



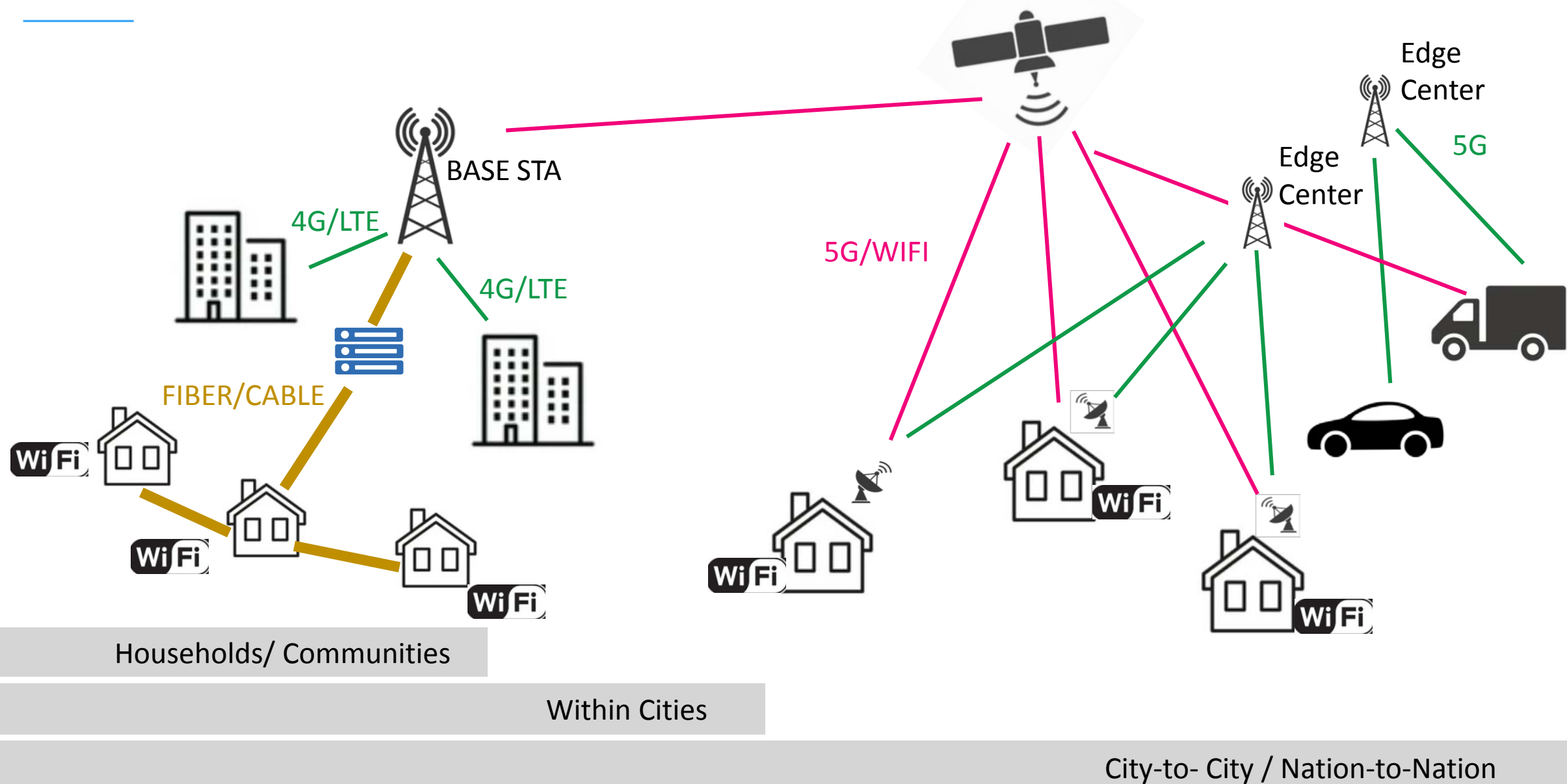
RichWave, Your Reliable RF Component Vendor

-WiFi and 5G

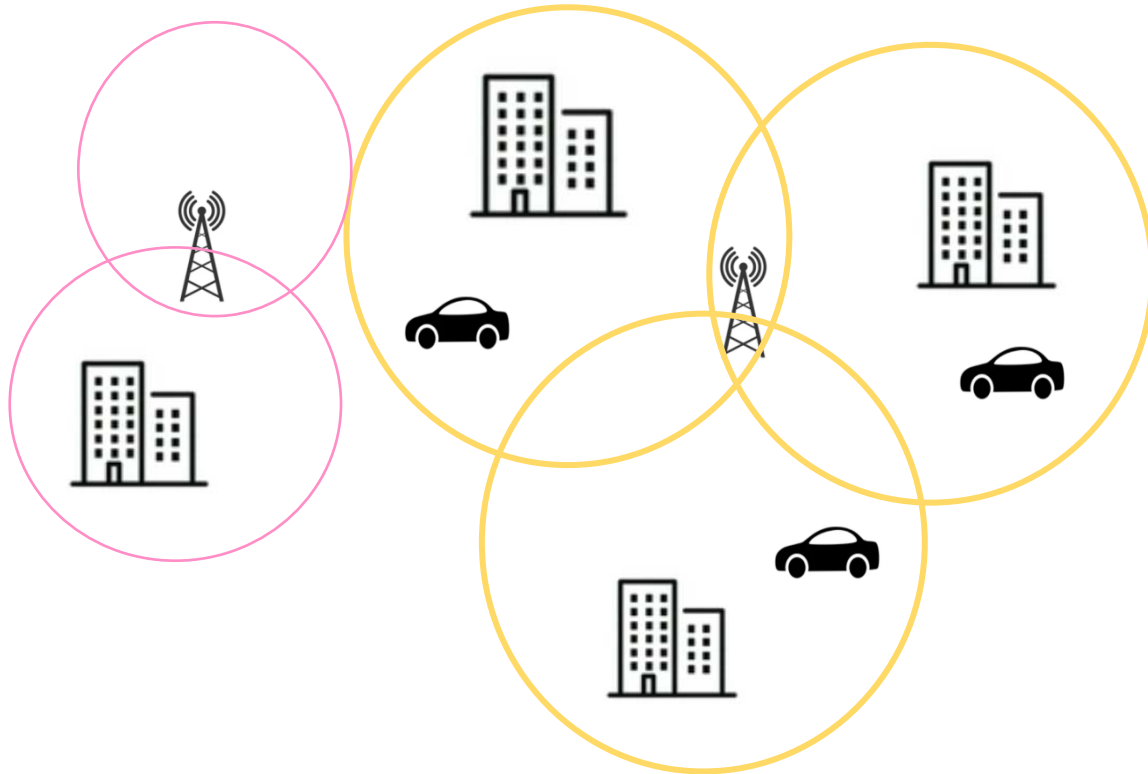
SC WONG

2021/12

WIRELESS IS FAR BEYOND THE TERRESTRIAL



5G + WiFi ARE COMPLEMENTARY TECH. TO LAST MILES



5G NR

SPEED	~ 50Mbps	~ 1Gbps	~ 4Gbps
COMBINATIONS			MIMO CA



WIFI WILL OFFLOAD
59% OF GLOBAL
MOBILE DATA
TRAFFIC IN 2022*

WIFI

~ 3.2Gbps	~ 6.5Gbps	~ 9.6Gbps	~ 46.1Gbps
2+2+2 (BW80)	4+4+4 (BW160)	MIMO	MIMO

* Global Mobile Data Traffic Forecast Update 2017-2022 by CISCO

RICHWAVE BOOSTs YOUR WIRELESS PRODUCTS



A GLOBAL INITIATIVE

3G^{'''} 2G^{'''} 4G^{'''} Lte^{'''} 5G^{'''}

*Antenna
Tuner SW*

*Antenna
Swap SW*

LFEM

5G SWITCH

*LNA
Module*



WiFi FEM

WiFi ePA

WiFi eLNA

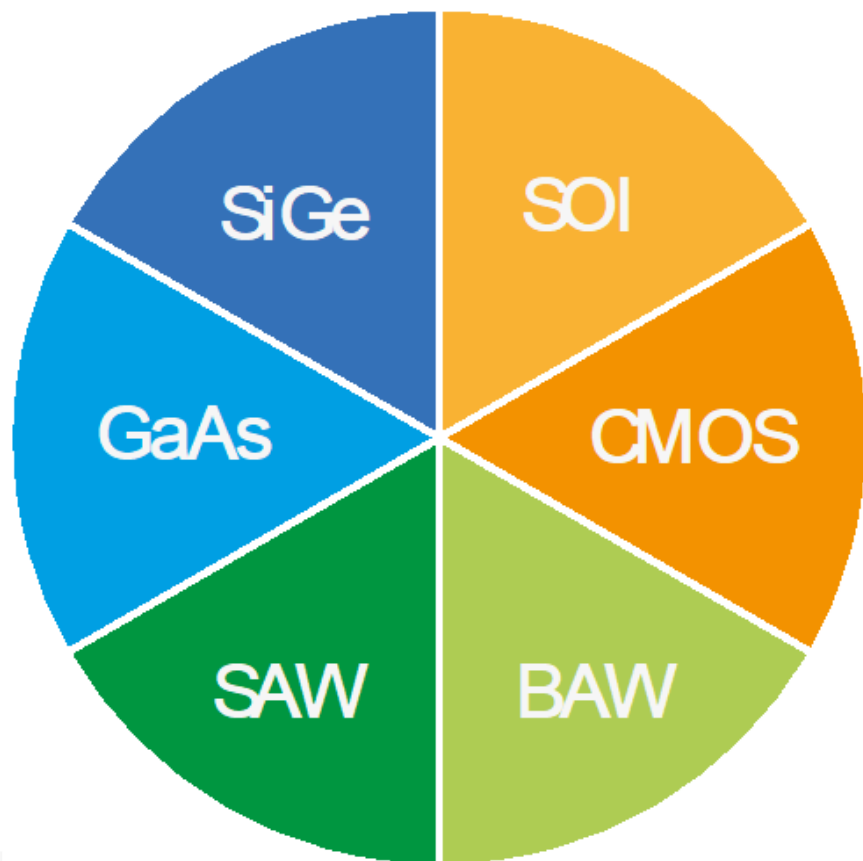
WiFi SW

OTHER CONNECTIVITY

FM

GPS

OUR COMPETITIVE ADVANTAGES ON PRODUCTS



> EXPERTISE IN LEVERAGING MULTI-TECH. PROCESS

GaAs and SiGe Process with our PA Design

SOI and CMOS Process with our LNA/SW Design

COST EFFECTIVE SOLUTIONS

> DIVERSIFY IN MULTI - SUPPLIERS

Dual sources of each upstream tech. process

With >4 partners for backend assembly and testing

TIME TO THE MARKET

> ALL-IN-HOUSE DESIGN

Provide all combinations of active RF circuits

Self-designed SAW/BAW filters to RF Needs

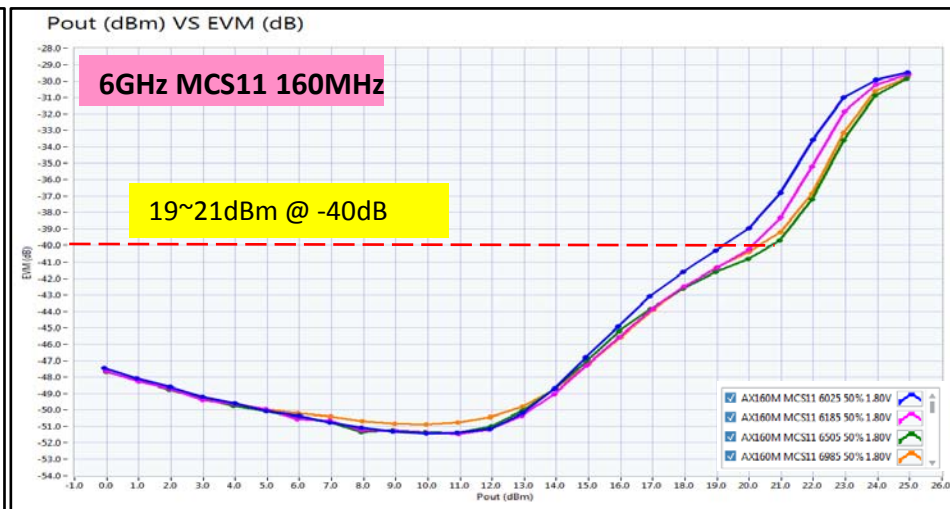
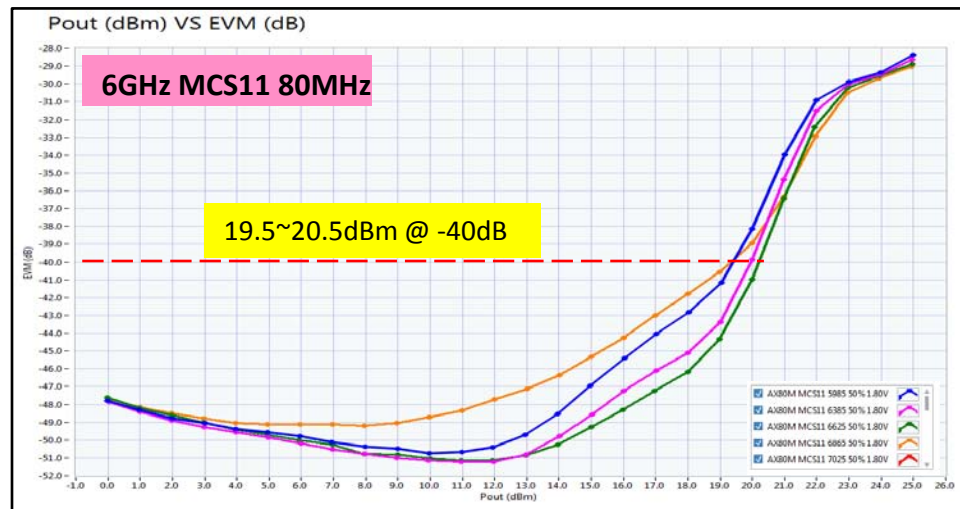
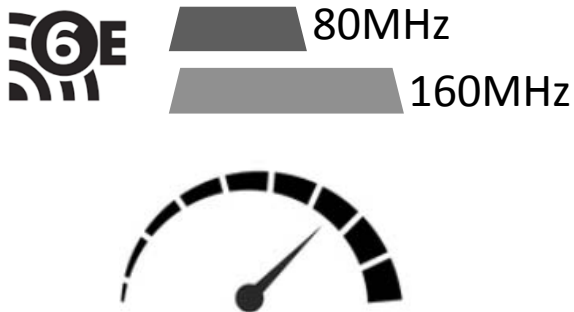
FLEXIBLE TO CLIENT NEEDS



