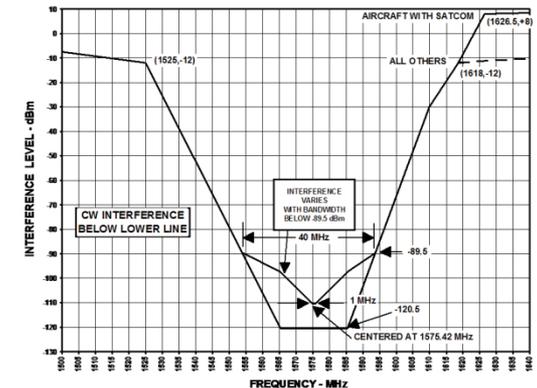
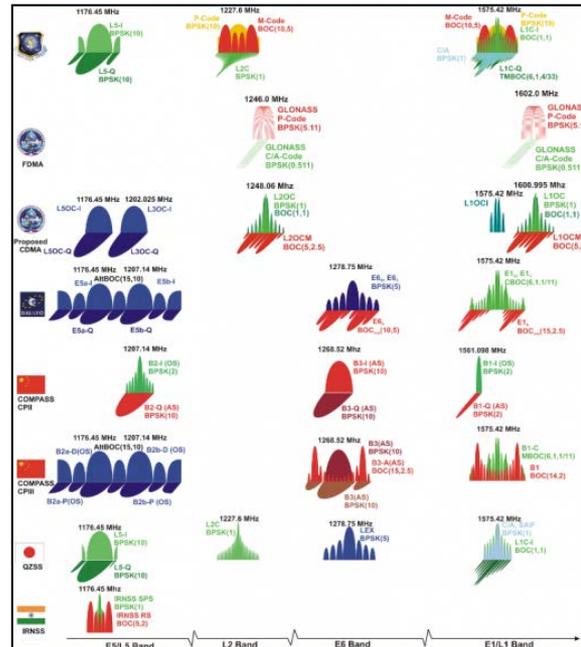
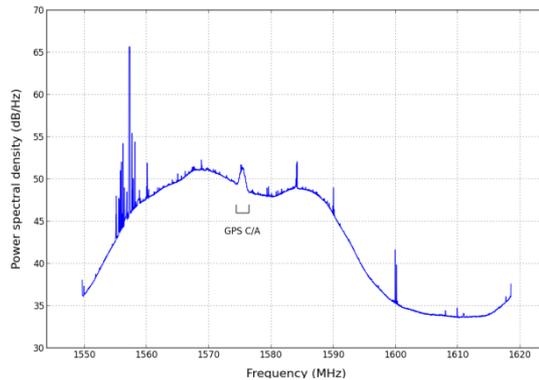


Automation and results of Adjacent Band Emission testing



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Agenda

- Problem Space
- Automation System – PANACEA
- Test Setups
- Example Test
- Example Results
- Findings
- Summary



Problem Statement

- Adjacent band testing is not fully defined
 - Multiple groups conduct tests in various ways
 - Outcomes vary based on test setup and assumptions
 - No standard has been established to conduct such tests
- Spectrum is scarce and the need for compliance testing will only increase
- Simplified process is needed across the enterprise to conduct testing and analyze results

What is PANACEA?

- GPS in-the-loop Test and Analysis Suite

- **Controls Environment**

- GPS Signals
 - Threat Signals
 - User Motion



- **Controls GPS Unit(s) Under Test**

- Receiver Initialization
 - Real-Time Monitoring

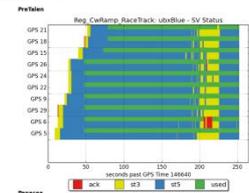
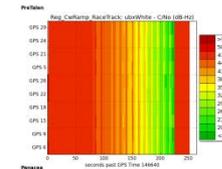


- **Collects and Stores Receiver Performance Data**

- Navigation, Measurement data collected and translated into common message structure

- **Produces Reports and Figures**

- Quick and Accurate way to begin Analysis of the results



PANACEA System Design

PANACEA Software

User Builds Scenario(s)



User Starts Scenario(s)

Test Plan Creation Software



PANACEA Analysis Software



Reports & Figures Created

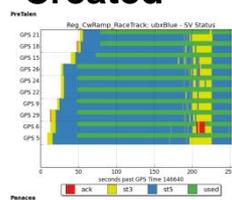
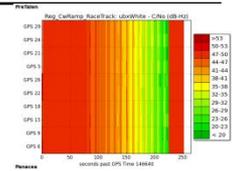
Scenario Control Software



UUT Collection Software



Database



Hardware



GNSS Signals



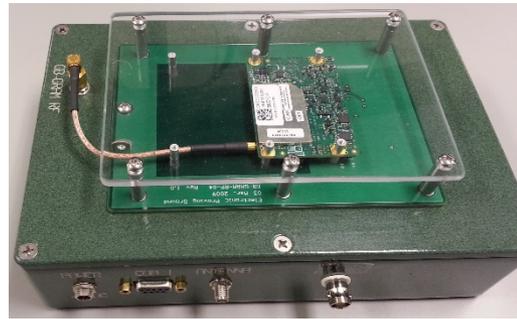
Interference Signals



GPS Receiver Array

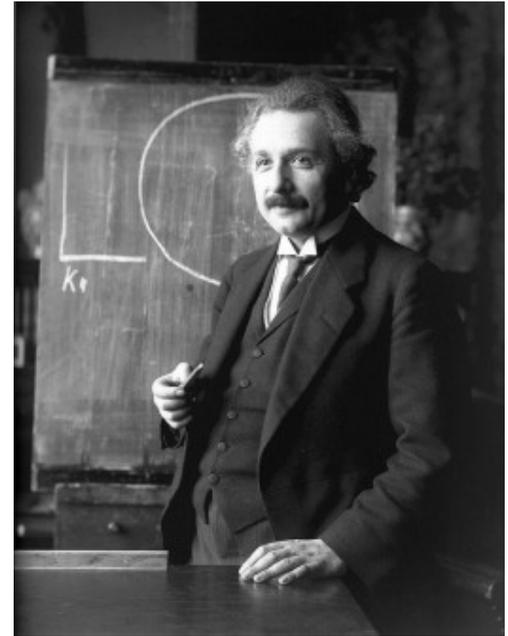
Capabilities

- Version 1.3 interfaces with:
 - **GNSS sources:** Spirent (GPS)
 - **Interference sources:** Agilent (443x)
 - **GPS Receivers:**
 - Interface via USB, RS-232, RS-422, 1553 Bus
 - DAGR (all variants), GB-GRAM (all variants), NavStrike (all variants), MicroGRAM, PLGR, D3
 - uBlox (all variants), Novatel ProPack, TA-24, Trimble Lassen iQ, Trimble SK II, H746G EGI, CommSync II, Symmetricom Xli, Magellan 5000



