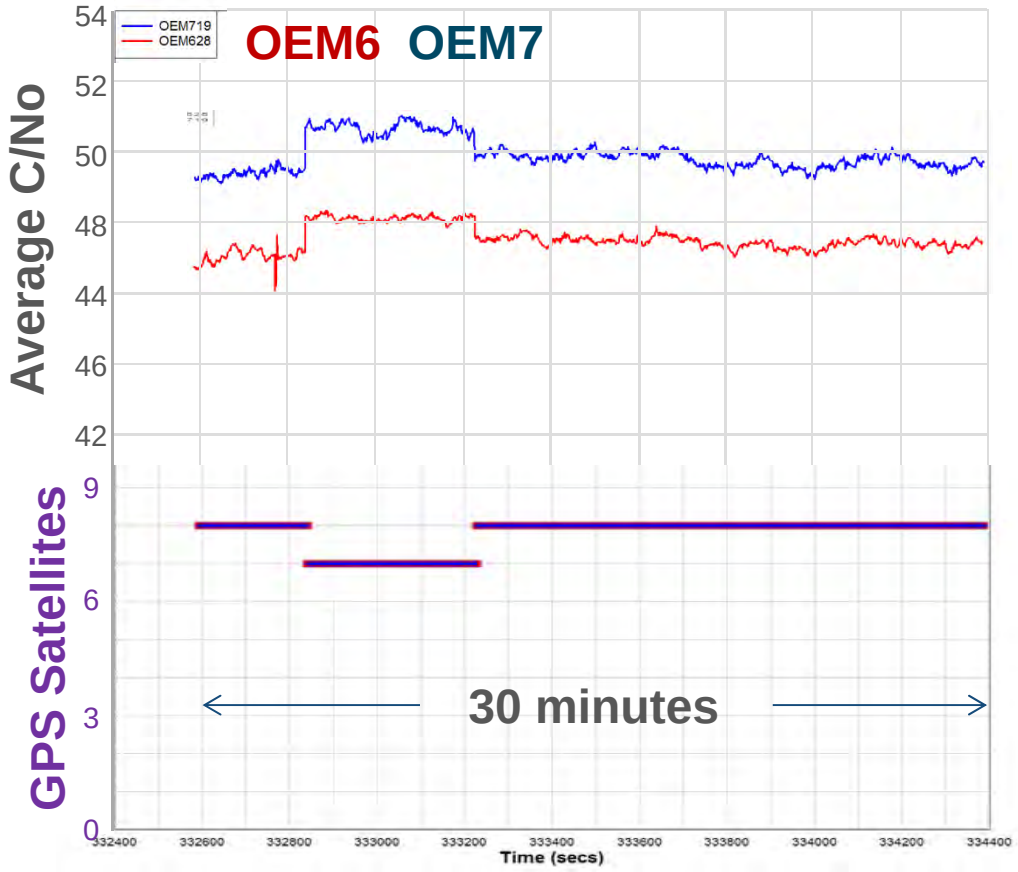
GPS L1 pre- and post- decimation, and post-filter