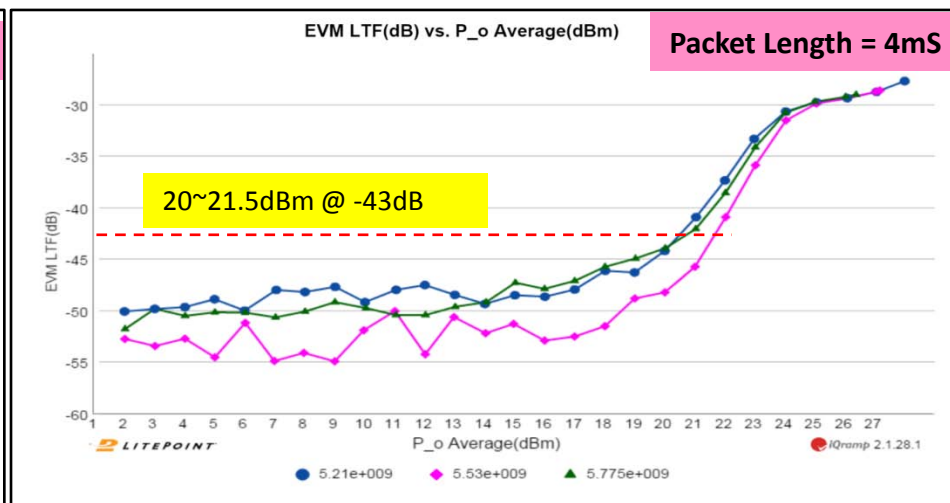
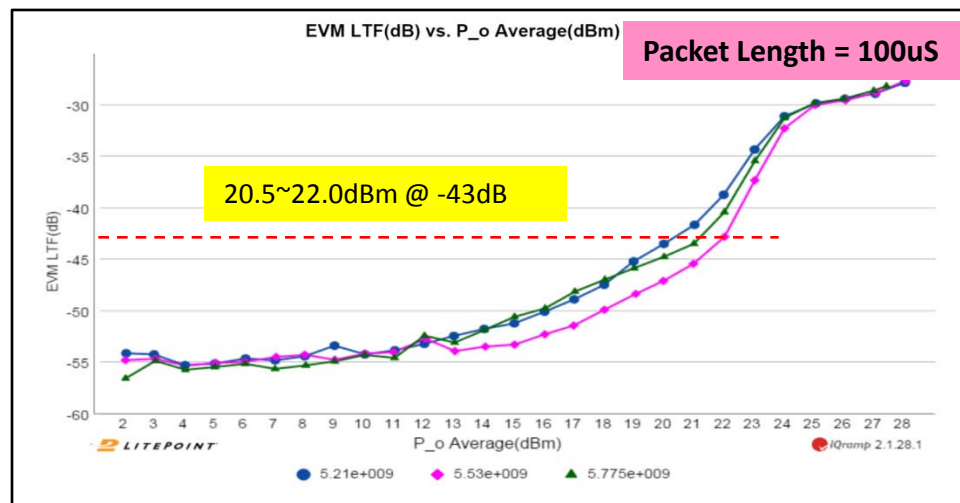
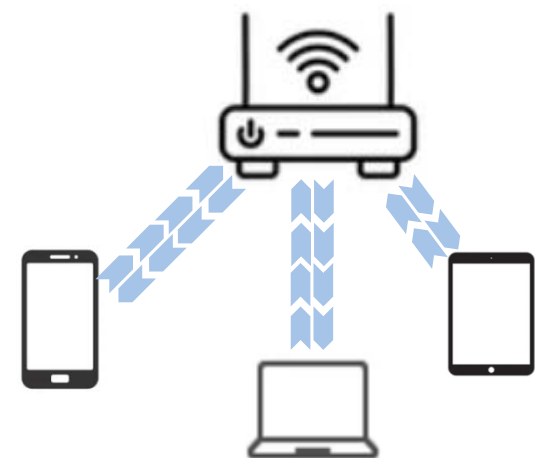
VALUES ON OUR WIFI PRODUCTS

