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LPW-201

Advanced Features Coming to Sub-GHz Networks

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Advanced Features Coming to Sub-GHz Networks: Content

- This session focusses on
  - Wi-SUN, and in particular some system features
    - Mode switch
    - Concurrent detection
    - LFN (Limited Function Node)
  - SUN/ Wi-SUN PHYs and their respective benefits for both Wi-SUN and proprietary applications
    - Wi-SUN FSK
    - Wi-SUN OFDM
    - SUN O-QPSK

SUN: Smart Utility Networks (802.15.4 reference)

Wi-SUN: Wireless Smart Ubiquity Networks (Wi-SUN alliance specifications)

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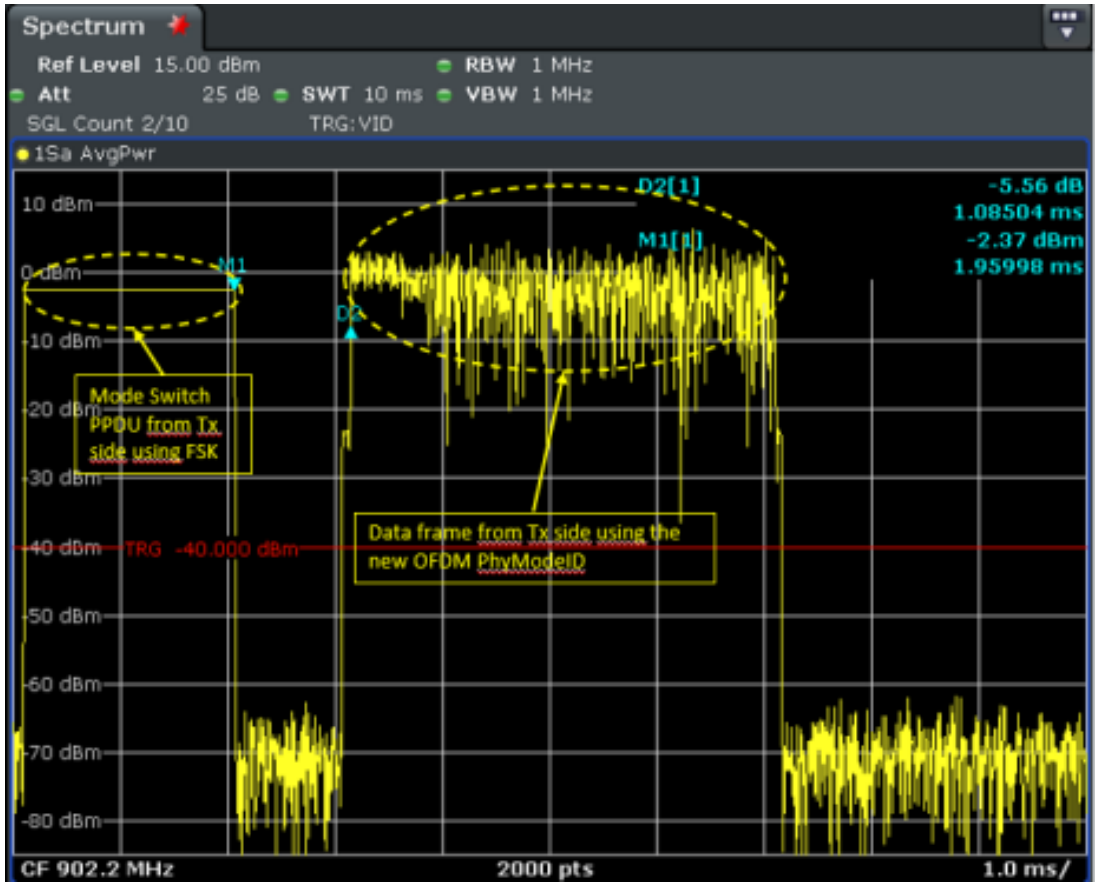
System aspects of Wi-SUN

Mode Switch

- **Wi-SUN introduces a mode switch mechanism option**
  - Different from 802.15.4
- **Principle:**
  - A Wi-SUN network is using a given FSK as **base PHY**
  - A given transmission can be done using an **alternate PHY**, with higher bit rate
    - Can be FSK to FSK or FSK to OFDM
    - Can be on a wider channel
  - To achieve this, a signaling packet is sent to provide the information on the new PHY
  - The devices can then communicate with the new PHY
  - See AN1403: Wi-SUN PHY mode switch on EFR32FG25
- **Benefit**
  - Increase of the bit rate for a dedicated period/purpose
  - Backward compatible
- **Drawback**
  - Requires a signaling packet



