



CEVA TECHNOLOGY  
SYMPOSIUM SERIES

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

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# 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.

# 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)

# 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

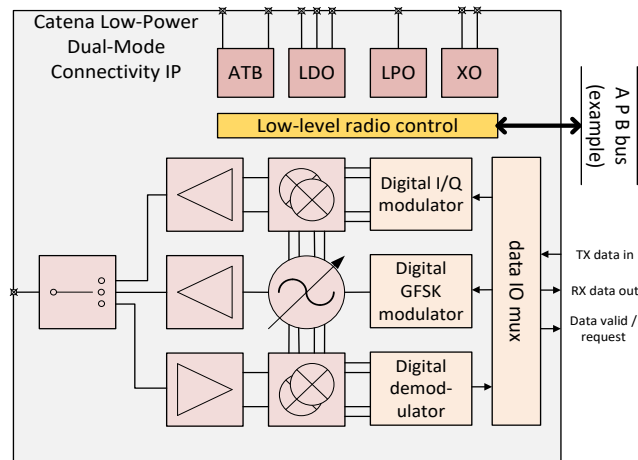
# Bluetooth Offerings



## 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

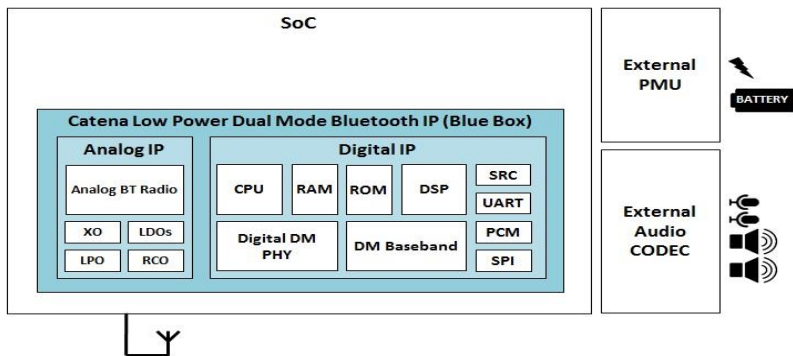


# Bluetooth Offerings



## 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

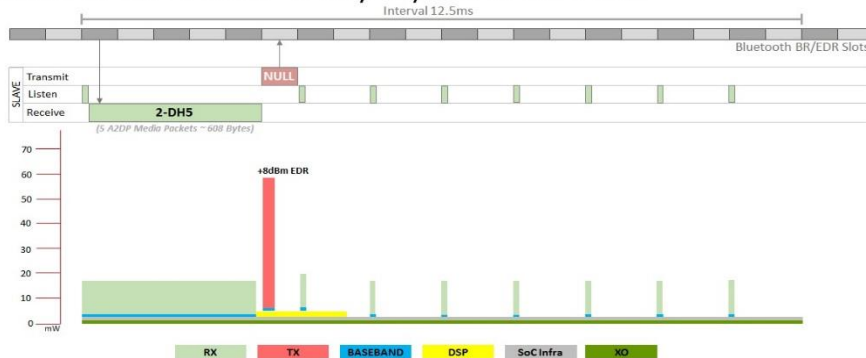
