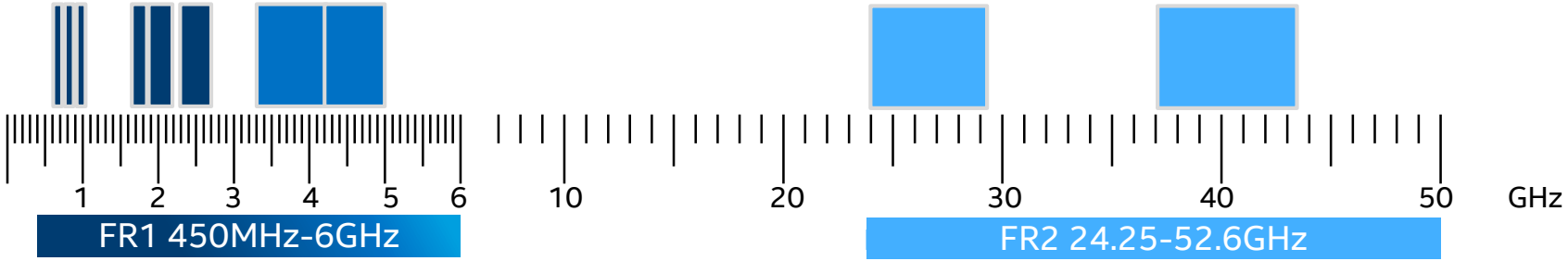
XMM™8162 RF Engine overview for Sierra Wireless

29th March 2018

Steve Hopper

5G New Radio (NR) Bands in focus

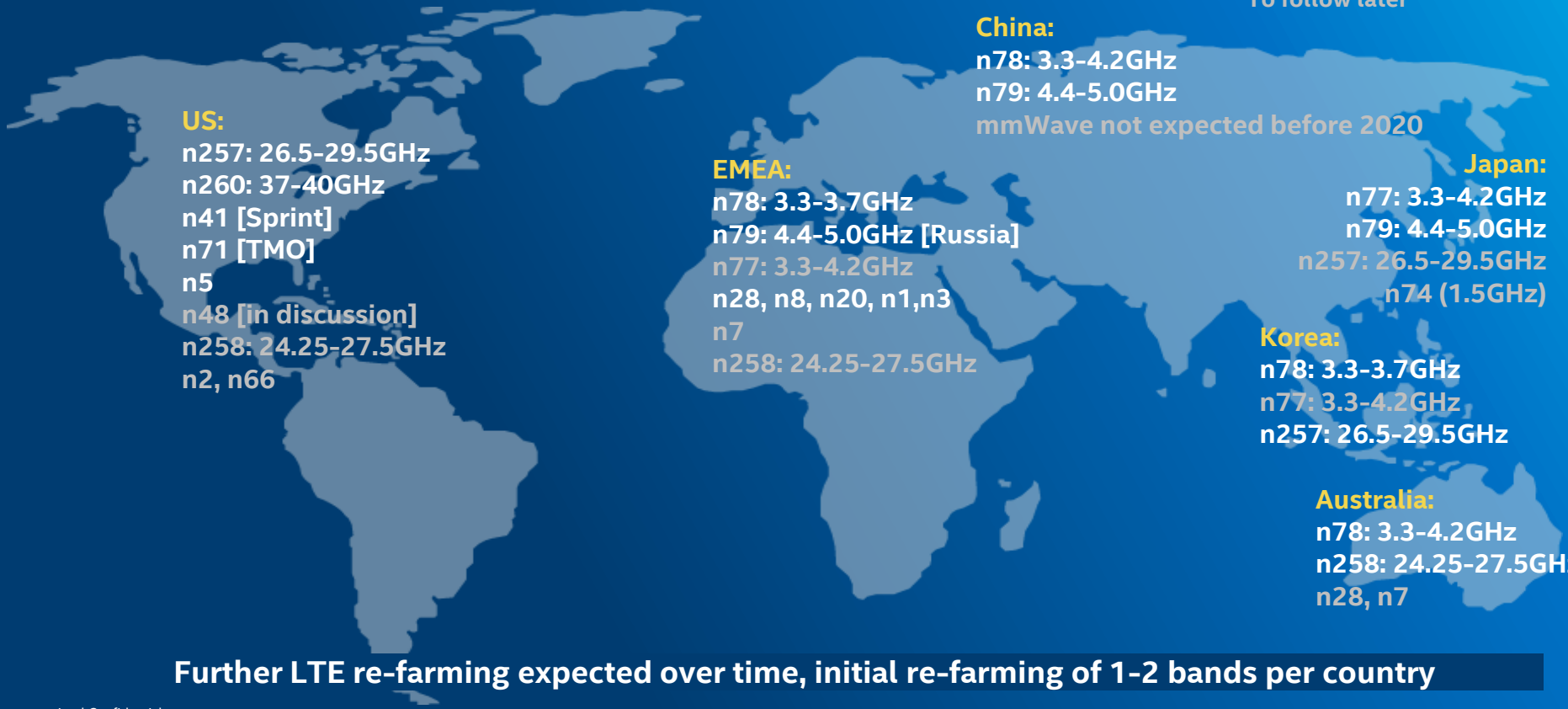


- **"LTE band re-farming" [n1,n2,n3,n4,n5,n7,n8,n20,n28,n38,n41,n66…]**
  - Re-farming of existing LTE spectrum to NR for geographic coverage and IoT applications
  - Many bands agreed within 3GPP as 5G re-farmed bands, others expected over time
  - Supplementary uplink bands also defined.
- **"sub 6 GHz NR" [n77,n78,n79]**
  - Wider bandwidth providing a trade-off for 5G applications that require both capacity and coverage
  - Expected in first wave of 5G deployments. Some overlap with LTE UHB bands (B42,43,48 etc)

