Real World Receiver Testing and the 1dB Criteria

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Introduction

Measurement of GNSS Receiver parameters

- Last year we examined measurement parameters when GNSS Receivers were subjected to Adjacent band interference
- 1dB degradation in CNR used in European ETSI standard for ABC
  - Established Interference Protection Criterion (USAF justification paper)
  - Some agencies have proposed use of GNSS accuracy or Time to First Fix as a preferable metric
- The 1dB IPC does not require the level of harmful RF interference to be specified..
- Spirent approach – use automated test bench to carry out many repeated measurements on sample receivers across increasing interference levels

Test Set-up

PNT Test Bench

Control commands

RF Simulator
Scenario Generation

Automated Test Execution
Receiver Logging & Control
Configurable Test Parameters
Report Generation

Receiver Data

Control commands

DUT
Receivers A,B,C,D,E,X

GNSS
Device under test

RF Navigation Data

Test Method

The GNSS RED Adjacent Band Interference test

Frequency band (MHz)	Test point centre frequency (MHz)	Adjacent frequency signal power level (dBm)	Comments
1518 - 1 525	1 524	-65	MSS (space-to-Earth) band
1 525 - 1 549	1 548	-95	MSS (space-to-Earth) band
1 549 - 1 559	1 554	-105	MSS (space-to-Earth) band
1 559 - 1 610		GUE RNSS band under test	
1 610 - 1 626	1 615	-105	MSS (Earth-to-space) band
1 626 - 1 640	1 627	-85	MSS (Earth-to-space) band

Frequency band (MHz)	Test point centre frequency (MHz)	Adjacent frequency signal power level (dBm)	Comments
960 - 1 164	1 154	-75	AM(R)S, ARNS band
1 164 - 1 215		GUE RNSS band under test	
1 215 - 1 260		GUE RNSS band under test	
1 260 - 1 300		GUE RNSS band under test	
1 300 - 1 350	1 310	-85	Radiolocation, ARNS, RNSS (Earth-to-space) band

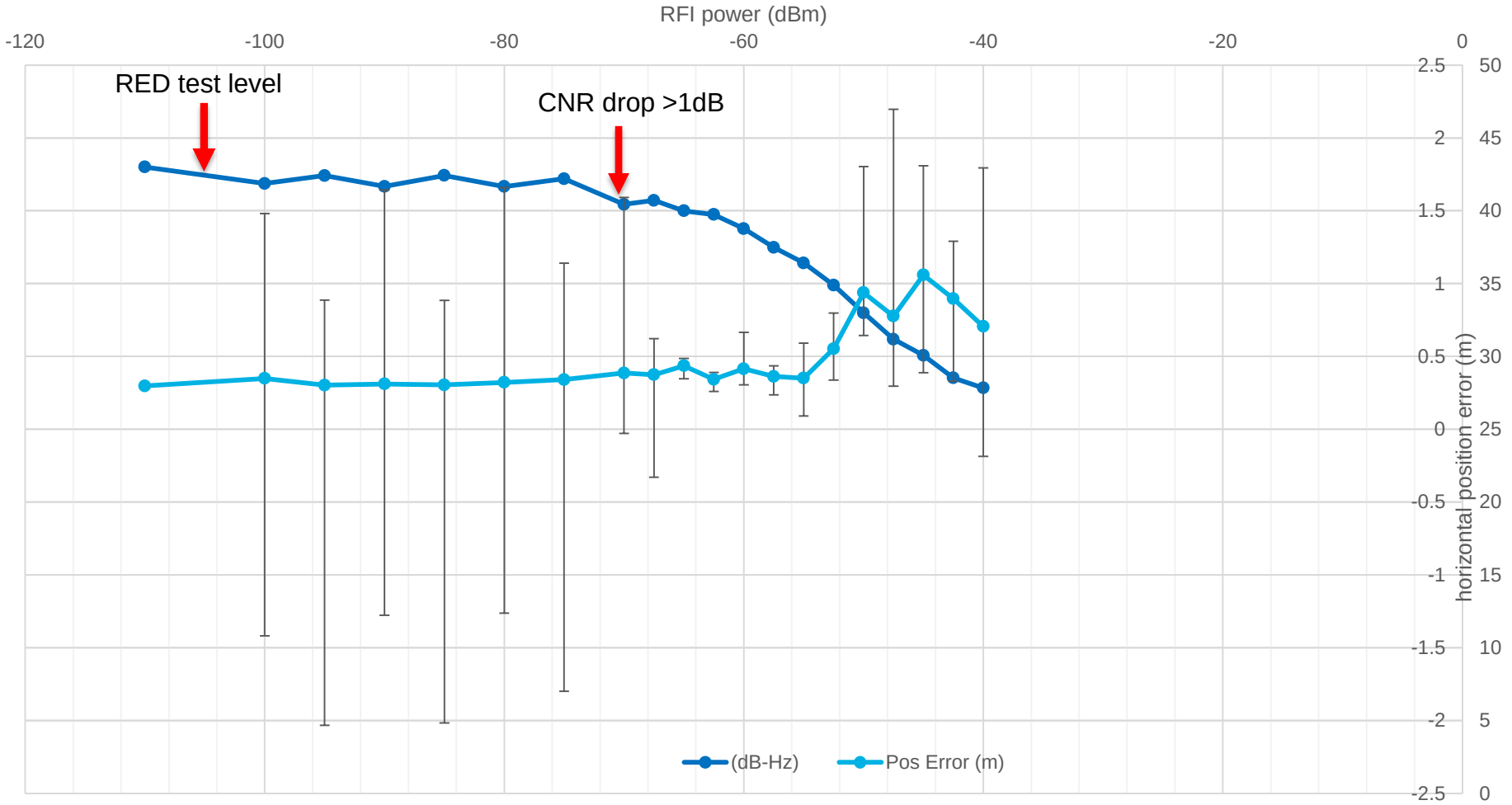
Parameter	Value	Comments
Frequency	See tables 4-2 and 4-3	
Power level	See tables 4-2 and 4-3	
Bandwidth	1 MHz	See clause B.1 for details
Format	AWGN	