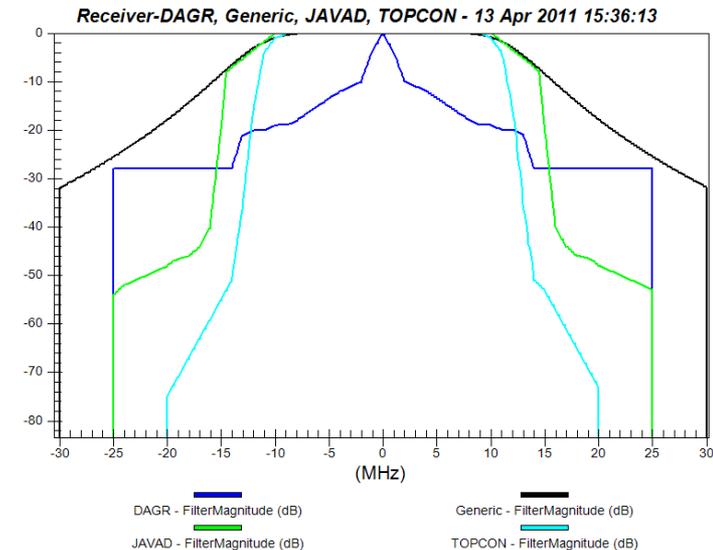
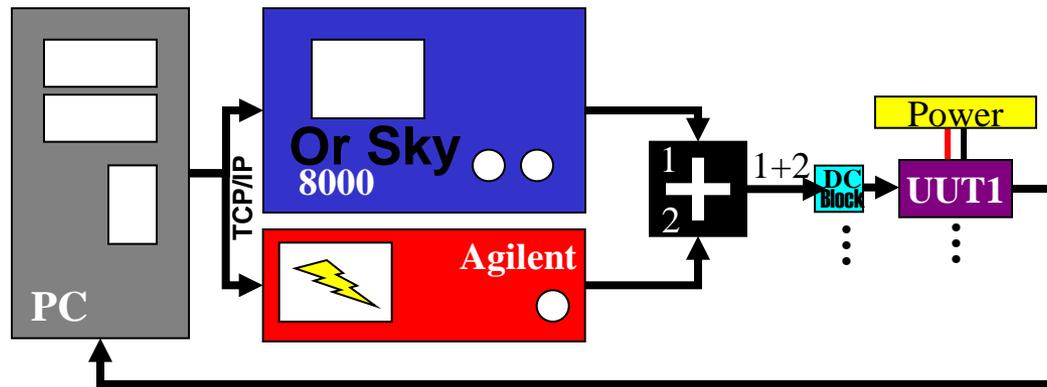
Test Setups

- Basic approach
 - Setup tests one at a time
 - Single unit under test
 - Collect/analyze data manually
- Production approach
 - Parametric tests / automated execution
 - Multitude of units under test
 - Collect/analyze data as a part of execution



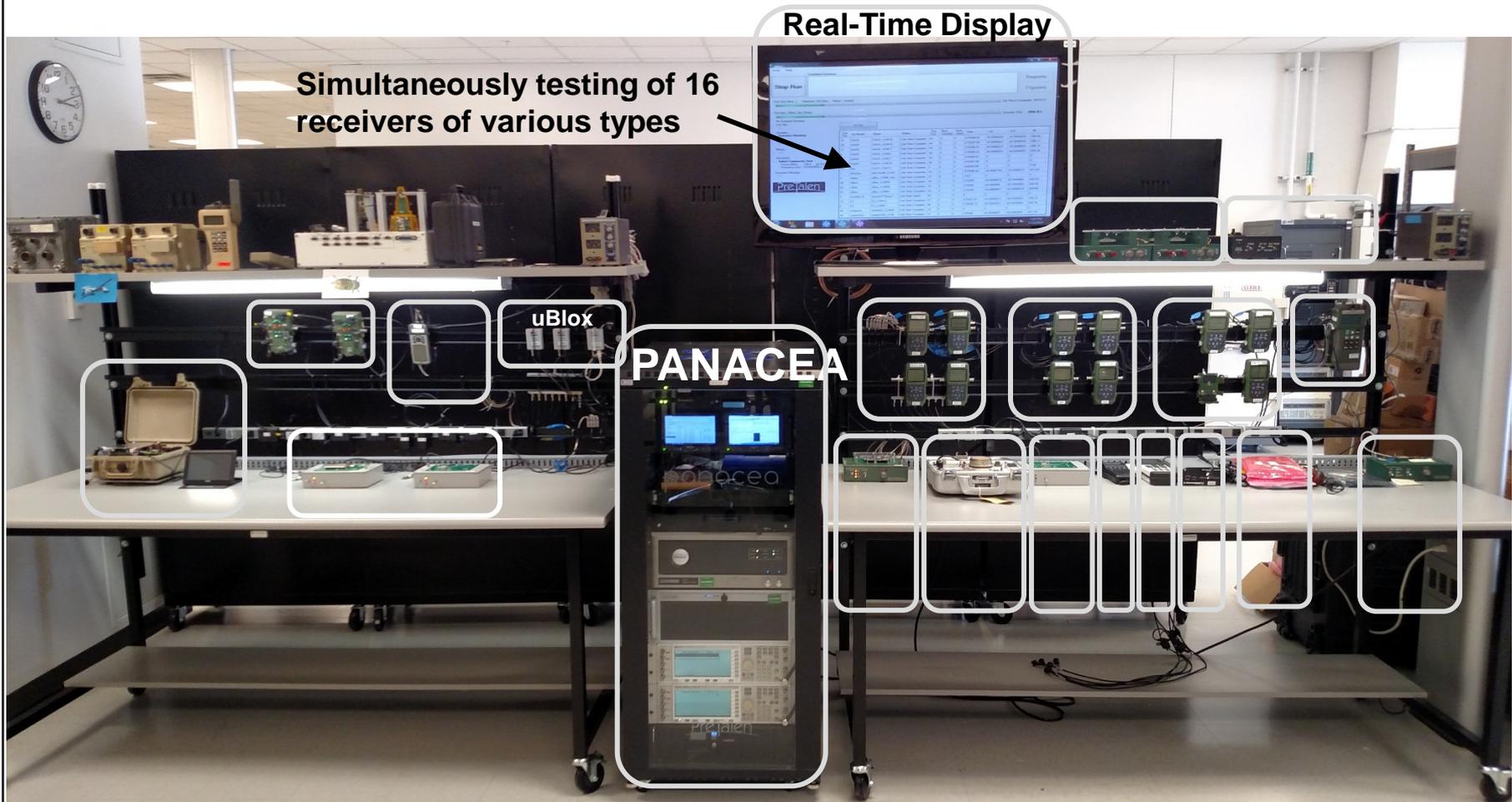
Basic Test Setup (prior to PANACEA)