- **"mmWave" [n257, n258, n260]**
  - Needed to accommodate very wide channel bandwidths for 5G applications requiring extremely high data rates
  - Requires mmWave antenna arrays

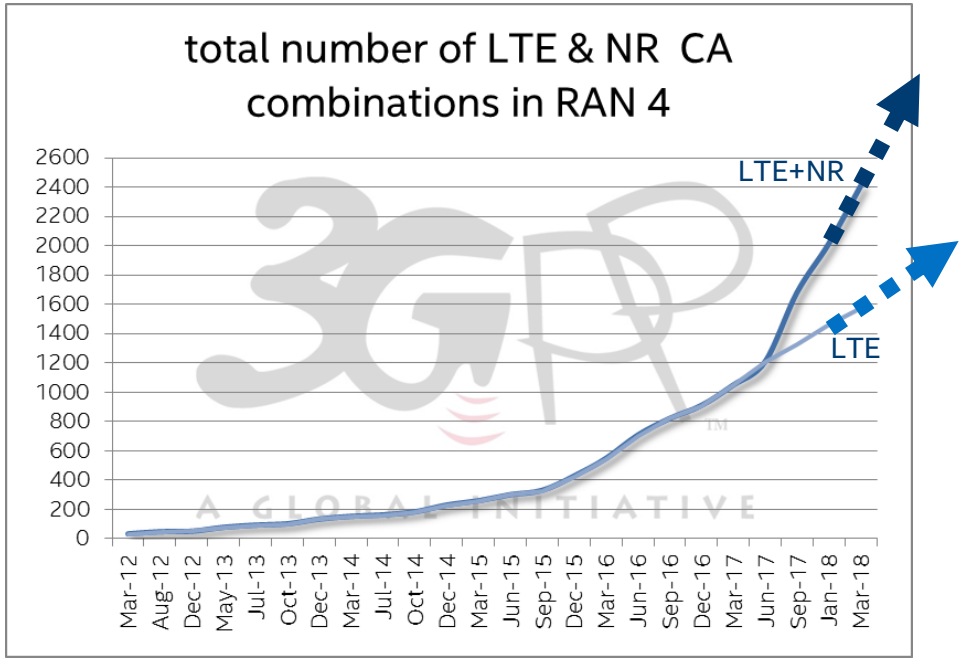
Last updated: 13 Mar 2018

Global 5G NR initial deployment bands expected



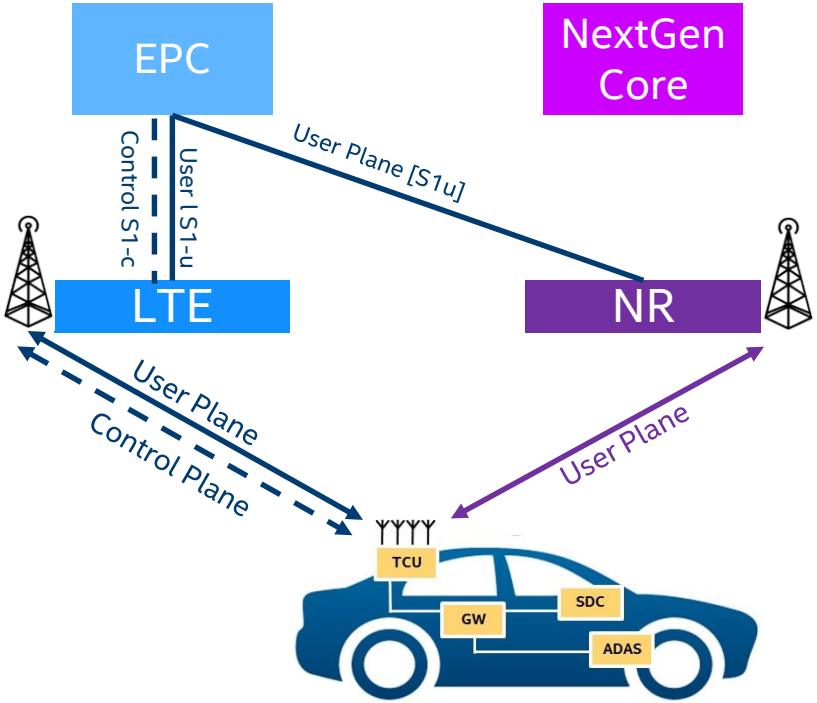
Further LTE re-farming expected over time, initial re-farming of 1-2 bands per country

LTE and NR Carrier Aggregation Combinations Complexity Growth



- Continuing rapid increase in LTE CA combinations, currently **1577** specified, with 35 LTE bands deployed, and upto DL-7CA combinations in standardisation
- NR CA combination (stand alone and dual connectivity) definition starting – already over **830** combinations, and 39 NR bands defined
- Operators continue to define and deploy new combinations
- Adoption of downlink 4x4 MIMO, and uplink combinations leads to further complexity and CA permutations

5G Architecture Option 3 [3GPP]
Non Stand Alone (NSA) - Dual Connectivity



Dual Connectivity Operation:
- LTE Control and User Plane
- NR User Plane

Two parallel Radio connections [Rx/Tx] required.

Impact on RF engine strongly dependant on the frequency bands used for simultaneous connections of LTE and NR and ability to utilise available resources (i.e. PAs)
(e.g LTE in Low Band, NR in UHB)
Options in discussion at 3GPP to minimise RF engine impacts on terminal side.