SUSTAIN STABLE Tx LINEAR POWER UNDER DIFFERENT SCENARIOS

HIGH THROUGHPUT

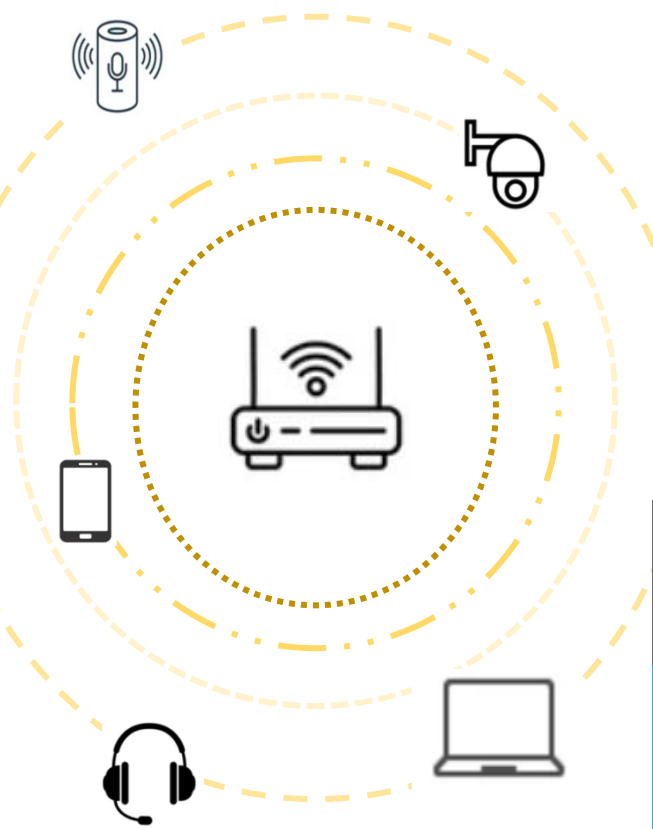


MU-MIMO

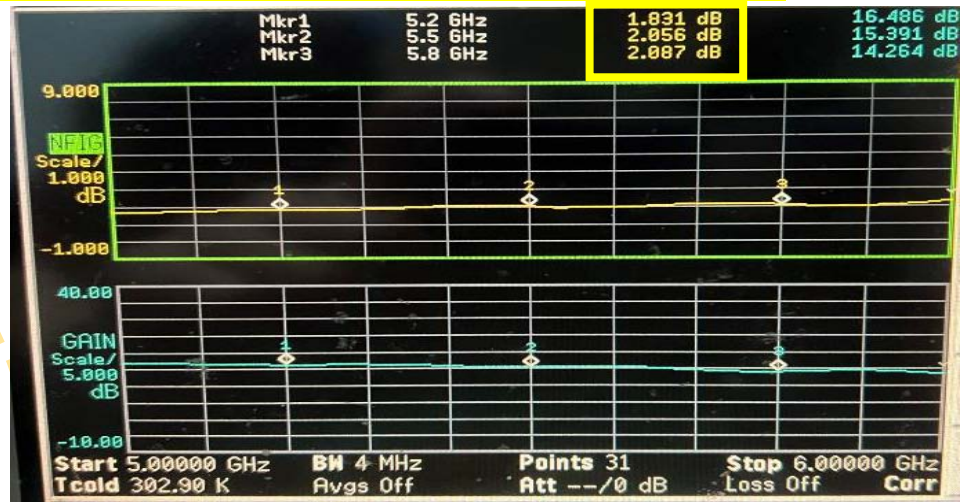


ENRICH COVERAGE W/ SURPERB Rx SENSITIVITY FOR APs AND STAs

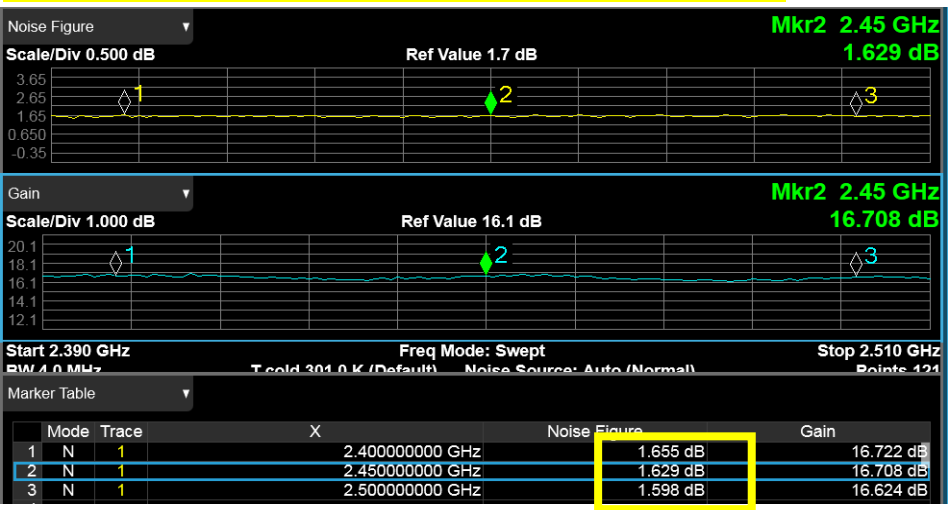
WIDER COVERAGE



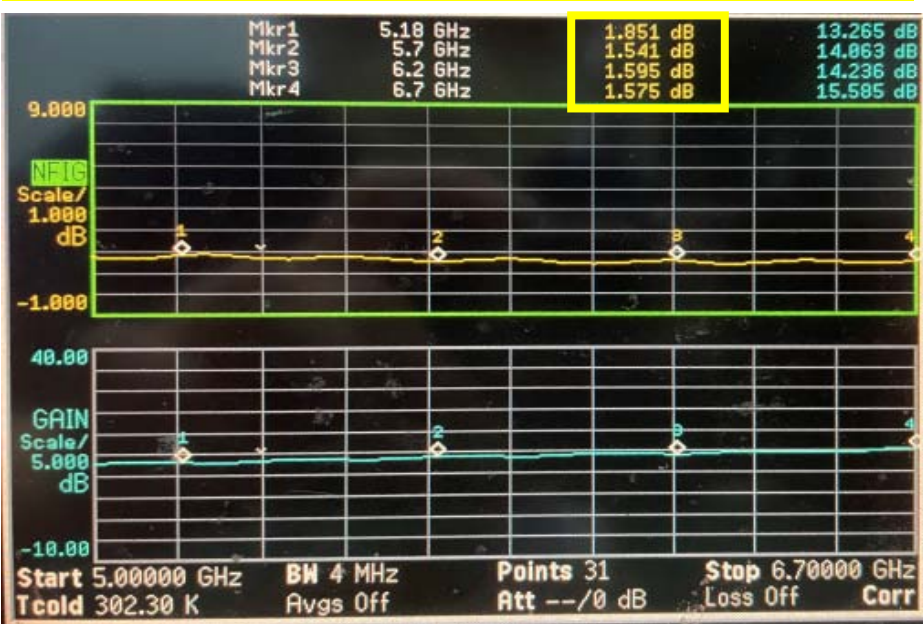
NOISE FIGURE =1.7dB @ 5GHz Band



NOISE FIGURE =1.4dB @ 2.4GHz Band



NOISE FIGURE =<2 dB @ 5GHz + 6GHz Band

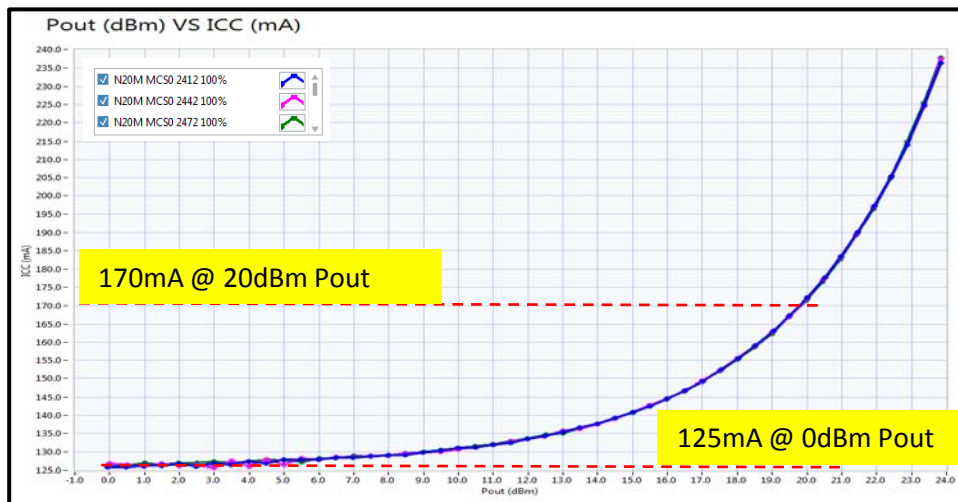


ENLARGE BATTERY LIFECYCLE W/ GOOD EFFICIENCY COMPONENTS

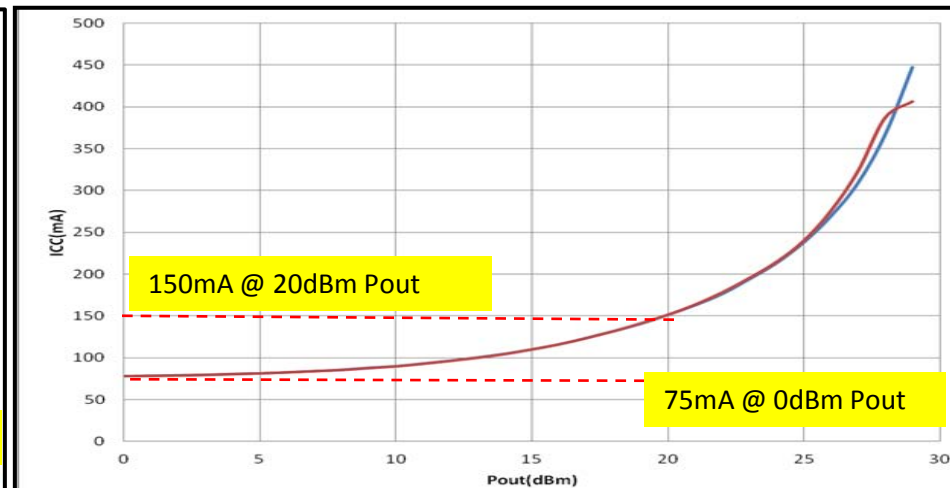
LONGER LIFECYCLE



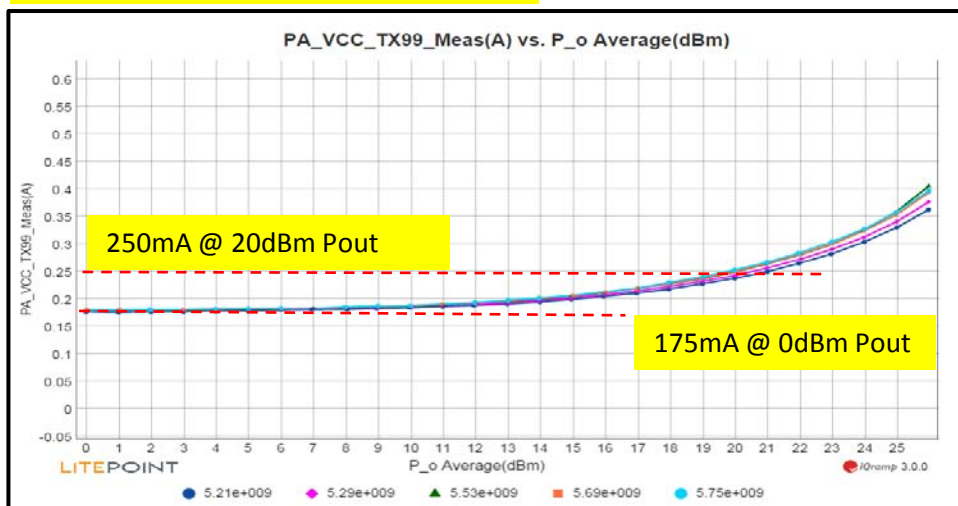
LINEAR FEM @ 2.4GHz FEM RTC66270



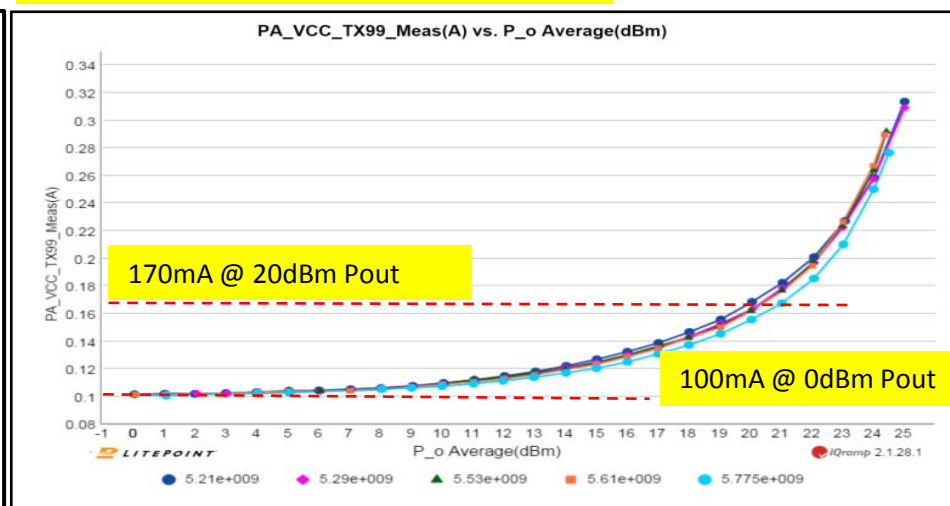
NONLINEAR FEM @ 2.4GHz FEM RTC66254



LINEAR FEM @ 5GHz FEM RTC7676EM

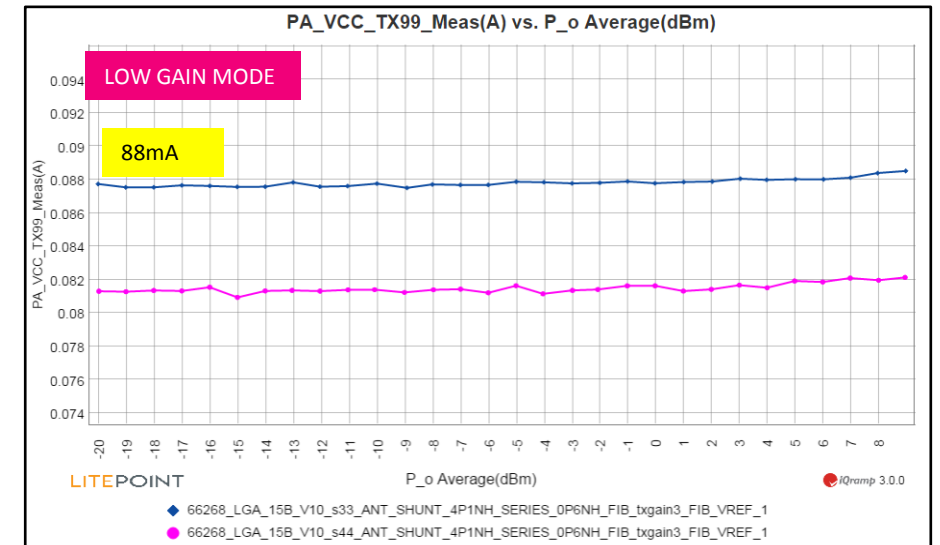
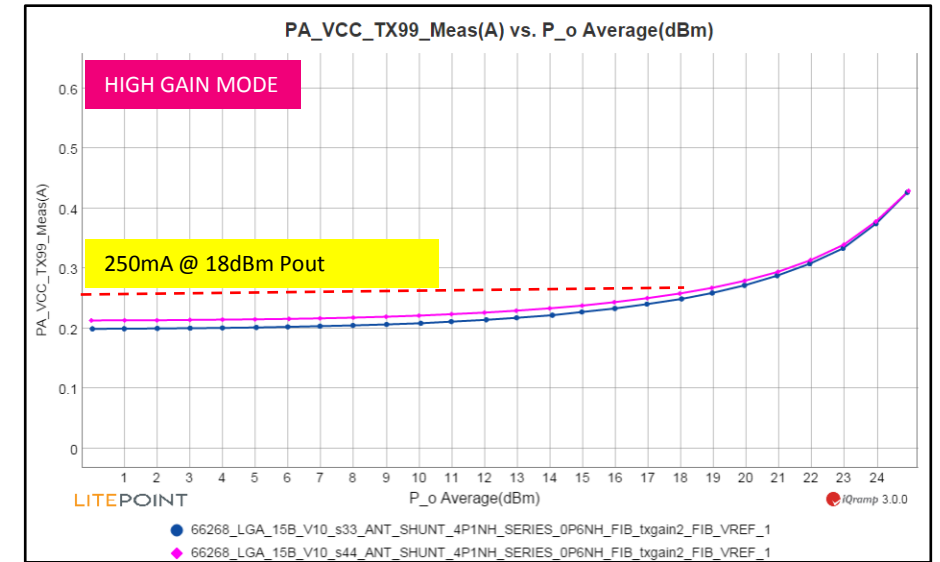
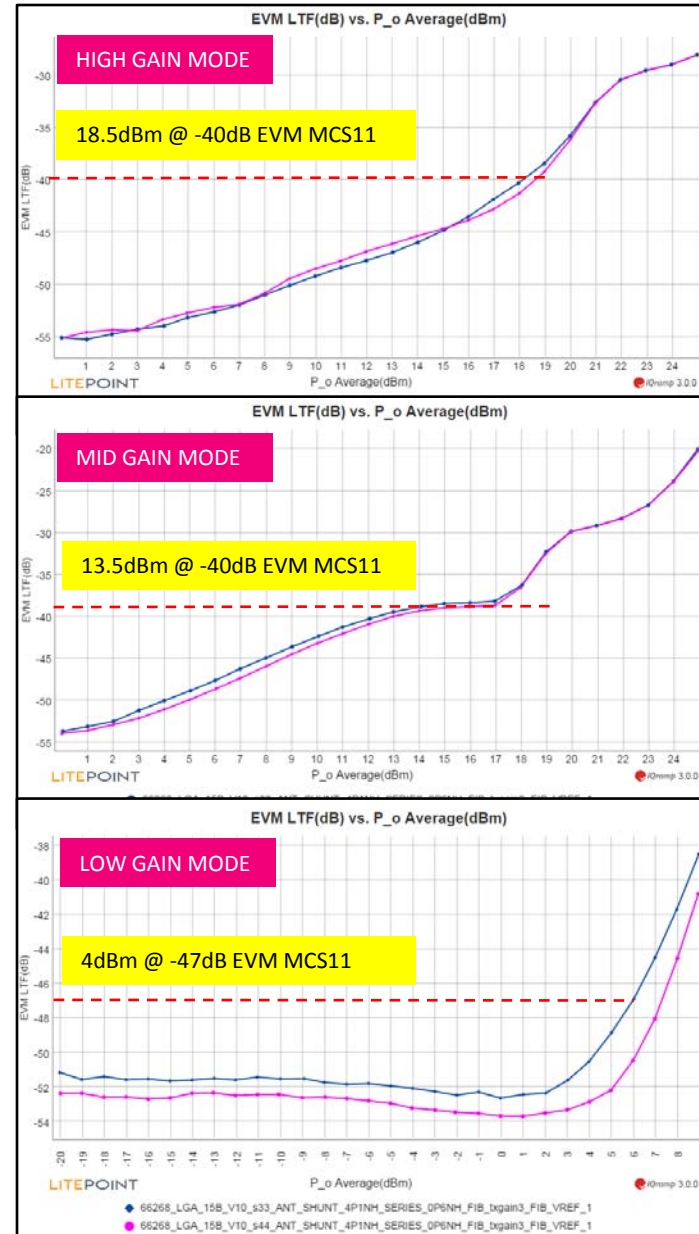


NONLINEAR FEM @ 5GHz FEM RTC66533



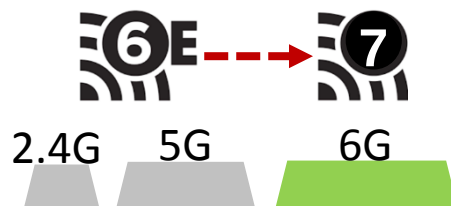
ADOPT MULTI-MODE FOR MOBILE/CLIENTs APPLICATIONs

3- GAIN STAGES

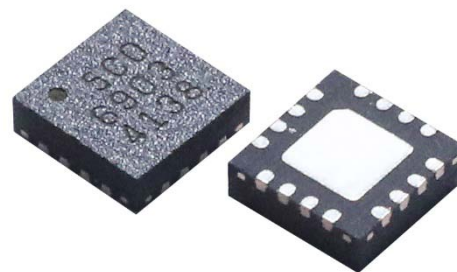


OFFER FULL LINE UP RF FEMs FOR 6GHz BAND

NEW 6GHz BAND



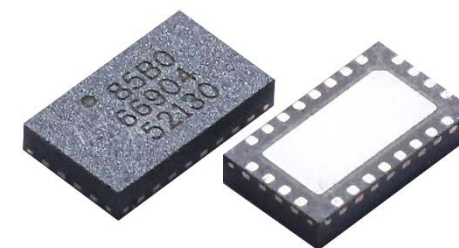
RTC66903



FEATURES

- SUPPORT 5.925-7.125GHz
- MCS11 HE160 19.5dBm Pout
- MCS0 HT20 25dBm Pout
- 3.0mm * 3.0mm PACKAGE

RTC66904



FEATURES

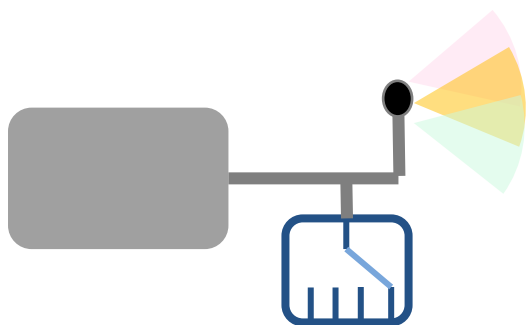
- SUPPORT 5.925-7.125GHz
- MCS11 HE160 20.5dBm Pout
- MCS0 HT20 26dBm Pout
- 3.0mm * 5.0mm PACKAGE



VALUES ON OUR 5G PRODUCTS

MAXIMIZE ANTENNA EFFICIENCY FOR MULTI-BANDs

> ANTENNA TUNNING SWITCH

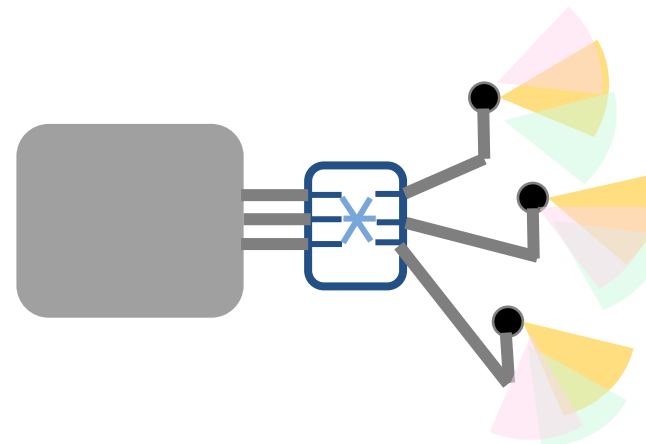


OFFER MORE
FREEDOM W/
DIFFERENT
RESONATE FREQ.
OR RAD. SPACIAL
PATTERN TO
REUSE SAME ANT.

