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CATENA

12th YEAR

CEVA TECHNOLOGY
SYMPOSIUM SERIES

Advanced 28nm Bluetooth and Wi-Fi RF Platforms for SoC Integration

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CTO & VP, Catena

CATENA Introduction

Partner of Choice in System IP and IC Design

- Catena was founded in Delft (NL) in 1986, with a vision on structured Analog and RF IC design methodology
- Continuous and steady growth of work force over the years, combined with office expansion at:
  - Delft (NL), Eindhoven (NL), Kista (SE), Vienna (A), Dresden (D) and Pavia (I)
- >150 highly skilled engineers: RF, Analog, Mixed-Signal, DSP and Embedded SW
- Providing advanced RF wireless IP and related IC design services
- Wide range of process technologies: CMOS and SiGe
- Multiple foundries: TSMC, GF, Samsung, UMC, ST, Tower/Jazz, etc.

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System Solutions Through Partnership

Catena/Ceva Joint Offerings

- Recognizing many customers appreciate system solutions instead of just licensing IPs, Catena has established a number of strategic partnerships to facilitate that
- Ceva is the partner for BT and Wi-Fi solutions
- BT: Radio (PHY) from Catena + BB (HCI Controller) from Ceva
  - Multiple modes: Dual-Mode (BR, EDR 2/3Mbps, BLE 5.0 (1/2Mbps), Long Range (125/500kbps) and IEEE802.15.4 (ZigBee)
- Wi-Fi: Transceiver from Catena + Modem/MAC from Ceva
  - Multiple standards: IEEE 802.11 ac/ax/ah
- Turnkey ASIC Partners: Delta (DK) and EnSilica (UK)

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Catena's 28nm Wireless Platform

Motivation

- Facilitate SoC integration for the rapidly expanding IoT market
- Providing high performance IPs in advanced process nodes
- Original IP development in TSMC 28nm-HPC
- Wi-Fi and BT IPs already ported to GF 28nm-LP
  - BT IP also available in TSMC 40nm-ULP
- Technology porting plans for 2019:
  - Samsung 28nm-FDX and LLP
  - TSMC 22nm-ULL
  - GF 22nm-FDX

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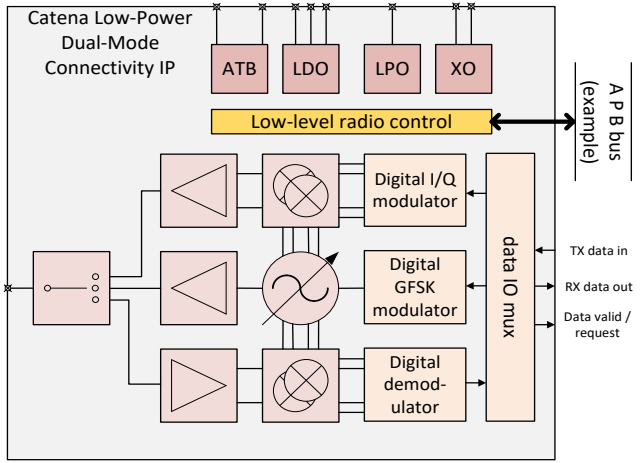
Bluetooth Offerings

Dual-Mode (5.x) for IoT and Audio Streaming Applications

- Motivation:
  - Time required for new BLE Audio standard to be ratified and adopted
  - Backward compatibility with installed base for several years
- Configurable transceiver covering BT and ZigBee standards
  - High sensitivity and interference immunity
    - Receiver Sensitivity
      - BR -95 dBm
      - EDR (2 Mb/s) -93 dBm
      - EDR (3 Mb/s) -86 dBm
      - LE (1 Mb/s) -98.5 dBm
      - LE (2 Mb/s) -95.5 dBm
      - LE (500 kb/s) -101 dBm
      - LE (125 kb/s) -103 dBm
      - 802.15.4 (250 kb/s) -100 dBm
    - Transmitter P_{out} +8 dBm (EDR)

