TAMPERE UNIVERSITY OF TECHNOLOGY

Reference Receiver Enabled **Digital Cancellation of Nonlinear Out-of-band Blocker Distortion** in Wideband Receivers

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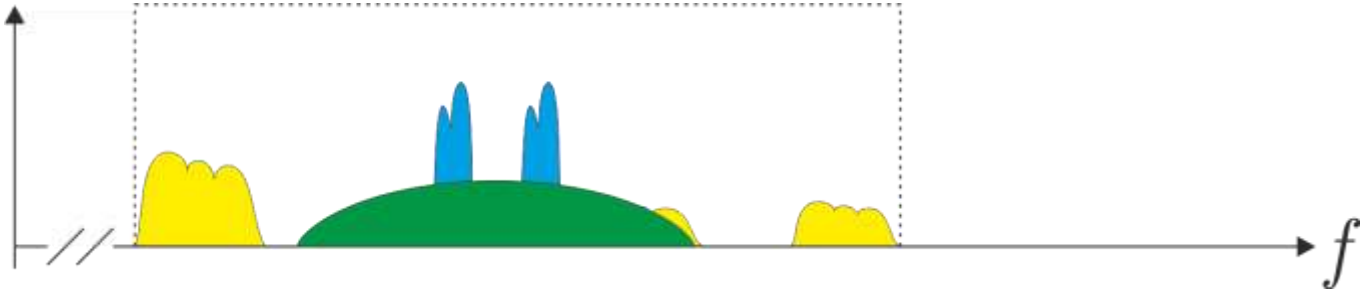
Outline of the Presentation

- Blocker and Nonlinearity Illustrations
- Considerations on 5G Systems
- Current Systems Example
- Reference Receiver Enabled Cancellation
- Conclusions

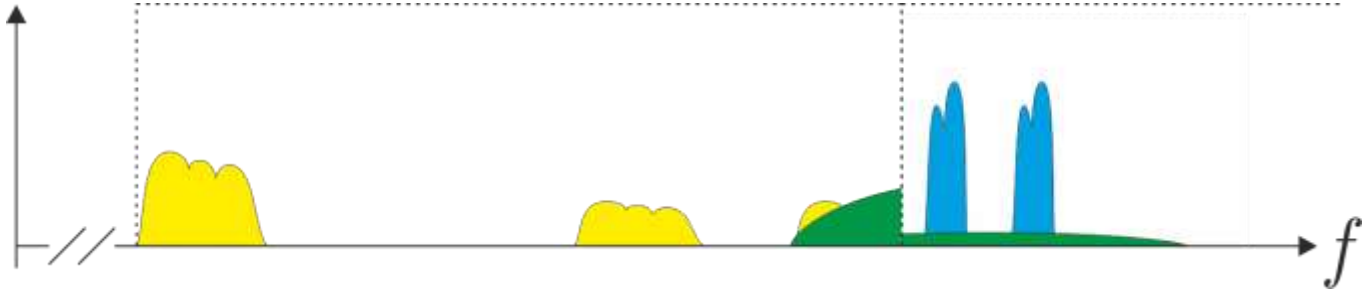
Inband Blockers

- Problem: the stong carriers **inside** the digital RX band create nonlinear distortion, interfering weaker carriers
  - Multiple solutions presented in the current literature



Out-of-Band Blockers

- Problem: the stong carriers **outside** the digital RX band enter the analog RX creating nonlinear distortion, interfering weaker carriers
  - Few solutions presented in the current literature