RTC8674A / RTC8674B / RTC8674C

- 4 PATHs SWITCH W/ INDIVIDUAL CTRL. (4*SPST)
- SUPPORT PEAK VOLTAGE LEVEL TO 45V/60V/80V
- 1.1mm * 1.5mm PACKAGE

> ANTENNA SWAPPING SWITCH



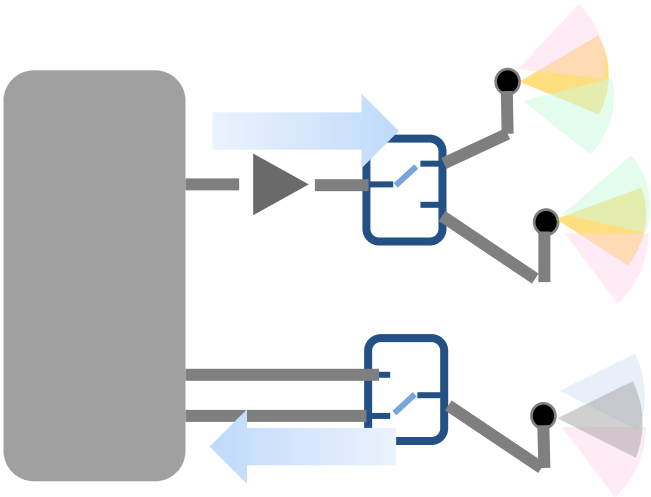
SUPPORT MIMO
UL/DL TO AGGREGATE
MULTI-LINKs SIGNAL
SIMULTANEOUSLY

RTC86524AU / RTC86522BU / RTC86533AU

- DPDT/DP4T/3P3T SWITCH COMBINATIONS
- SUPPORT HIGH P0.1dB TO 36dBm
- 1.1mm * 1.5mm / 2.0 mm * 2.0 mm PACKAGE

SUPPORT VARIOUS NEEDs IN RF DESIGN ARCHITECTURE

> GENERAL SWITCHs

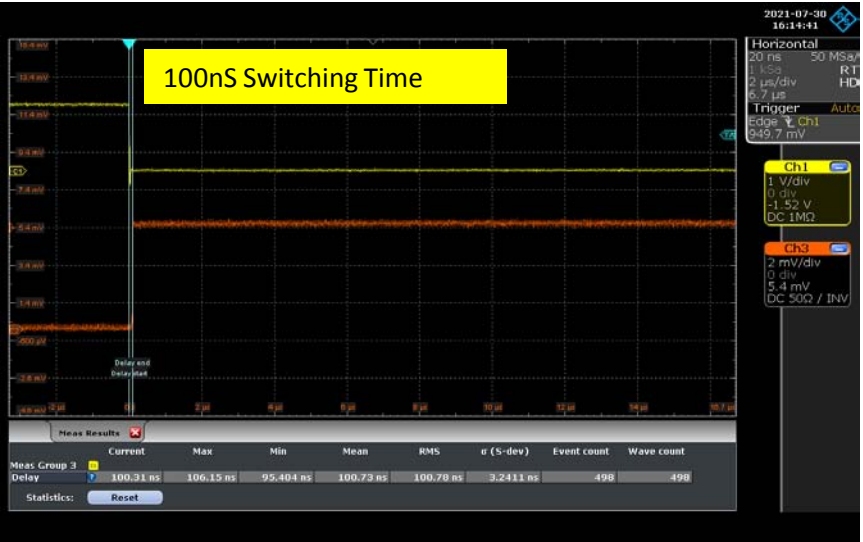


USE SWITCHs TO
CONSOLIDATE THE RF
TOPOLOGY, FLEXIBLE
TO ADAPT DIFFERENT
REGIONs

RTC86102x/ RTC86104x SERIES

- SPDT/SP4T SWITCH COMBINATIONS
- SUPPORT HIGH P0.1dB to 40dBm FOR TX PATH
- ALSO PROVIDE TYP. P0.1dB 33dBm FOR DIV. PATH
- 1.1mm * 0.7mm / 0.95 mm * 0.6 mm PACKAGE

> OTHER ADV. TO OUR SW



FAST SWITCHING TIME TO
SUPPORT SOUNDING REF.
SIGNAL(SRS) FEATURE BY 5G
REQUIREMENT

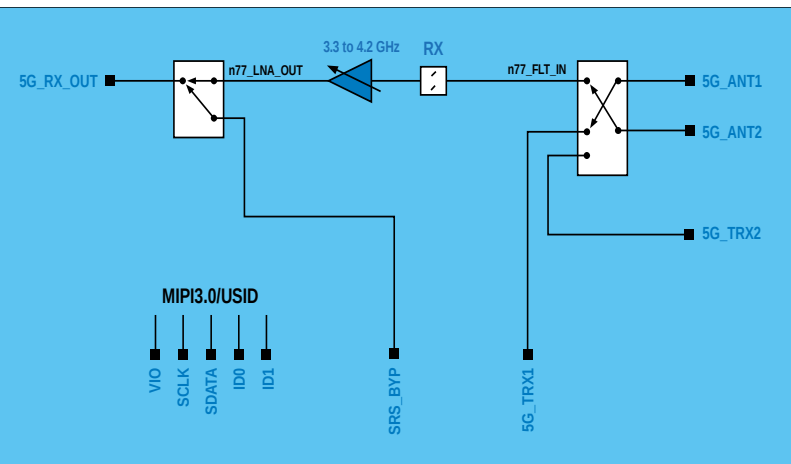
Parameter	Unit	Test condition	RichWave RTC86102GU (P0.1dB=33dBm)	RichWave RTC86102HU (P0.1dB=40dBm)
Insertion Loss	dB	617-960MHz	0.27	0.25
		960-2170MHz	0.27	0.35
		2170-2700MHz	0.29	0.36
		3300-3800MHz	0.30	0.39
		3800-4200MHz	0.30	0.41
		4400-5000MHz	0.32	0.44
		5150-5925MHz	0.35	0.48
		6000-7000MHz	0.42	0.64
		7000-8000MHz	0.60	0.87
		8000-8250MHz	0.64	0.96

WIDE FREQUENCY
SUPPORT, CAN BE USE
ON 5G SUB-6G AND
Ultra-Wide-Band (UWB)
APPLICATIONS

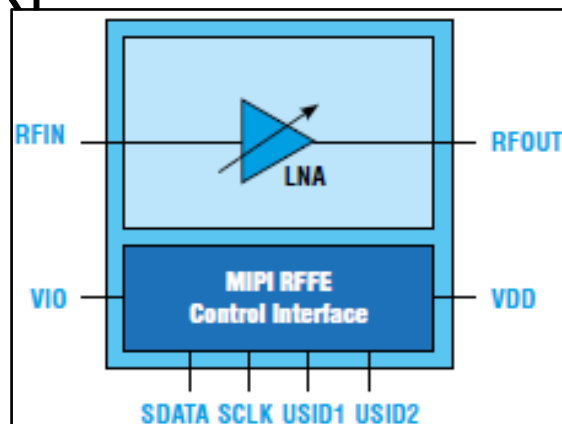
OFFERs Rx COMBINATIONs FOR 5G SUB-6G BANDs

BAND N77 LNA FAMILY

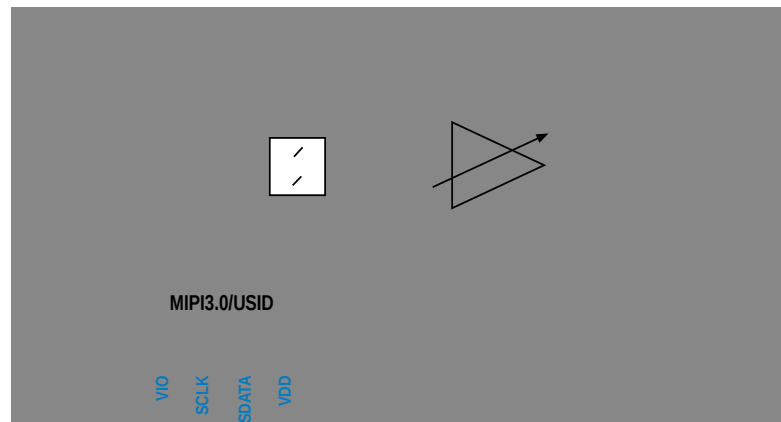
RTC86902



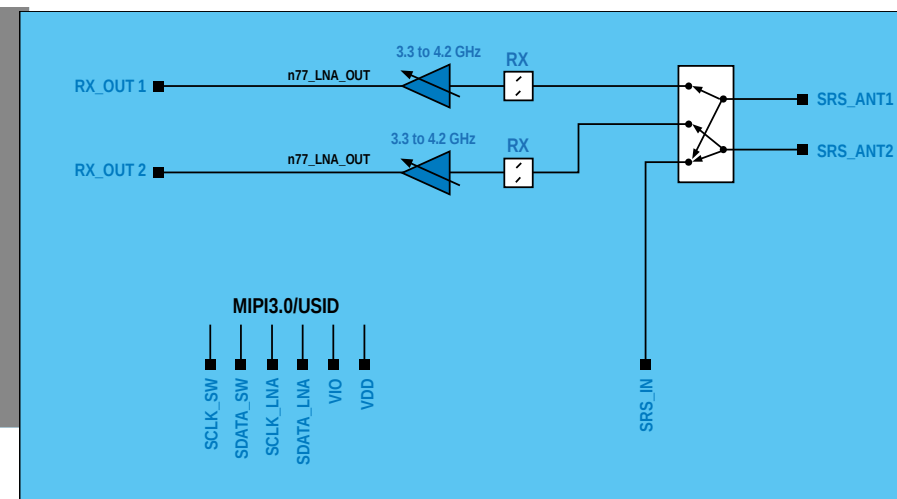
MULTI-GAIN LNA W/ LAA SUPPORT



RTC86903



RTC86904



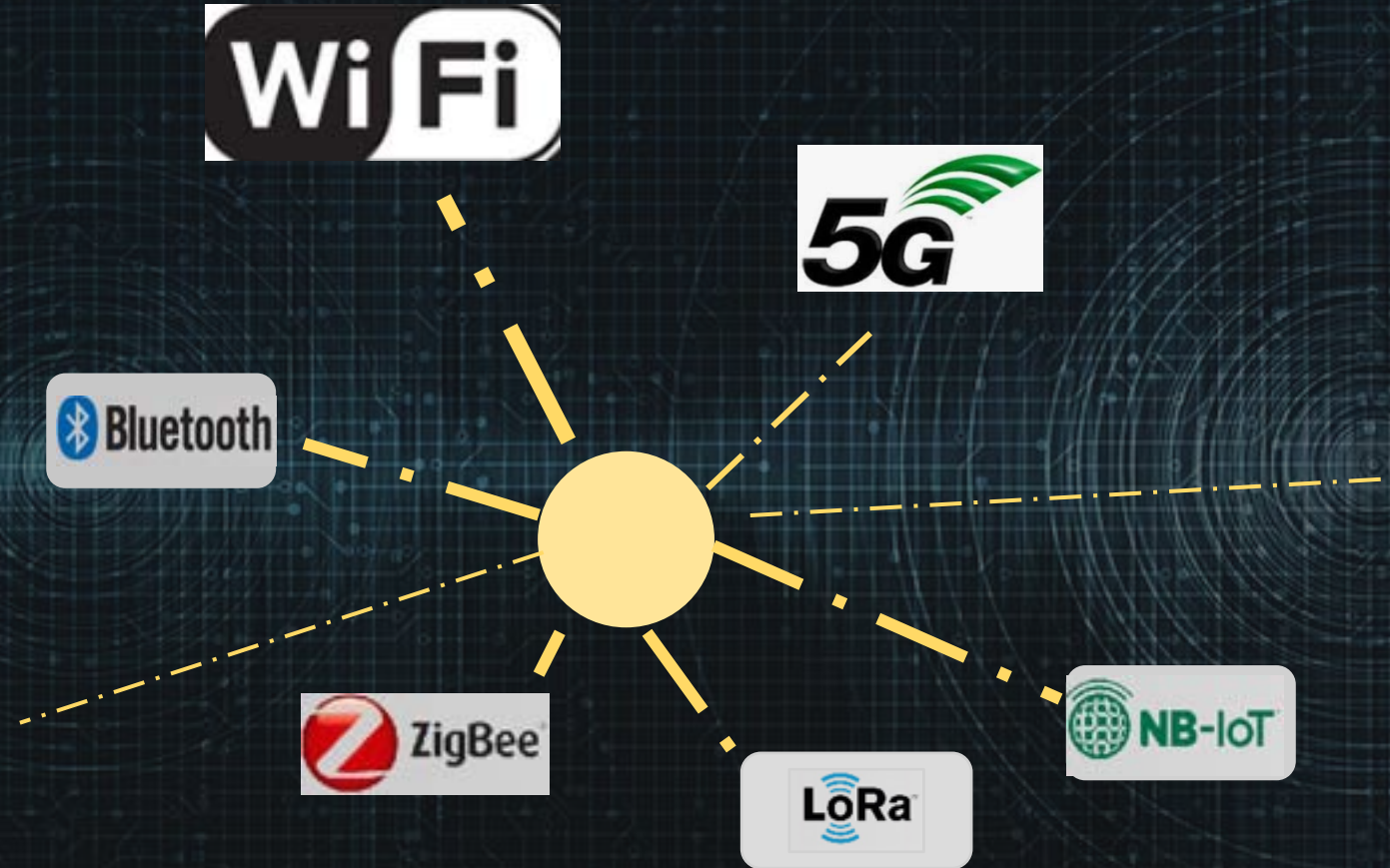
RTC86006U

- COVER 5.150~5925MHz
- WITH **MIPI** COMPLIANCE INTERFACE CONTROL
- SUPPORT UP TO **6 STAGE GAIN STEPS**
- 1.5mm * 1.1mm PACKAGE