Demo



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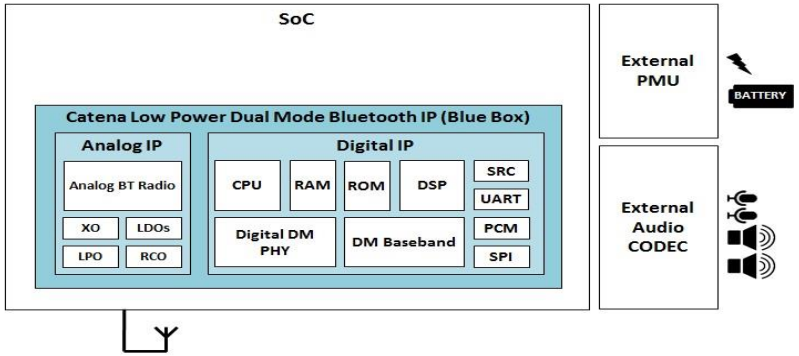
Bluetooth Offerings

Audio Streaming System Concept

- Catena/Ceva can provide complete system solution including Audio Processing
- System architecture (Blue Box) and Radio IP optimized for lowest power dissipation when used for Audio application



Peak Power

Function	Peak Power (mW)
Radio receiver	14.5
Radio transmitter	54.0 (+8dBm @EDR-mode)
Baseband	0.1
Audio DSP	2.3
SoC Infrastructure	0.3
Crystal oscillator	0.9

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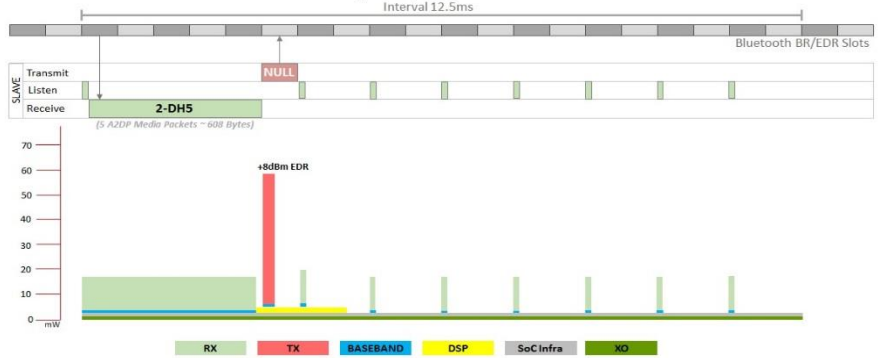
Bluetooth Offerings

Average Power Dissipation for Audio Streaming Use Case

- Dissipation figures based on 28nm Catena IP and Blue Box system architecture

Bluetooth A2DP Duty Cycle Overview



Average Power

Function	Duty	Power (mW)
Host (OFFLOADED)	1%	0.0
Radio receiver	22.5%	3.3
Radio transmitter	1.0%	0.5
Baseband	24.8%	0.03
Audio DSP	11.2%	0.3
SoC Infrastructure	100%	0.3
Crystal oscillator	100%	0.9

5.3 mW

1.7mA @ 3.7V

85% DCDC Efficiency

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Wi-Fi Offerings

Dual-Band IEEE802.11ac

- Access Point (AP) and Station (STA) applications
- Facilitating SoC integration
- Multiple configurations to meet diverse market requirements
- Catena provides customer-specific configurations on customer request
  - Concurrent dual-band (AP)
  - Non-concurrent dual-band (STA)
  - 2x2 MIMO configuration
  - Wi-Fi/BT combo (Mobile Phone)

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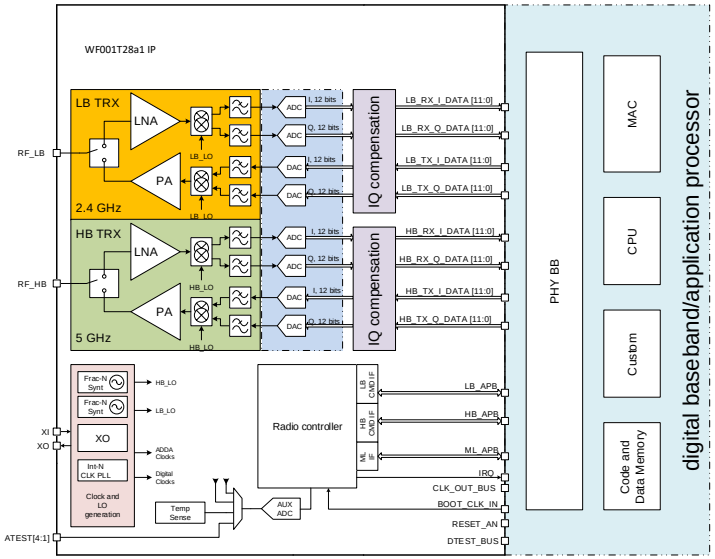
1x1 Dual-Band IEEE802.11ac