Concurrent Detection

- Concurrent detection further improves network performance

- Principle:
  - The device listens to both FSK and OFDM at the same time
  - The first incoming signal triggers reception, the other one is aborted
  - Behaves like mode switch, without the need for the signaling packet

- Benefit
  - Allows hybrid networks, FSK for robustness and legacy, OFDM for high bit rates
  - Increase throughputs without the overhead of a signaling packet

- Note: this is not specified in Wi-SUN, but a capability of EFR32**FG25**

LFN: Limited Function Node

- LFN allows battery powered applications as nodes can be sleeping most of time
- Introduced within Wi-SUN FAN 1.1
- The typical use case is a node transmitting 1-2 kB per day
  - The goal is to reach a battery life of 20 years
- These nodes cannot be routers, so this is limited to leaf nodes
- Available for both EFR32**FG28** (FSK only) and EFR32**FG25** (FSK & OFDM)

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SUN and Wi-SUN PHYs

Wi-SUN FSK

- Wi-SUN FSK PHYs are a subset of SUN-FSK specification (IEEE802.15.4g)
- Specification: Wi-SUN PHY Working Group (PHYWG) - PHY Technical Profile Specification (TPS) Rev 2V01
  - Now covers FSK worldwide and OFDM in a single document
- 5 data rates coming with different channel spacing
  - Flexibility is limited
  - The more bit rate you want, the more bandwidth you need
- FEC is available and brings ~2 to 4 dB better sensitivity, but
  - it has strong impact as it divides by 2 the bit rates
  - Or requires a wider bandwidth for similar bit rate

  => in practice, this is barely used

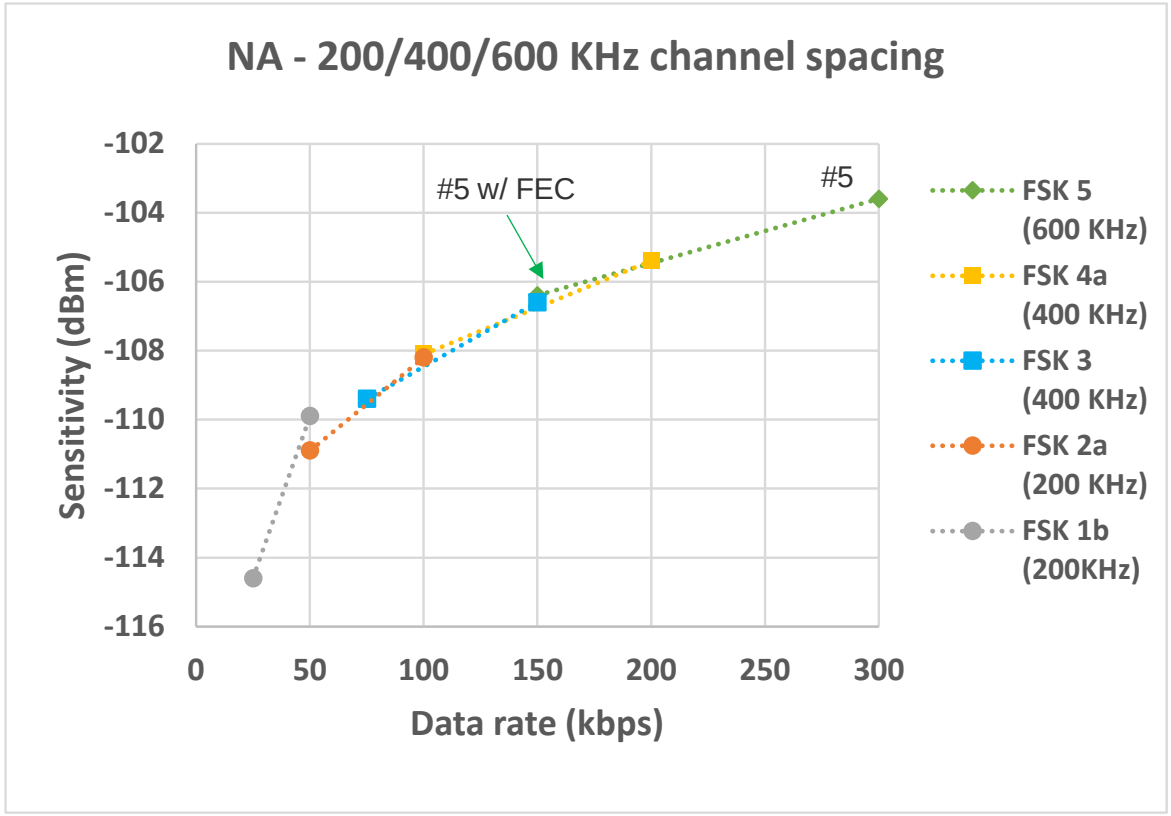
Bit rate (kbps)	Modulation index	BW – ch spacing (KHz)	Operating mode	With FEC: Net bit rate (kbps)
50	0.5	100	**#1a**	25
50	1.0	200	**#1b**	25
100	0.5	200	**#2a**	50
100	1.0	400	**#2b**	50
150	0.5	200 – 400*	**#3**	75
200	0.5	400	**#4a**	100
200	1.0	600	**#4b**	100
300	0.5	400 – 600*	**#5**	150