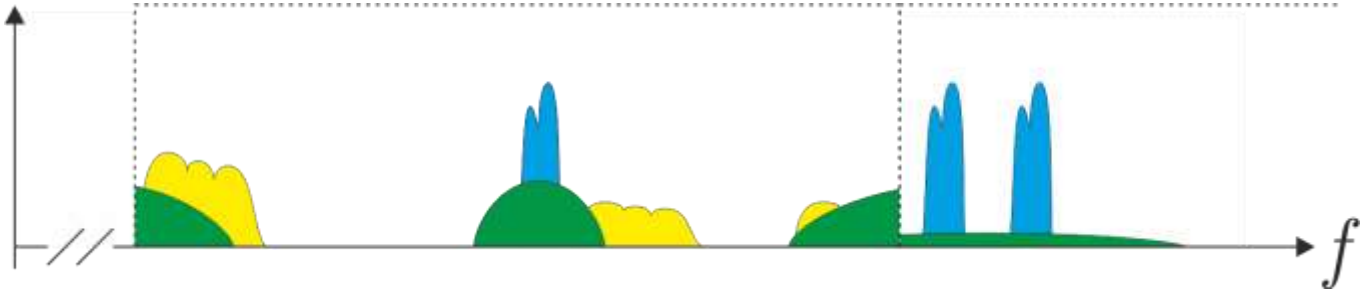


E. Keehr and A. Hajimiri, “Equalization of third-order intermodulation products in wideband direct conversion receivers,” *IEEE J. Solid-State Circuits*, vol. 43, no. 12, pp. 2853–2867, Dec. 2008.

E. Keehr and A. Hajimiri, “Successive regeneration and adaptive cancellation of higher order intermodulation products in RF receivers,” *IEEE Trans. Microw. Theory Tech.*, vol. 59, no. 5, pp. 1379–1396, May 2011.

IB and OOB Blockers

- Problem: the stong carriers **both inside and outside** the digital RX band enter the analog RX creating nonlinear distortion, interfering weaker carriers
  - IMD between IB and OOB blockers can’t be modeled separately