- Analyzed GPS receiver performance across the band
 - Stepped 2 MHz noise in 1 MHz steps from 1575-1550
 - Started power below the noise and stepped up 1dB / 5 sec
 - Collected transfer function across the band
 - Includes front end filter/gain and processing in the receiver
 - Does not include antenna/external gain effects



Realistic receiver effects to interference

PANACEA Test Setup



Courtesy of Army CERDEC - APG

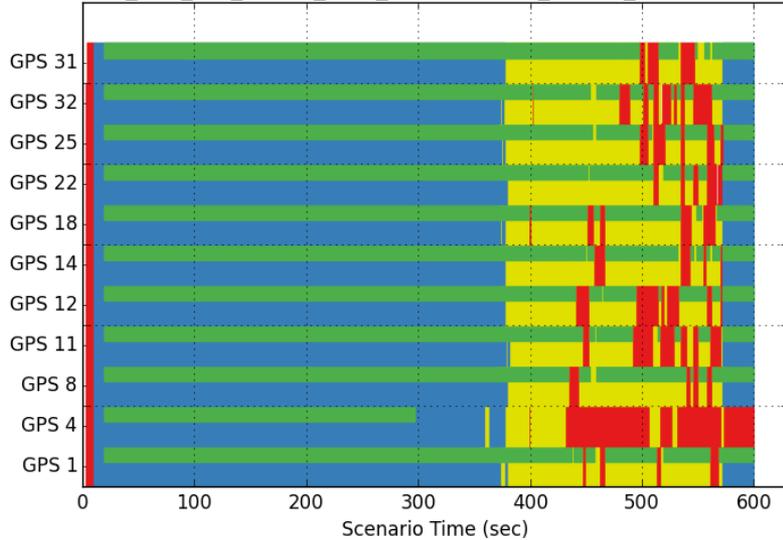
Example Test

- Purpose: Determine adjacent band interference susceptibility
- Tested uBlox5, 6, 8 and MicroGRAM Rcvrs
- Tested CW, AWGN, and Swept CW
- Test 1 – discrete frequencies ramping up power starting at 90 seconds (after good track) 0.5 dB every 3 seconds
- Collected tracking data – pulled results once 1 SV dropped and when track was lost

Example Outputs

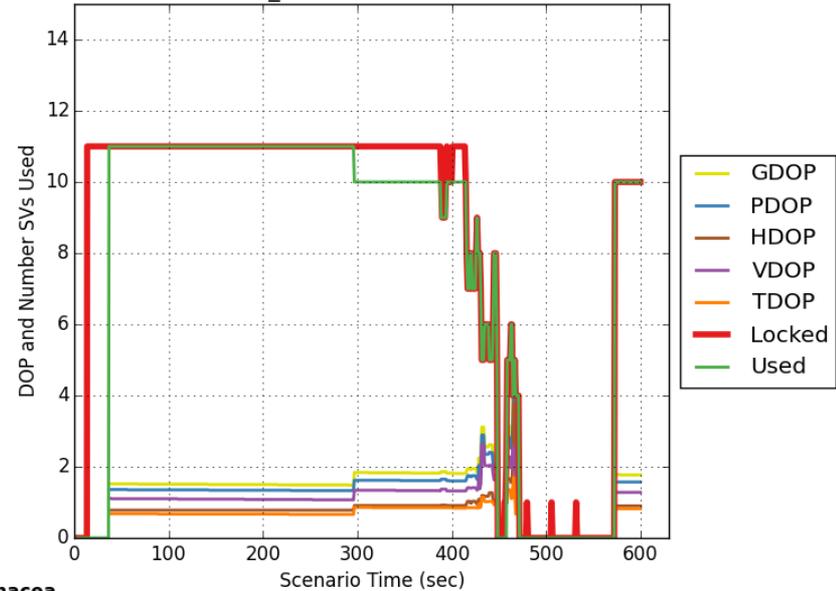
PreTalen

OOB_test_CW_AWGN_SWP_00004: uBlox_LEA6H_23 - SV Status



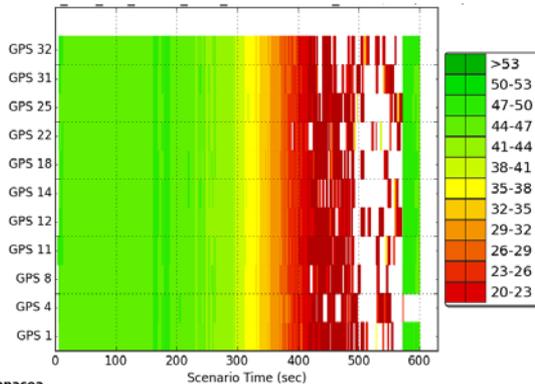
PreTalen

ublox5_24 - DOP, Tracked, Used

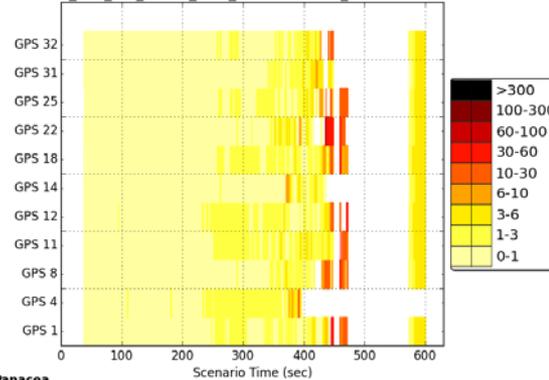


Pre1

Panacea



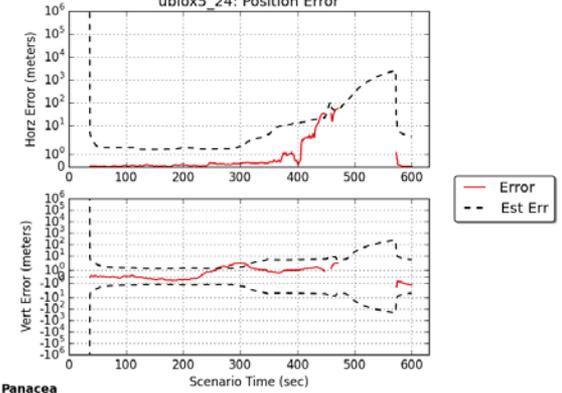
OOB_test_CW_AWGN_SWP_00004: ublox5_24 - PR Resid(m)