RichWave

RichWave

WILL BE THE
SOLID BACKUP
FOR YOUR
WIRELESS
PRODUCTS





Thank you

Follow us on:  

For more information, visit us at:
www.richwave.com.tw



Guiding You with Desired Signals ---- Filter Solution

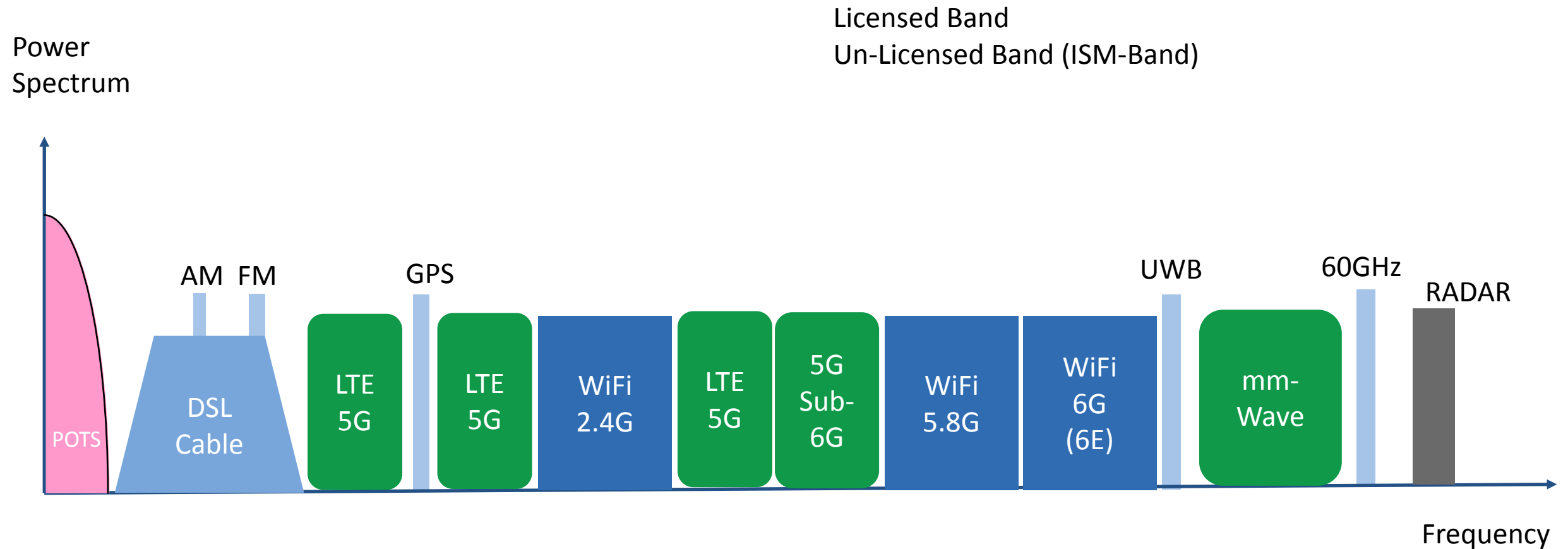
Champion Fu

Dec. 2021

What is Communication?

- Same Frequency
 - V.90 MODEM (0~4K Hz) → DSL MODEM (>30K Hz)
 - Signal Interference
 - Signal Bandwidth $\leftrightarrow$ Sampling Rate (Nyquist Rate)
- Same Protocol
 - You could hear what I say, and I could hear what you say
 - You could know what I say, and I could know what you say
- Noise
 - 98% Engineer Will Lose Job if the Transmission Medium is Noise-Free

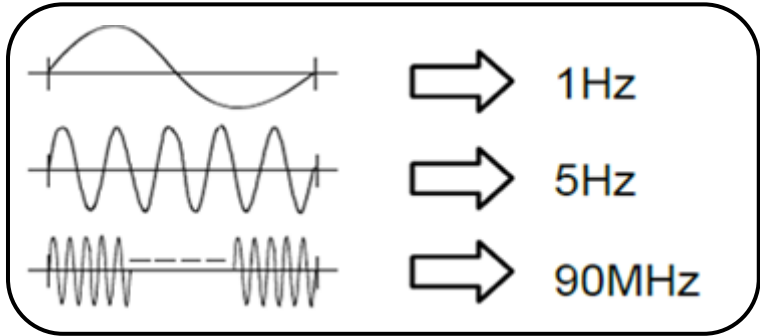
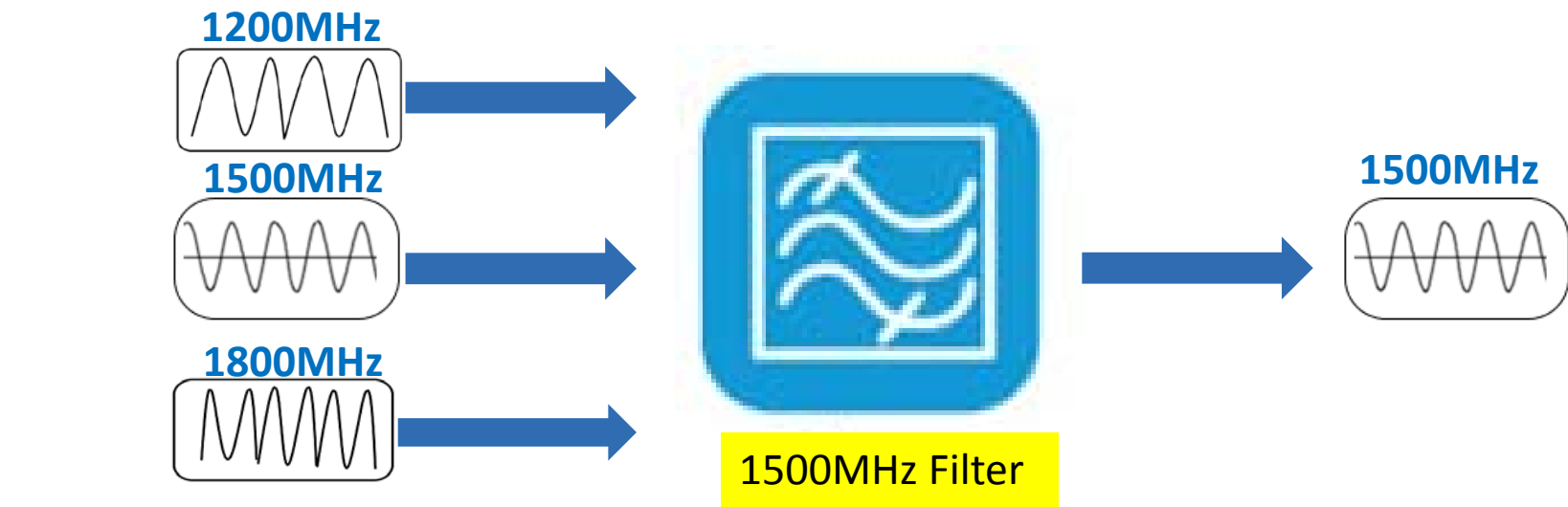
Frequency Band Allocations



Applications for Filter



What Is Filter

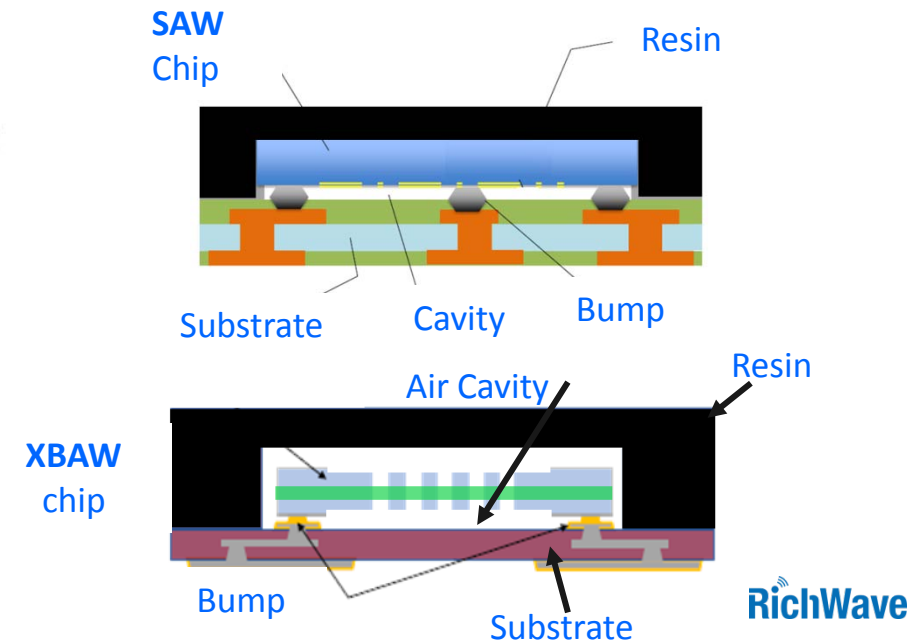
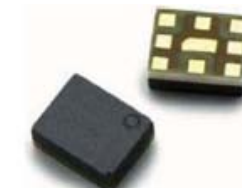
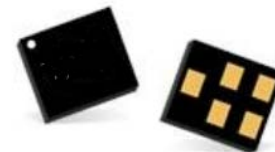
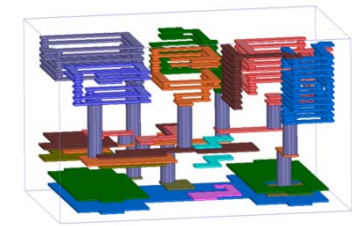
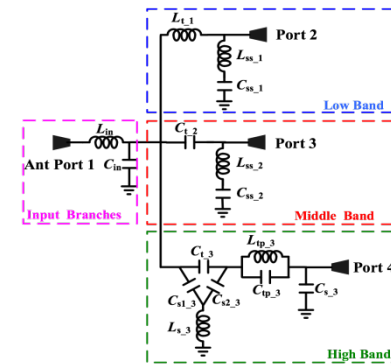


Band	Classification	Frequency range
LF	Low Frequency	30kHz ~ 300kHz
MF	Medium Frequency	300kHz ~ 3MHz
HF	High Frequency	3MHz ~ 30MHz
VHF	Very High Frequency	30MHz ~ 300MHz
UHF	Ultra High Frequency	300MHz ~ 3GHz
SHF	Super High Frequency	3GHz ~ 30GHz
EHF	Extremely High Frequency	30GHz ~ 300GHz

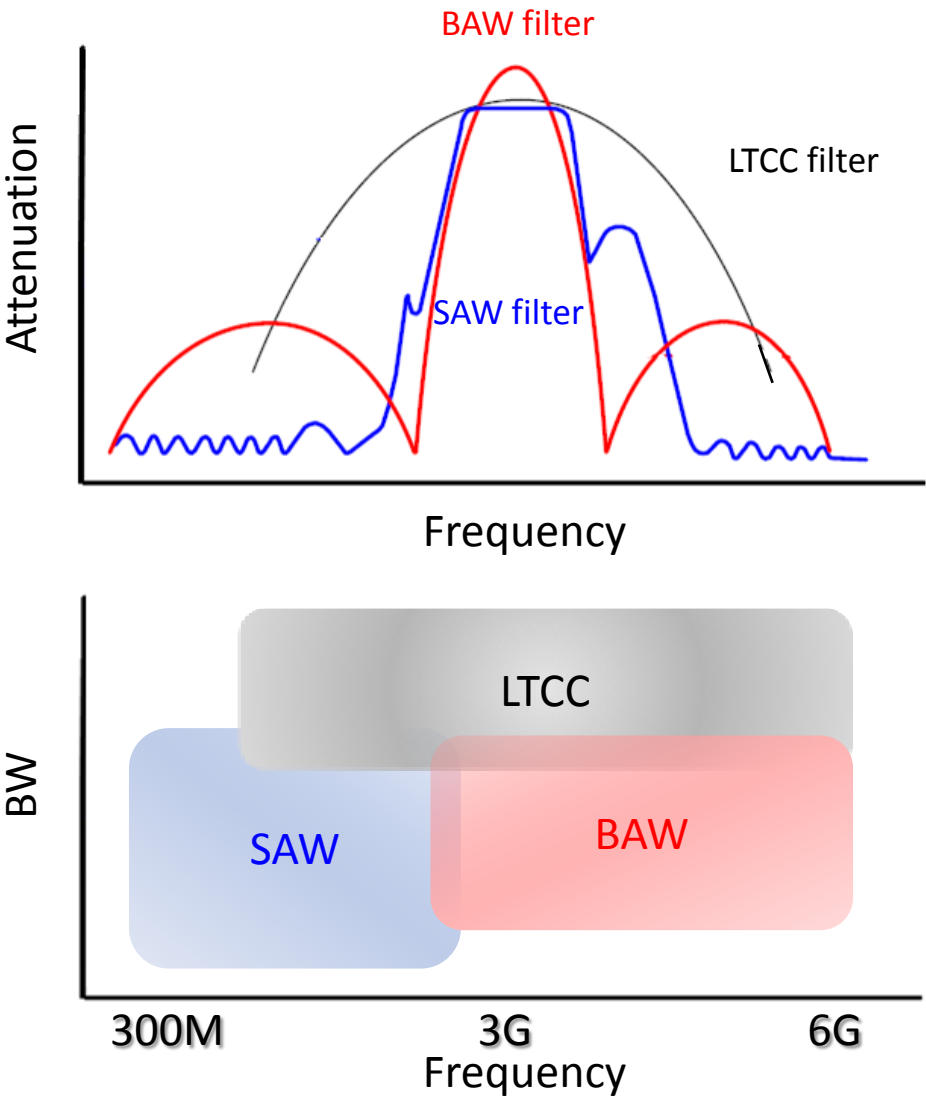
SAW Filter

Categories of Filter

- Discrete Filter
 - L/C
- LTCC (Low Temperature Ceramic Co-firing)
 - Ceramic, Ag/Cu
 - Frequency Range : 150M ~ 100G Hz
- SAW (Surface Acoustic Wave)
 - Frequency Range : 50M ~ 3.5G Hz
- BAW (Bulk Acoustic Wave)
 - Frequency Range : 400M ~ 10G Hz