RED: “Radio Equipment Directive”
GNSS RED: ETSI EN 303 413
Detail of requirements and tests necessary for GNSS receivers

Note: The GNSS RED also includes an emissions test – not covered in this presentation…….

RFI effects on CNR and Position

Manual Analysis 5 datasets, 60 samples

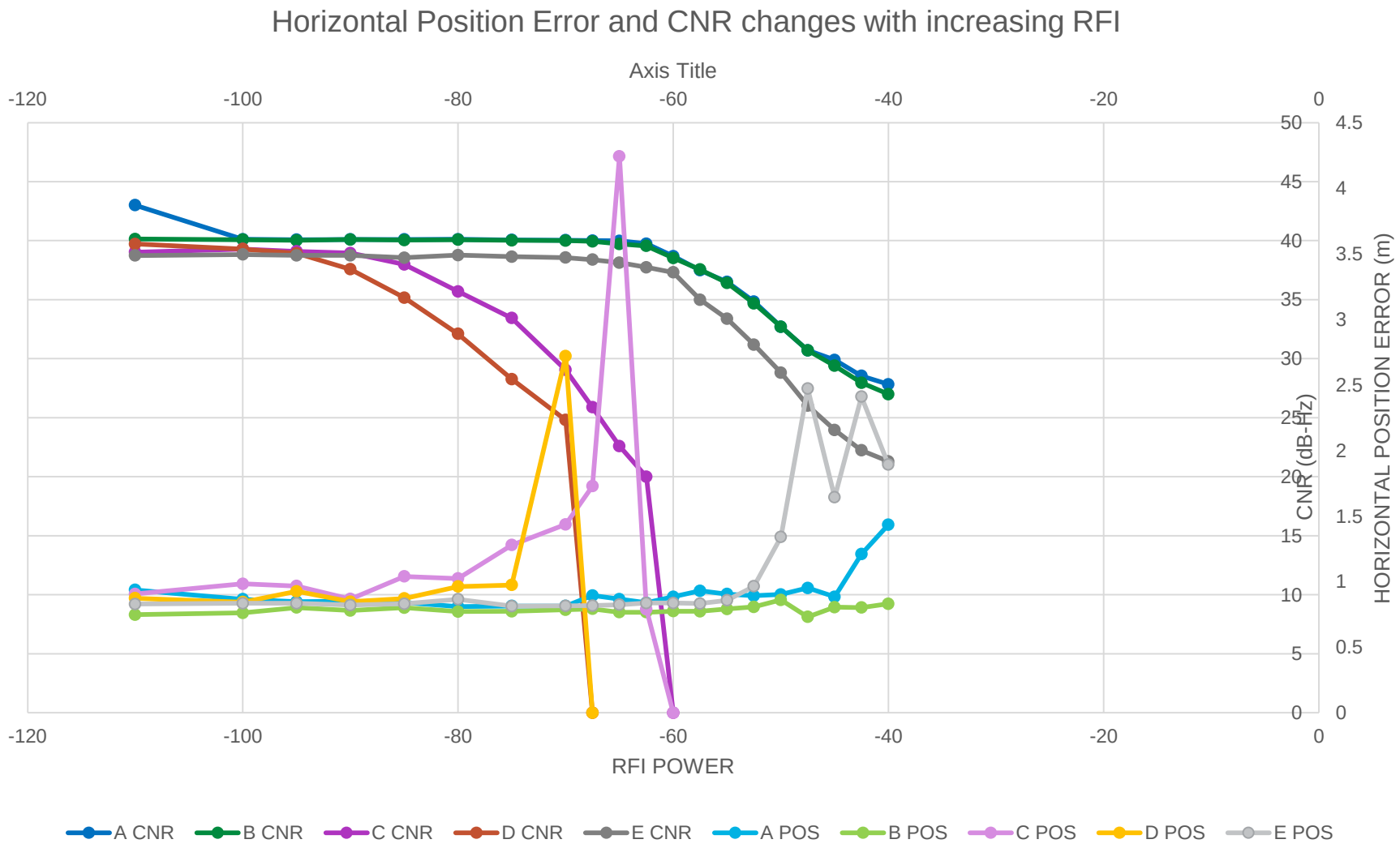


RFI Power and Horizontal position error at 1554MHz with measurement range (HPE) added - Receiver A

- Monitoring CNR and Horizontal Position Error with increasing RFI
