We2A-319-EZ65

System Model-to-Lab Methodology for GNSS Desensitization Testing

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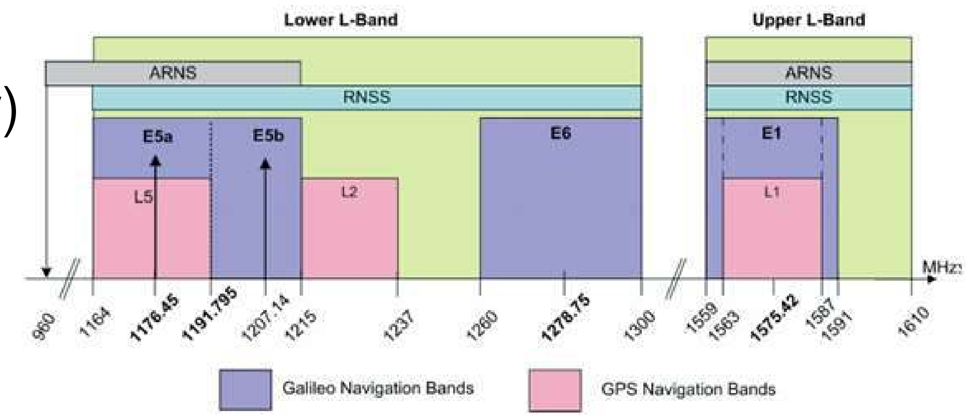
oneNav

Outline

- Introduction to GNSS
  - Frequency bands L1 and L5
  - Challenge integrating receivers in mobile devices
- Methodology to generate in-band interference
  - OFDM and GFSK signal generation
  - Nonlinearity model
- Description and validation of methodology
  - Simulation system model
  - Lab measurements
- Conclusions

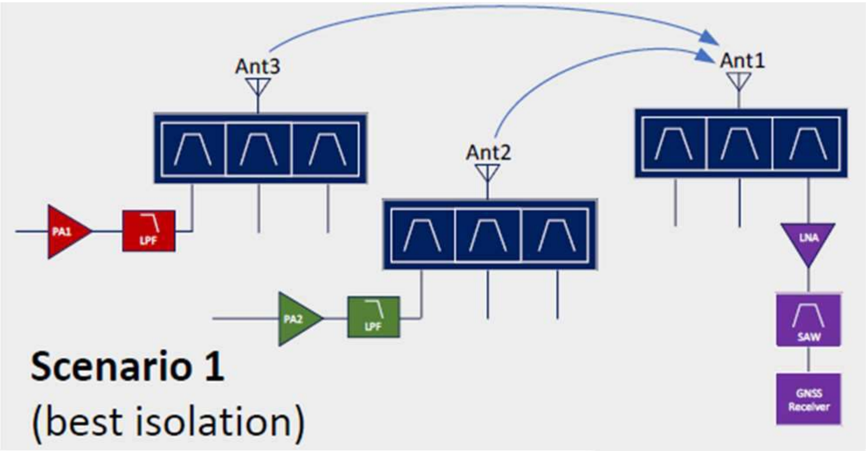
Radio Navigation Satellite Service

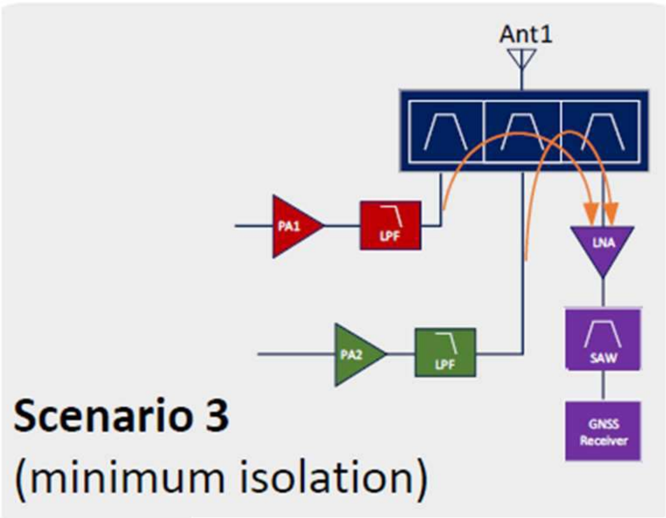
- 4 Global Navigation Satellite Systems:
  - Global Positioning System (USA)
  - Galileo (European Space Agency)
  - BeiDou (China)
  - GLONASS (Russia)
- Frequency bands dedicated exclusively for radio navigation
- Received signals on ground are extremely weak – below noise floor!