XMM™ 8160 CA and Dual Connectivity targets

- The DL-CA target list is based on the requirements of ~20 Tier 1 worldwide operators, collected from Intel® close operator engagements, plus 5G/NR combinations defined in 3GPP - and results in over ~2000 DL-CA / MIMO combinations (including mmWave) for a worldwide LTE+5G/NR platform.
  - Operators:
    - North America: AT&T, VZW, TMO, Sprint
    - China: CMCC, CTC, CUC,
    - EMEA/RoW: VDF, TEF, Orange, EE, DTAG, Hutchinson, Optus, Telstra, Swisscom
    - Korea: KT, LGU+, SKT
    - Japan: DoCoMo, KDDI, SBM

XMM™8162 RF Front End Architecture
Managing the complexity

- **FR1 [sub6]**
  - Highly integrated, single RF transceiver for 2G/3G/4G/5G – SMARTi™9
  - Scalable RF Front End Engine architecture based on RF modules ("PAMiD*1)" aka "SPAD*1)") which integrate: PA, Duplexers, Filters, switches etc for each band group - Low Bands / Mid-High Bands / Ultra High Bands, with complementary receive modules.

- **FR2 [mmWave]**
  - VirginaPeak mmW front end module with patch antennas
  - SMARTi9m to convert RF to digital interface

*1) PAMid = **PA** Module **i**ntegrated **D**uplexers, also known as "SPAD" (**S**uper **PA** **D**uplexer module)

SMARTi™ 9 RF Transceiver Overview

Supporting 2G, 3G, 3G, TDSCDMA, CDMA, 4G, 5G(NR)

Receiver
- Frequency support from 600MHz to 6GHz
- 28 Receive ports
- 4x4 MIMO support for LTE/NR
- 6 RX LO support supporting up to 6 bands/sub-blocks

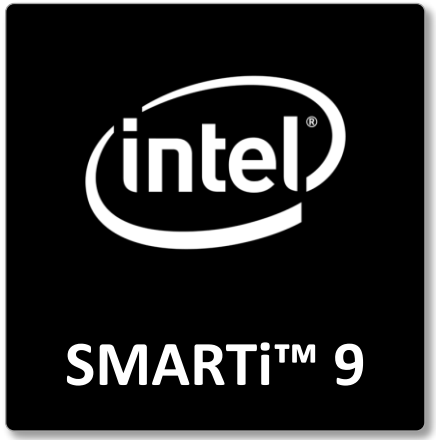
Digital Transmitter
- 2 transmitters for DB-ULCA LTE or DC-LTE/5G NR
- UL 2x2 MIMO support for 5G NR
- UL BW of up to 200MHz (contiguous) for 5G NR

GNSS
- 6-mode dual receive GNSS (L1, L5/L2)

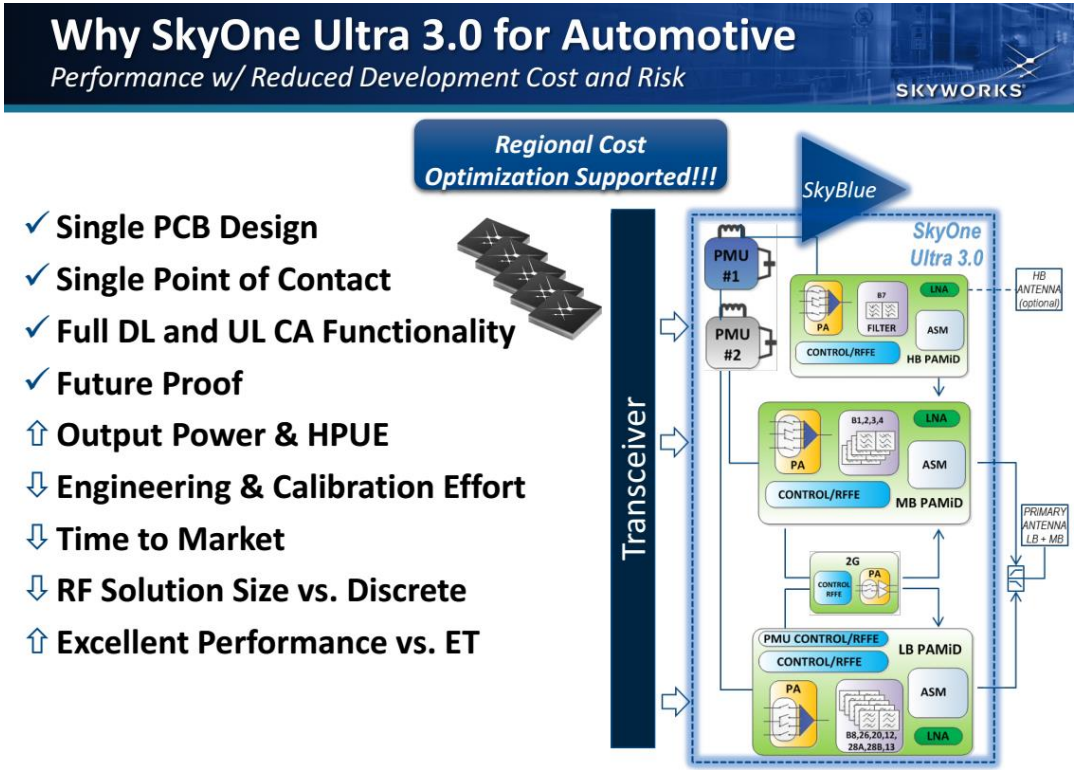
RF/BB-Interface
- SMARTiConnect - High speed digital interface

Reference Clock
- 76.8 MHz reference clock frequency

Miscellaneous
- Reduced amount of external components/discretes



SPAD*1 RF Engine Architecture example: XMM™7662 with Skyworks® SkyOne® Ultra3.0



Shared with the permission of Skyworks®

Skyworks SkyOne® Ultra3.0 solution consists of a set of highly integrated PAMiD*1) modules compatible to SMARTi™ 8, enabling a complete RF front end to be realised from a single supplier:

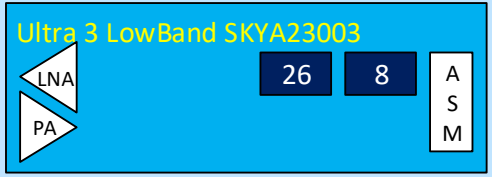
- PAMiD*1) (SPAD*1)) modules for
  - Low, Mid, High Bands
- Diversity Module
- GSM PA
- Satellite PA modules for
  - B11/21 and B42
- PA PMIC

Optional:
- 4x4 MIMO Modules

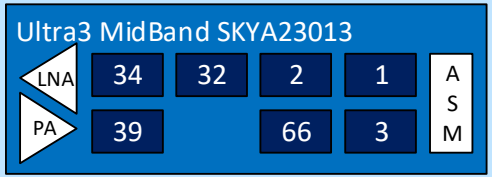
*1) PAMid = **PA** Module **i**ntegrated **D**uplexers, also known as "SPAD" (**S**uper **PA** **D**uplexer module)

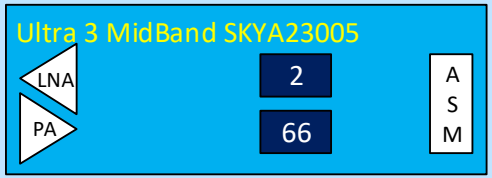
Skyworks® Ultra3 SPAD Regional variants

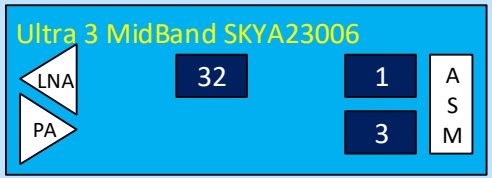
Low Band Modules

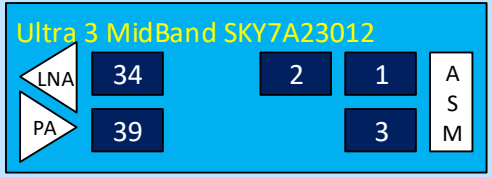


Mid Band Modules

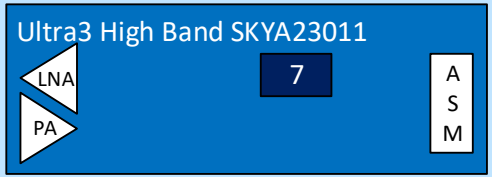


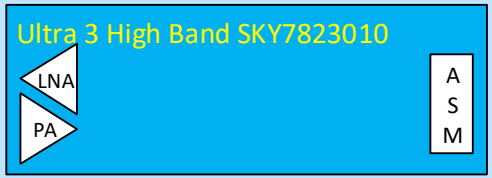






High Band Modules



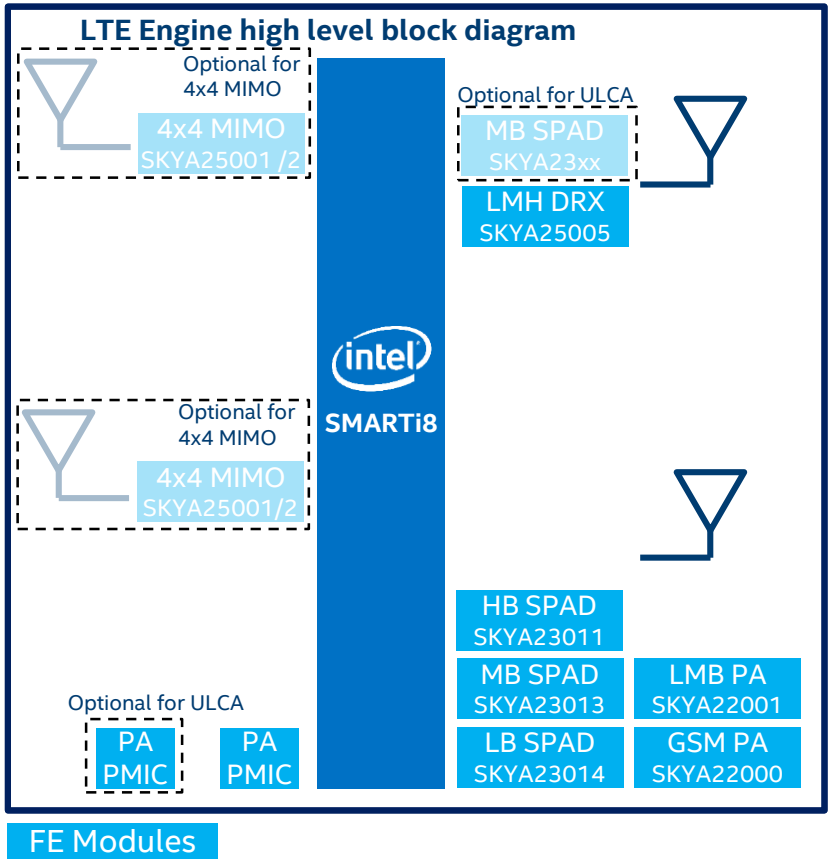


Drop in replacement variants for Low, Mid and High Ultra3 modules. Footprint and software compatible. Modules can be combined with each other and complemented with external duplexers and filters as required to create desired regional SKU