- Full Range error bars displayed
- RED Test level and point of 1dB CNR drop marked out

RFI effects on CNR and Position

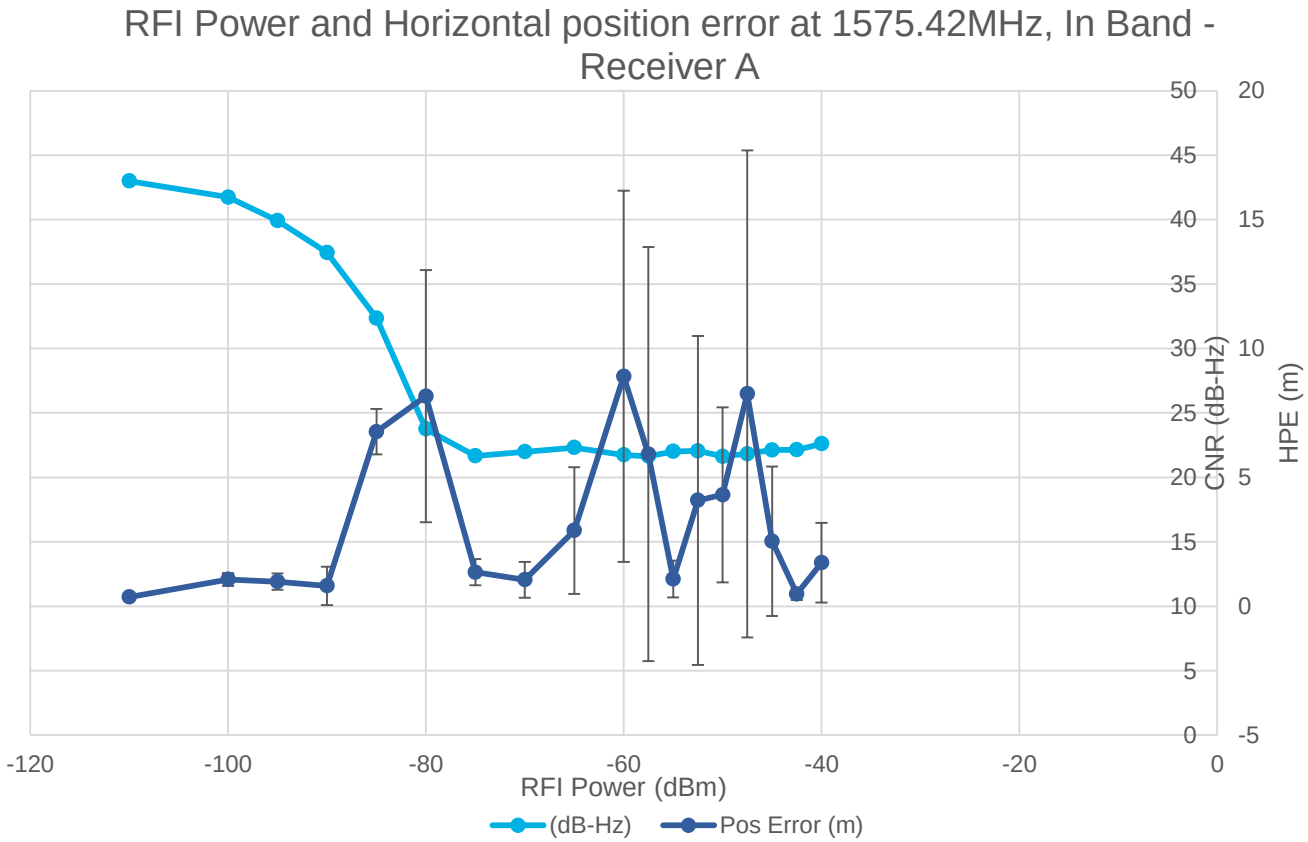
Manual Analysis 5 datasets, 60 samples, All receivers



- CNR and Horizontal Position error plotted for all Receivers with increasing RFI
- Note that CNR drop off (for all 5 TURs) occurs before HPE starts to fluctuate..
- Some of the TURs clearly much more susceptible to the RFI than others….