*: depends on the region

FSK: Frequency Shift Keying, FEC: Forward Error Correction

Wi-SUN FSK

- **Example of FSK performance for North America (NA) modes**
  - EFR32FG25 sensitivity figures



Summary on FSK

- **Advantages**
  - Simple, well known, a lot of use cases
  - Low complexity
  - Constant envelope
    - Can use a Power Amplifier at saturation
    - Power efficient at Tx side

    ⇒ low power
- **Drawbacks**
  - Limited flexibility
  - Increased bit rate requires higher bandwidth
  - FEC not really helpful, except for 50 kbps mode
  - Limited performance

Wi-SUN OFDM: Introduction

- OFDM
  - Orthogonal Frequency Division Multiplex
  - Invented in 1980's for DAB
  - Became popular in 1990's with Digital TV (Europe and Japan), then in Wi-Fi (802.11g/n/…)

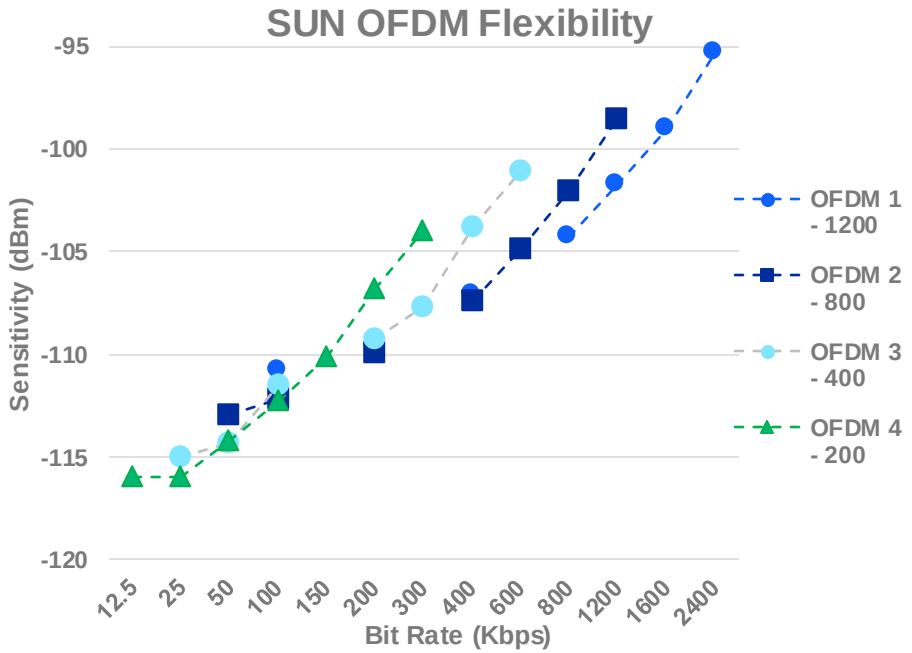
- Main advantages
  - Multi-carrier modulation
    - Combines carriers which brings robust synchronization and data carriers which very efficient modulation and coding
  - OFDM has built-in flexibility/scalability
    - Same synchronization for all MCS modes
    - In-packet signaling => easy switch between modes without configuration
  - Robustness to multipath

- Main drawback
  - OFDM is sensitive to non-linearity, then requires a linear Power Amplifier which has higher power consumption