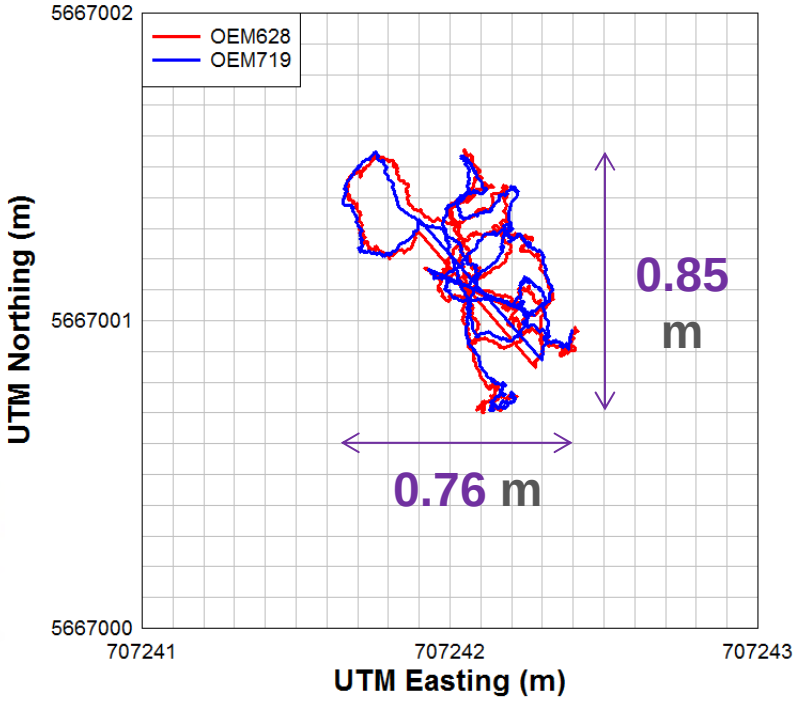


Adding interference



Performance – no interference, no mitigation, 30 minutes



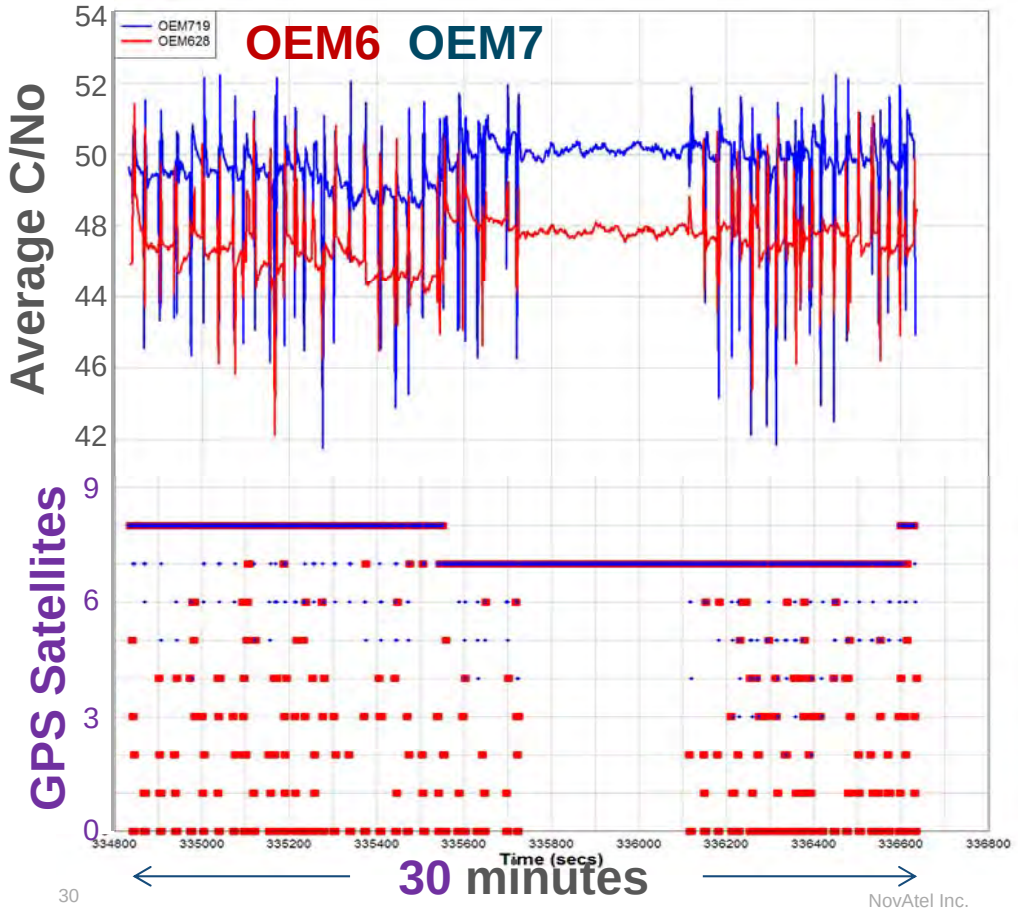


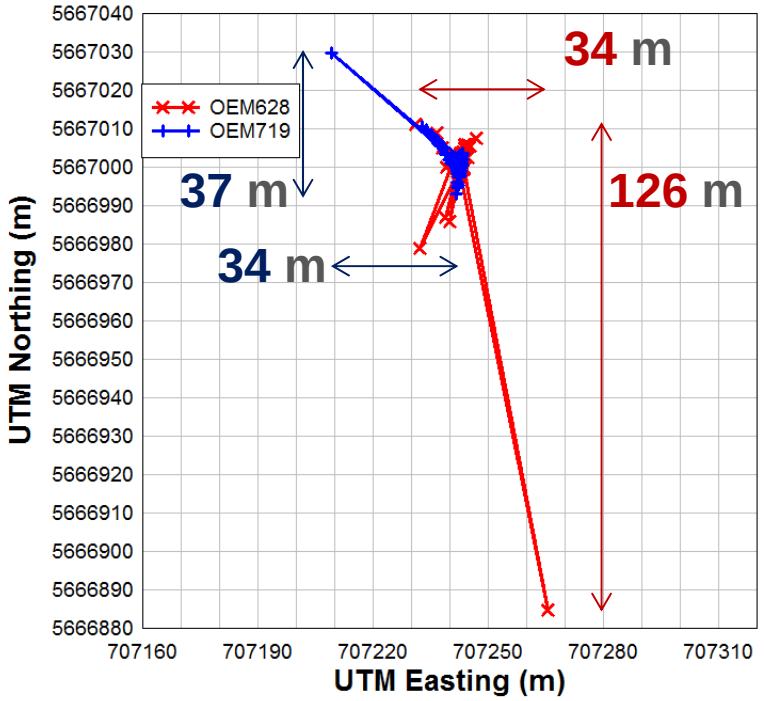
Horizontal Standard Deviation

OEM6 0.28 m

OEM7 0.28 m

Performance – with interference, no mitigation, 30 min.