Panacea

PreTalen

ublox5_24: Position Error



Panacea

Panacea

PreTalen

Considerations / Assumptions

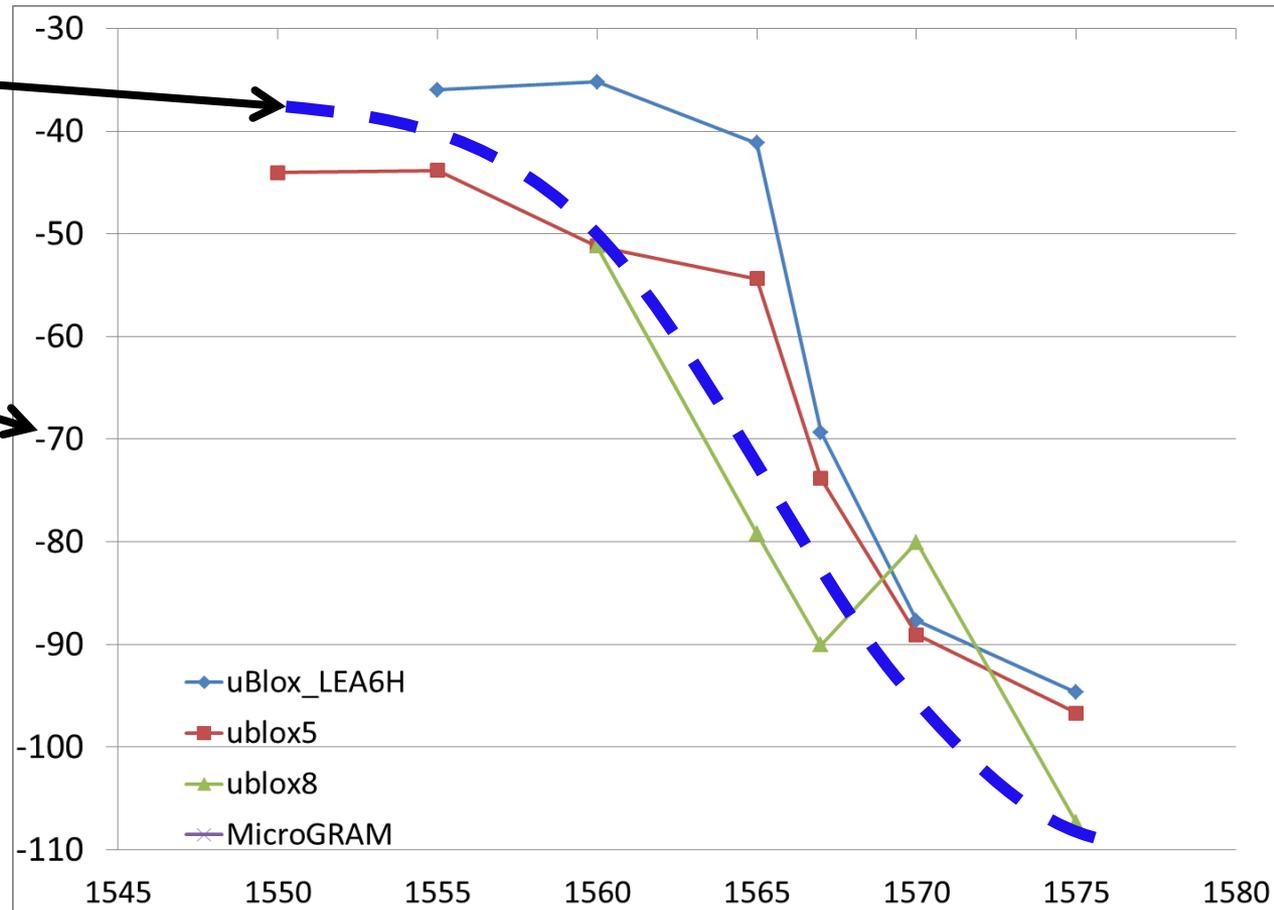
- Antenna and resulting filtering effects are not present
- Signals are “perfect” and free from intermodulations and environmental effects
- These conclusions are for demonstration purposes only and should not be used to make purchase or evaluation decisions

Description of Results

Receiver “mask”
can be
approximated

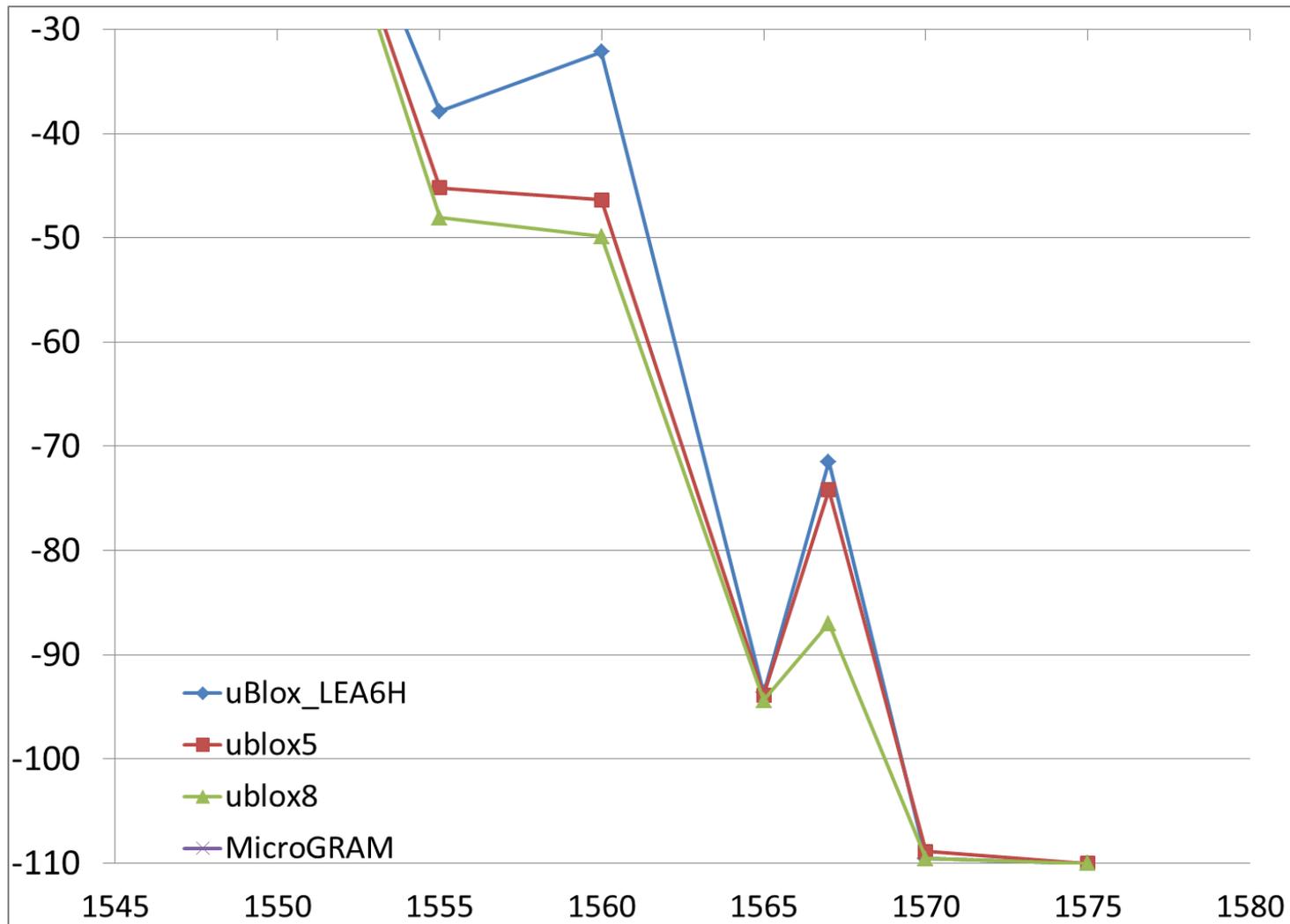
RF power (dBW)
required to cause
effect – less
negative the
number the better
the receiver is in
handling the
interference