MCS: Modulation & Coding Scheme

SUN & Wi-SUN OFDM

- **SUN OFDM**
  - Part of IEEE.802.15.4g specification
  - Defines 4 options for different bandwidth
  - Each option has 7 Modulation and Coding Schemes
    - MCS0 (low bit rate) to MCS6, in-packet signaling
    - Sometimes referred to as MR-OFDM (multi rate)
      - Packet by packet flexibility
  - Wide bit rate range
  - Flexible performance levels
- **Wi-SUN specifies a subset of SUN OFDM modes**
- **EFR32FG25 supports all SUN OFDM modes**
  - And adds MCS7 (*) to bring 50% bit rate increase
    - Up to 3.6 Mbps in option 1
- **OFDM PHYs can be used in proprietary applications, not only for Wi-SUN**

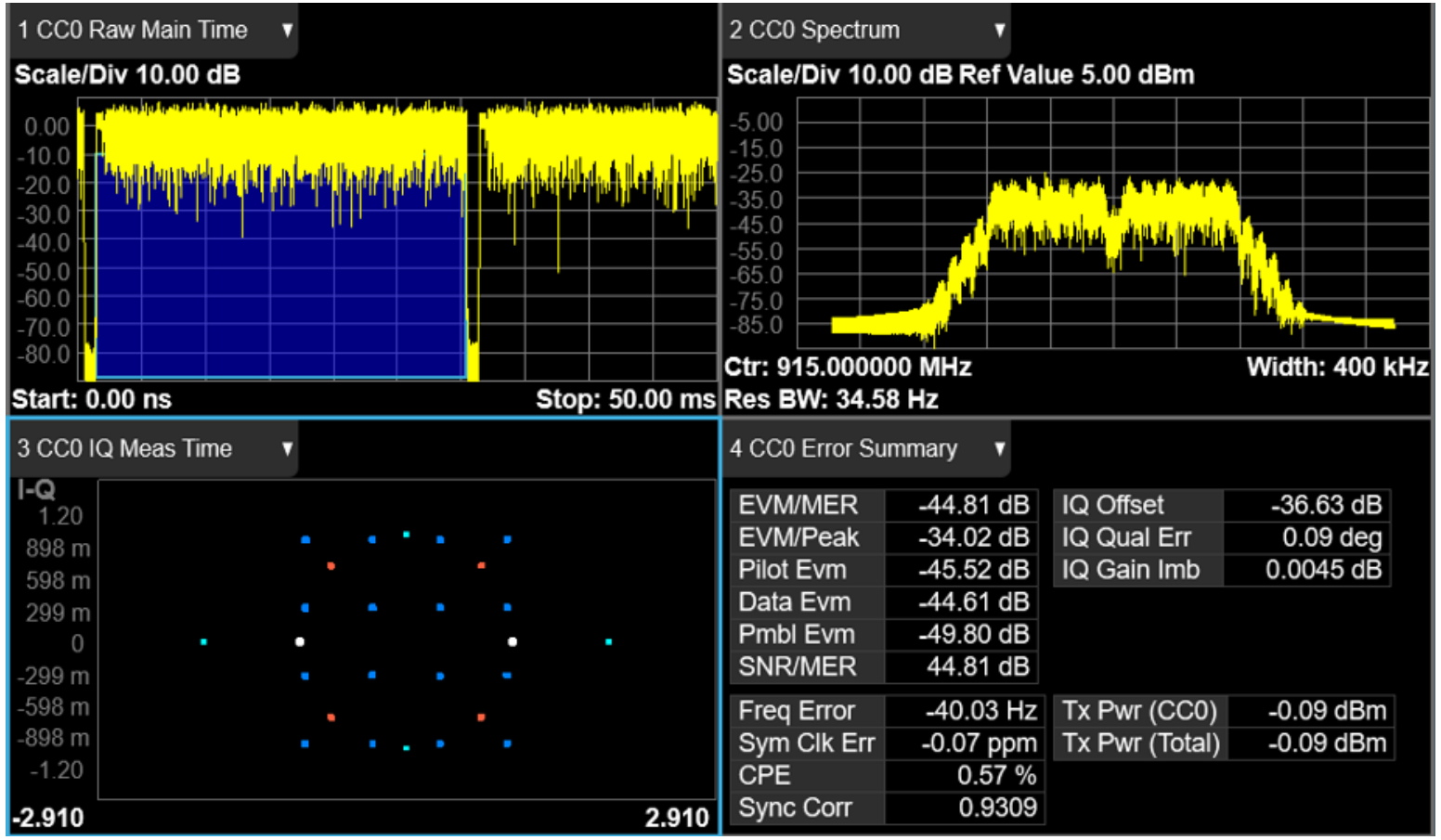


OFDM option	Bandwidth (kHz)	Main regions	Bit rates (kbps)	Sensitivity (dBm)
1	1200	NA, BZ	100 to 2400 (3600*)	-111 to -95
2	800	NA, BZ, JP	50 to 1200 (1800*)	-113 to -98
3	400	NA, BZ, JP	25 to 600 (900*)	-115 to -101
4	200	NA, BZ, JP, EU	12.5 to 300 (450*)	-116 to -104