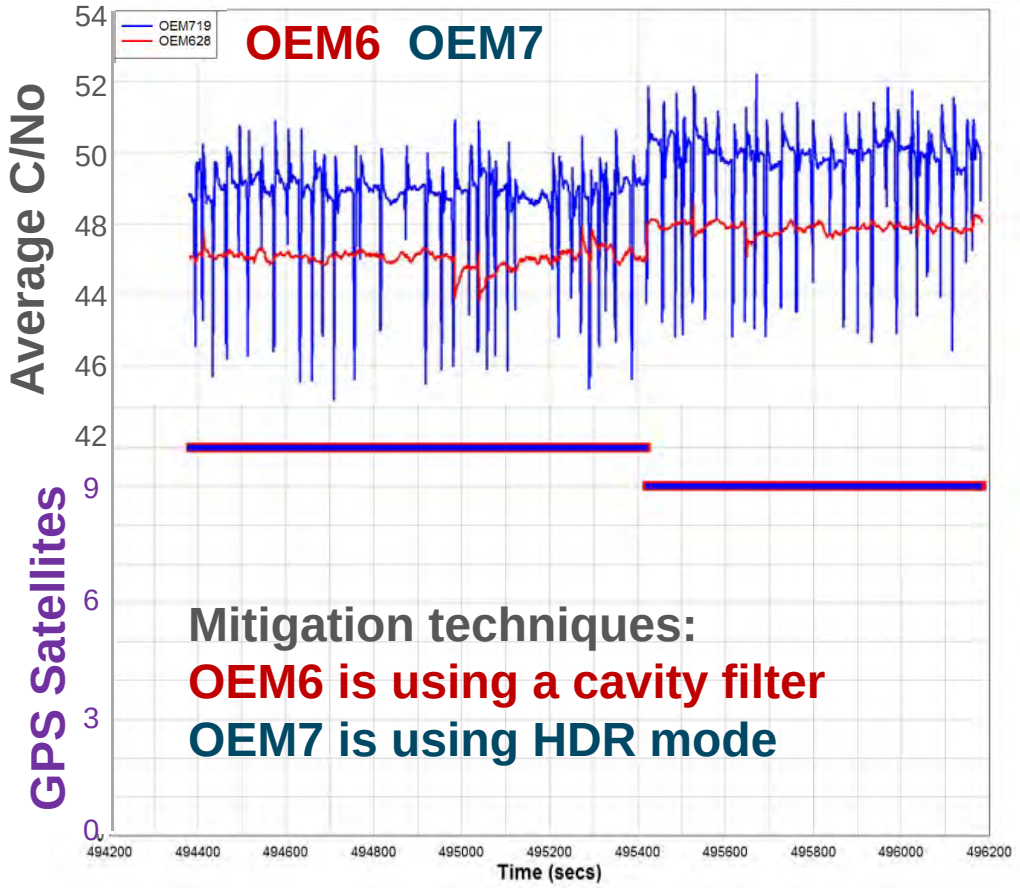


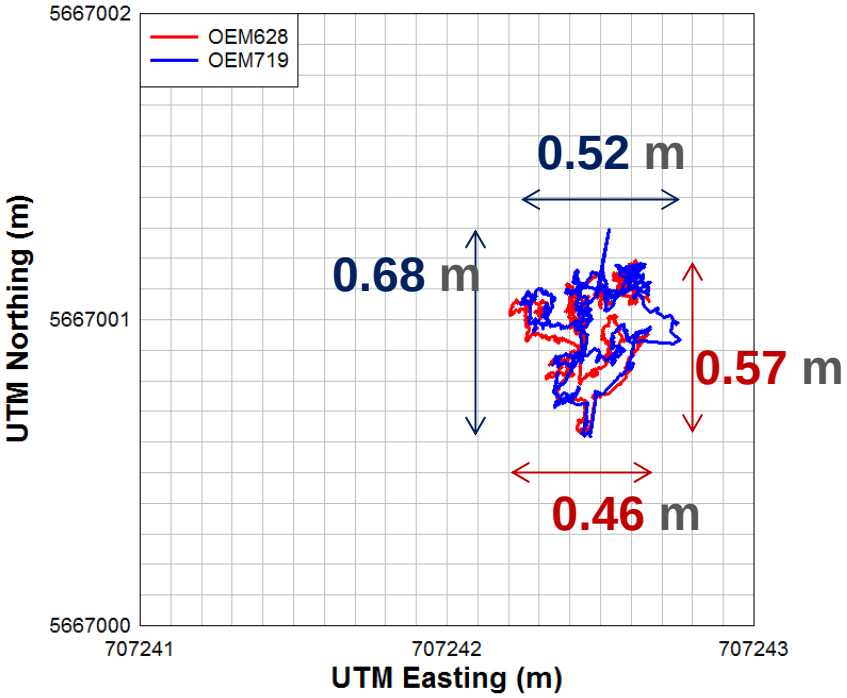
Horizontal Standard Deviation

OEM6 3.56 m

OEM7 1.83 m

Performance – with interference, with mitigation, 30 min.