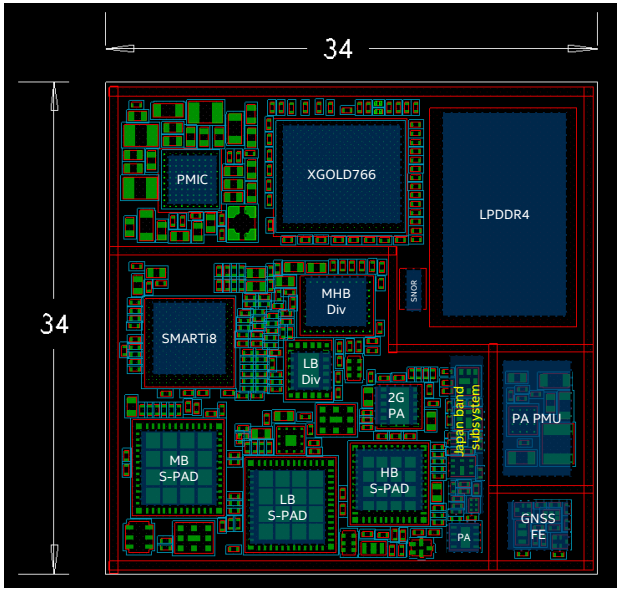
SPAD architecture advantages - Summary

	SPAD	Discrete	SPAD benefits
Single PCB design for all regional variants	☑	☒	**Reduced R&D Efforts and faster TTM**
Single Point of Contact	☑	☒	Total system solution from single supplier **simplifies support and logistics**
High Integration Level	☑	☒	Complexity abstracted to SPAD modules – simpler PCB design **Reduced R&D Efforts and faster TTM**
Lowest PCB area	☑	☒	**Smallest module size – reduced PCB costs** Enabling 5G DSDA within confines of a single LGA module
Common architecture	☑	☒	Common architecture across high and low segments **Reduced R&D Efforts and faster TTM**
Comprehensive band and DL-CA support	☑	☒	**Addressing market needs** Integrated quadplexers enabling **Reduced R&D efforts**
Future Proof	☑	☒	Easy to add new bands to **meet future market needs** without complete redesign SPAD solutions will be mainstream highest volume solutions in XMM™ 8162 timeframe **Reduced R&D Efforts and faster TTM**
Excellent Performance	☑	☒	Lower losses and integrated temperature compensation. Integrated LNAs offer improved sensitivity **Excellent Rx and Tx performance**
Automotive Quality	☑	☒	**Ensures high reliability over lifetime - reducing chances of failure and expensive field returns. Guaranteed product availability**

SPAD RF Engine Architecture: LTE – XMM™ 7662

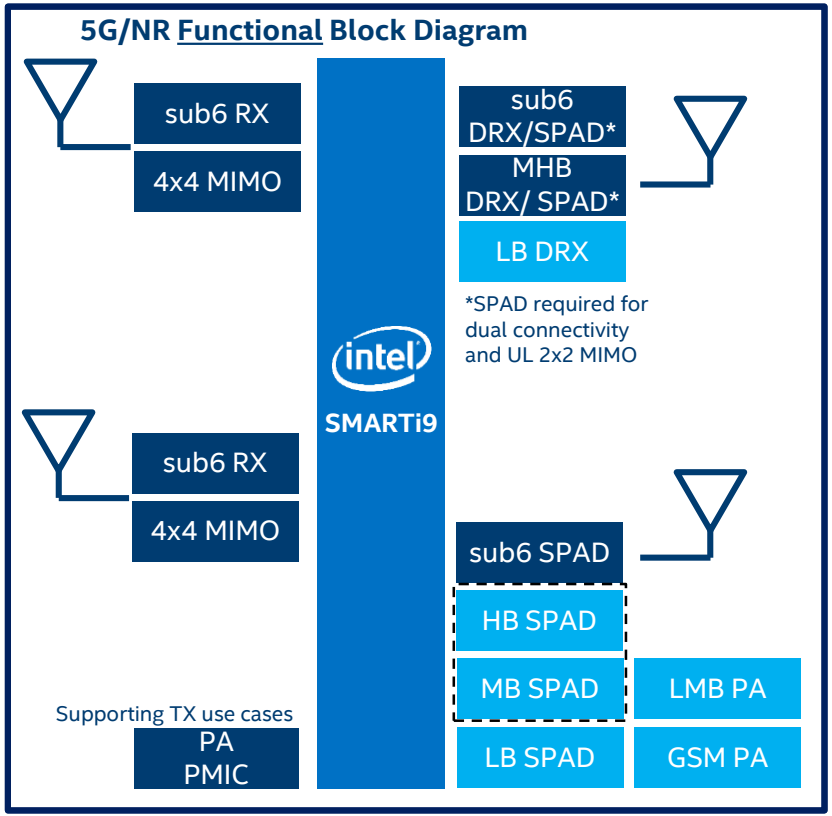


- Common Global PCB design SPAD based engine with population options for regional SKU
  - Module derivatives and external components



First draft placement proposal, not a final design!
Based on initial block diagram.
No ULCA2B and no 4x4 MIMO. FLASHLESS example

SPAD RF Engine Architecture: Extension to 5G/NR



- Additions to LTE engine needed for 5G/NR:
  - Support for 5G/NR waveforms
    - Legacy band PA modules need to support 5G/NR re-farm
  - Support for 4x RX antenna / DL 4x4 MIMO
    - 4Rx antenna required for high and ultra high NR bands by 3GPP
    - 4x4 MIMO typically operator deployment in mid band and above for both LTE and 5G/NR for spectral efficiency.
  - Support for sub6 NR bands in 3.3-5GHz [n77/n78/n79]
    - Region dependant – key 5G/NR bands in many regions
    - “Sub6” SPAD and RX modules required.
  - Support for Dual Connectivity – concurrent transmit
    - In same band group, requires 2nd TX chain*
    - Region dependant: e.g. US e.g. 41A-n41A, 2A-n66A
    - Alternative options in discussion at 3GPP e.g. (n)71B
  - Support for Uplink 2x2 MIMO
    - Sub6: 2nd sub6 SPAD required in exchange for DRX module*
    - High Band – use of 2nd HB TX chain for dual connectivity*