NA: North America, BZ: Brazil, JP: Japan, EU: Europe

OFDM Characteristics: Option 4 MCS6 Example

Power vs time: High PAPR => requires linearity



Flat spectrum => good spectrum usage

16QAM constellation (data in blue) Pilots and preamble (white & red)

EVM is the indicator of signal quality: highly affected by linearity

PAPR: Peak to Average Power Ratio, QAM: Quadrature Amplitude Modulation, EVM: Error Vector Magnitude

High Bit Rates Benefits

- **Higher bit rate translates to higher throughputs**

  => Throughputs is important for some use cases like Firmware update (OTA)

- **Higher bit rates translates to shorter on-air frame duration**
  - Example for a 1500-Byte PHY Payload

bandwidth (KHz)	modulation	bit rate (kbps)	Tx duration (ms)
200	FSK 1b	50	241.92
	FSK 2a	100	120.96
	OFDM 4 MCS6	300	41.52
400	FSK 3	150	80.85333333
	FSK 4a	200	60.64
	OFDM 3 MCS6	600	21.48
600	FSK 5	300	40.74666667
800	OFDM 2 MCS6	1200	11.52
1200	OFDM 1 MCS6	2400	6.12

- **Shorter on-air duration brings significant advantages**
  - Better network performance and less congestion in a dense environment or in countries with narrow bands.
    - E. g. India band is 3MHz only
  - More robustness to pulse interferers
  - Reduced Tx duration also reduces Power Amplifier consumption