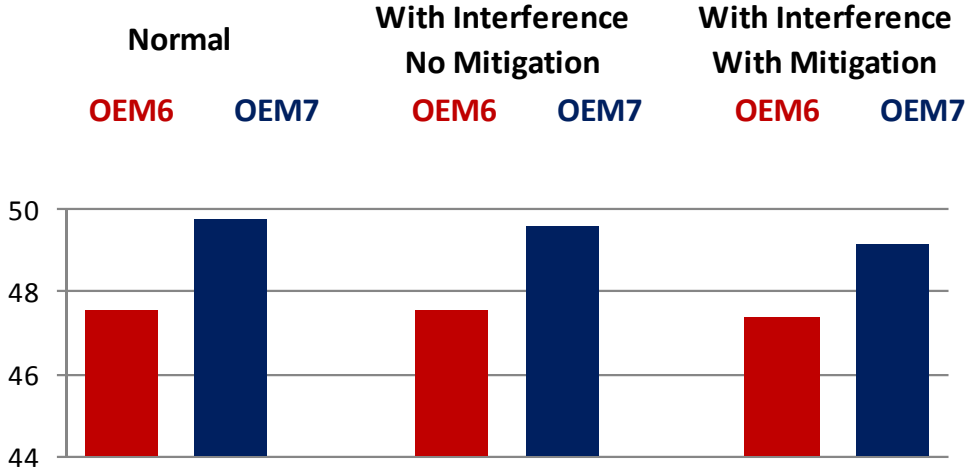
Horizontal Standard Deviation

OEM6 0.17 m

OEM7 0.17 m

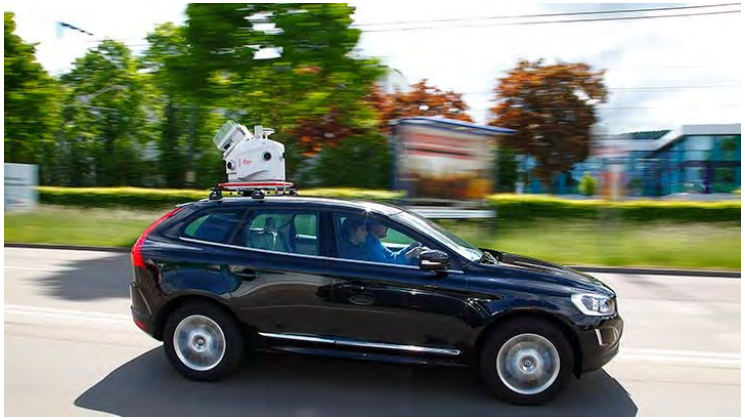
Conclusion

- Using Interference Toolkit, OEM7 performs the same as OEM6 does with a cavity filter



	Normal		With Interference No Mitigation		With Interference With Mitigation	
	OEM6	OEM7	OEM6	OEM7	OEM6	OEM7
C/No (dB-Hz)	47.5	49.8	47.6	49.6	47.4	49.2
Satellites	7.78	7.78	6.20	7.23	9.58	9.58
	Same				*Same*	
Hor. StDev. (m)	0.28	0.28	3.56	1.83	0.17	0.17
	Same				*Same*	