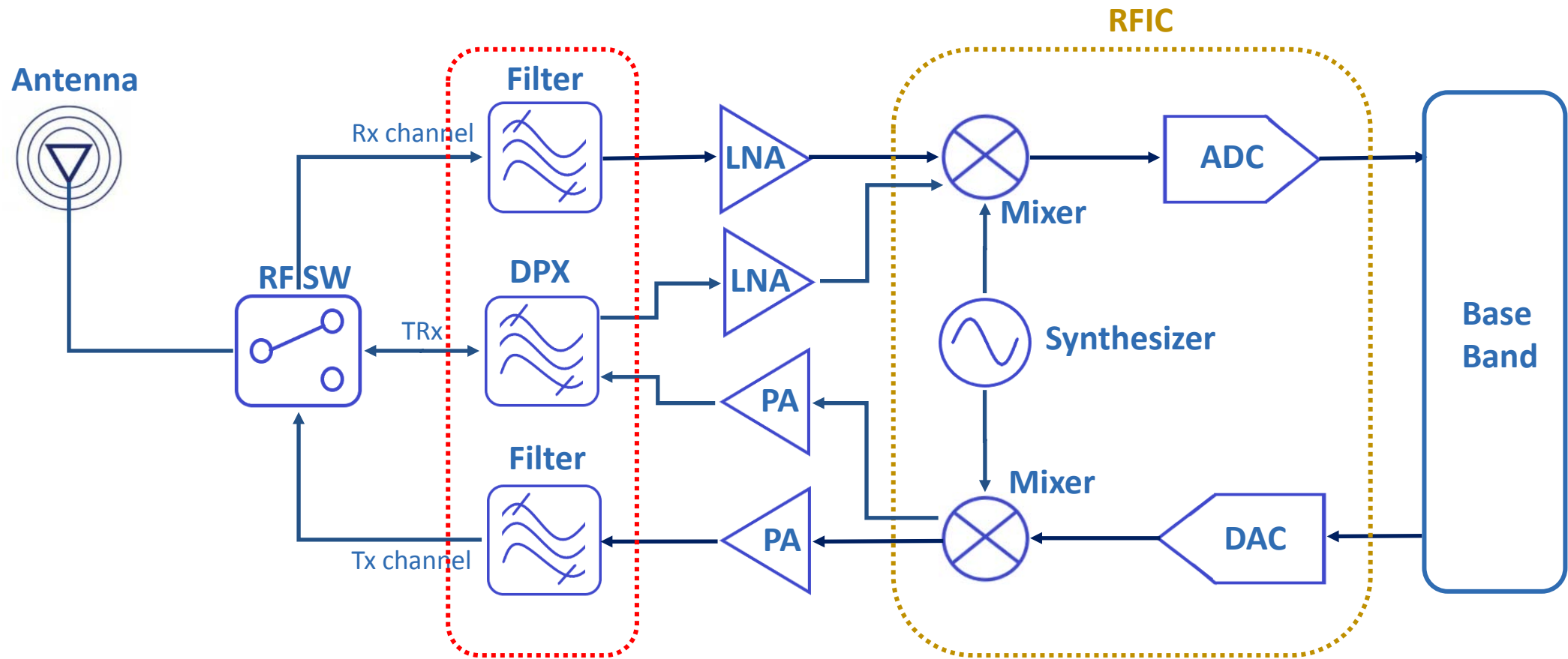
Frequency Response for Different Filters



	SAW	BAW	LTCC
Q	△	○	X
Loss	△	○	X
Att.	△	○	X
TCF	△	○	△
Size	○	X	○
Price	△	X	○
Power	X	○	○

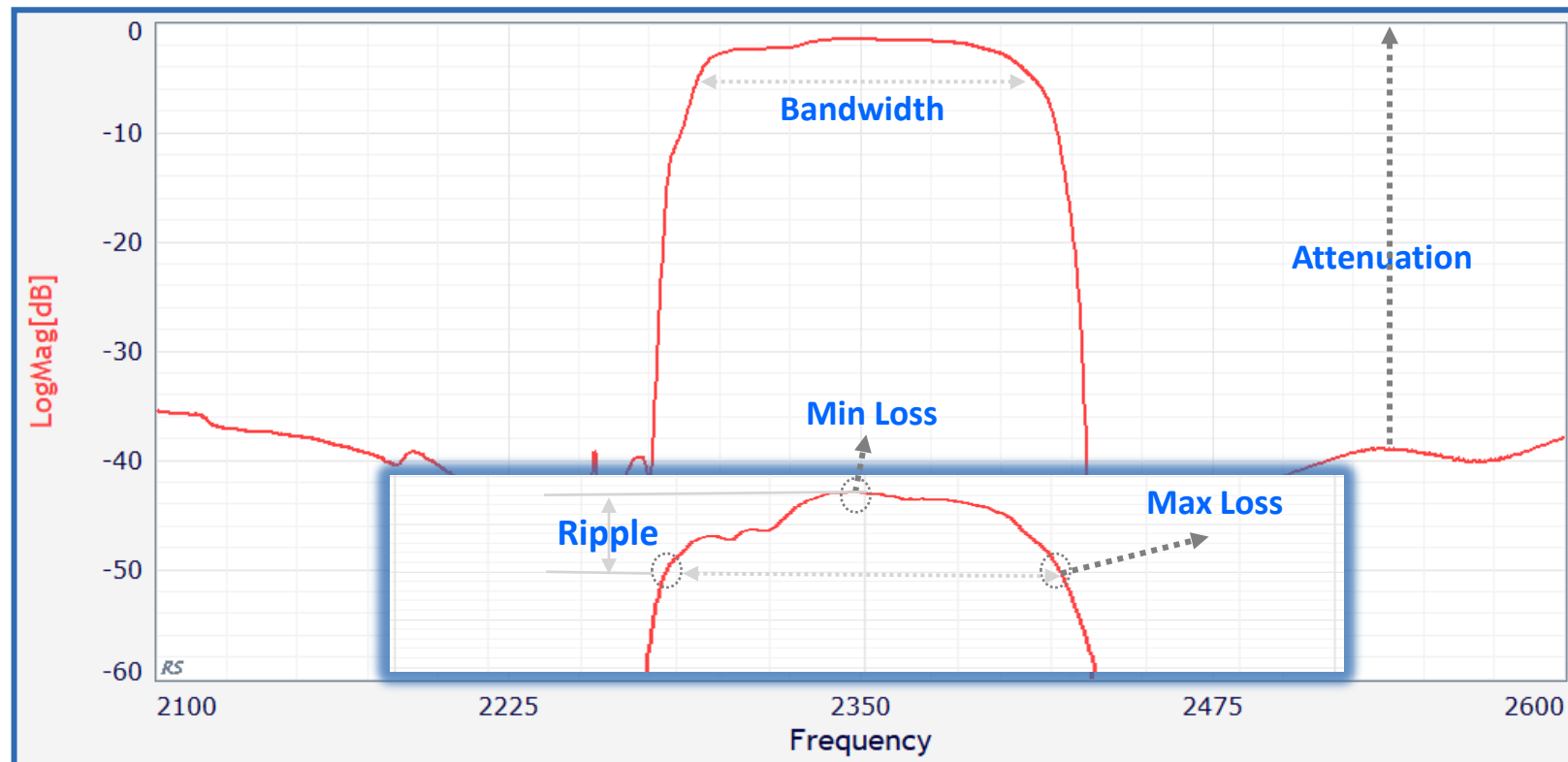
○: Good; △: average; X: Not so good

Filters in Wireless System



Key Specification for Filter

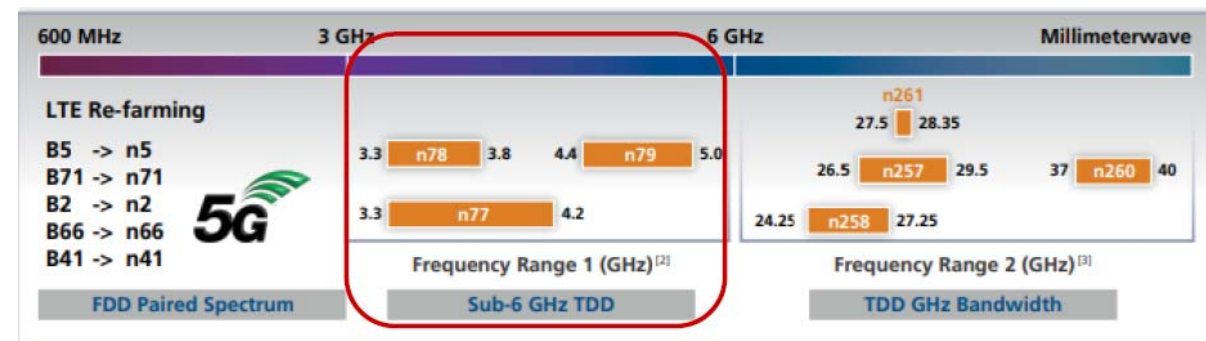
1. F_o: Center Frequency.
2. Max Loss: Max Loss in Pass Band.
3. Ripple: Max IL – Min IL in Pass Band.
4. Pass Band Bandwidth:
High Freq Point FH – Low Freq Point FL
5. Attenuation: Side Band Attenuation (Reference 0dB)



LTE/5G Band Allocations

5G NR FR1 Band	Uplink Freq (MHz)	Downlink Freq (MHz)	BW (MHz)	Duplex Mode
n1	1920 ~1980	2110~2170	60	FDD
n2	1850~1910	1930~1990	60	FDD
n3	1710~1785	1805~1880	75	FDD
n5	824~849	869~894	25	FDD
n7	2500~2570	2620~2690	70	FDD
n8	880~915	925~960	35	FDD
n12	699~716	729~746	30	FDD
n20	832~862	791~821	30	FDD
n25	1850~1915	1930~1995	65	FDD
n28	703~748	758~803	45	FDD
n34	2010~2025	2021~2025	15/4	FDD
n39	1880~1920	1880~1920	40	FDD
n40	2300~2400	2300~2400	100	TDD
n41	2496~2690	2496~2690	194	TDD
n50	1432~1517	1432~1517	85	TDD
n51	1427~1432	1427~1432	5	TDD
n66	1710~1780	2110~2200	70/90	FDD
n70	1695~1710	1995~2020	15/25	FDD
n71	663~698	617~652	35	FDD
n74	1427~1470	1475~1518	43	FDD
n75	X	1432~1517	85	SDL
n76	X	1427~1432	5	SDL
n77	3300~4200	3300~4200	900	TDD
n78	3300~3800	3300~3800	500	TDD
n79	4400~5000	4400~5000	600F	TDD

Frequency Range Designation	Corresponding Frequency Range
FR1	450 MHz ~ 6000 MHz
FR2	24250 MHz ~ 52600 MHz



RichWave Filter for LTE/5G

5G Mobile focus product

	Band 1	Band 2 Band 25	Band 3	Band 4	Band 5 Band 26	Band 7	Band 8	Band 12	Band 13	Band 20	Band 34	Band 39	Band 40	Band 41
US	v	v	v	v	v		v	v	v					v
EU	v		v		v	v	v			v				
China	v		v		v		v				v	v	v	v