RFI effects on CNR and Position

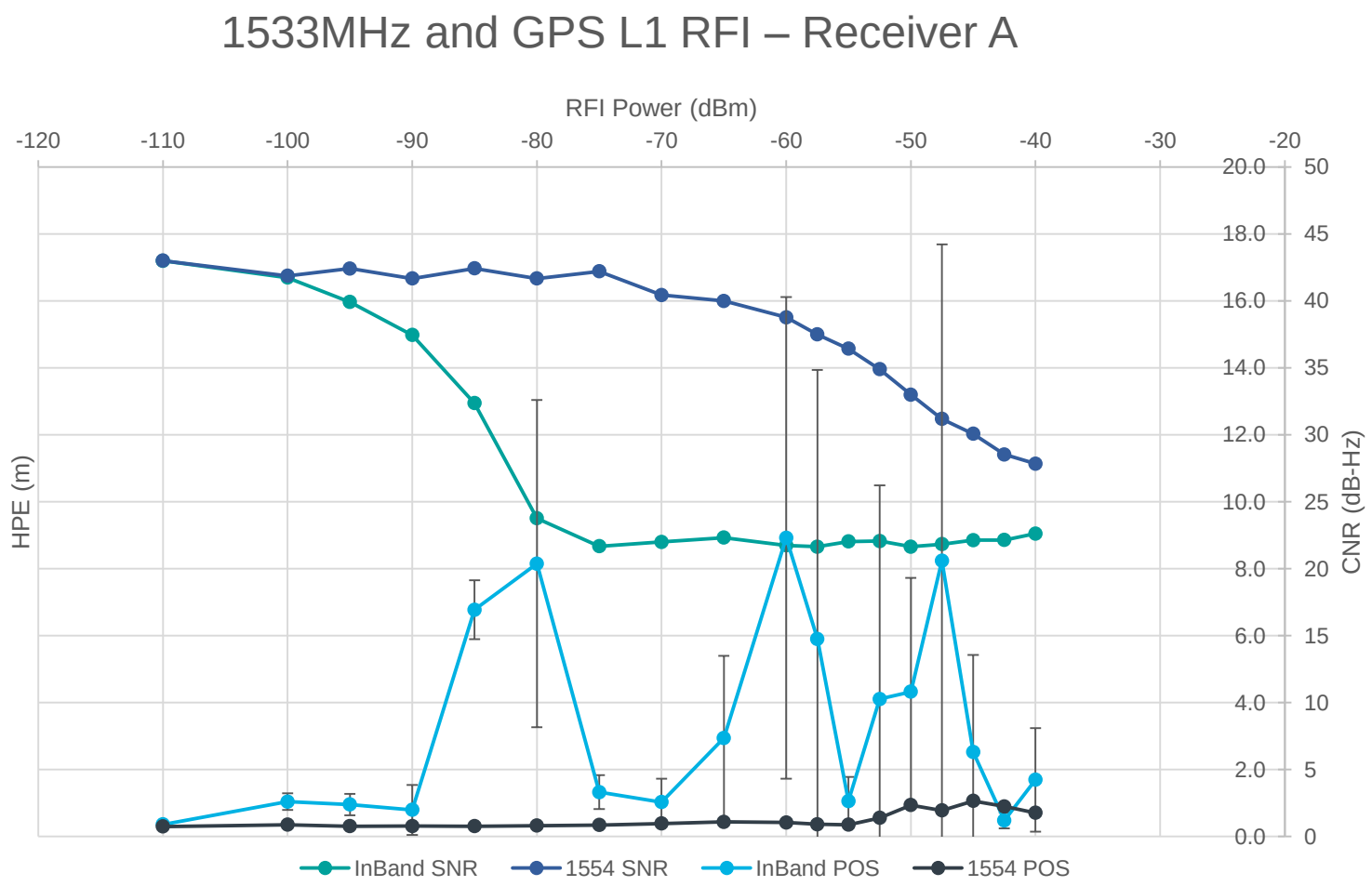
In-Band interference at GPS L1 Frequency



- Note Receiver A HPE fluctuations once CNR has degraded to minimum value of around 22.5 dB-Hz