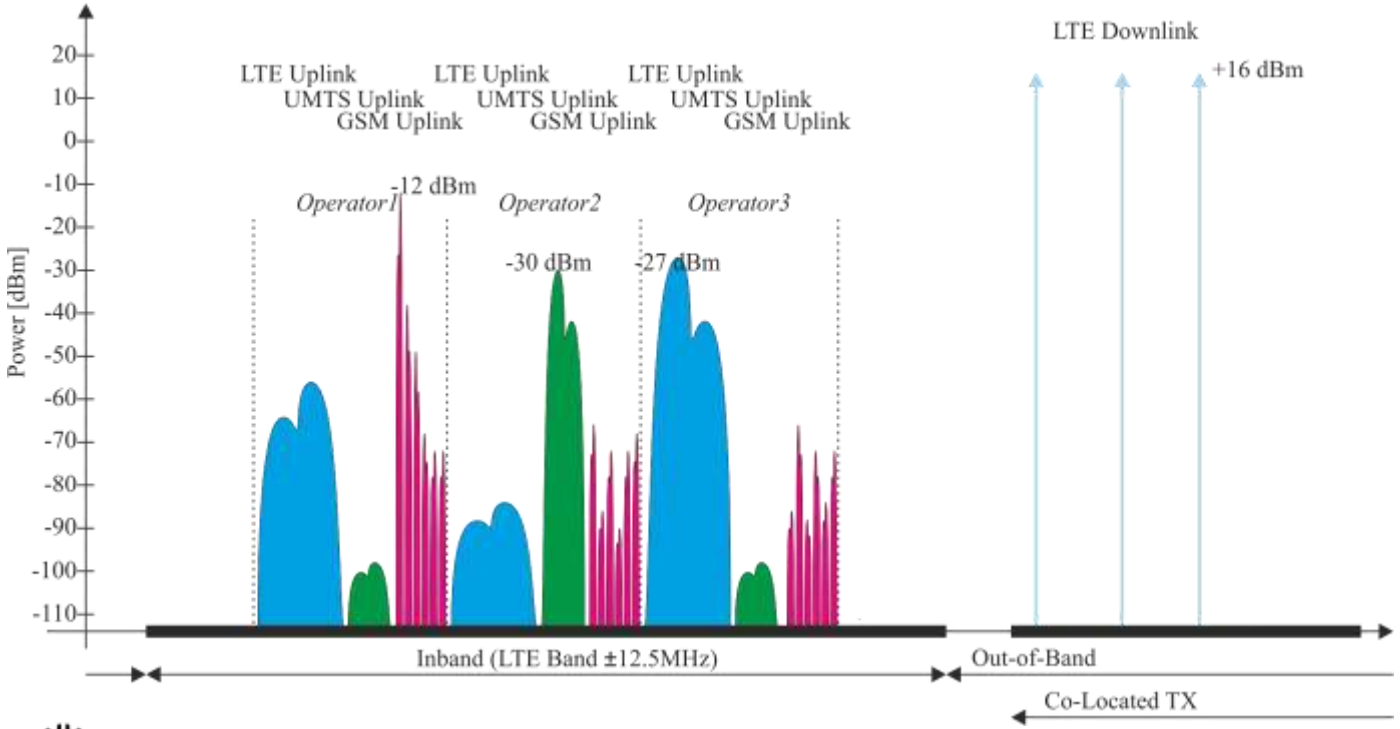


5G

P. Pirinen, “Challenges and possibilities for flexible duplexing in 5G networks,” in *Proc. IEEE 20th Int. Workshop Comput.-Aided Modeling, Anal. and Design of Commun. Links and Networks*, Guildford, UK, Sep. 2015, pp. 6–10.

- In FDD, the **downlink (DL) and uplink (UL) bands tend to be close**
  - Expected to continue in the **future 5G systems**, in terms of **flexible duplexing**, especially at carrier frequencies below 6 GHz
- Improvements in RX blocker tolerance allow more flexibility in the analog component design and increased reception dynamic range
  - Expected to be critical in the emerging 5G systems, with increased requirements for flexible duplexing and RF spectrum use
- *For example, an UL BS RX can suffer from nonlinear distortion caused by co-located DL transmission entering the low-noise amplifier (LNA) and the distortion falling inside the UL band*

Current Systems Example

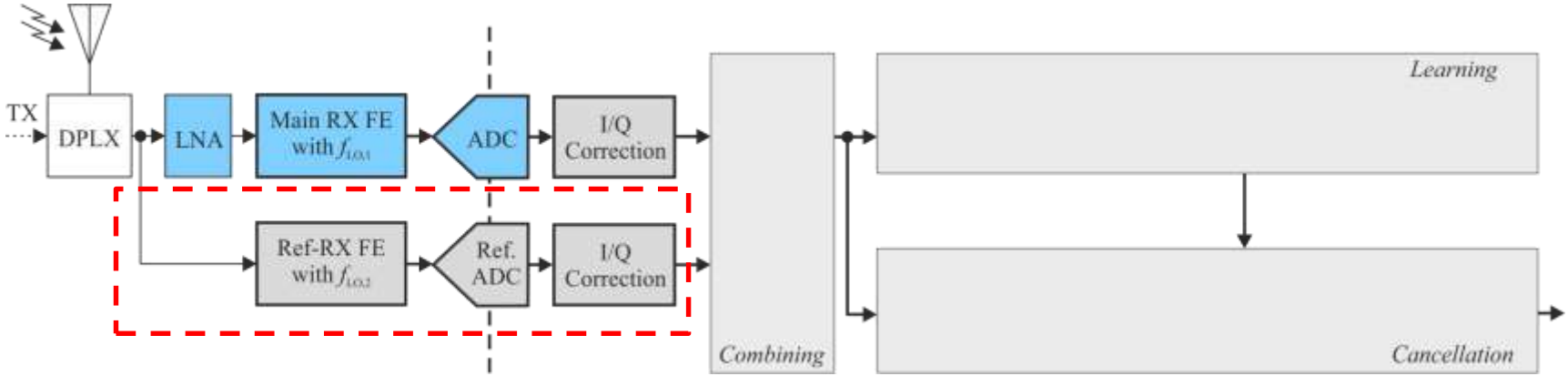


Digital cellular telecommunications system (Phase 2+); Radio transmission and reception, 3GPP TS 45.005 version 11.4.0 Release 11, Jan. 2014