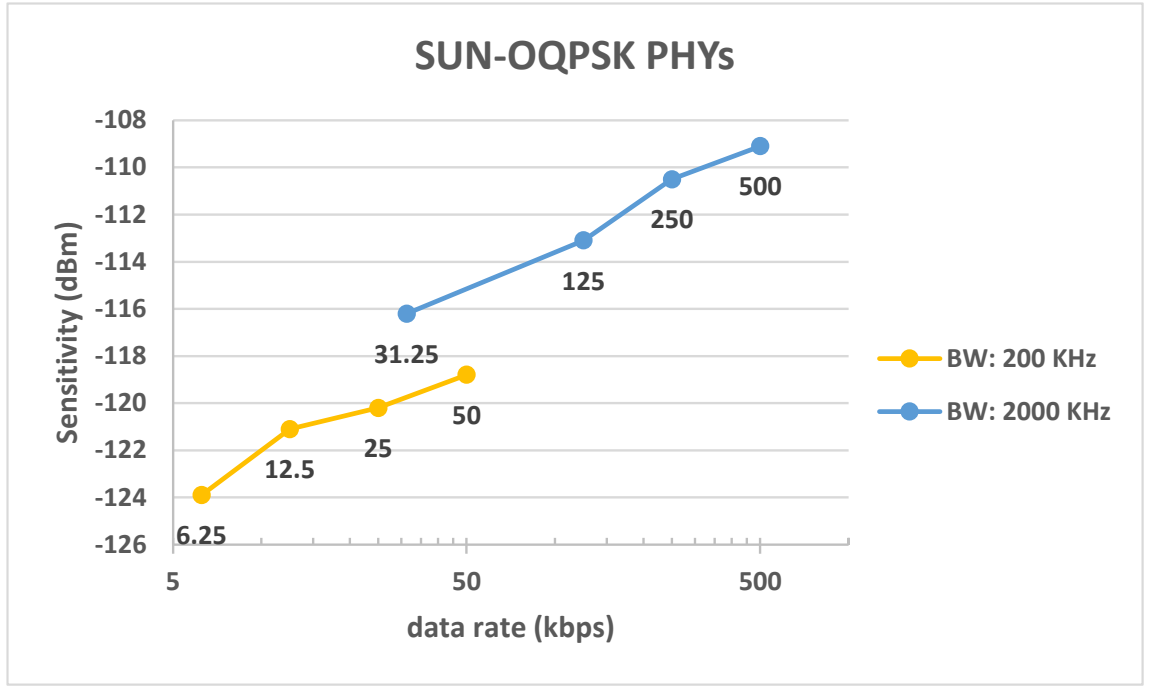
SUN O-QPSK

- **SUN O-QPSK**
  - Part of IEEE.802.15.4g specification
  - Targets low sensitivity with low/medium bit rates
    - Uses DSSS (Direct Sequence Spread Spectrum)
  - In-packet signaling: MR-O-QPSK (multi rate)
  - Defines 2 options, each of them with 4 Rate Modes
- **SUN O-QPSK is not part of Wi-SUN yet**
  - Planned within FAN 1.2 or 2.x

Chip rates (kcps)	Bandwidth (kHz)	Main regions	Bit rates (kbps)	Sensitivity (dBm)
100	200	Worldwide	**6.25 to 50**	**-124 to -119**
1000	2000	NA, BZ, KR	**31.25 to 500**	**-116 to -109**

O-QPSK: Offset Quaternary Phase Shift Keying
kcps: kilo chip per second

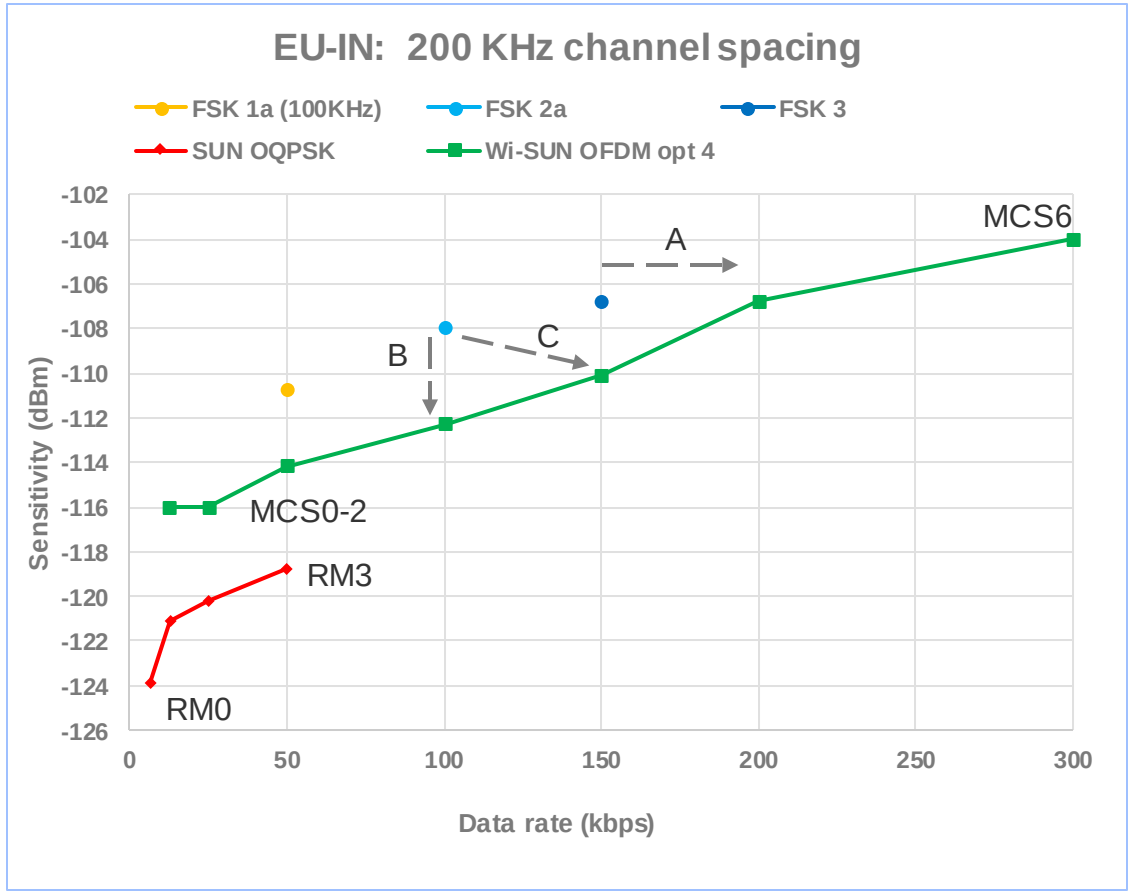
NA: North America, BZ: Brazil, KR: Korea