RFI effects on CNR and Position

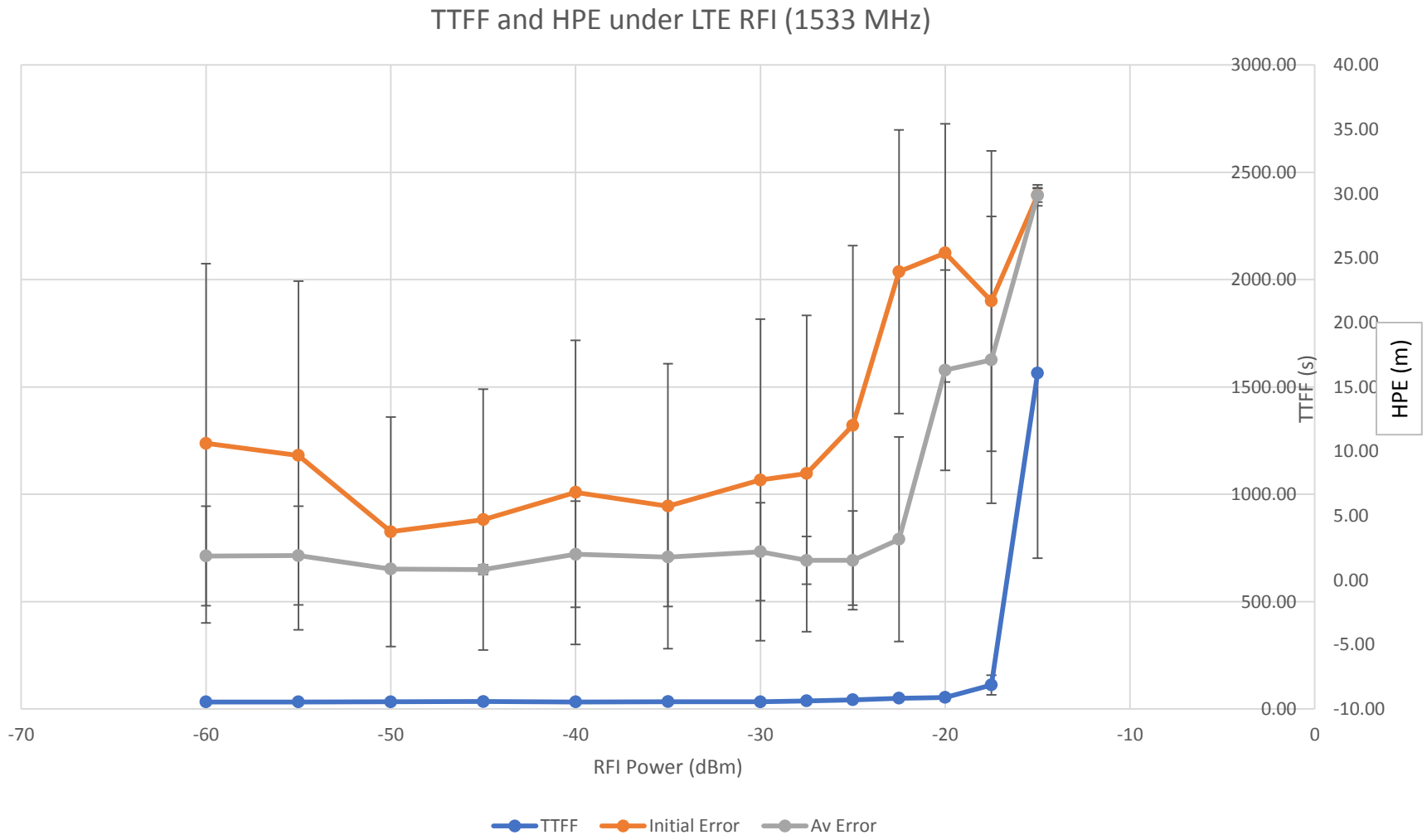
In-band and out of band interference comparison



- Interesting comparison of receiver behaviour – for both out of band and in-band interference CNR drop-off seen to precede degradation in HPE values…