1109 Filter : B1, 2, 3, 5(26), 7, 8, 12, 13, 20, 28FB, 39, 40, 41

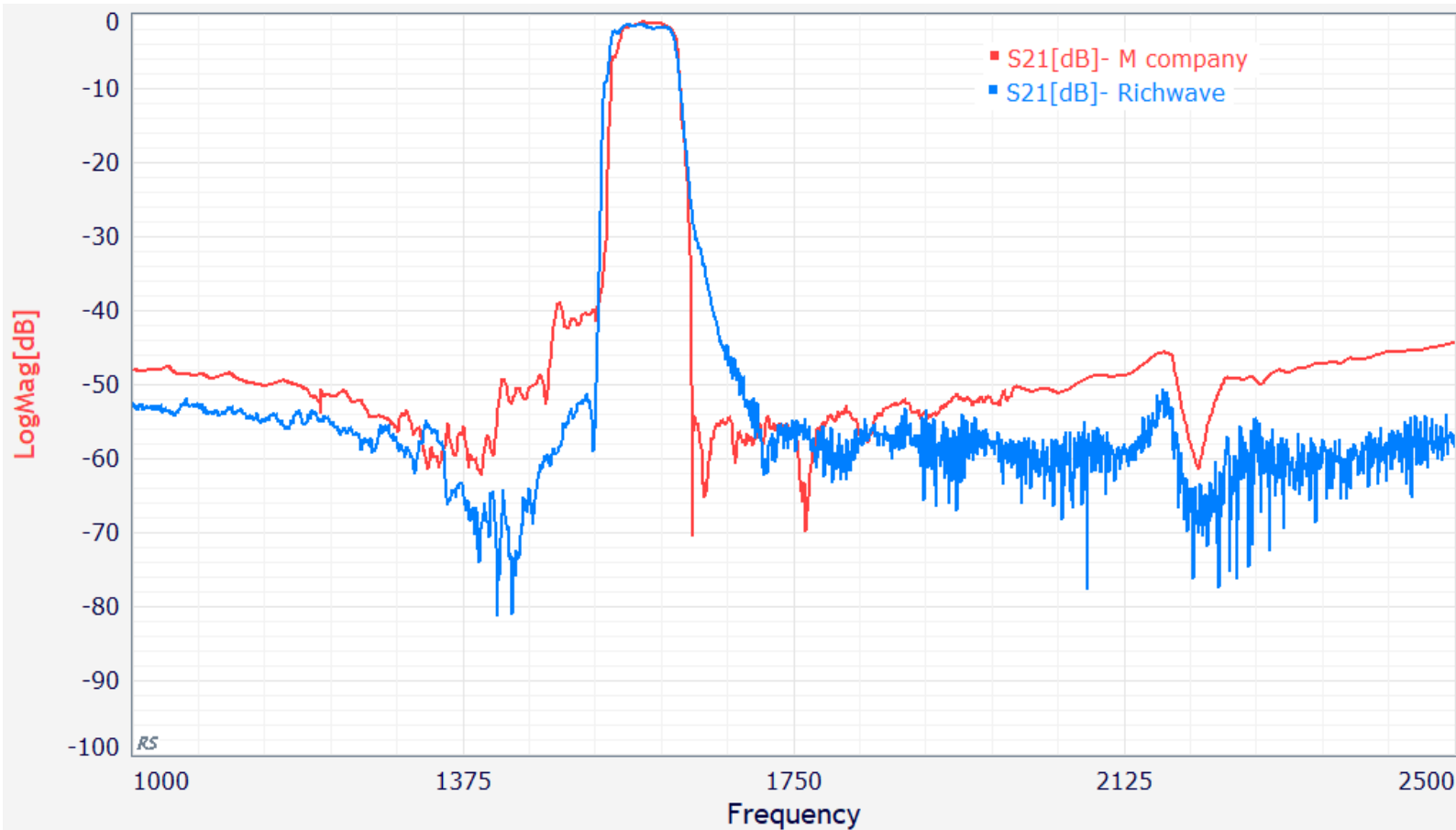
0907 Filter : n1, n2, n3, n5, n7, n8, n12, n20, n28FB, n39, n40, n41FB, n66.

1814 DPX : B1, 2, 3, 5, 7, 8, 12, 13, 28

1511 Dual : B1+B3, B25+B66, B39+B41

- Available part
- Developing
- Plan

SAW Filter Performance Benchmark



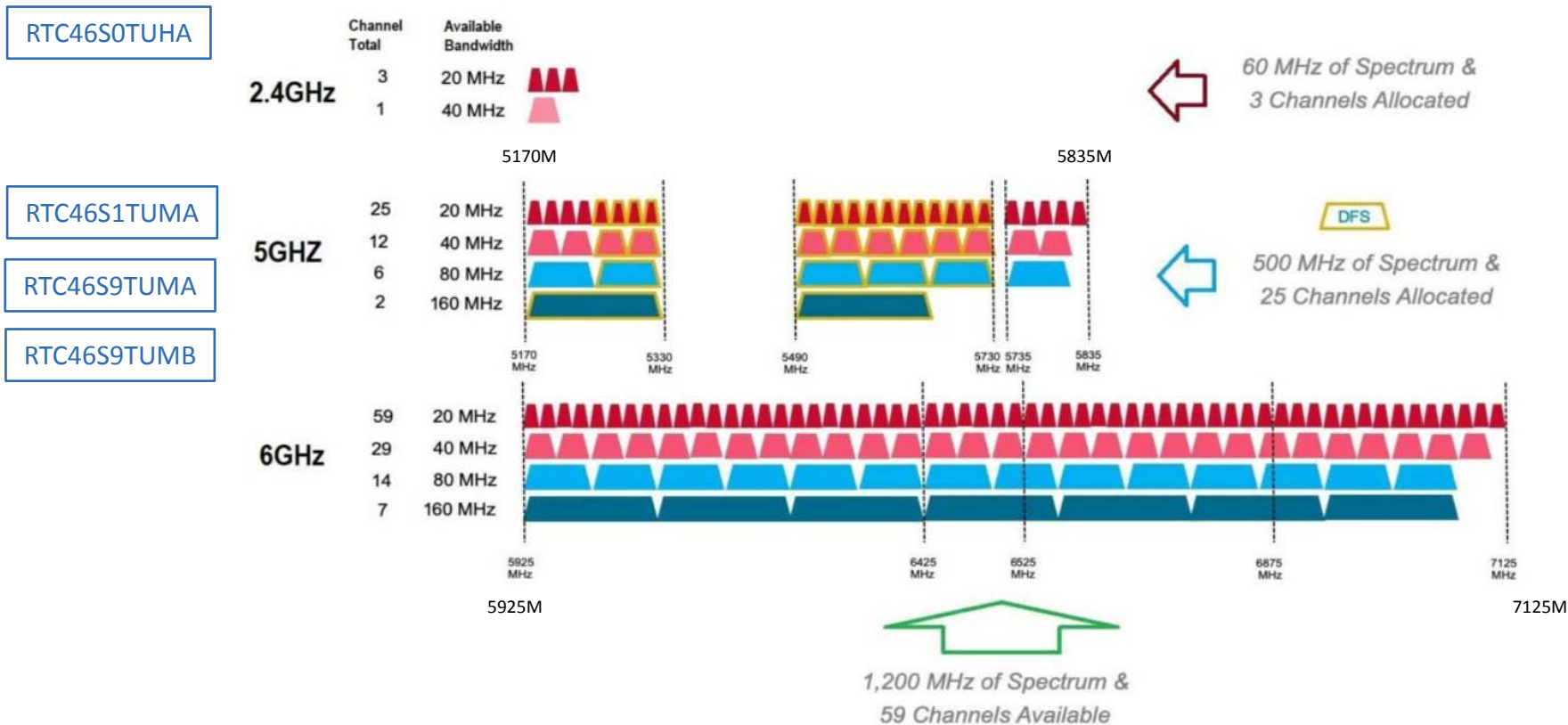
■ RTC46S2RUHA

■ Key Features

- Freq. : 1559~1605 MHz
- IL:
 - 1.8dB @ 1559MHz
 - 1.3dB @ 1575MHz
 - 1.6dB @ 1605MHz
- Attenuation:
 - 58dB @ B13 Tx (777~798MHz)
 - 57dB @ B5,B8 Tx (824~915MHz)
- Package: 5L QFN 1.1mm x 0.9mm

SAW/BAW Filter for WiFi Access

Wi-Fi Frequency Bands

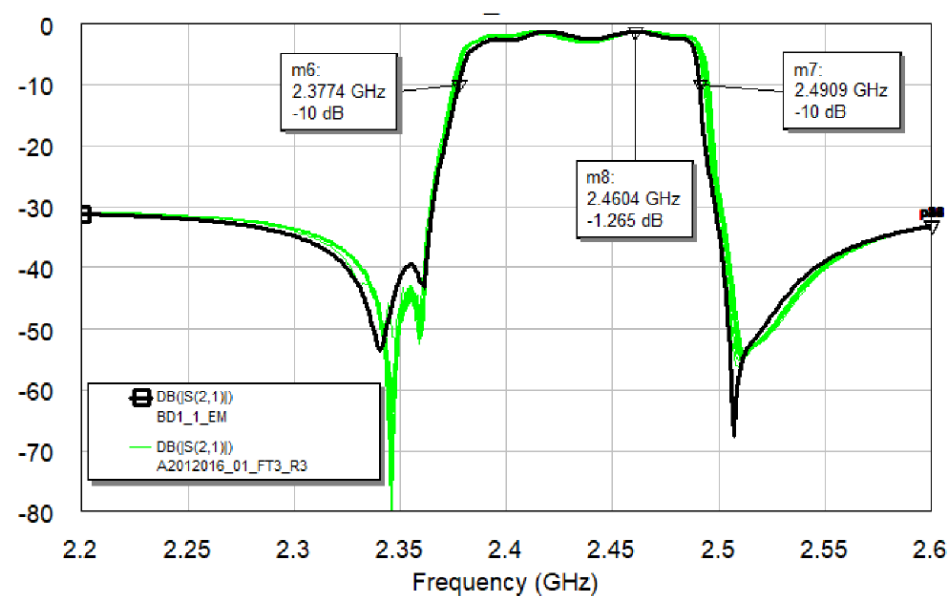


Sourced from Wi-Fi Alliance
RichWave

WiFi BAW Filter

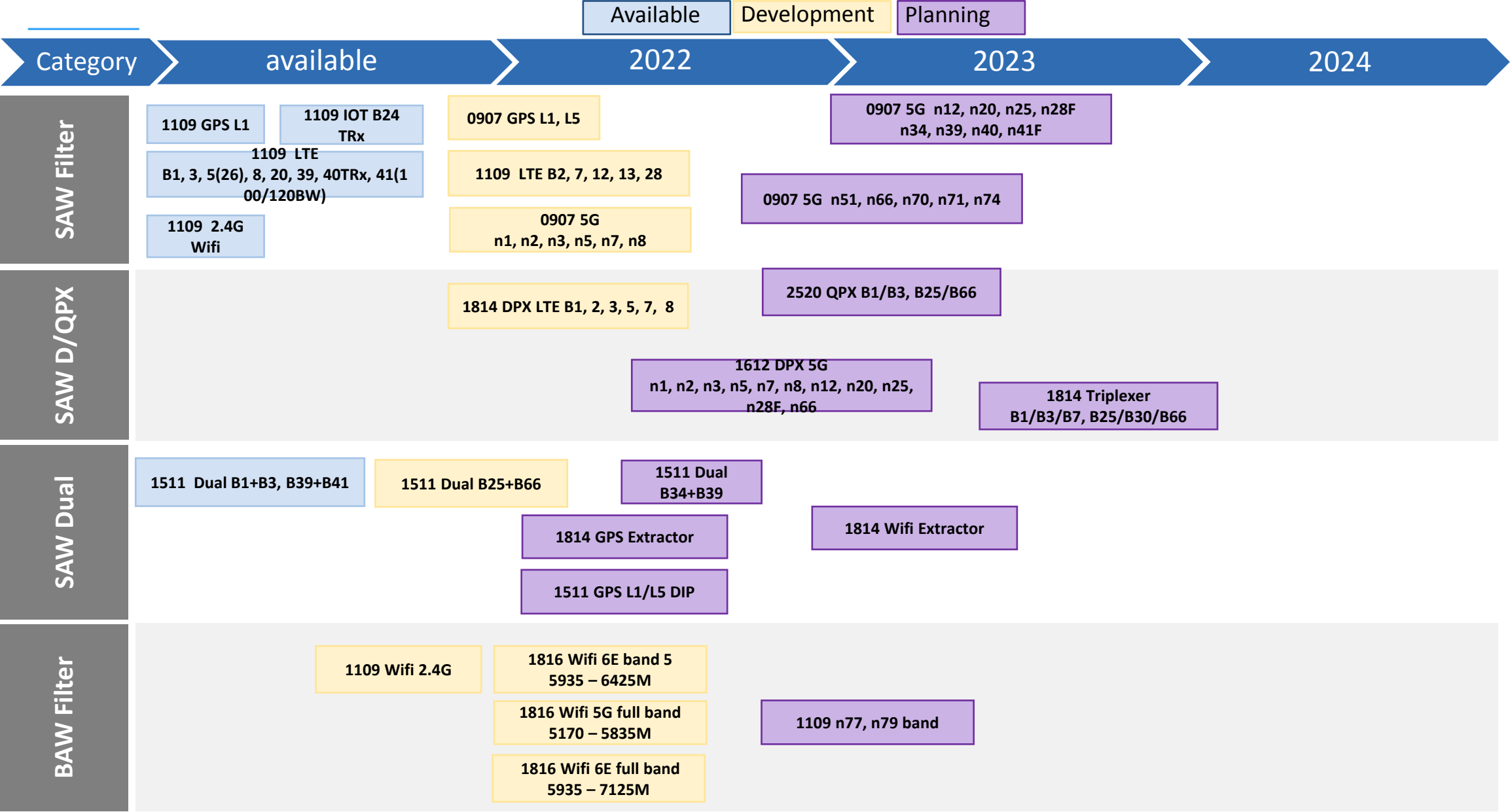
— Simulation
— Measured
on wafer

**Tested Filter on Wafer:
Measured and Simulated on Wafer**



- Pass Band : 2.4~2.483 GHz
- Insertion Loss (CH1~CH13)
 - 0.9~1.2 dB
- Rejection
 - 38dB @700~2370 MHz
 - 14dB @2496~2500 MHz
 - 38dB @2500~2520 MHz
 - 40dB @2520~2690 MHz
 - 36dB @3300~7200 MHz
 - 26dB @7200~10000 MHz

RichWave Filter Product Roadmap (WIFI/GPS/Mobile)