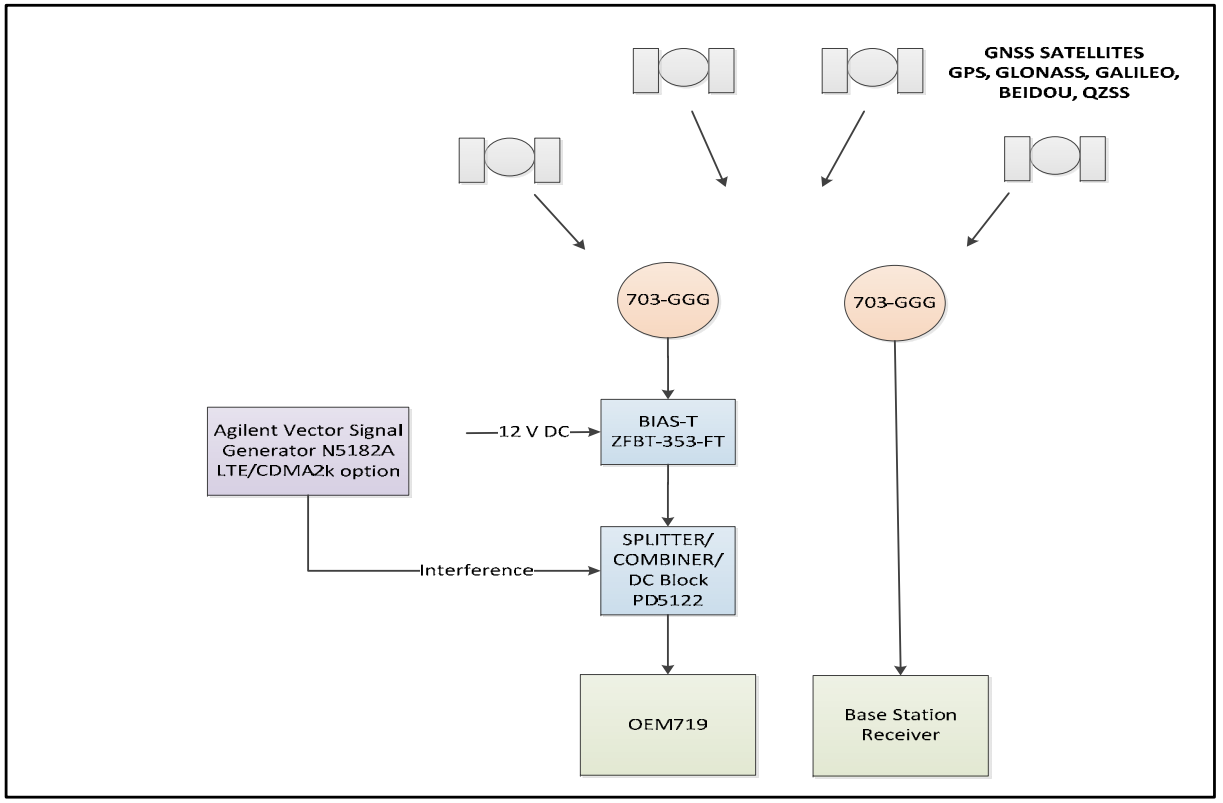
But what about precise multi frequency GNSS users



- Need minimum RTK or PPP
- Cannot move antenna away from the interference
- Not practical to use multiple cavity filters…..
- Can our alternative mitigation work?

Test Setup – As presented at ION 2016

- Live satellite tracking on NovAtel's roof
- Injected interference signal at receiver input from signal generator
- OEM719 is the unit under test
- "Clean" base station receiver used to compute a 5m baseline RTK solution



Test Cases

Three types of interferer presented

» In-band Continuous Wave (1582.5 MHz, -44 dBm)

» Out of band Narrowband (1625 MHz, 1.2288 MHz BW CDMA, -14 dBm)

» Out of band Wideband (1625 MHz, 10 MHz, LTE, -28 dBm)

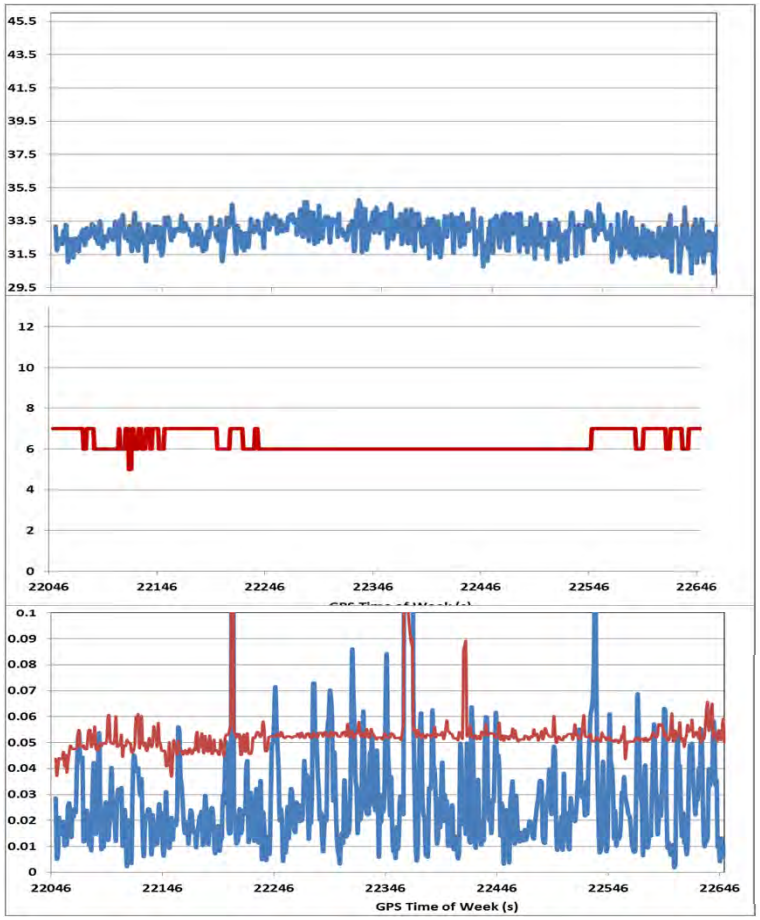
Receiver performance shown before and after mitigation