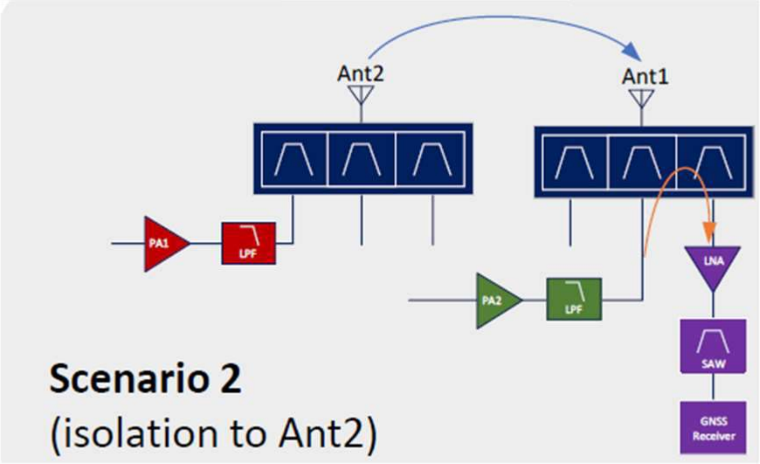


Source: https://gssc.esa.int/navipedia/index.php/Galileo_Signal_Plan

GNSS coexistence is a challenge







oneNav pioneering pureL5 receiver

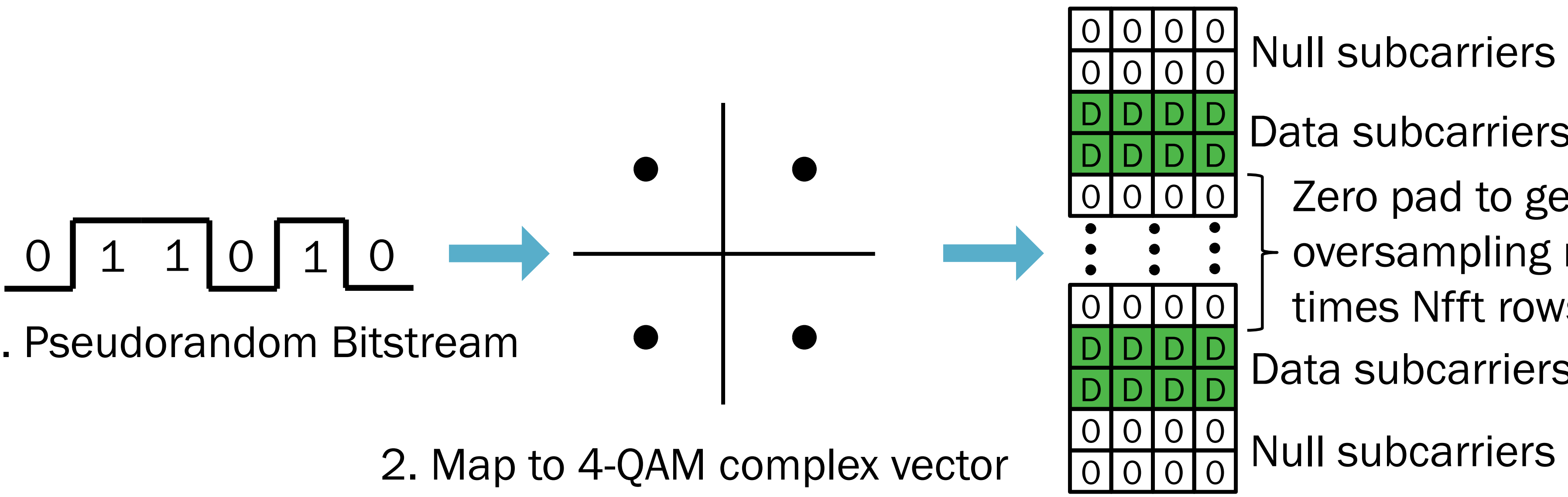
- Most GNSS receivers acquire L1/E1 (1575.42 MHz) signal before moving to acquire L5/E5a (1176.45 MHz)
- L1/E1 faces more intermodulation interference products than L5/E5
- **one**Nav has built the first and only GNSS receiver that acquires only the L5/E5 signal.
- Still need to characterize receiver's immunity to interference

Three interference scenarios

- Three potential out-of-band signals identified in this study:
  - 5 MHz bandwidth LTE (OFDM)
  - 20 MHz bandwidth Wi-Fi (OFDM)
  - Bluetooth basic rate (GFSK)
- From those signals, three scenarios considered:
  - IM3 of LTE Band3 (~1785 MHz) and Bluetooth (~2400 MHz)
  - IM3 of LTE Band3 (~1785 MHz) and Wi-Fi (~2400 MHz)
  - IM2 of LTE Band72 (~455 MHz) and LTE Band28 (~721 MHz)