MicroGRAM
results removed

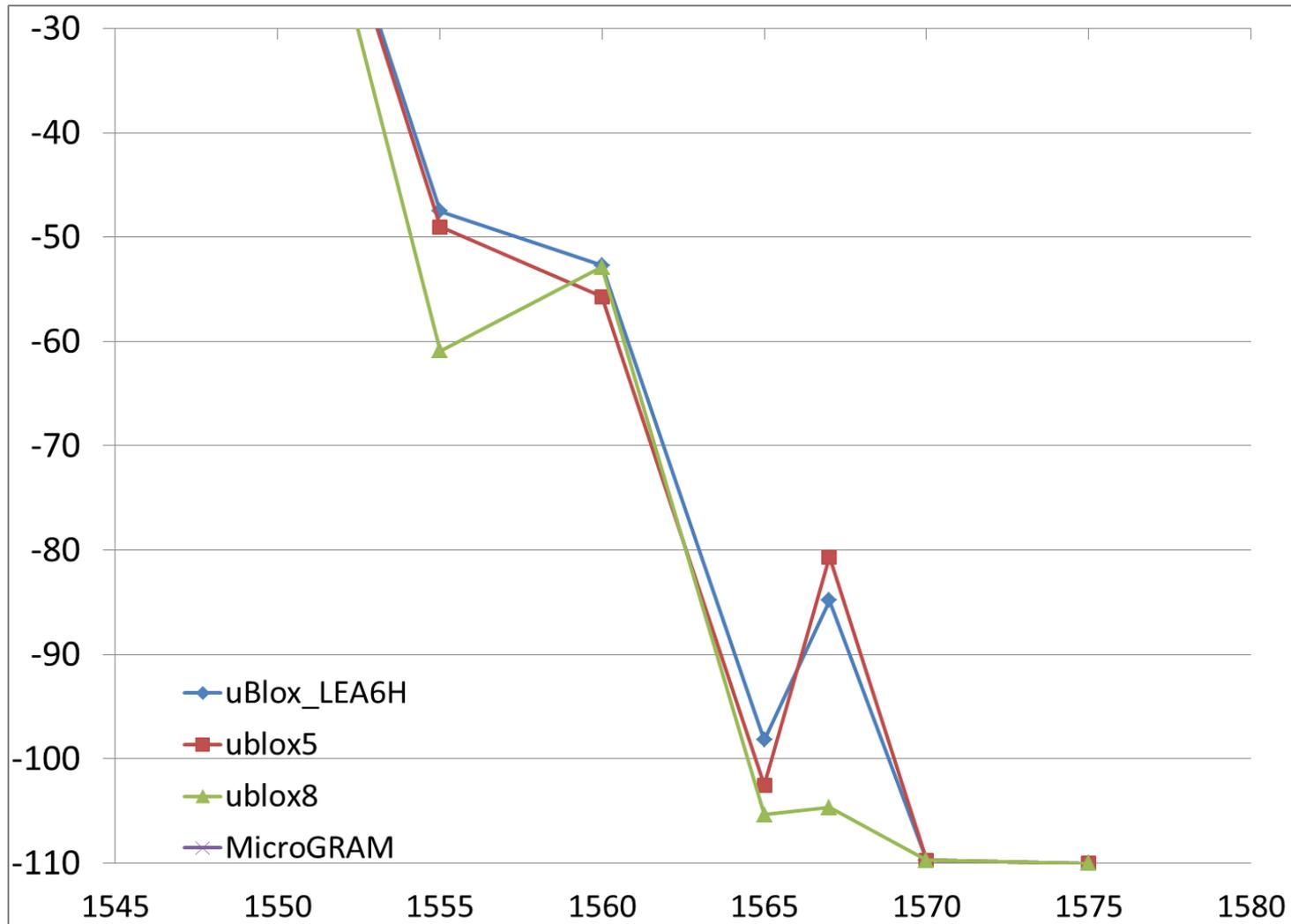


Frequency (MHz) of the interfering signal –
power ramped 0.5 dB every 3 sec – started
90 sec into the scenario