» Average GPS L1 C/No, over all satellites tracked for each epoch

» Number of Satellites tracked

» RTK position accuracy

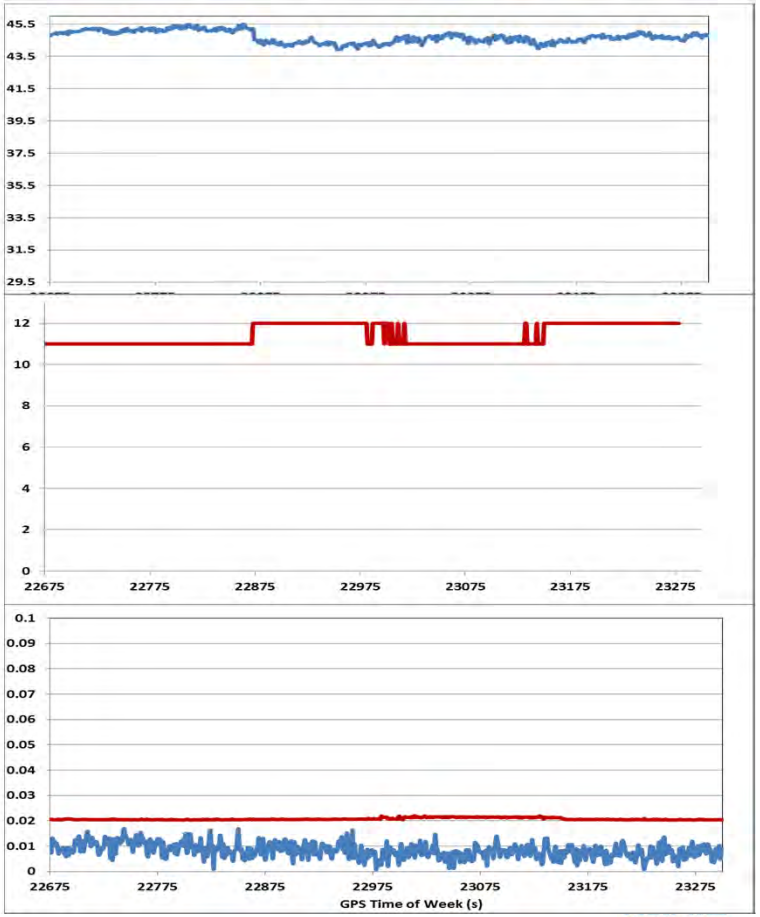
In Band CW: Before and After Mitigation



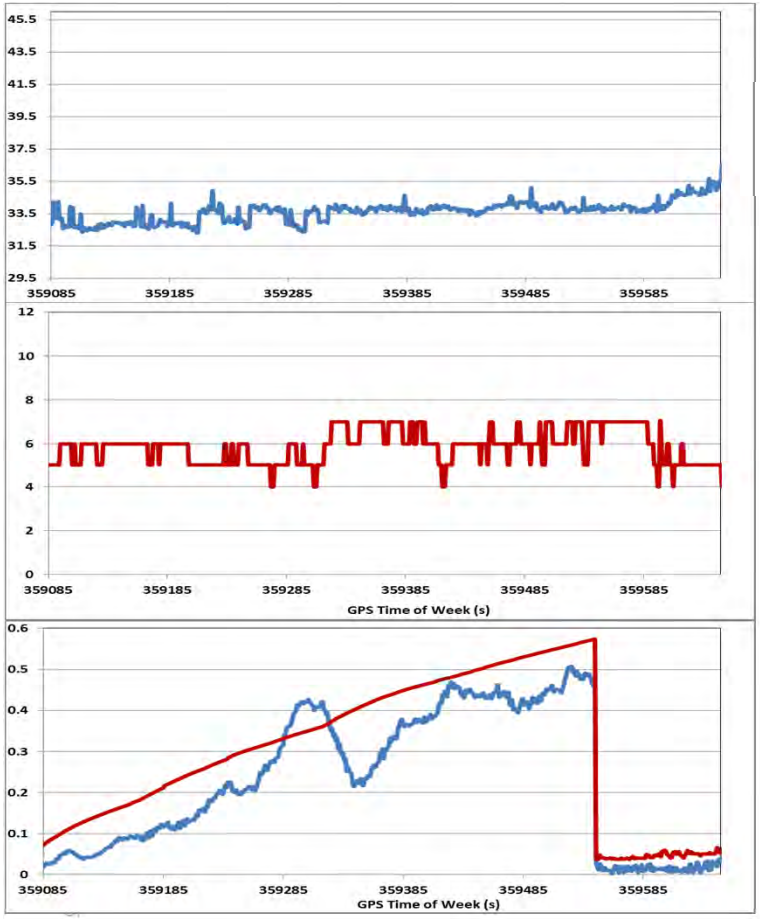
Average C/No (dB-Hz)