Concurrent Operation for Access Point Application

Demo

- First customer product available in the market
  - Embedded PA/LNA/Switch
  - Includes data converters and clocking
- Frequency bands
  - 2.412 GHz - 2.484 GHz
  - 4.920 GHz - 5.825 GHz
- Receiver NF
  - 4.5dB, low band
  - 5.5dB, high band
- Transmitter Output Power
  - 16dBm, low band (MCS6)
  - 14.5dBm, high band (MCS9)



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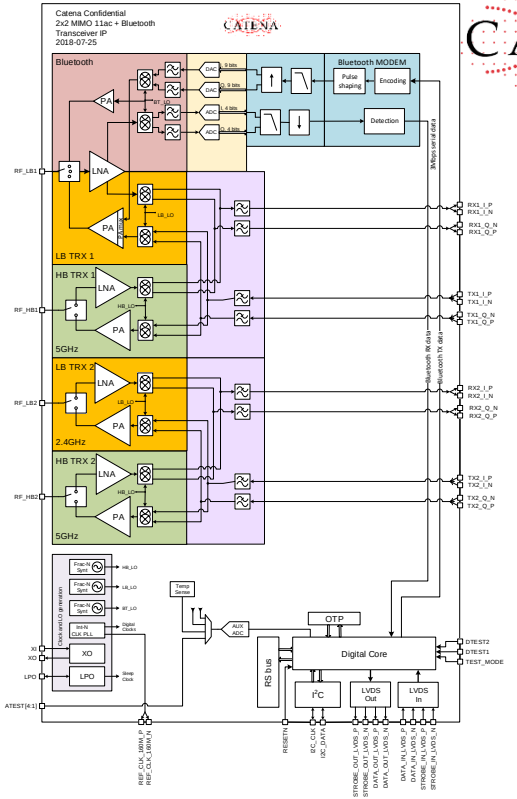
2x2 MIMO 11ac / BT-DM Combo IP

Under Development

- Increasing demand for 2x2 MIMO configuration
- 1st silicon tape-out November, 2018
  - TSMC 28nm-HPC
- Combo with BT-DM
- 1st silicon tape-out planned for end of Q2, 2019
  - Combined BT and WiFi antenna connection
    - Shared antenna, LNA/PA/Switch
    - Simplifies application
    - Reduces costs



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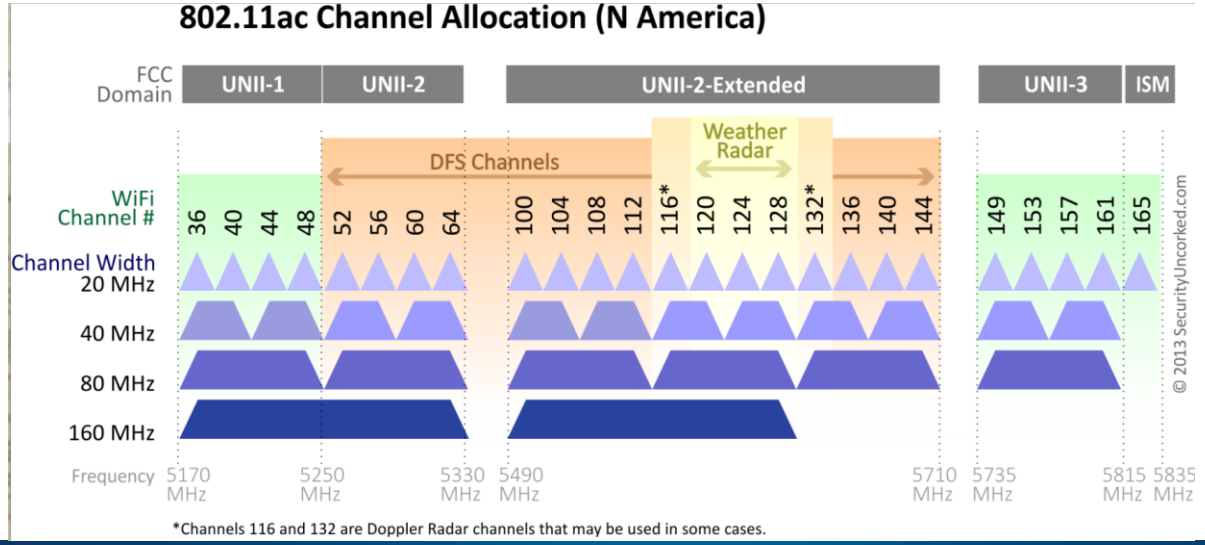
5GHz Frequency Band Allocations