Intel is working closely with FE vendor to define 5G/NR RF engine for XMM™816x

Future Flexibility & Scalability

potential TRX Configurations within XMM™ 8162

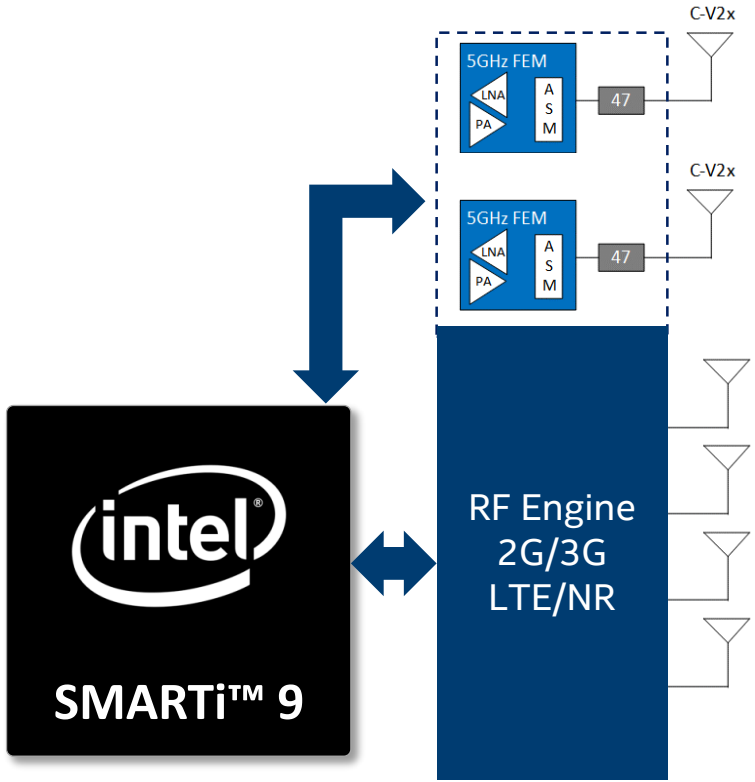
		1x SMARTi 9	2x SMARTi 9	3x SMARTi 9	Comment
Single SIM	NR-SA	Yes			
	NR-SA + PC5	Yes			Most Cost sensitive offering if PC5 mandated
	NR-NSA	Yes			
	NR-NSA + PC5		Yes		
Dual SIM	NR-NSA + NR-SA		Yes		
	NR-NSA + NR-NSA		Yes		
	NR-NSA + NR-SA + PC5		Yes		Maximum of NR-SA or LTE on Modem with PC5 support.
	NR-NSA + NR-NSA + PC5			Yes	Super set solution with maximium future flexibility, dedicating one S9 to PC5 sidelink

- Priority configuration needs to be aligned with Customer
- mmWave configuration are not shown on this table, but can only exist with 1 or 2 SMARTi 9 configurations
- LTE is considered a subset of NR-SA mode.

SMARTi™ 9 and C-V2x [PC5] support in B47

Receiver
- 28 Rx ports
  - 4 ports supporting upto 5.925 GHz for either:
    - n79 with 4x4 MIMO
    - or C-V2x [PC5]

Digital Transmitter
- 3 transmit blocks with multiple output ports:
  - TX1 – upto 4.2GHz
    - 3G / LTE / NR bands upto n77
  - TX2 – upto 5.925GHz, for:
    - 3G / LTE / NR bands upto n79
    - ULCA or EN-DC together with TX1
    - or C-V2x[PC5]
  - TX2m – upto 5.925GHz for:
    - UL 2x2 MIMO [MB, UHB, n79] with TX2 [same freq]
    - or C-V2x[PC5] Tx Diversity

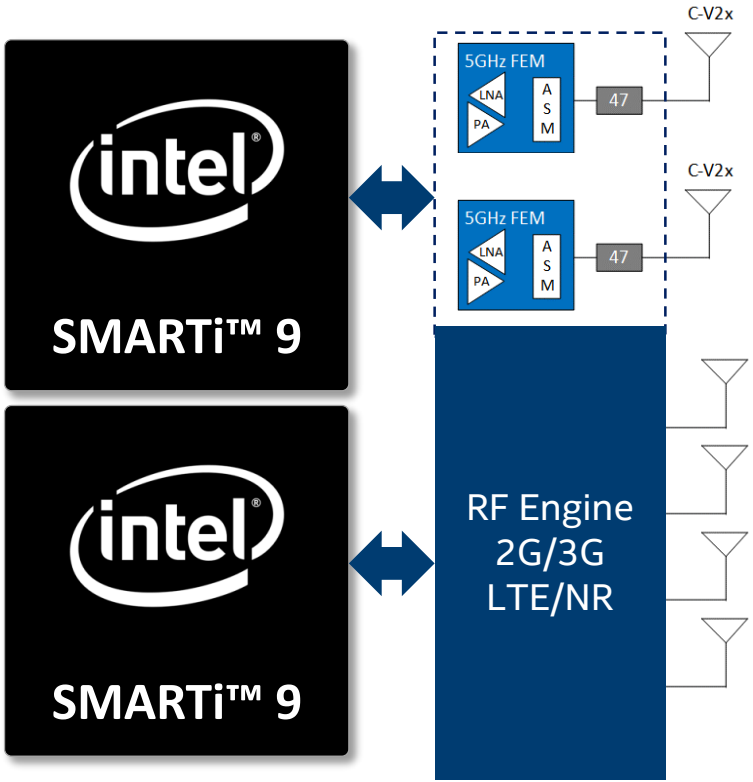


1x SMARTi9 can support either: **LTE [UL-2CA 2B] , 5G [NSA mode] w/ UL 2x2 MIMO without C-V2x[PC5]**
or **LTE [UL-2CA 1B] , 5G [SA mode] w/o UL 2x2 MIMO with C-V2x[PC5]**