Satellites Tracked

3D RTK Position Error Reported 3D Std. Dev. (m)



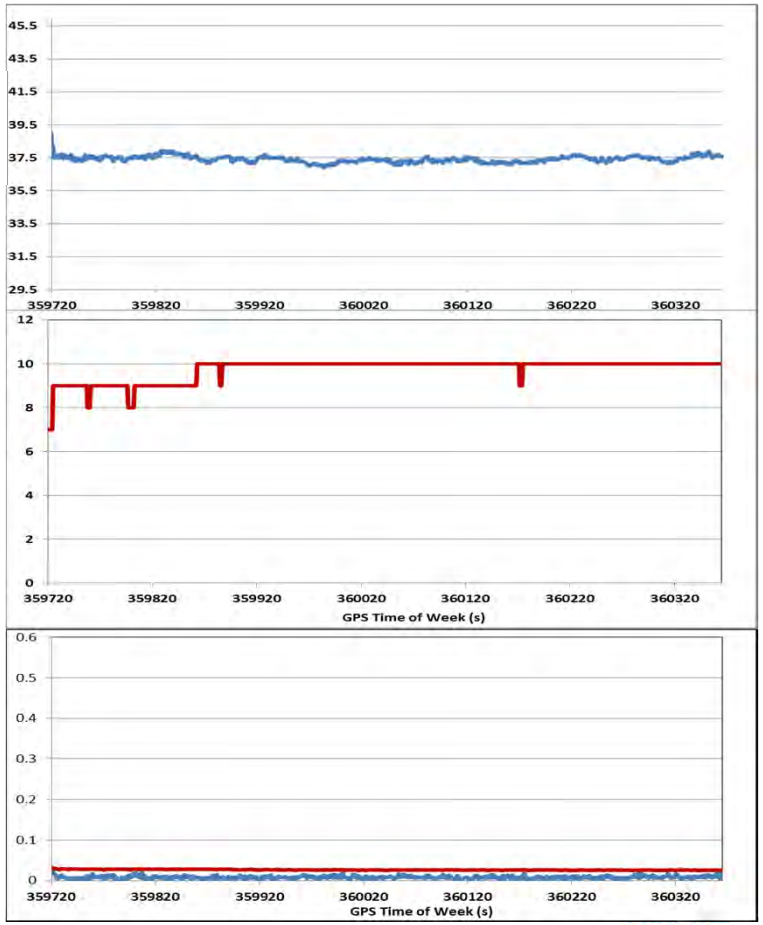
Out of Band NB: Before and After Mitigation



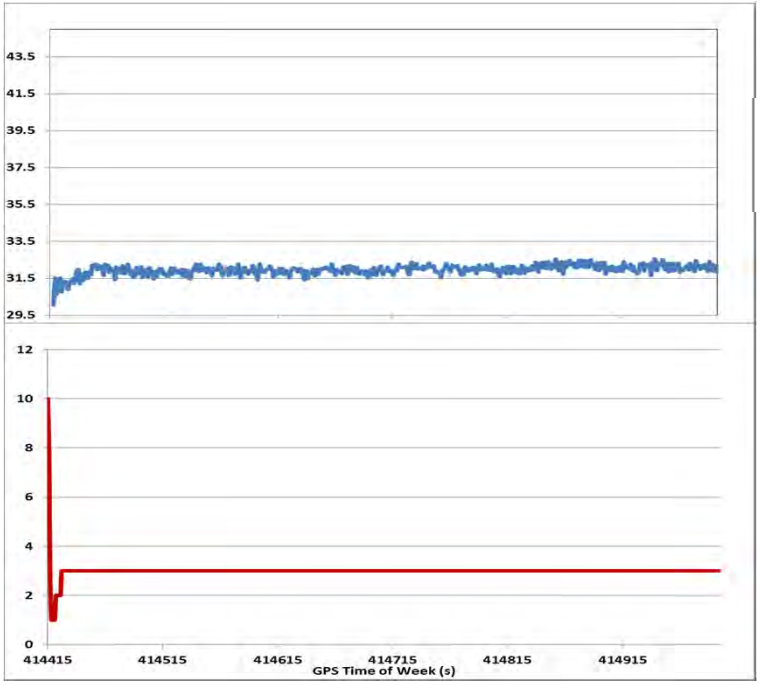
Average C/No (dB-Hz)