# Bluetooth Offerings



## 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

# 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)



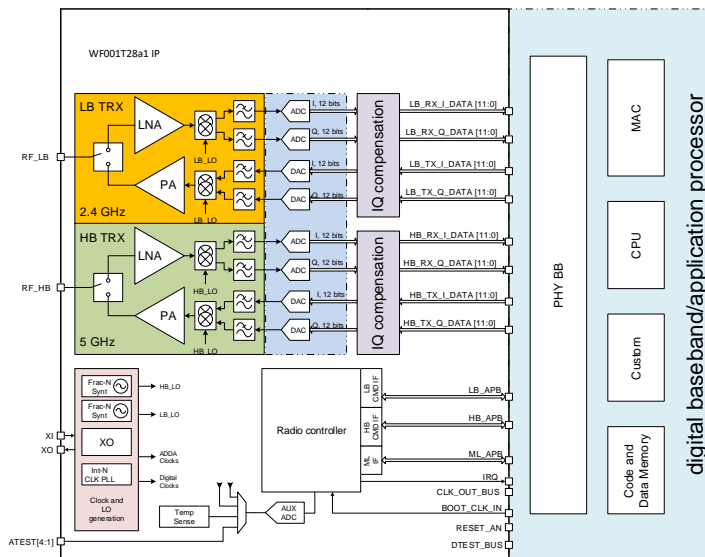
# 1x1 Dual-Band IEEE802.11ac



## 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)

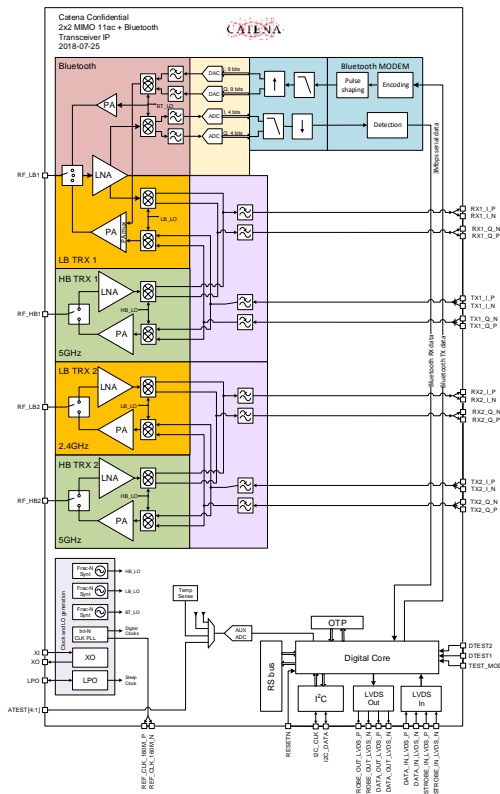


# 2x2 MIMO 11ac / BT-DM Combo IP



## Under Development

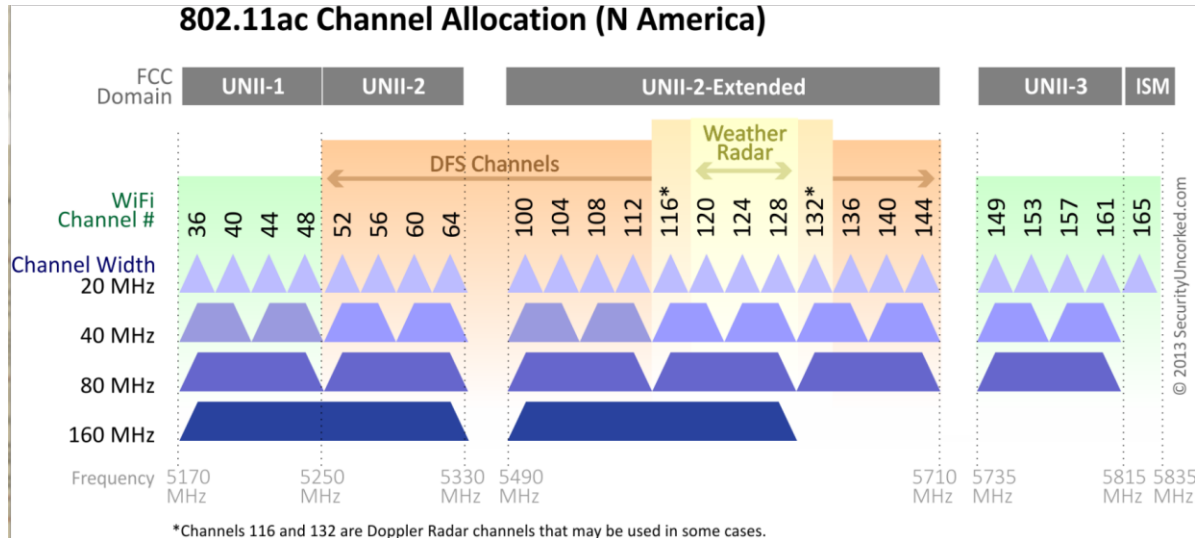
- ▶ Increasing demand for 2x2 MIMO configuration
- ▶ 1<sup>st</sup> silicon tape-out November, 2018
  - ▶ TSMC 28nm-HPC
- ▶ Combo with BT-DM
- ▶ 1<sup>st</sup> silicon tape-out planned for end of Q2, 2019
  - ▶ Combined BT and WiFi antenna connection
    - ▶ Shared antenna, LNA/PA/Switch
    - ▶ Simplifies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