Congested Frequency Band Limiting Data Throughput

- The need for continuously higher data rates in congested frequency bands necessitates more complex modulation formats and therefore new standard – 11ax



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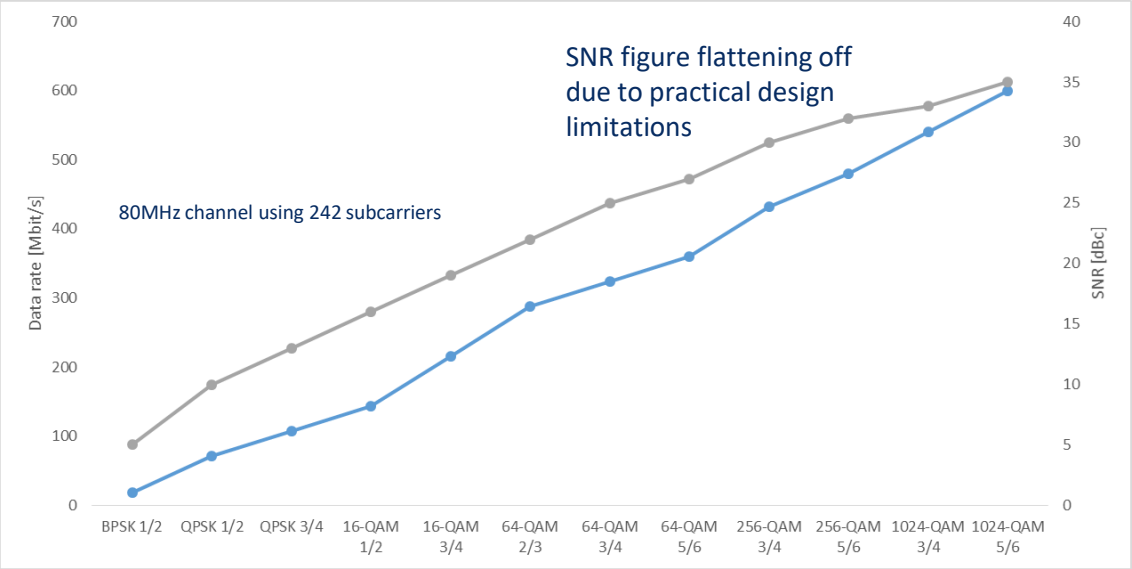
Data Rate/SNR Requirements vs Modulation Format

Tougher Specifications as we move from 11b/g to 11ac, to 11ax

- Circuit impairments (noise and linearity) limiting performance



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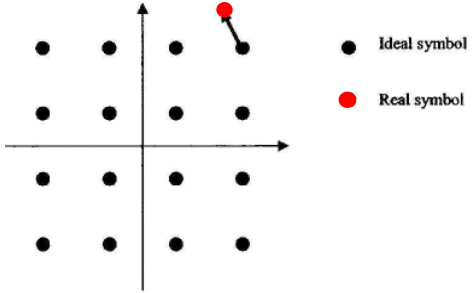
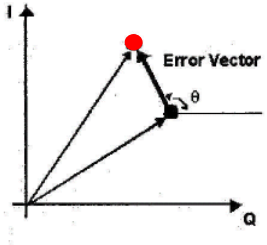
Error Vector Magnitude

Important System Performance Parameter

- Ability to distinguish the correct position of symbols in the constellation
- Different EVM sources are added as RMS
  - Noise, distortion, intermodulation, Mismatch, etc.
- Often EVM is given as positive number, similar to SNR