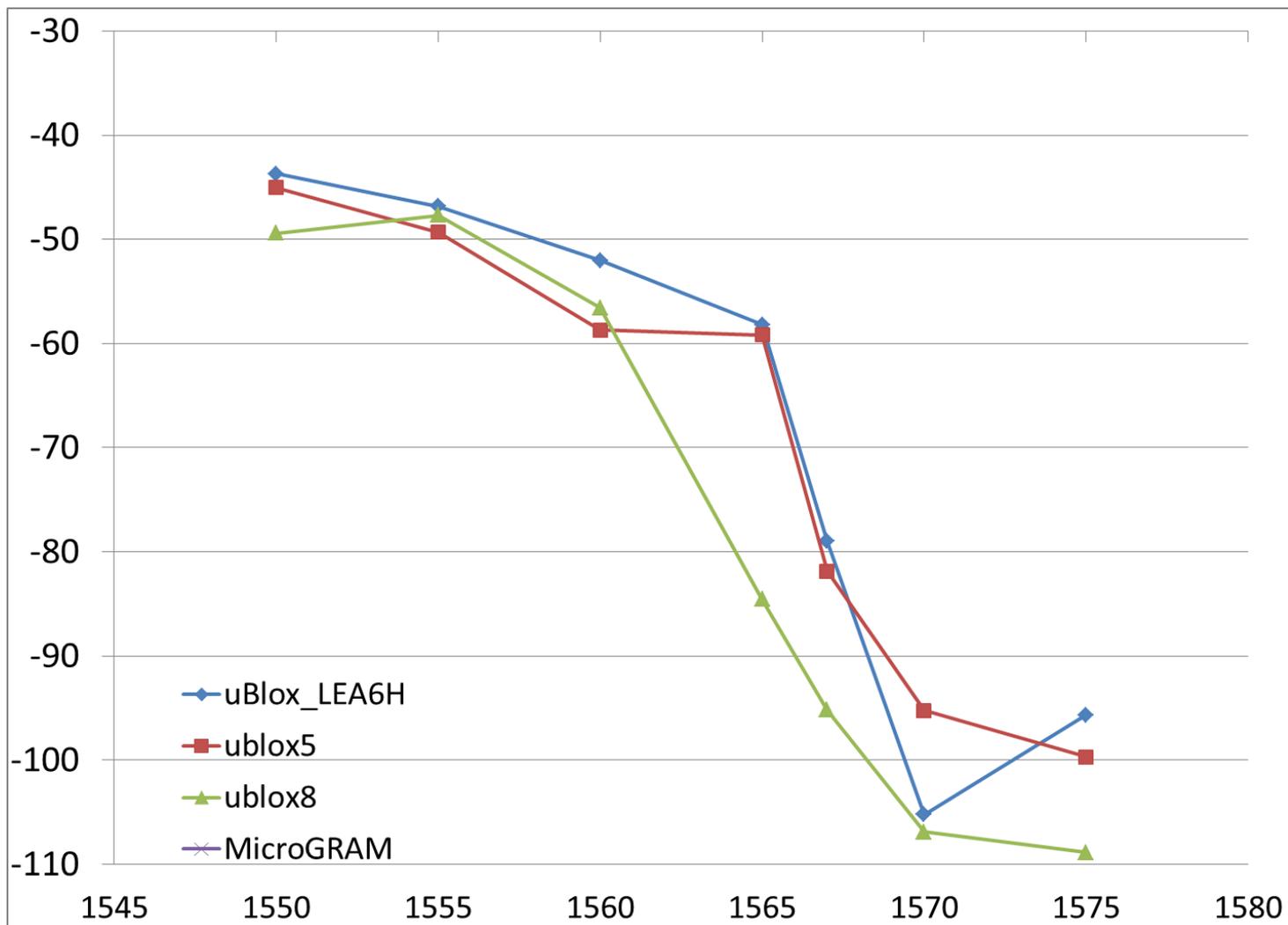
Swept CW Effect Noticed



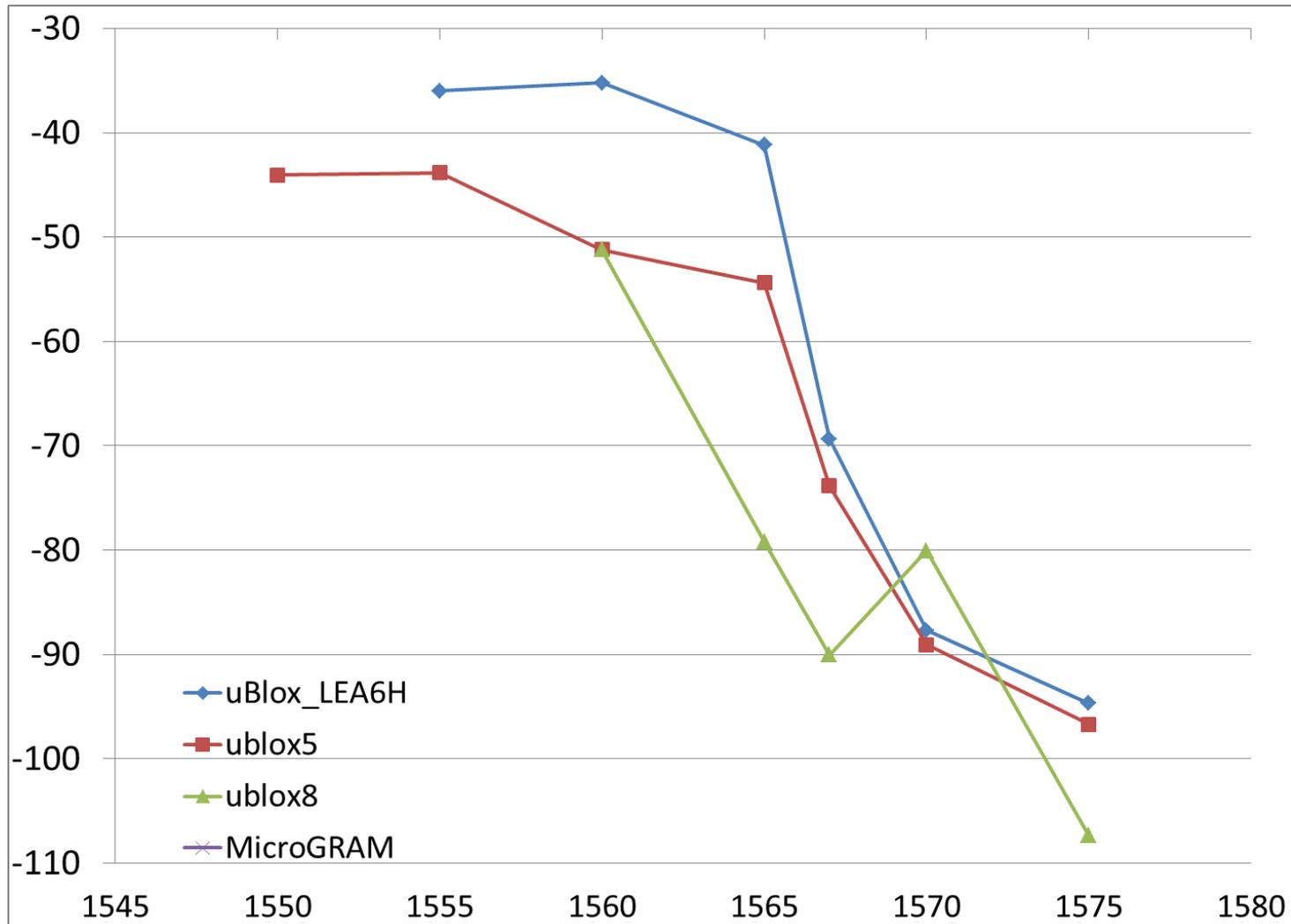
Swept CW - Denied



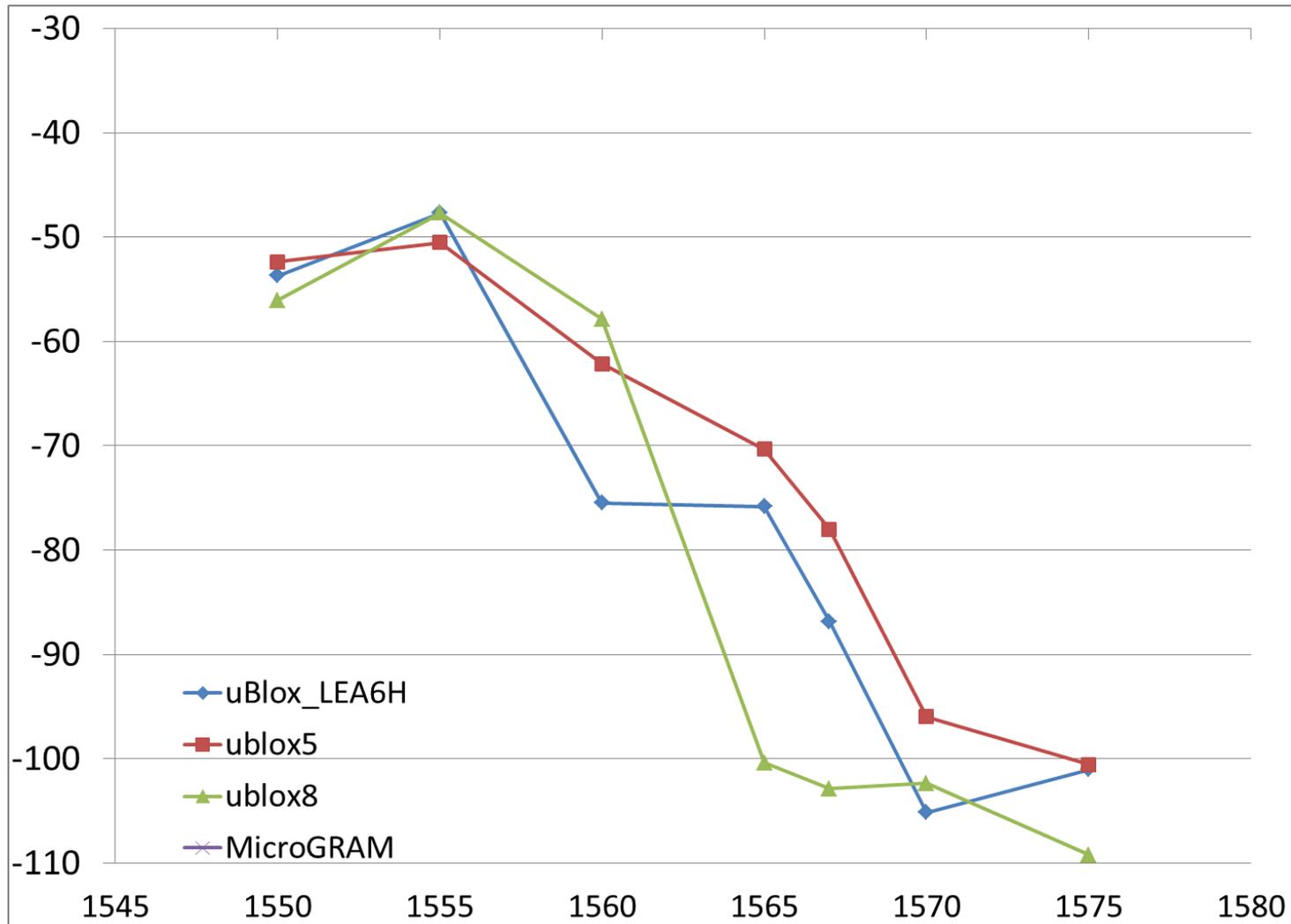
CW Effect Noticed



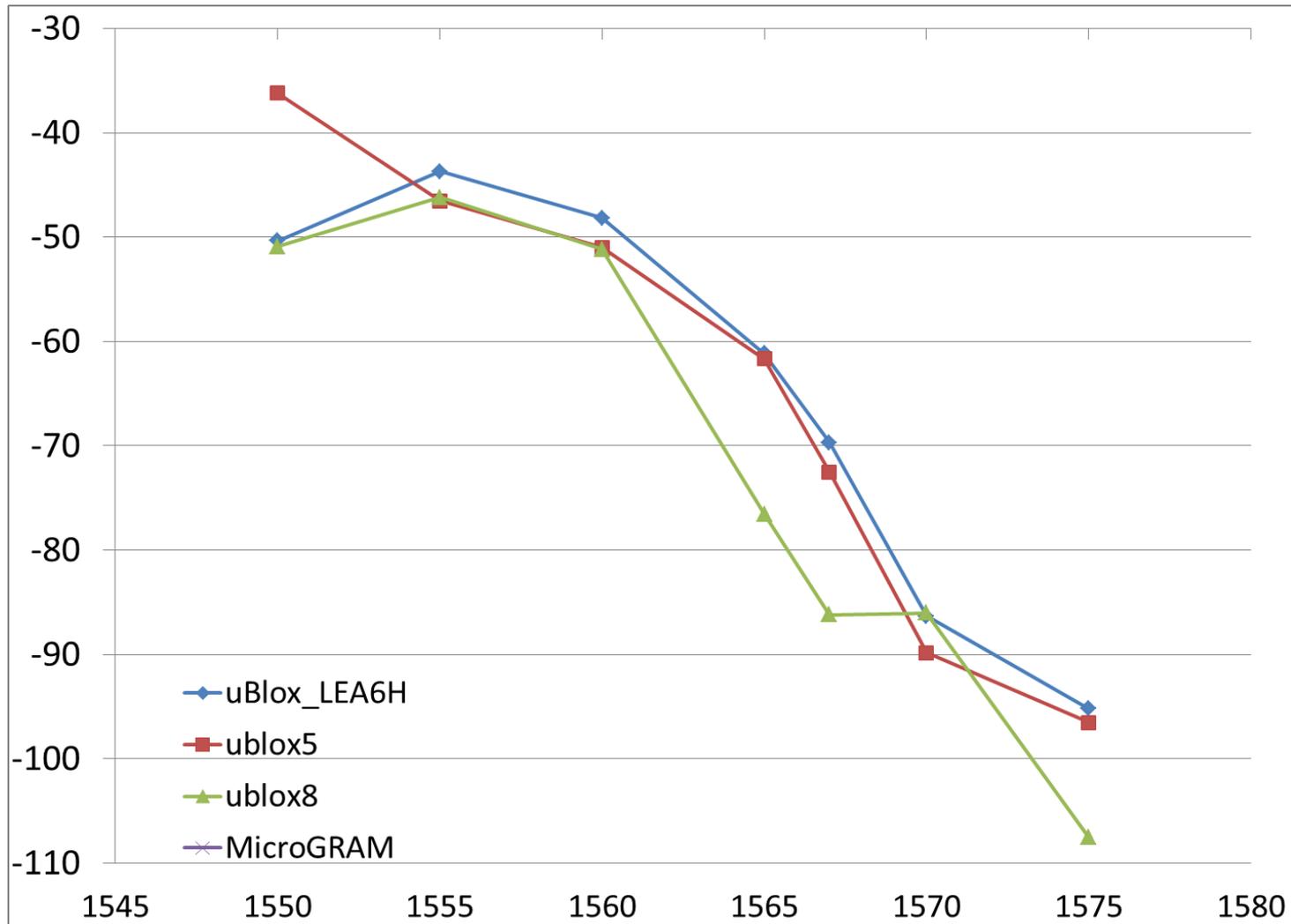
CW - Denied



AWGN Effect Noticed



AWGN - Denied



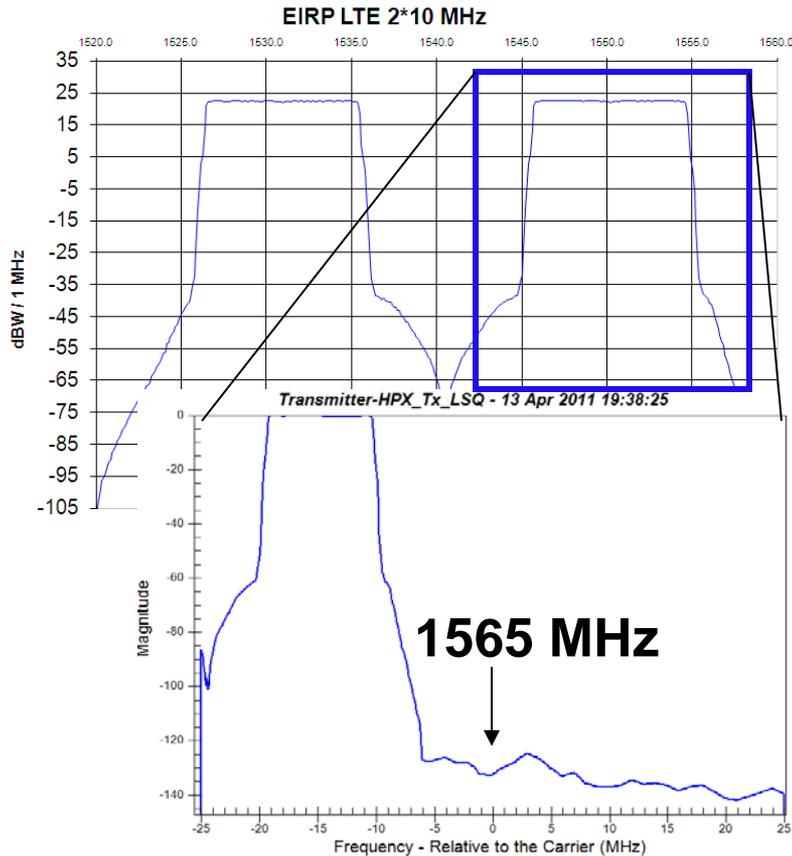
Findings

- Receiver front end/susceptibility can be determined by the placement of test signals