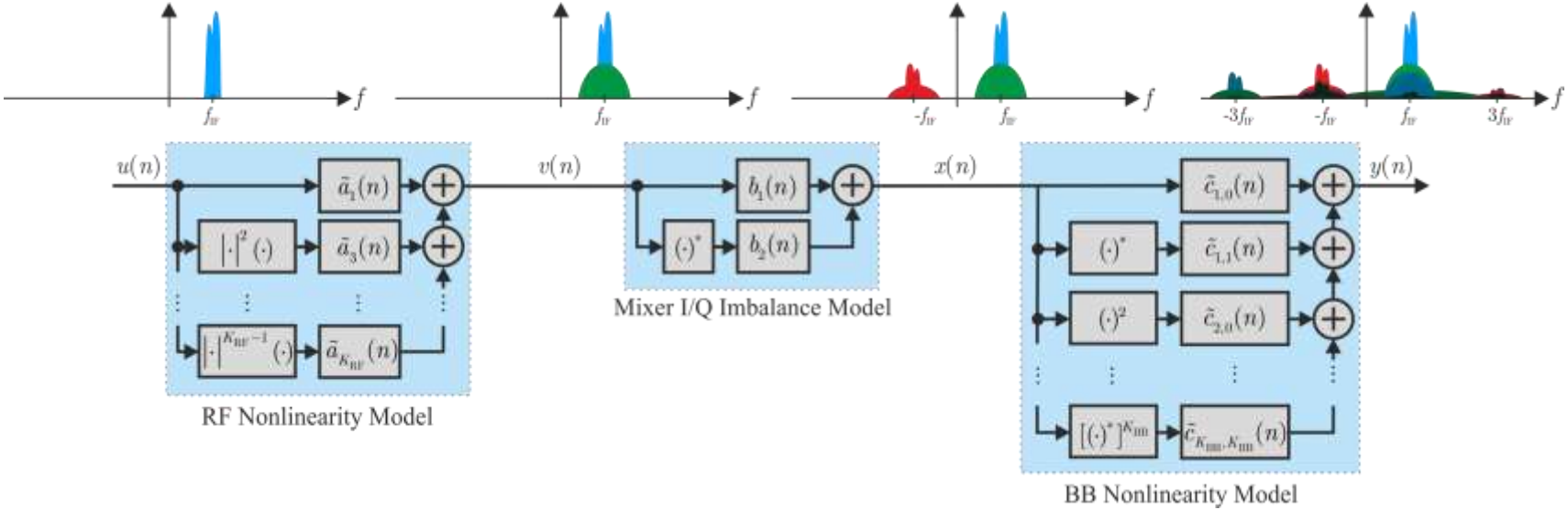
Universal Mobile Telecommunications System (UMTS); Base Station (BS) radio transmission and reception (FDD), 3GPP TS 25.104 version 11.8.0 Release 11, Jan. 2014.

LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception, 3GPP TS 36.104 version 11.7.0 Release 11, Jan. 2014