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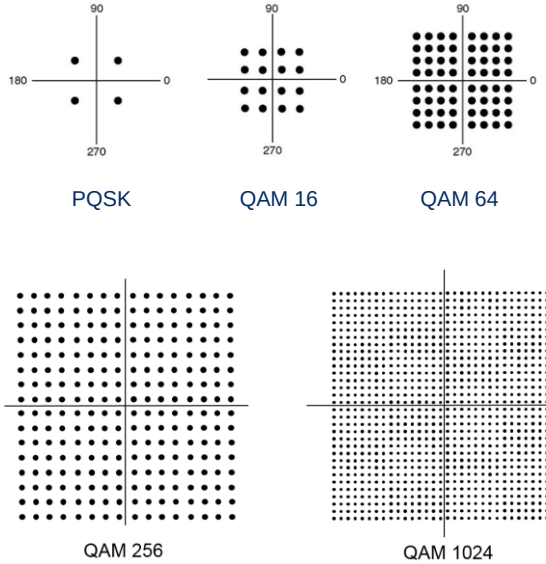
EVM Requirements

More Complex Modulation Formats Require Higher EVM



- Max EVM in AWGN
  - Absolute requirement limits
- QPSK ≈ -3 to -6 dBc (50%)
- QAM 16 ≈ -9 to -13 dBc (25%)
- QAM 64 ≈ -17 to -19 dBc (12.5%)
- QAM 256 ≈ -23 to -25 dBc (6.25%)
- QAM 1024 ≈ -29 to -31 dBc (3%)

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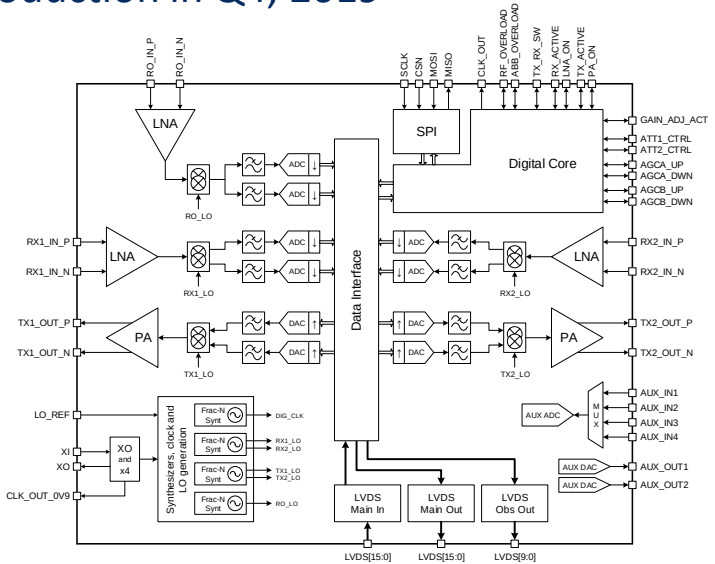
IEEE 802.11ax

Professional Router Applications

- Catena's 28nm 11ax IP has been licensed by 2 customers
  - 1st customer in production, the 2nd will start production in Q4, 2019
    - High performance Transceiver with digital I/Q interface
      - EVM = -40dB
      - Better interferer immunity than in 11ac
    - 2x2 MIMO covering 4.9-6GHz
    - FDD support
    - Observation receiver for background scanning

Demo



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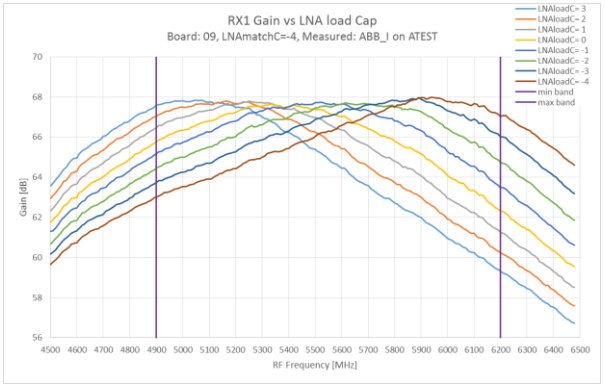
WiFi-11ax Measurements