- **EFR32FG25 supports all SUN O-QPSK modes**
  - Except MDSSS modes
- **SUN O-QPSK PHYs are available for use in Proprietary applications, not only with Wi-SUN**

Performance Comparison: Europe – India

- **Europe, India mainly use 200 kHz channel spacing**

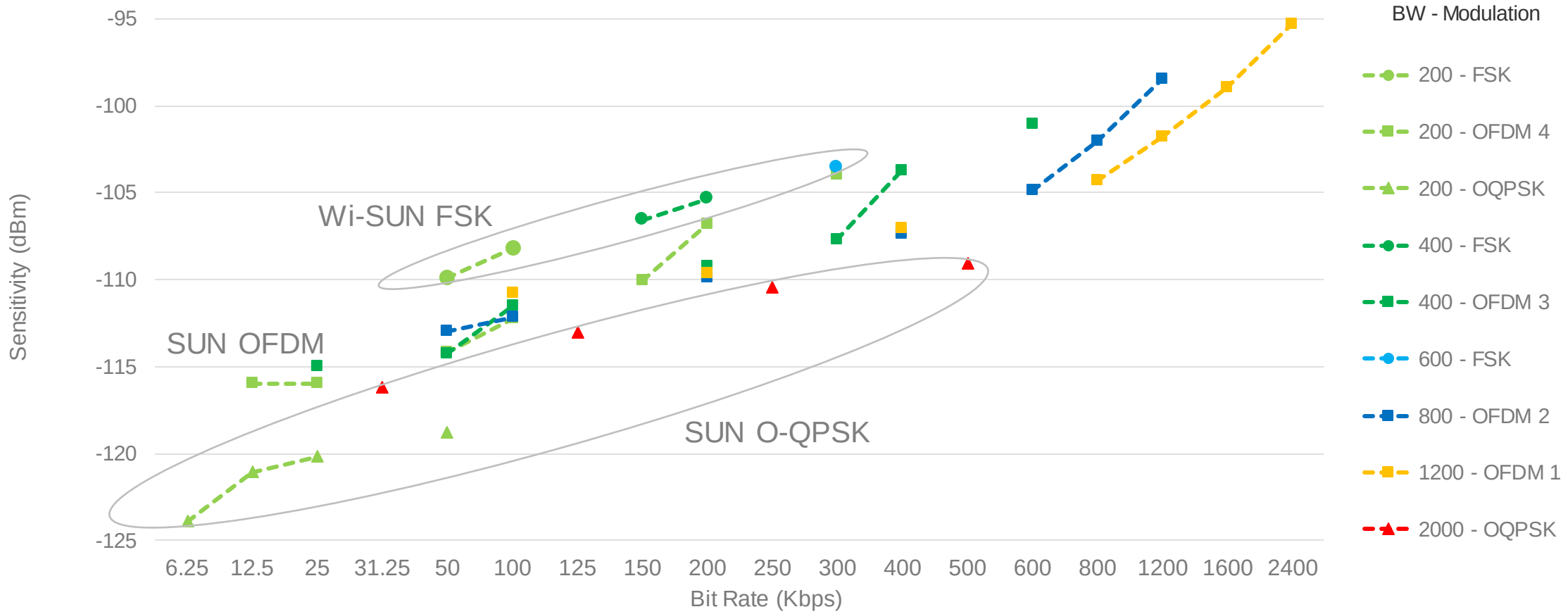


- **OFDM advantage vs FSK:**
  - A: increased bit rate for same range
    - +30 to 50%
    - + 200% from FSK 50kbps (100 KHz BW)
  - B: improved range for same bit rate
    - About 4 dB better sensitivity
  - C: can be a combination of both
    - +50% and 2 dB

- **O-QPSK complement to OFDM**
  - O-QPSK brings another step on range extension
  - 4 to 5 dB better sensitivity

Performance Comparison: North America

- North America group allows the use of all these schemes
- Fair comparisons must be done with similar bandwidth: higher bit rate is expected with wider bandwidth



EFR32 devices supporting the features presented

Feature		xG12	xG23	FG25	xG28
system	Mode switch	N	N	FSK to FSK FSK to OFDM	FSK to FSK
	Concurrent detection	N	N	**Y**	N
	LFN support	**Y**	N	**Y**	**Y**
PHY	Wi-SUN FSK	**Y**	**Y**	**Y**	**Y**
	SUN OFDM	N	N	**Y**	N
	SUN O-QPSK	N	N	**Y**	N

Demo

Demonstration

Goal:

- Compare FSK vs OFDM performance based on Ping and iPerf tests.