Generating OFDM Signals

Wi-Fi: Nfft = 64
LTE: Nfft = 512



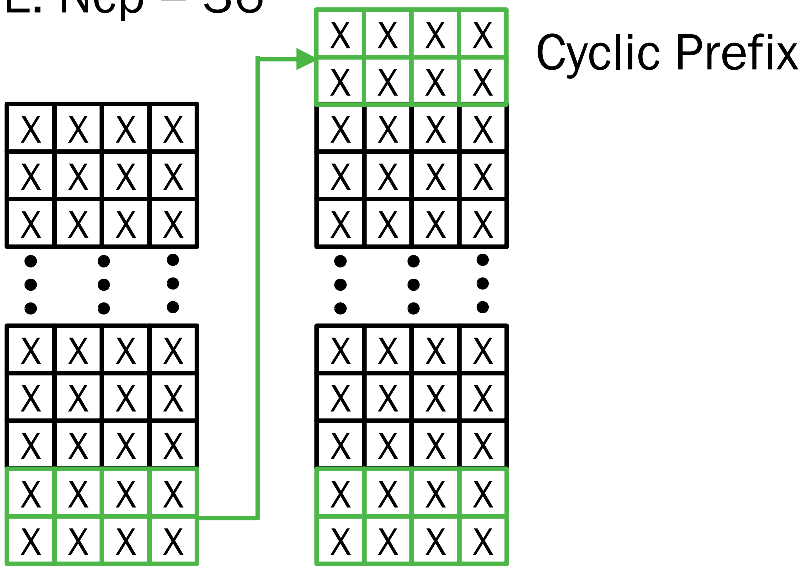
1. Pseudorandom Bitstream

2. Map to 4-QAM complex vector

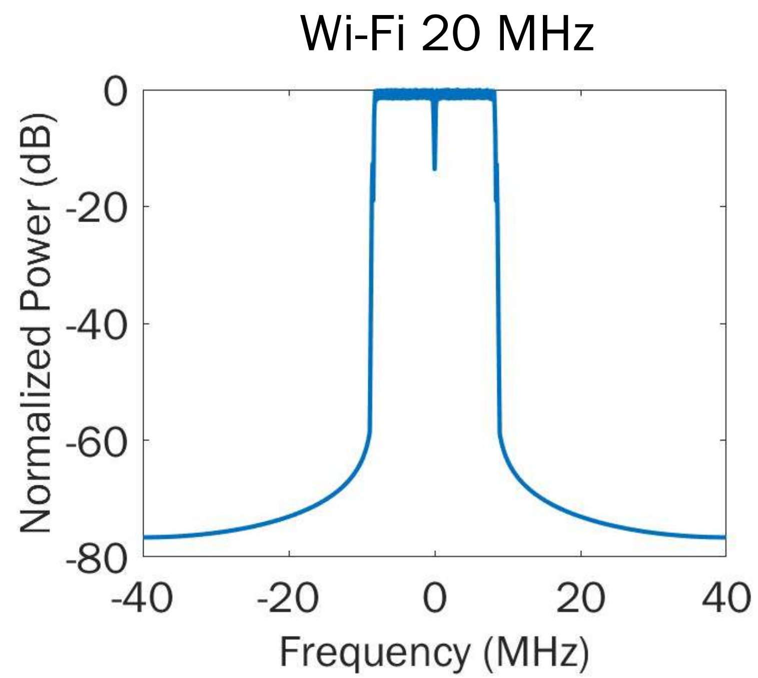
3. Fill in the data subcarriers and then take the inverse Fourier transform of each column