SMARTi™ 9 and C-V2x [PC5] support in B47

Receiver
- 28 Rx ports
  - 4 ports supporting upto 5.925 GHz for either:
    - n79 with 4x4 MIMO
    - or C-V2x [PC5]

Digital Transmitter
- 3 transmit blocks with multiple output ports:
  - TX1 – upto 4.2GHz
    - 3G / LTE / NR bands upto n77
  - TX2 – upto 5.925GHz, for:
    - 3G / LTE / NR bands upto n79
    - ULCA or EN-DC together with TX1
    - or C-V2x[PC5]
  - TX2m – upto 5.925GHz for:
    - UL 2x2 MIMO [MB, UHB, n79] with TX2 [same freq]
    - or C-V2x[PC5] Tx Diversity



2x SMARTi9 can support: **LTE [UL-2CA 2B] , 5G [NSA mode] w/ UL 2x2 MIMO with C-V2x[PC5]**

XMM™ 8162 Regional RF SKU Strategy

- Common RF FE architecture.
- Four Regional SKU proposed to cover key automotive markets
- Band support for each region shown, vs XMM™7662 LTE platform for reference

Illustration purposes - Overview of key region coverage
Not detailed country level analysis

Region	Conf	Low Bands 617-960MHz																Mid-Low 1428-1511			Mid Bands 1695-2200MHz									High Bands 2300-2690MHz						UHB 3.3-4.2 / 4.4-4.99					CB 5.1-5.9	
		71	26	5	6	18	19	8	12	17	20	13	14	28	a	b	29	11	21	32	1	25	2	3	3	66	4	34	39	7	30	40	41	41	38	42	48	n 77	n 78	n 79	46	47
Global Superset		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	✱
SKU#1 North America	XMM8162	●		●				●	●	●	●	●	●				●				●	●	●	●	●	●				●	●		●				○					✱
	XMM7662	●		●				●			●	●	●				●				●	●	●	●	●	●				●	●		●									
SKU#2 EMEA	XMM8162			●				●	●		●			●	●					●	●		●	●		●			●		●			●	●		●	●	●		✱
	XMM7662			●				●	●		●			●	●					●	●		●	●		●			●		●			●							
SKU#3 China	XMM8162			●				●	●		●										●		●	●		●	●	●	●		●		●	●				●	●		✱
	XMM7662			●				●	●		●										●		●	●		●	●	●	●		●										
SKU#4 RoW incl Japan	XMM8162		●	●	●	●	●	●	●		●			●	●			●	●		●		●	●		●			●		●		●	●	●		●	●	●		✱
	XMM7662		●	●	●	●	●	●	●		●			●	●			●	●		●		●	●		●			●		●		●	●							

- Legacy RAT (one of more of 2G,3G,4G)
- C-V2x PC5
- supported by chipset [auto use TBD]
- Vehicle Tracking (option)

- 5G refarm band
- 5G/NR
- Potential 5G/NR

DRAFT TARGET PROPOSAL
WORK IN PROGRESS
SUBJECT TO CHANGE

Existing spectrum expected to be partially re-farmed to 5G/NR in timeframe of XMM™8162. current view based on 3GPP and operator insights.

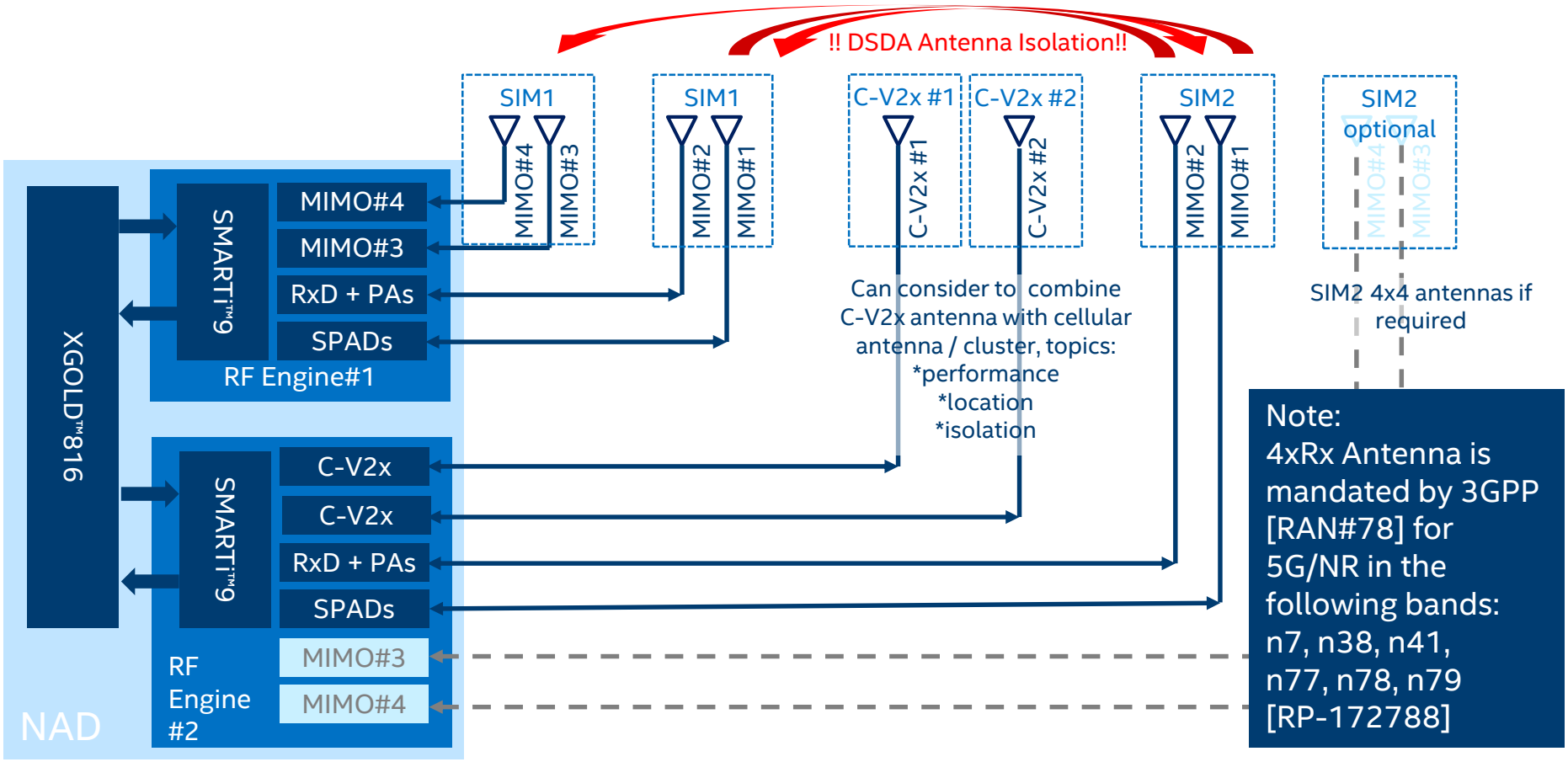
XMM7662: 2G/3G/4G
XMM8162: 2G/3G/4G/5G(NR)