HPE and TTFF under RFI

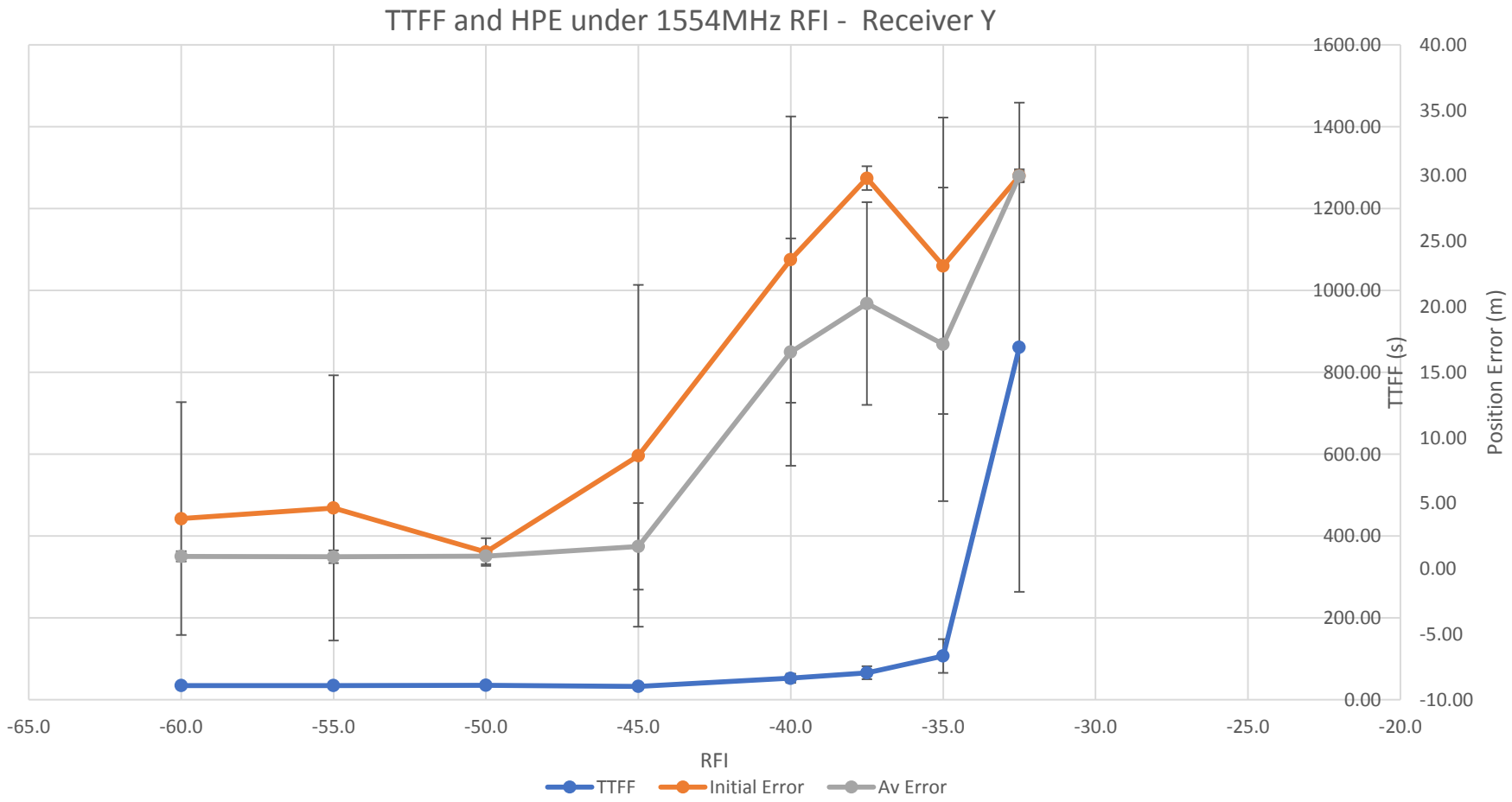
TTFF and HPE Comparison – Test Receiver A



- We see that (for this receiver –and all others we've tested so far) the HPE increases before any degradation in TTFF

HPE and TTFF under RFI

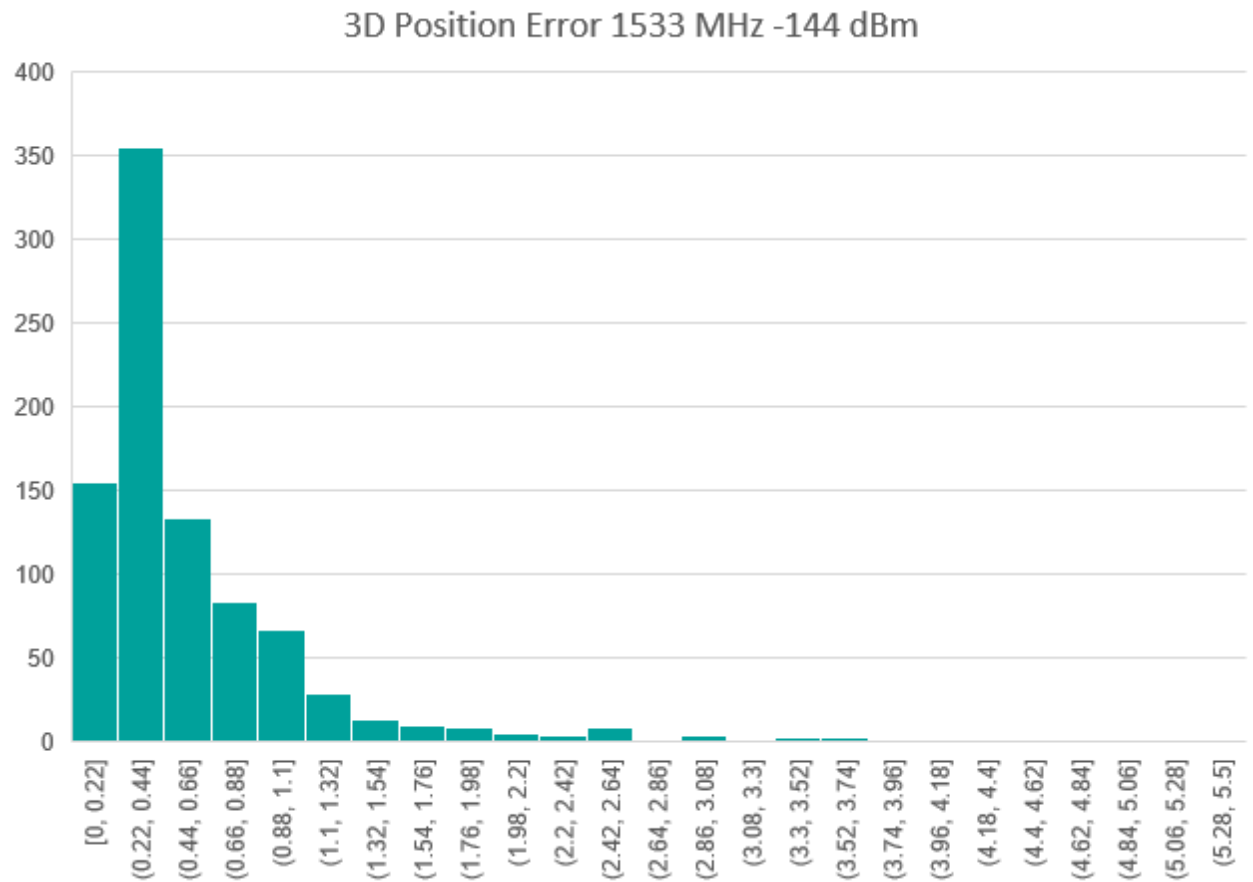
TTFF and HPE Comparison – Test Receiver A