Resulting OFDM Signals

Wi-Fi: Ncp = 16
LTE: Ncp = 36

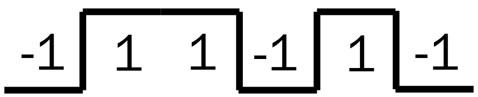


4. Copy last Ncp rows to beginning

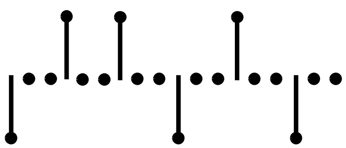


5. Serialize and low-pass filter

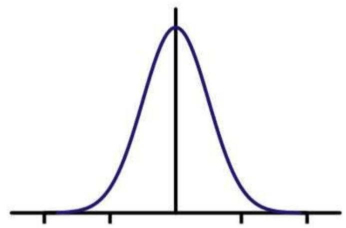
Generating GFSK Signals



1. NRZ Bitstream

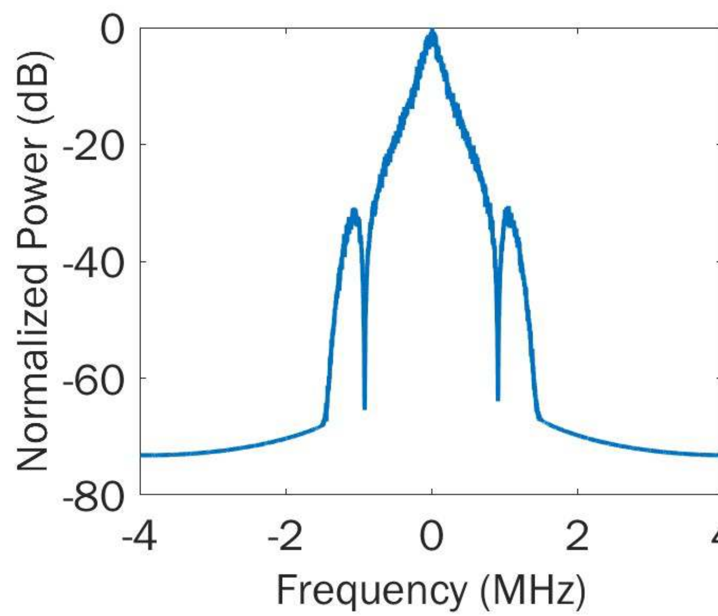


2. Upsample



3. Gaussian Filter
3-dB BT = 0.5

Bluetooth BR



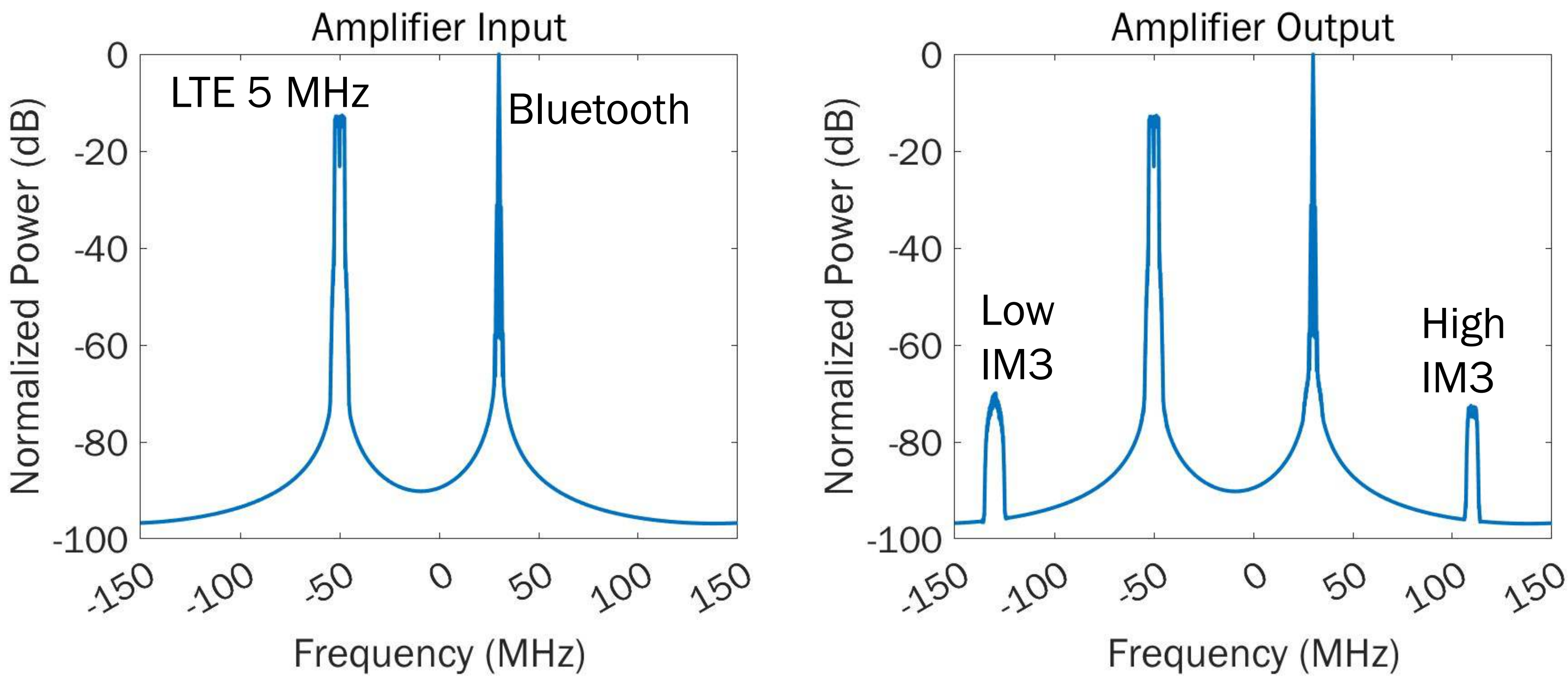
4. Frequency modulate
(index = 0.32) and low-pass filter