# 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

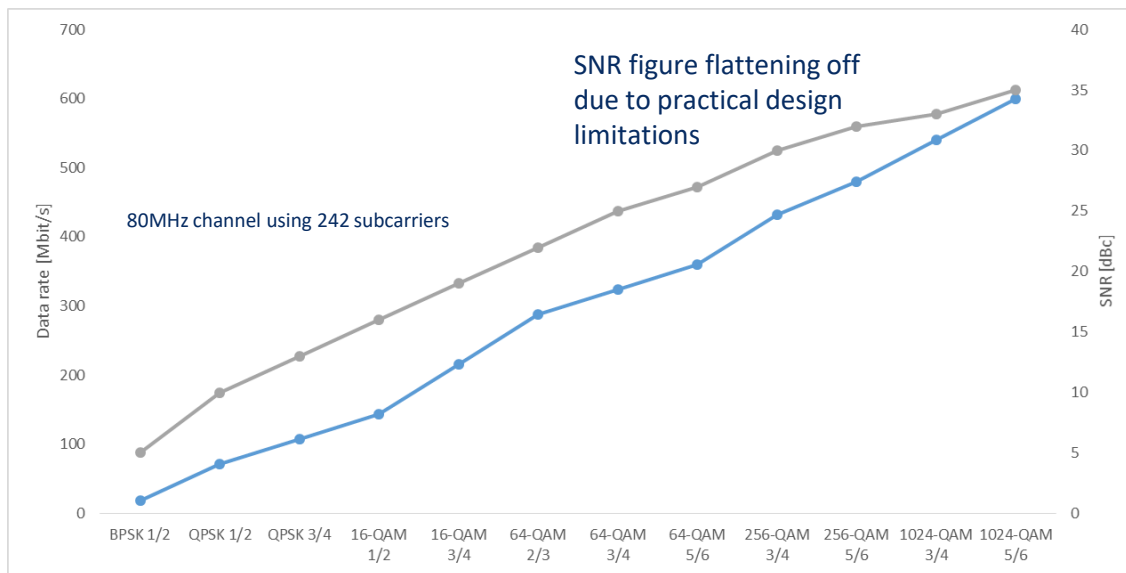


# Data Rate/SNR Requirements vs Modulation Format



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

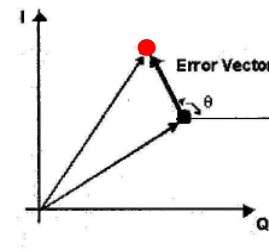
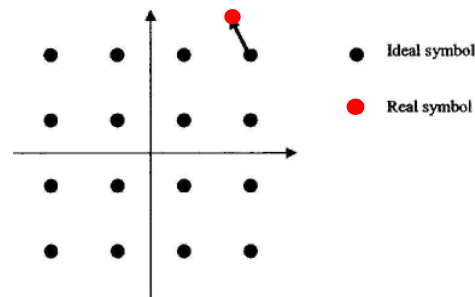
- Circuit impairments (noise and linearity) limiting performance