- Whilst CNR not plotted for these two tests, we saw that CNR was a precursor to increasing HPE on this receiver

Variability in GNSS measurements

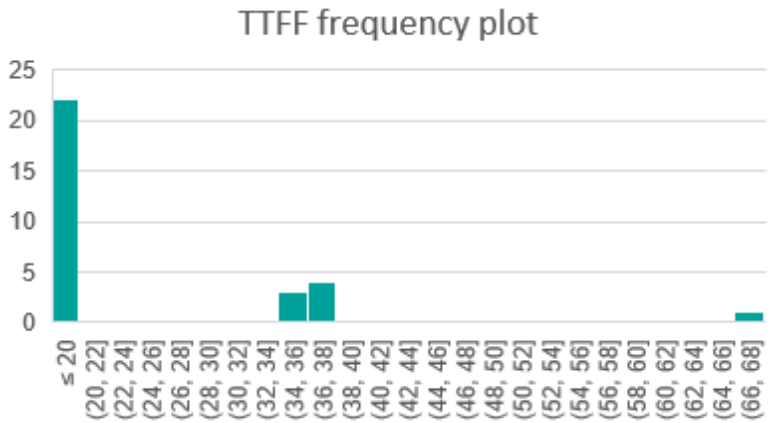
Example – 3D positioning accuracy



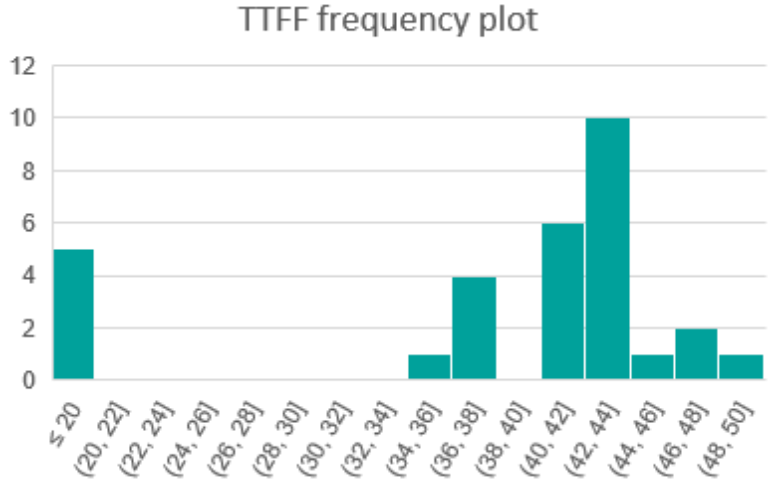
- Receiver “X” – this time 800 measurements taken using automated test bench
- Probability distribution can now be modelled and monitored across interference levels…
- Too few measurements could be problematic….