Reference Receiver Enabled Digital Cancellation

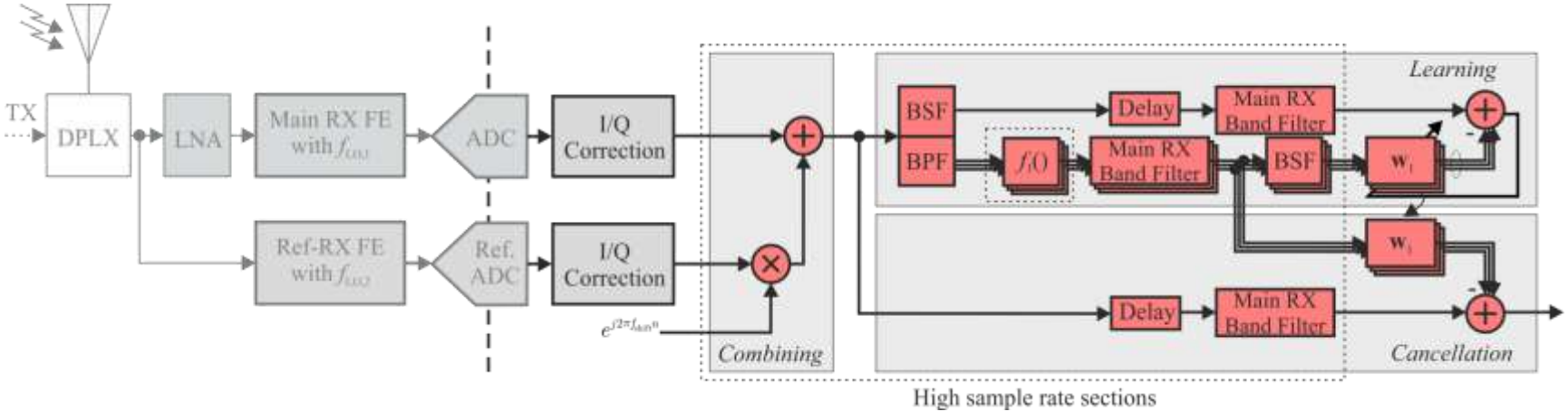


Applied Cascaded Nonliearity Modelling



J. Marttila, M. Allén, M. Valkama, M. Kosunen, K. Stadius, and J. Ryynänen, "Reference receiver enhanced digital linearization of wideband direct-conversion receivers," *IEEE Trans. Microw. Theory Tech.*, 2016, accepted.

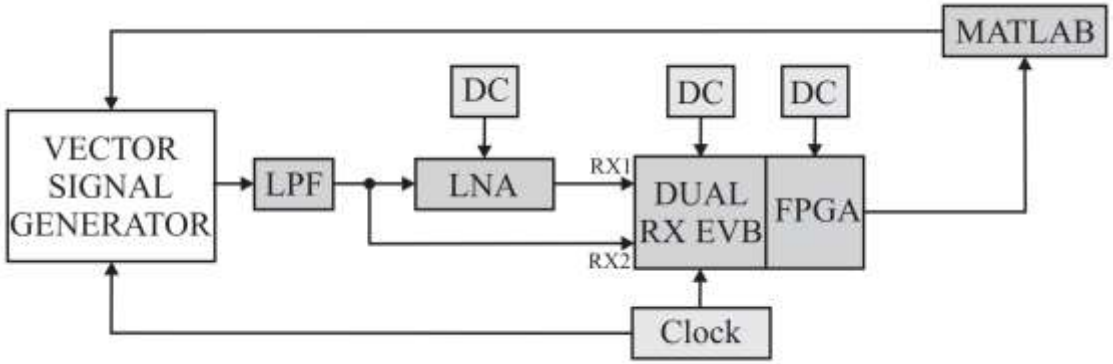
Reference Receiver Enabled Digital Cancellation



Single-RX inband linearization principle presented in M. Allén, J. Marttila, M. Valkama, S. Singh, M. Epp, and W. Schlecker, "Digital full-band linearization of wideband direct-conversion receiver for radar and communications applications," in *Proc. 49th Asilomar Conference on Signals, Systems and Computers*, Pacific Grove, CA, Nov. 2015, pp.1361–1368.

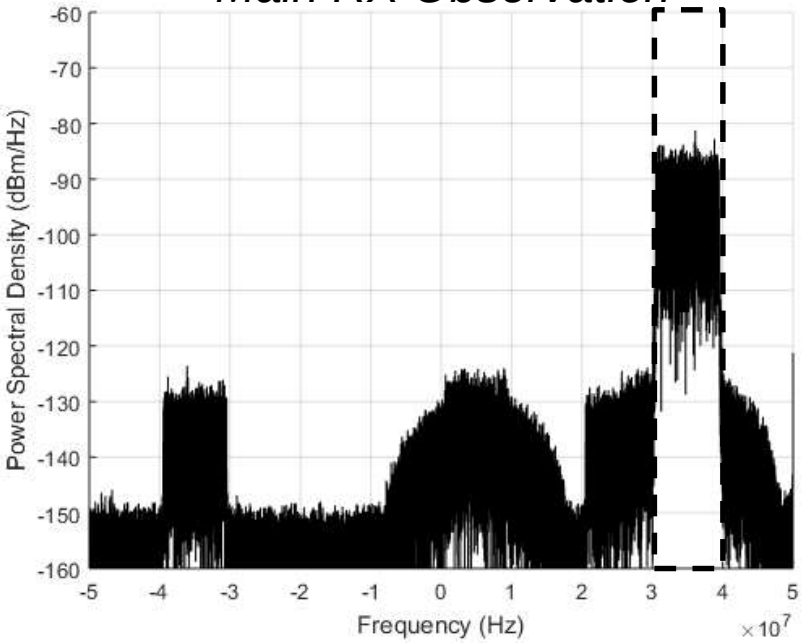
Measurement Setup

- Four carriers on LTE band 3 DL and UL duplexing bands
  - **Two weak UL carriers**
  - **Two strong carriers; one UL, one DL** (mimicing a nearby interfering BS transmitter)
- Split to
  - **Main RX** (100 MHz bandwidth) receiving the UL band
  - **ref-RX** (100 MHz bandwidth) tuned for the DL band
- HD Communications Corp. HD24089 wideband LNA
  - 22 dB gain, -7 dB IIP3
- Pre-commercial v. of AD9371 dual RX EVB