IM3 nonlinearity model

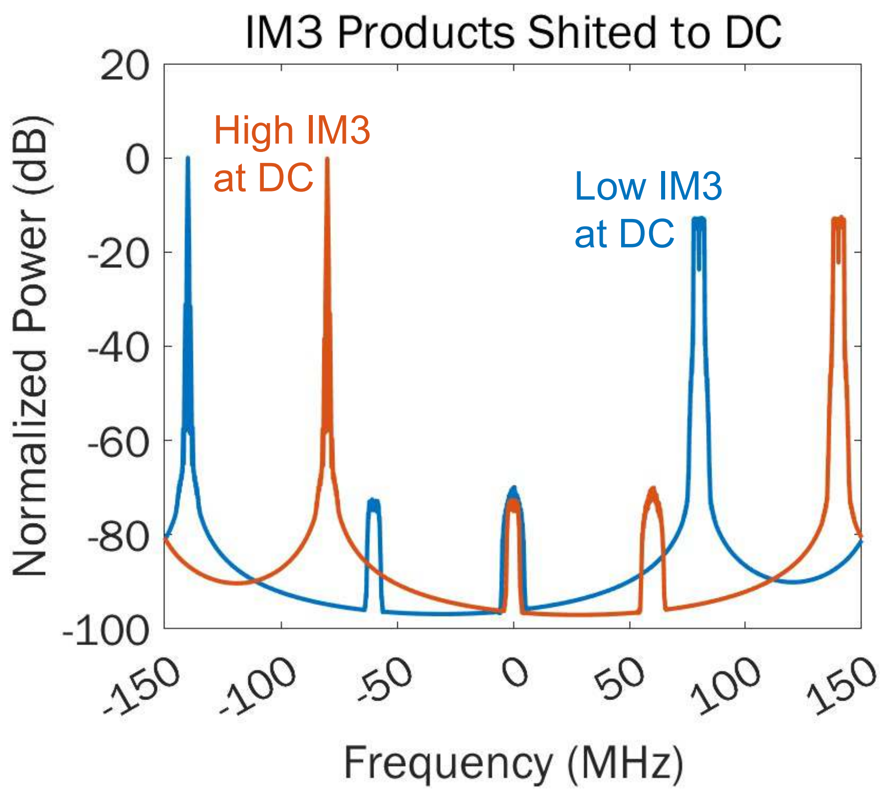
- Impractical to simulate at RF – required sampling frequency too high
- Instead, use complex baseband-equivalent model
- For input $a(t)e^{j\phi(t)}$, simple third-order nonlinear amplifier output (assuming no phase distortion) is

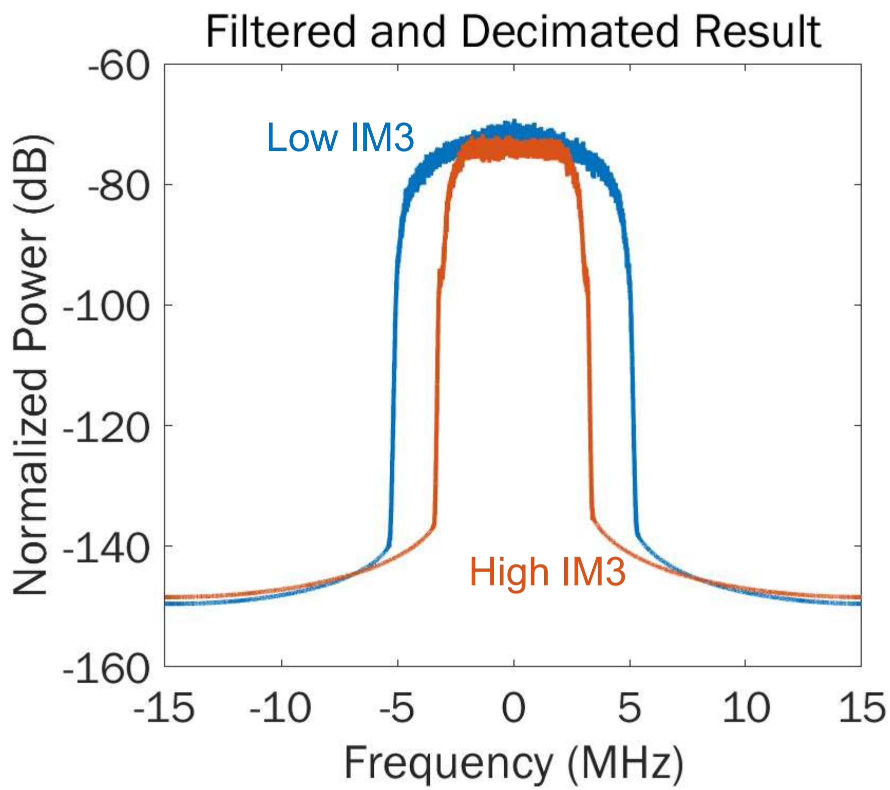
$$g_3(a(t)) = \left(c_1 + \frac{3}{4}|a(t)|^2\right)a(t)$$