Variability in GNSS measurements

Example – Time To First Fix



-144 dBm



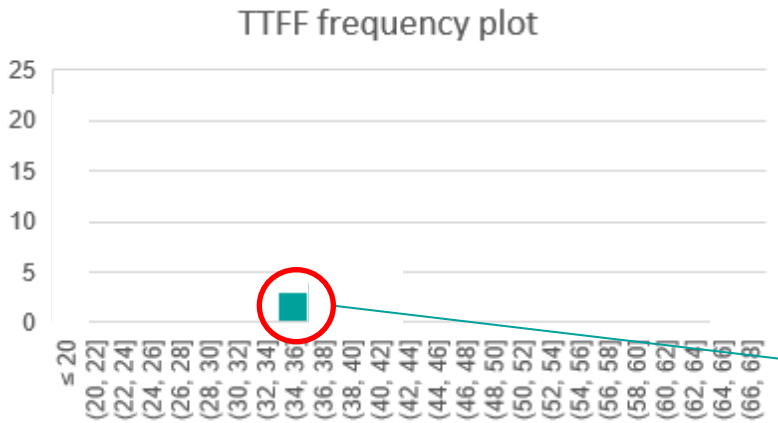
-30dBm

Receiver “X” with 1533MHz interferer (simulating LTE base station)
30 Measurements taken using automated Test Bench

- Any evidence of anomalous behaviour?

Variability in GNSS measurements

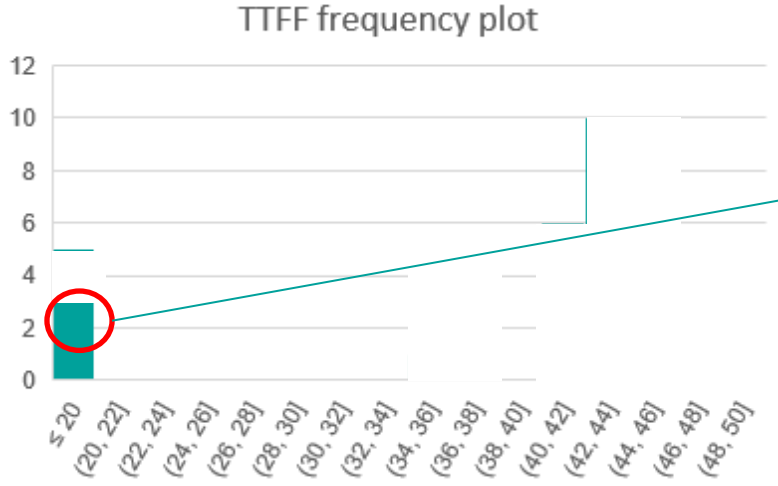
Example – Time To First Fix data



-144 dBm

Receiver “X” with 1533MHz interferer (simulating LTE base station) – Tester makes 3 measurements at each power level…

3 measurements



3 measurements

-30dBm

“Unlucky” – this small set of measurements might result in incorrect conclusions/decisions being made…..

Spirent Insights

…and further work

- Our results serve to confirm that under test conditions a 1dB degradation in CNR whilst subject to interference, is a precursor to reduced or erratic performance (HPE etc…) in GPS receivers
- Rather than just testing to a mandated level of RFI, the work we've done highlights testing past the 1dB degradation in CNR provides much deeper understanding of receiver behaviour
- Results also demonstrate stochastic nature of GNSS measurements – Too few measurements in a Live Sky scenario (with even more variables) can give misleading results
- So far concentrated on single interference source – however LTE deployment plans means there is a need for multiple interferer scenarios to test against…

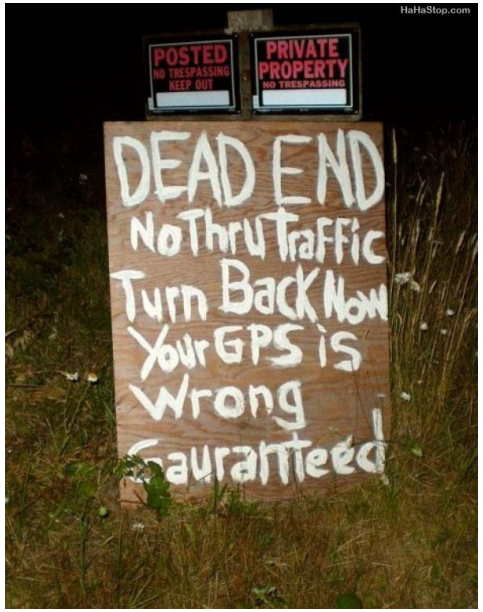
Spirent Insights

…and further work

- We are building up our “Big data” characterization/certification of receiver behaviour including more parameters including:-
  - RFI vs
    - TTFF (Cold, Warm, Hot)
    - Reacquisition
    - 1PPS and NTP/PTP accuracy
  - Control Segment Errors
  - Signal and Navigation data health status
  - RAIM
  - Multipath (Sim3D)

- RTK and MCMF

Trust but Verify



Join the GNSS Vulnerabilities group on Linked In to find out more about GNSS jamming and spoofing