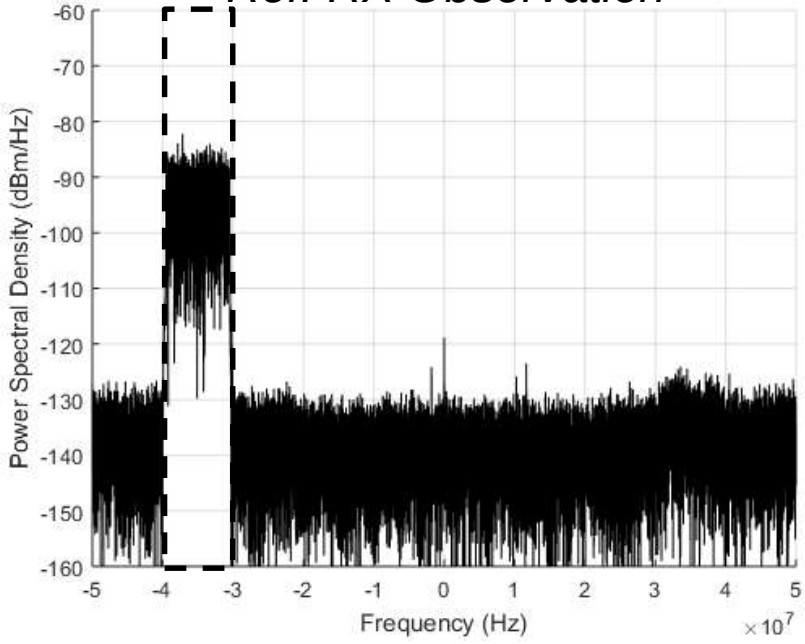


Measurement Results

Main RX Observation

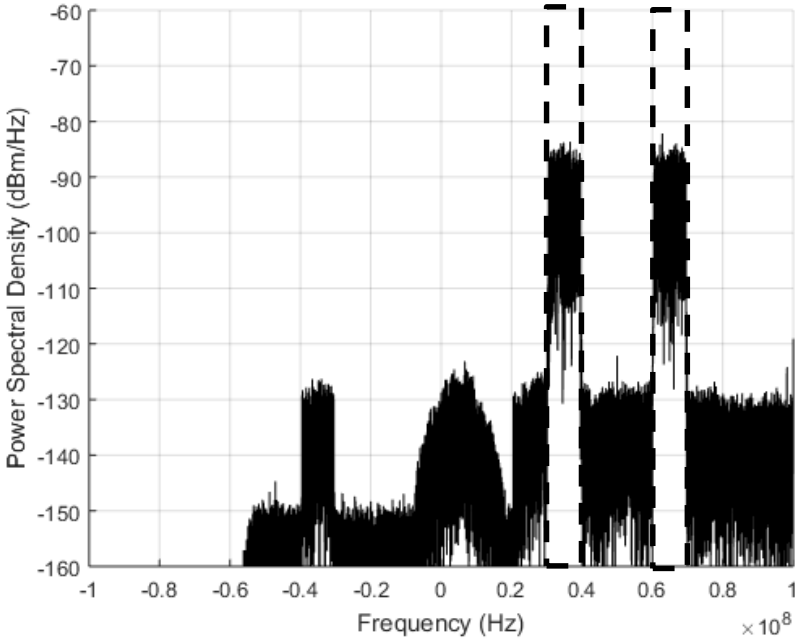


Ref. RX Observation

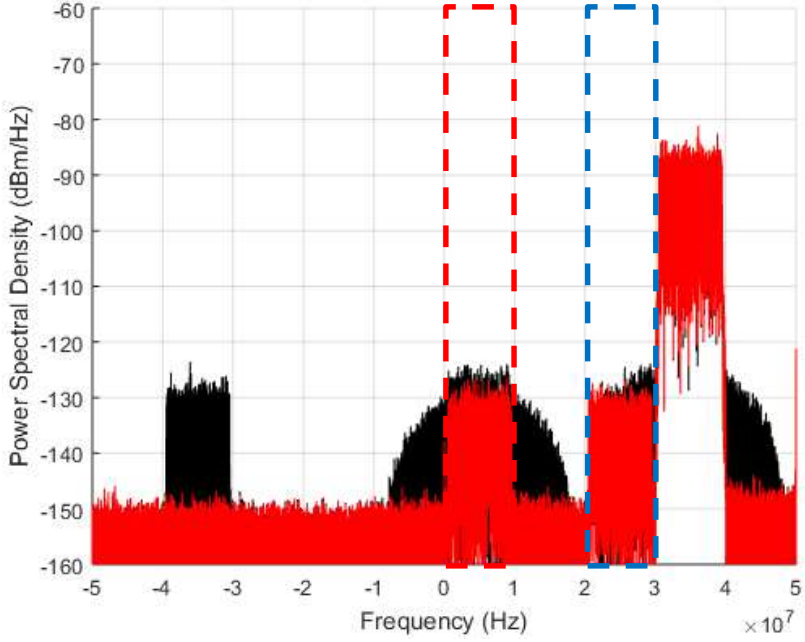


Measurement Results

Combined RX Observation

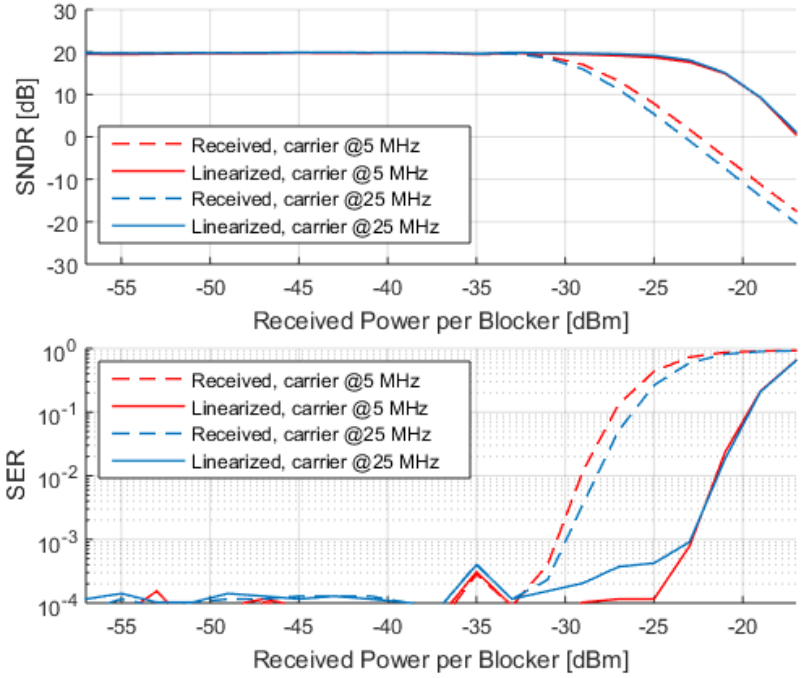


Linearization Result



Measurement Results

- With −27 dBm blocker powers
  - SNDRs improved
    - **From 13 dB to 19 dB (5 MHz)**
    - **From 11 dB to 20 dB (25 MHz)**
  - SERs improved
    - **From 13 % to 0.01 % (5 MHz)**
    - **From 5 % and 0.03 % (25 MHz)**
- 14 dB SNDR and 1 % SER maintained with **7 dB and 8 dB higher blocker powers**



Conclusions

- The proposed solution
  - Combines main RX observation with **OOB blockers captured by a ref-RX**
  - Regenerates an estimate of nonlinear distortion induced by the RX analog front-end components
  - **Estimate is used to cancel the distortion** present in the main RX observation

- Improvement in RX blocker tolerance allows more flexibility in the analog component design and increased reception dynamic range
  - expected to be critical in the emerging 5G systems, with increased requirements for flexible duplexing and RF spectrum use, especially at carriers below 6 GHz