- Modulation of the adjacent band signal also should be considered (many receivers incorporate a narrow band filter)
- Both the transmission filter mask and the receiver mask should be considered

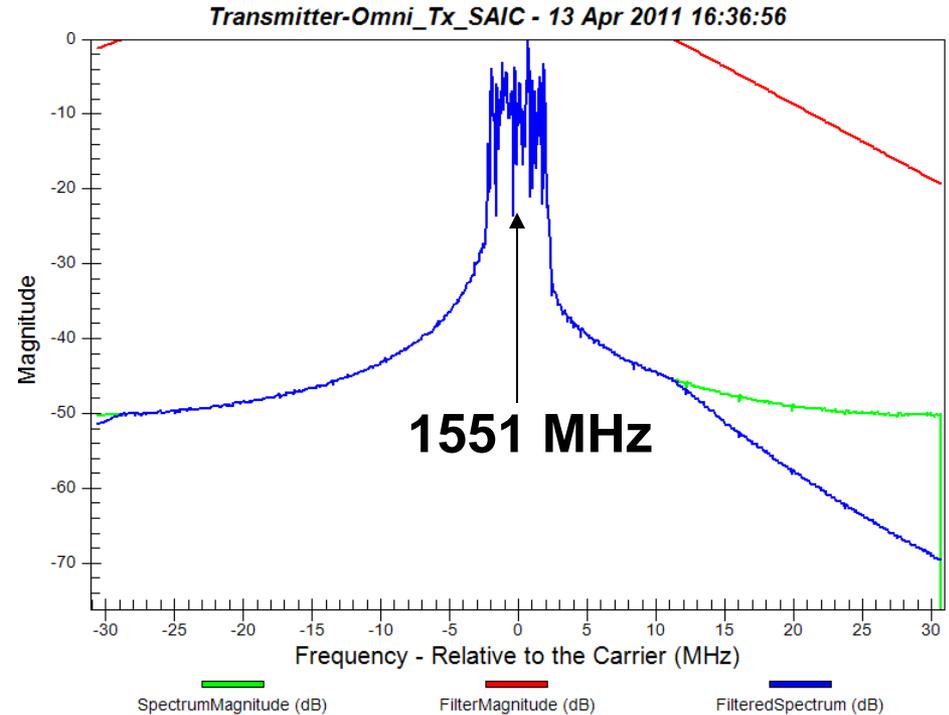
LTE Signals – which is right....

Hypothetical Data Only

LSQ provided envelope



Actual signal emulating LSQ-OFDM



Assumptions on signal out-of-band emission is key

Summary

- Problem exists for a prescribed and consistent test setup/process for adjacent band emission testing across the PNT enterprise
- Numerous tests have been conducted and lessons learned/shared will arrive at a best of breed solution – working group fosters growth
- Several solutions are possible to resolve spectrum issues – tests will prove the potential