8162 DSDA

Information in this section refers to 8162 **Premium** variant only

Preliminary – subject to change

XMM™8162 DSDA RF Engine and antenna configuration



XMM™ 8162 Premium DSDA and Cellular V2X

NR-sub6 NSA on both SIMs

XMM8162 Premium Chipset capability		Single SIM		DSDA	
		C-V2x disabled	C-V2x*1) enabled	C-V2x disabled	C-V2x*1) enabled
SIM1	**Peak DL Data** Max Agg. BW	**4.7Gbit/s** 200MHz(4x4)	**2.35Gbit/s** 100MHz(4x4)	**2.35Gbit/s** 100MHz(4x4)	**1.175Gbit/s** 50MHz(4x4)
	Peak UL Data Max Agg. BW	**2.5Gbit/s** 200MHz(2x2)	**2.07Gbps**	**1.25 Gbps**	**1.035Gbps**
SIM2	**Peak DL Data** Max Agg. BW			**2.35Gbit/s** 100MHz(4x4)	**1.175Gbit/s** 50MHz(4x4)
	Peak UL Data Max Agg. BW			**1.25 Gbps**	**1.035Gbit/s**

SIM1: OEM Telematics SIM.
SIM2: user SIM

*1) V2X PC5 assuming 2x10MHz contiguous Rx + Tx

XMM™ 8162 Premium DSDA and Cellular V2X

LTE on both SIMs

XMM8162 Premium Chipset capability		Single SIM		DSDA	
		C-V2x disabled	C-V2x*1) enabled	C-V2x disabled	C-V2x*1) enabled
SIM1	**Peak DL Data** Max Agg. BW	**3.2Gbit/s** 200MHz(4x4)	**1.6Gbit/s** 100MHz(4x4)	**1.6Gbit/s** 100MHz(4x4)	**0.8Gbit/s** 50MHz(4x4)
	Peak UL Data Max Agg. BW	**0.5Gbit/s**	**0.333Gbps**	**0.25Gbps**	**0.167Gbps**
SIM2	**Peak DL Data** Max Agg. BW			**1.6Gbit/s** 100MHz(4x4)	**0.8Gbit/s** 50MHz(4x4)
	Peak UL Data Max Agg. BW			**0.25Gbps**	**0.167Gbps**

SIM1: OEM Telematics SIM.
SIM2: user SIM

*1) V2X PC5 assuming 2x10MHz contiguous Rx + Tx

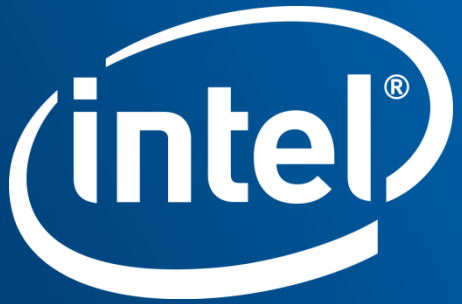
XMM™ 8162 Premium DSDA and Cellular V2X

NR-sub6 NSA on SIM 1 and LTE on SIM 2

XMM8162 Premium Chipset capability		Single SIM		DSDA	
		C-V2x disabled	C-V2x*1) enabled	C-V2x disabled	C-V2x*1) enabled
SIM1	**Peak DL Data** Max Agg. BW	**4.7Gbit/s** 200MHz(4x4)	**2.35Gbit/s** 100MHz(4x4)	**2.35Gbit/s** 100MHz(4x4)	**1.175Gbit/s** 50MHz(4x4)
	Peak UL Data Max Agg. BW	**2.5Gbit/s** 200MHz(2x2)	**2.07Gbps**	**1.25 Gbps**	**1.035Gbps**
SIM2	**Peak DL Data** Max Agg. BW			**1.6Gbit/s** 100MHz(4x4)	**0.8Gbit/s** 50MHz(4x4)
	Peak UL Data Max Agg. BW			**0.25Gbps**	**0.167Gbps**

SIM1: OEM Telematics SIM.
SIM2: user SIM

*1) V2X PC5 assuming 2x10MHz contiguous Rx + Tx



Intel Communication and Devices Group