# Error Vector Magnitude

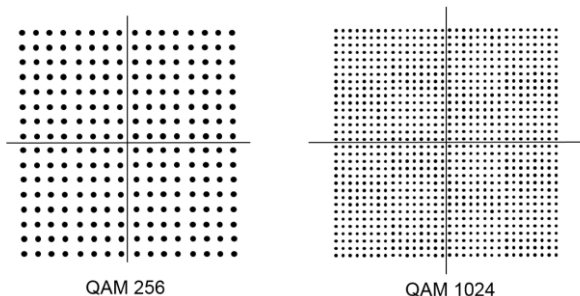
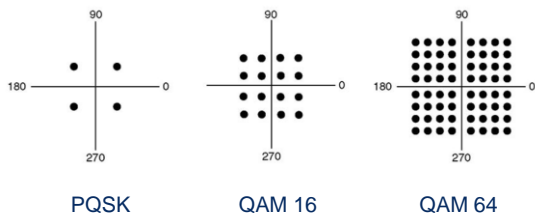
## Important System Performance Parameter

- ▶ 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



# EVM Requirements

## More Complex Modulation Formats Require Higher EVM



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

# IEEE 802.11ax

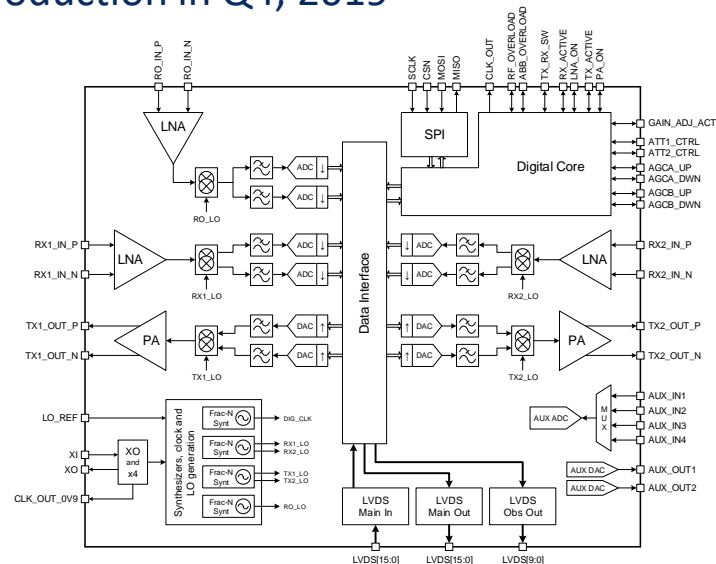


## Professional Router Applications

- ▶ Catena's 28nm 11ax IP has been licensed by 2 customers
- ▶ 1<sup>st</sup> customer in production, the 2<sup>nd</sup> will start production in Q4, 2019