IM3 nonlinearity model output



Extracting IM3 products





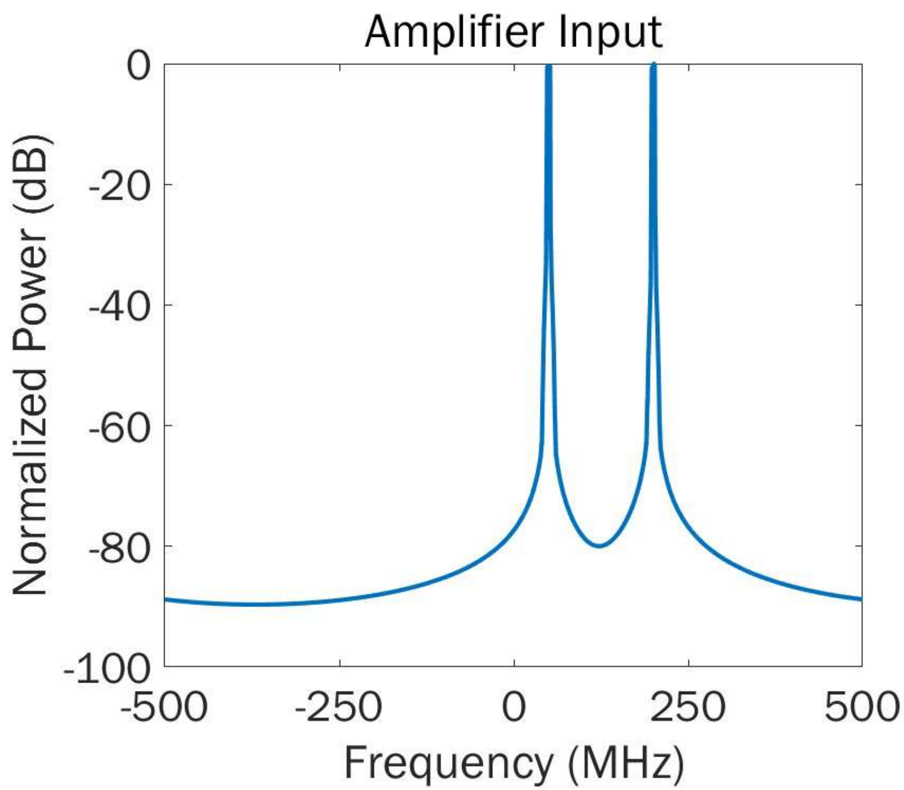
IM2 nonlinearity model

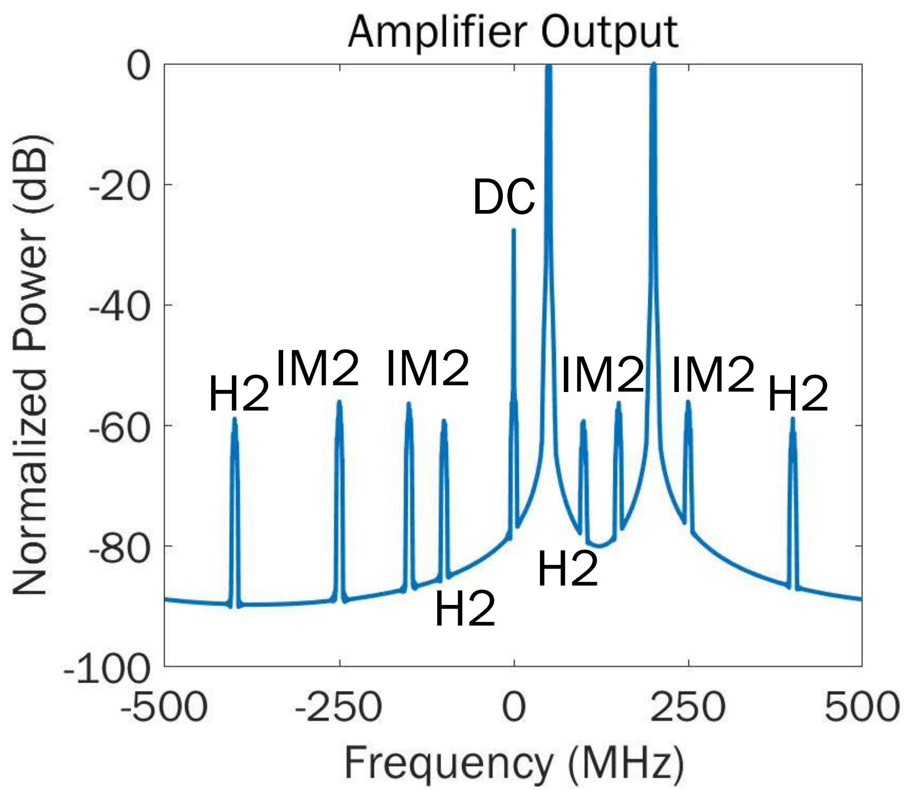
- Complex-baseband equivalent OK for intermodulation products close to RF signals themselves like IM3.
- For IM2, need to simulate at actual baseband.