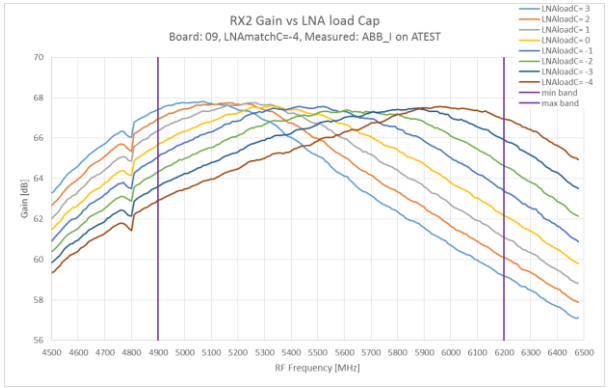
RX Gain vs Frequency

- Internal cap-bank ensures very flat gain response over the >1GHz range

- RX1



- RX2



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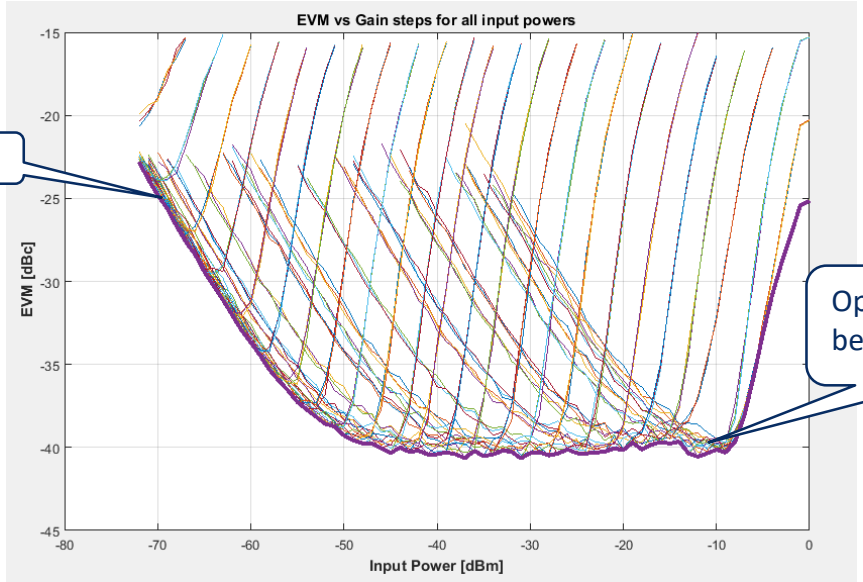
WiFi-11ax Measurements

RX EVM Measurements

- NF and EVM performance meeting requirements



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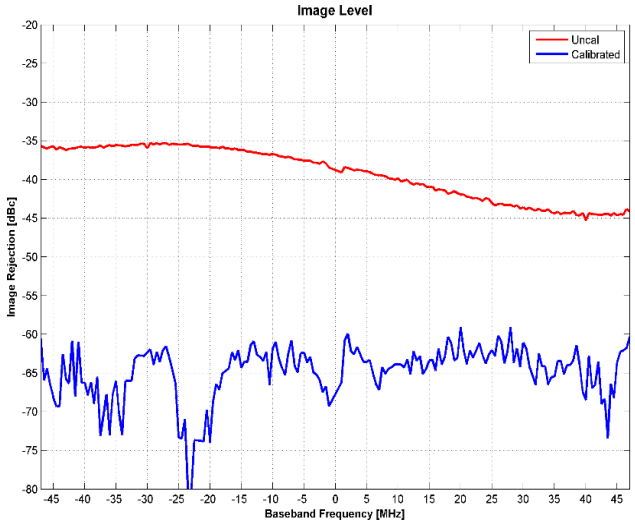
WiFi-11ax Measurements

TX I/Q Error Compensation

- Challenge: keeping I/Q error below 50dB over a wide frequency range
  - Frequency-dependent I/Q error compensation
    - Internal test tone generator
    - Internal one bin FFT
  - Plot shows algorithm applied to TX I/Q error
  - IRR ≤ -60 dBc over 100MHz BW