Demo

- ▶ 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



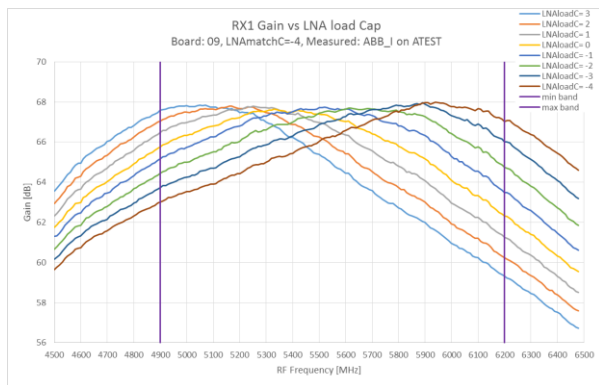
# WiFi-11ax Measurements



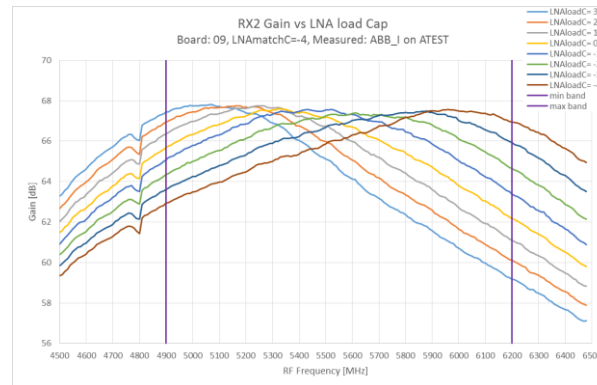
## RX Gain vs Frequency

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

### ► RX1



### ► RX2

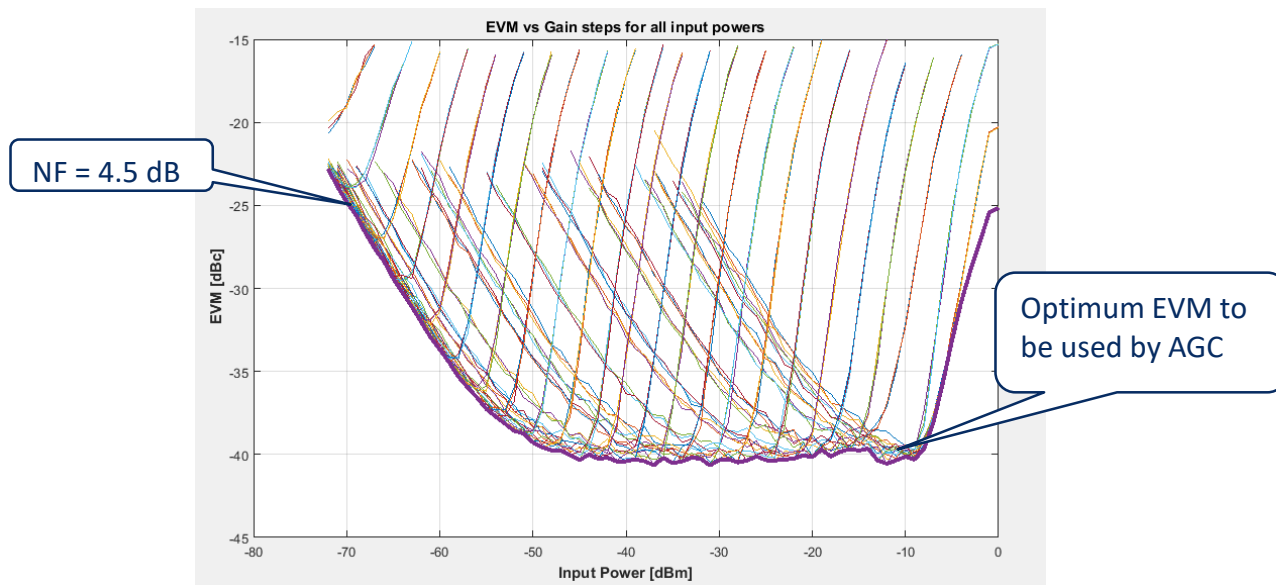




# WiFi-11ax Measurements

## RX EVM Measurements

- NF and EVM performance meeting requirements



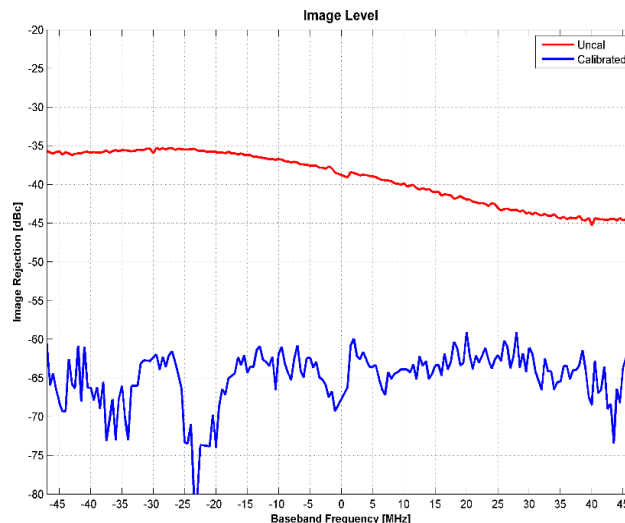