- Given input $p(t) + jq(t)$, output is:

$$s_2(t) = c_1 p(t) + c_2 p^2(t) + j\left(c_1 q_1(t) + c_2 q_2^2(t)\right)$$

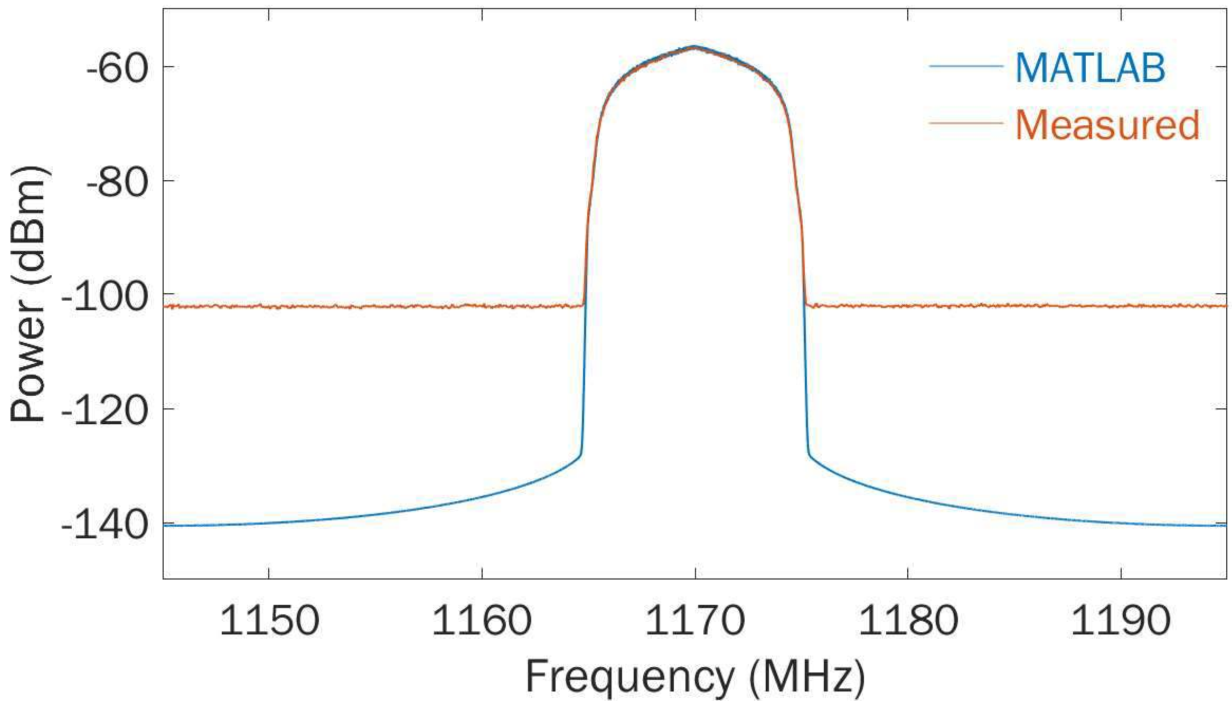
- Same principle as IM3 applies: No need to simulate at full RF! But more harmonic terms need to be filtered.