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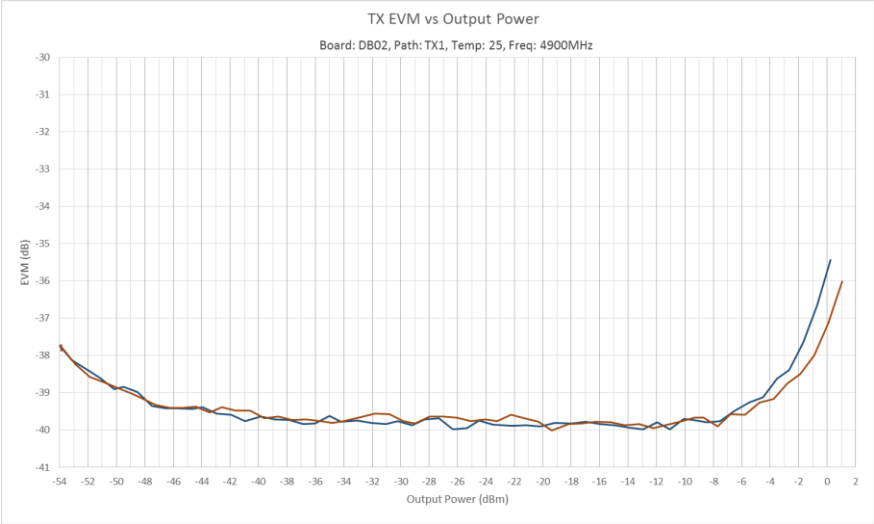
WiFi-11ax Measurements

TX EVM (2 paths) as function of output power

- Both transmitters meeting EVM requirement



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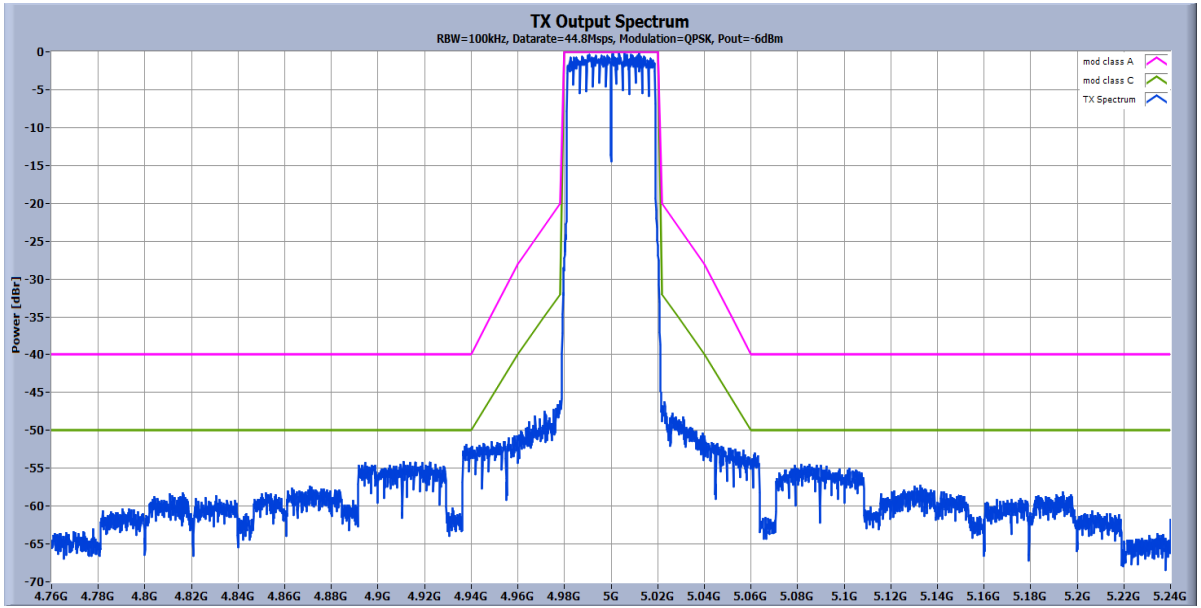
WiFi-11ax Measurements

TX Output Spectrum: 40MHz BW, -6 dBm

- Excellent spectrum mask compliance



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Conclusions

28nm Wireless Platform

- Catena provides a wide range of Wi-Fi and BT IPs in advanced process nodes
  - BT: Dual-Mode/ZigBee, Wi-Fi: IEEE 802.11ac/11ax, Dual-Band, Concurrent, MIMO and BT/Wi-Fi combo
- System solution together with Ceva's Baseband offerings
- A number of successful product releases
- Support for customer-specific configurations on request
- Demos available at Catena (BT and Wi-Fi 11ac) and Ceva (Wi-Fi 11ax) booths

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Thank You

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