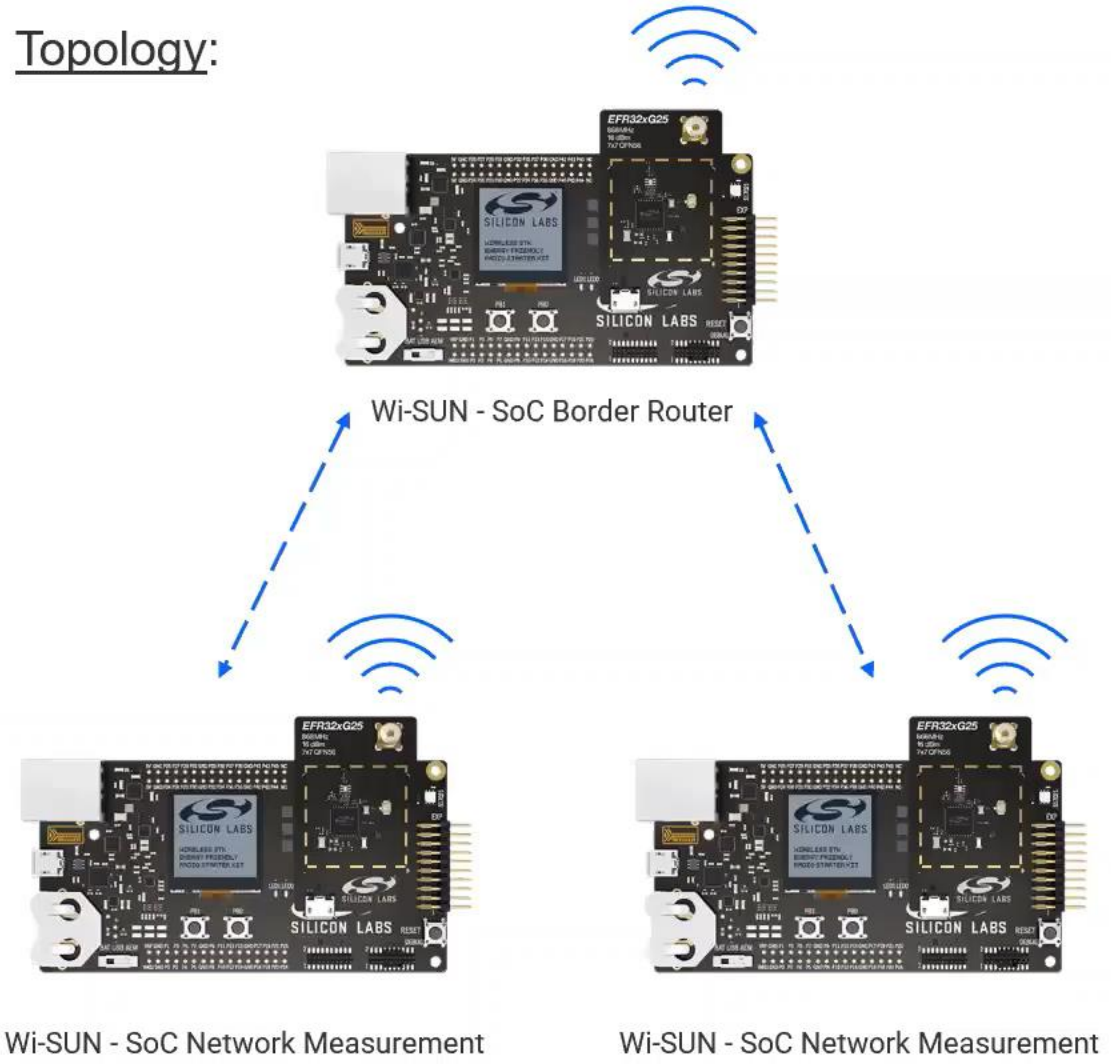
Prerequisites:

- 3 x EFR32FG25
- 3 x Wireless Pro Kit Mainboard
- Simplicity Studio v5
- GSDK 4.3.0

Network PHY Configuration:

- FSK: **50kbps**, 100 KHz spacing
  - EU – 1 – 32
- OFDM: Option 4 MCS6, **300kbps**, 200 kHz spacing
  - EU – 86 – 37

Topology:



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