IM2 extraction results



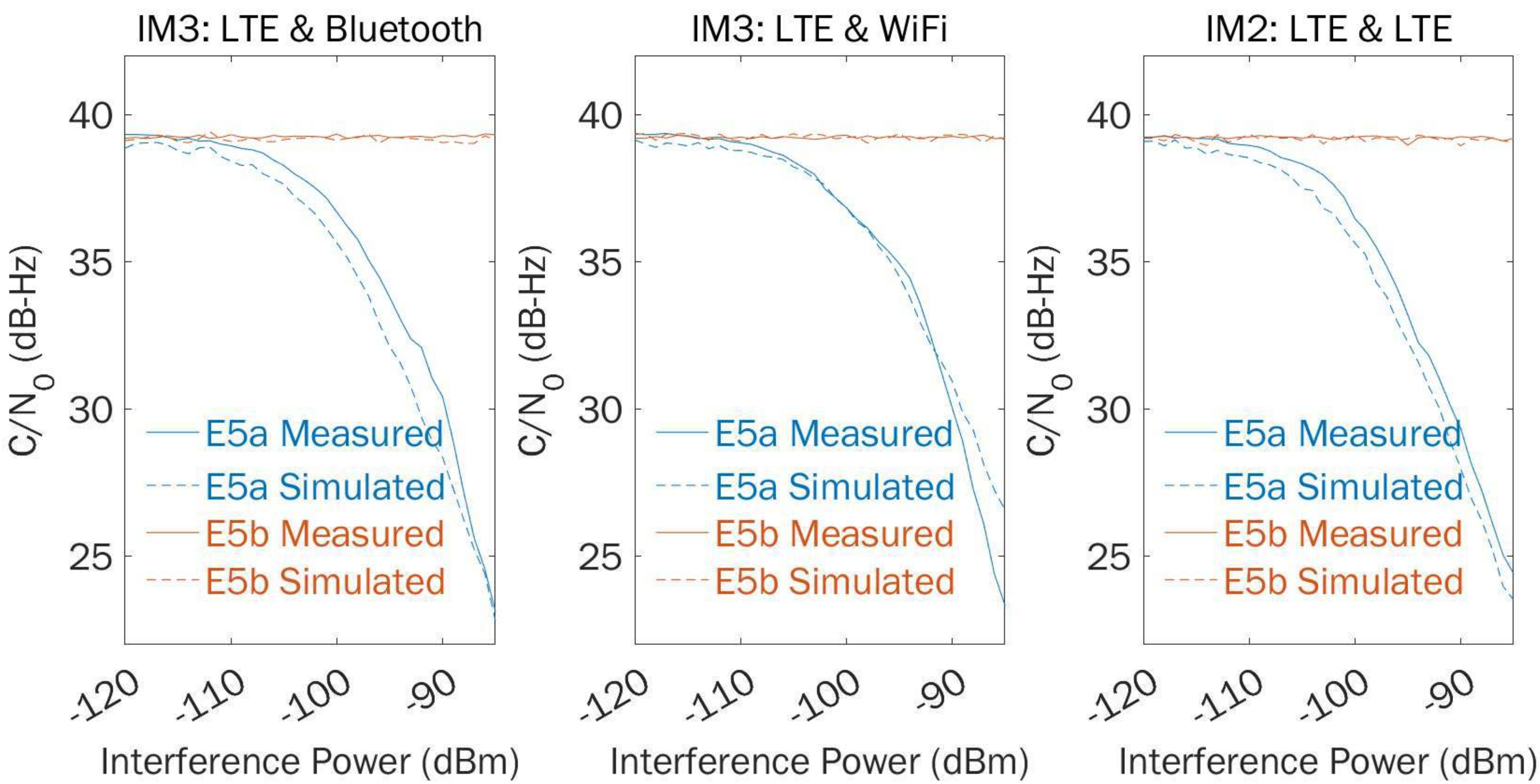


Lab measurement setup/validation



- Independent of each interfering waveform power level: Only a function of the final IM product present at the receiver

Results


IM3: LTE & Bluetooth
IM3: LTE & WiFi
IM2: LTE & LTE
C/N$_0$ (dB-Hz)
40
35
30
25
E5a Measured
E5a Simulated
E5b Measured
E5b Simulated
-120
-110
-100
-90
Interference Power (dBm)

Conclusions

- GNSS receiver coexistence on mobile platforms is challenging due to nonlinear intermodulation products
- Demonstrated a computationally efficient method to generate nonlinear intermodulation products
- Methodology to measure pureL5 GNSS receiver desensitivity validated both in lab and simulation model
- Given isolation specification, can estimate GNSS receiver desensitization.