Satellites Tracked

3D RTK Position Error Reported 3D Std. Dev. (m)



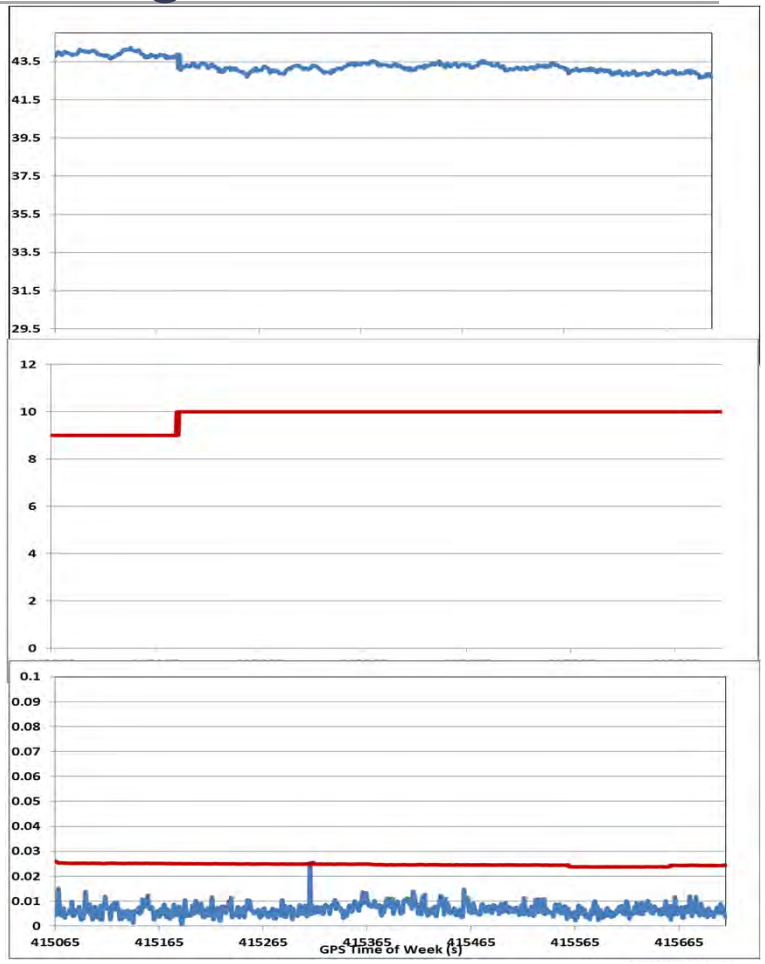
Out of Band WB: Before and After Mitigation



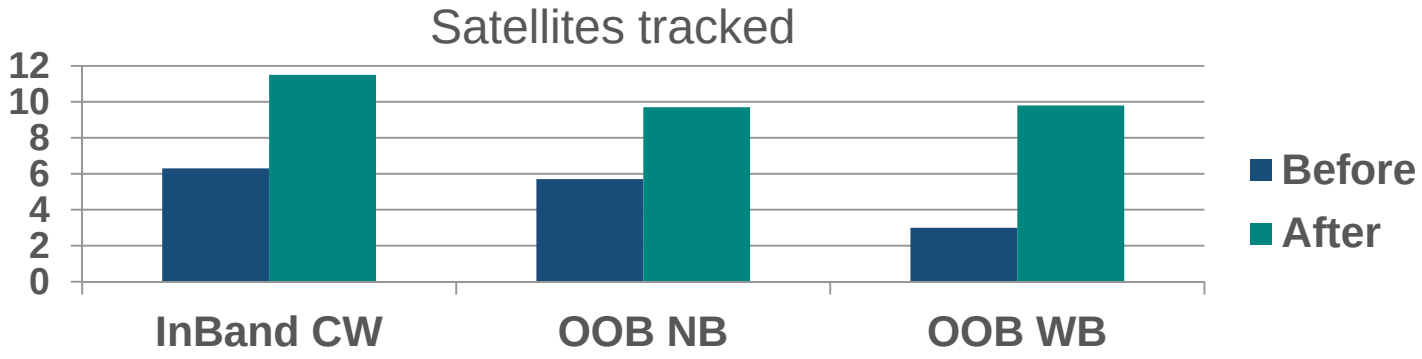
Average C/No (dB-Hz)

Satellites Tracked

3D RTK Position Error Reported 3D Std. Dev. (m)



Conclusion



3D RMS RTK Position Error	Before	After
In band CW	0.040 m	0.009 m
OOB NB	0.279 m	0.009 m
OOB WB	N/A	0.007 m

- Using the Interference Toolkit, OEM7 improves availability and accuracy for RTK in the presence of interference

NovAtel® Inc.

Ensuring your success.