# WiFi-11ax Measurements



## 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
- $IRR \leq -60$  dBc over 100MHz BW

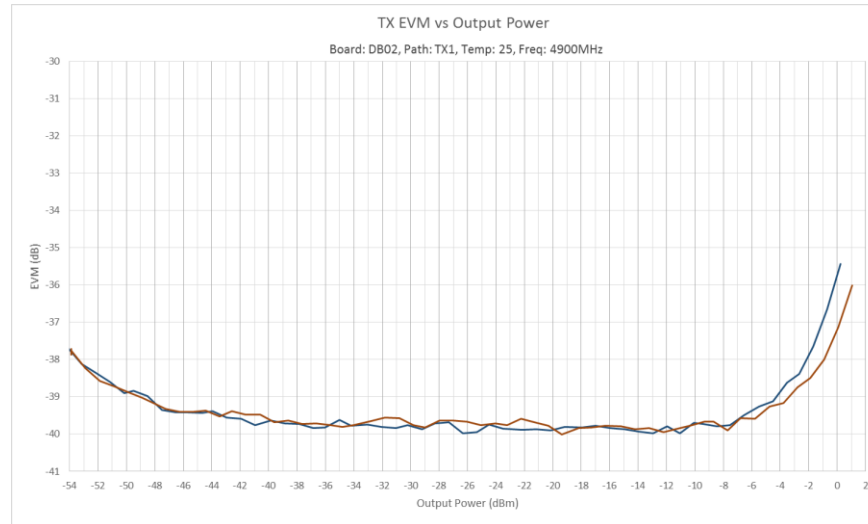


# WiFi-11ax Measurements



## TX EVM (2 paths) as function of output power

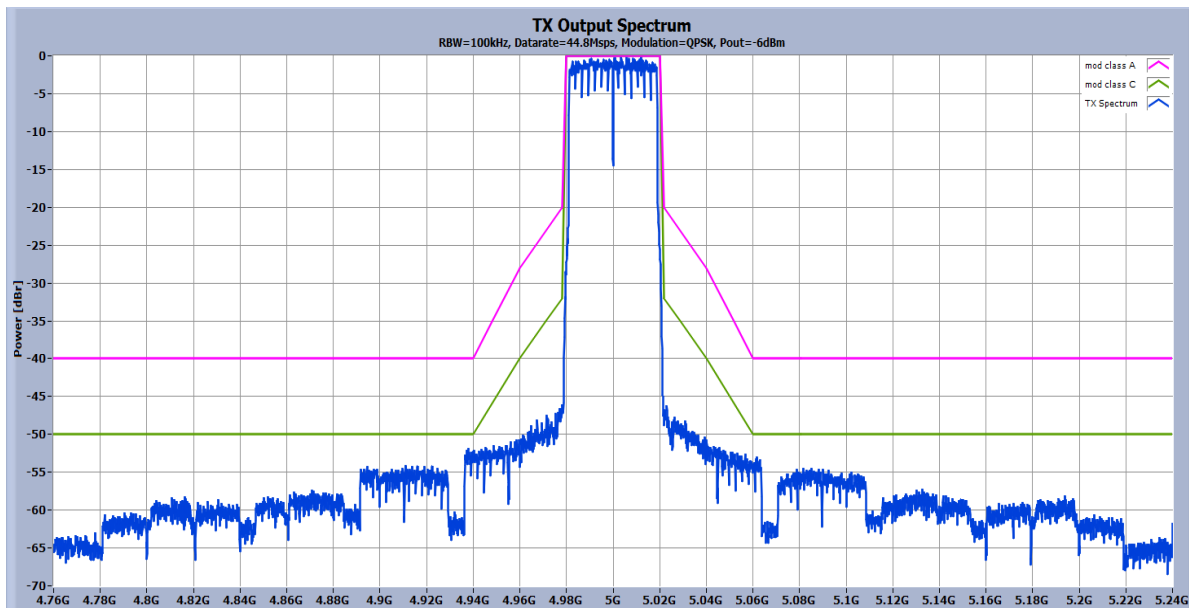
- Both transmitters meeting EVM requirement



# WiFi-11ax Measurements

TX Output Spectrum: 40MHz BW, -6 dBm

► Excellent spectrum mask compliance



# 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

# Thank You

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