Make Your Life Be Smarter with RichWave RF Offerings

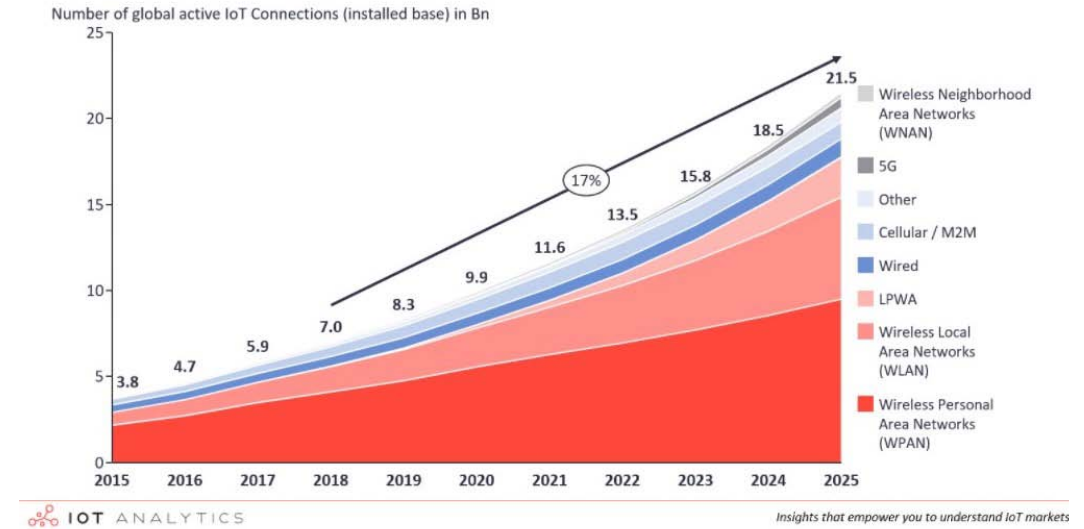
Champion Fu

Dec 2021

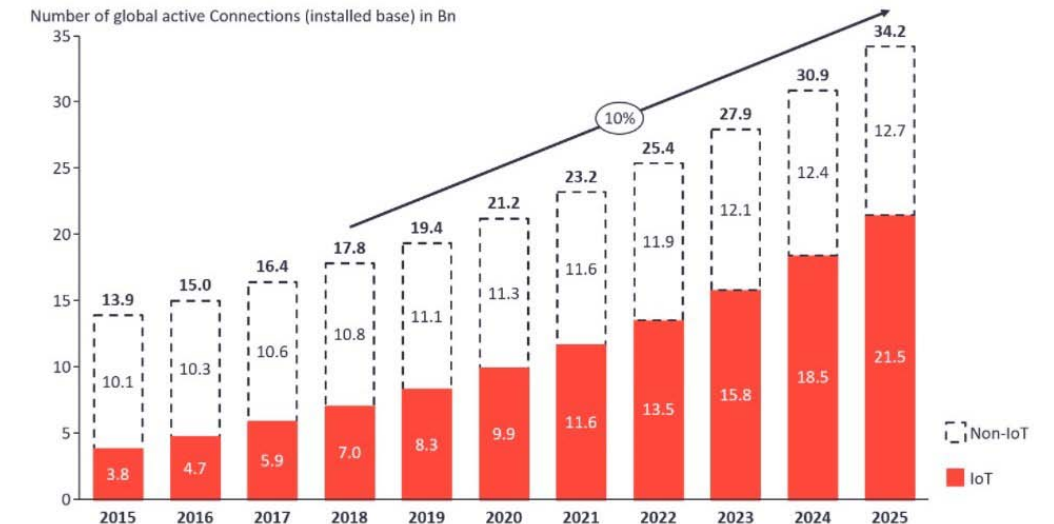
AIoT

- AI (Artificial Intelligence)
- IoT (Internet of Things)
- Big Data
 - Fuzzy Theory
 - Signal Feedback
 - Database Analysis

Global Number of Connected IoT Devices



Total number of active device connections worldwide



Sourced by IOT Analytics

Smart City, Smart Home, Smart Ecosystems



- Smart City
 - Bus Station, Parking Space
- Smart Home
 - Mobile/Gateway
 - TV, Air Conditioner, Refrigerator, Lighting, Plug
- Automotive
 - TPMS, ADAS
 - Autopilot

IoT on System Design Consideration

- Data Rate
 - High Throughput, High Signal Resolution (WiFi)
 - Low Data Rate, Access by Request (Low Power Wireless)
 - LPWAN – LoRA, NB-IoT
 - LPLAN – BT/BLE, Zigbee
- Power Consumption
 - AC Power Adaptor
 - Battery Based

Product Application



speaker



Home appliances

IP Cam

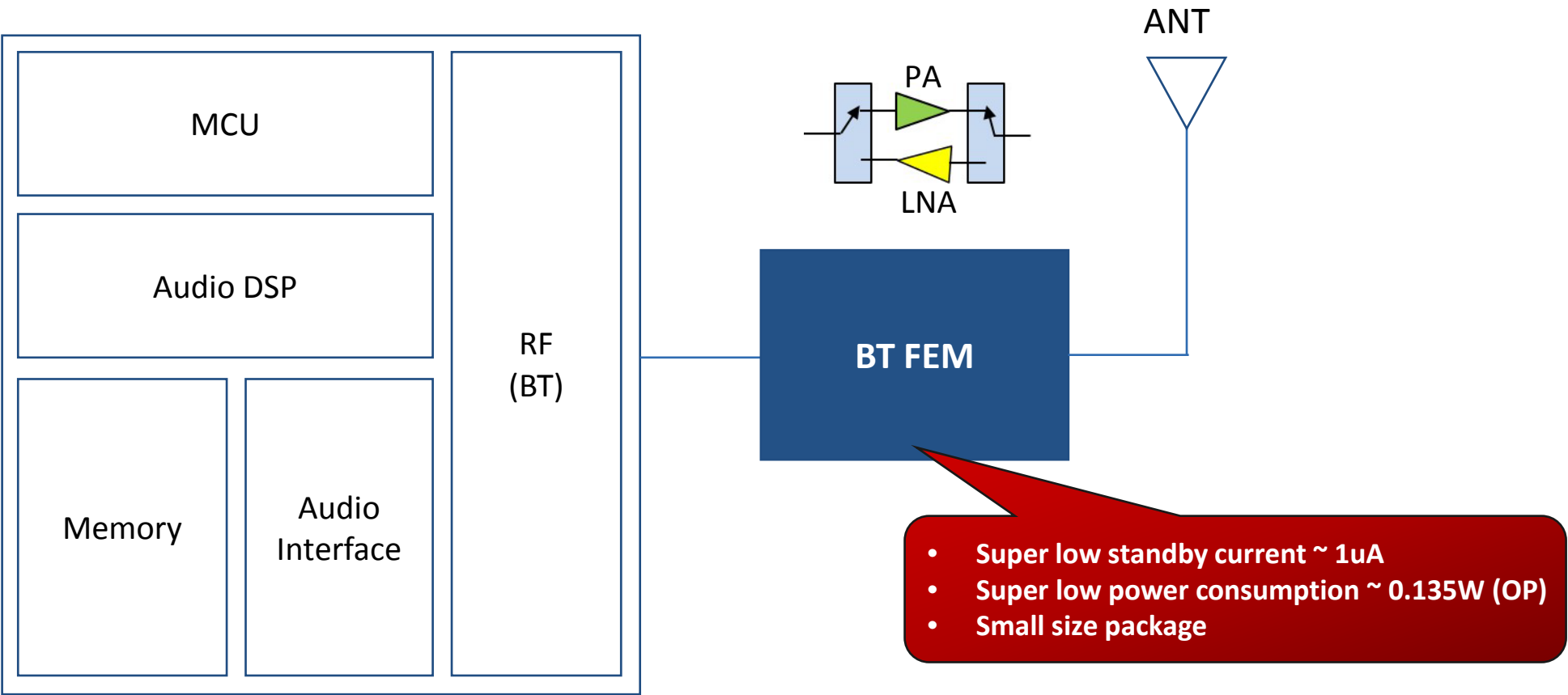


Doorbell

Smart Meter



FEM for Bluetooth/Zigbee



Part Number	Feature	Size	Support EDR	Status
RTC2624	Full FEM	16L QFN 2.4x2.4x0.8 mm	NO	MP
RTC26203	RX FEM	6L QFN 1.1x0.9x0.55 mm	NO	Developing

Ultra-Low Loss IoT Switches

Feature	Part No.	Insertion Loss (dB)	Isolation (dB)	P0.1dB (dBm)	Package (mm)
DPDT	RTC6615H	0.70 @ 2.40 GHz 1.00 @ 6.00 GHz	30 @ 2.45 GHz 29 @ 6.00 GHz	31	6L QFN 1.5x1.5x0.55
SPDT	RTC6603U	0.38 @ 2.45 GHz	23 @ 2.45 GHz	30	SC70
	RTC66080U	0.24 @ 2.45 GHz	35 @ 2.45 GHz	32	6L QFN
		0.35 @ 5.80 GHz	26 @ 5.80 GHz		1.0x1.0x0.45
		0.65 @ 7.125 GHz	22 @ 7.125 GHz		
	RTC7608U	0.21 @ 2.45 GHz	35 @ 2.45 GHz	32	6L QFN
		0.35 @ 5.80 GHz	25 @ 5.80 GHz		1.0x1.0x0.35
		0.53 @ 7.125 GHz	23 @ 7.125 GHz		
	RTC6619U	0.33 @ 2.45 GHz	34 @ 2.45 GHz	34	6L QFN
		0.43 @ 5.80 GHz	25 @ 5.80 GHz		1.0x1.0x0.35
SP3T	RTC6617U	0.31 @ 2.45 GHz 0.53 @ 5.90 GHz	22 @ 2.45 GHz 19 @ 5.90 GHz	30	8L QFN 1.5x1.5x0.45
SP4T	RTC8614U	0.2 @ 1.0 GHz	49 @ 1.0 GHz	32	14L QFN
		0.3 @ 2.7 GHz	34 @ 2.7 GHz		2.0x2.0x0.6
		0.4 @ 3.8 GHz	29 @ 3.8 GHz		



Automotive Product Portfolio

WiFi FEM

5GHz full FEM

- RTC1630 (3mmx3mm)
- PA+LNA+SW
- pass AEC-Q100 Level 2
- support 802.11p

5GHz RX FEM

- RTC1631 and RTC16504
- SW+ LNA
- pass AEC-Q100 level 2

6GHz RX FEM

- RTC16xx
- SW+LNA

2.4GHz full FEM

- RTC1620 (3mmx3mm)
- PA+LNA+SW
- pass AEC-Q100 Level 2

2.4GHz RX FEM

- RTC1621 and RTC16206
- SW+ LNA
- pass AEC-Q100 level 2

WiFi SW

SPDT and SP3T for WiFi 6

- RTC1602 (SPDT)
- RTC1603 (SP3T)
- pass AEC-Q100 Level 2

SPDT and SP3T for WiFi 6E and UWB

- RTC16004 (SPDT)
- RTC16006 (SP3T)

5G/NR SW

SPDT (Up to UWB)

- RTC86102EU/FU (1.1mmx0.7mm)
- RTC86102GU/HU (0.95mmx0.6mm)

SP4T (Up to UWB)

- RTC86104CU (1.1mmx1.1mm)
- RTC86104DU (0.95mmx0.95mm)
- ES: 2021/Q2

LNA

LTE LNA (L/M/H)

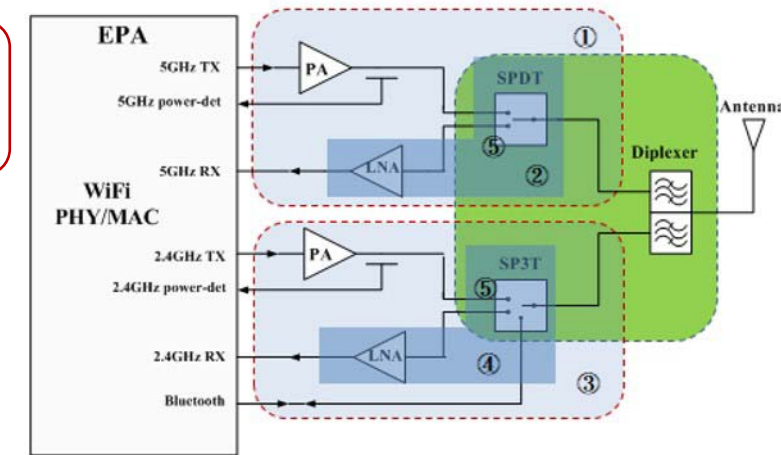
- Non-Bypass
- Bypass Mode
- QFN1.1*0.7

LNA Module

- LNA+SP5T
- QFN1.1*1.9

GPS LNA

- RTC8604 (L1 Band)
- RTC9601N (L5 Band)



Compliant with AEC-Q100



RichWave

Radar Sensor in Home, Consumers, Industrial and Car

V1.3

Dec 2021

Radar Sensor's applications

Home



Smart Lighting



Smart white goods



Smart Speaker



Smart Security



Presence Detection

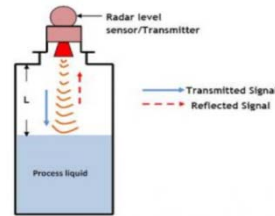
Industrial



UAV



Industrial transport
and Robotics



Level Detection

Consumer



NB



Vital sensing



Gesture

Car



STO



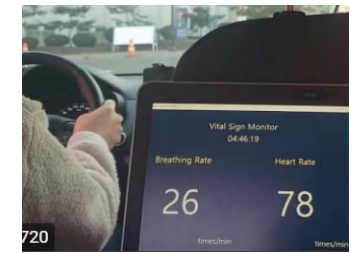
Blind side/ parking



Child Presence



Anti-Theft



Driver Monitoring

WW Radar Sensor Market



Global **RADAR SENSOR** Market OPPORTUNITIES AND FORECAST, 2021-2030

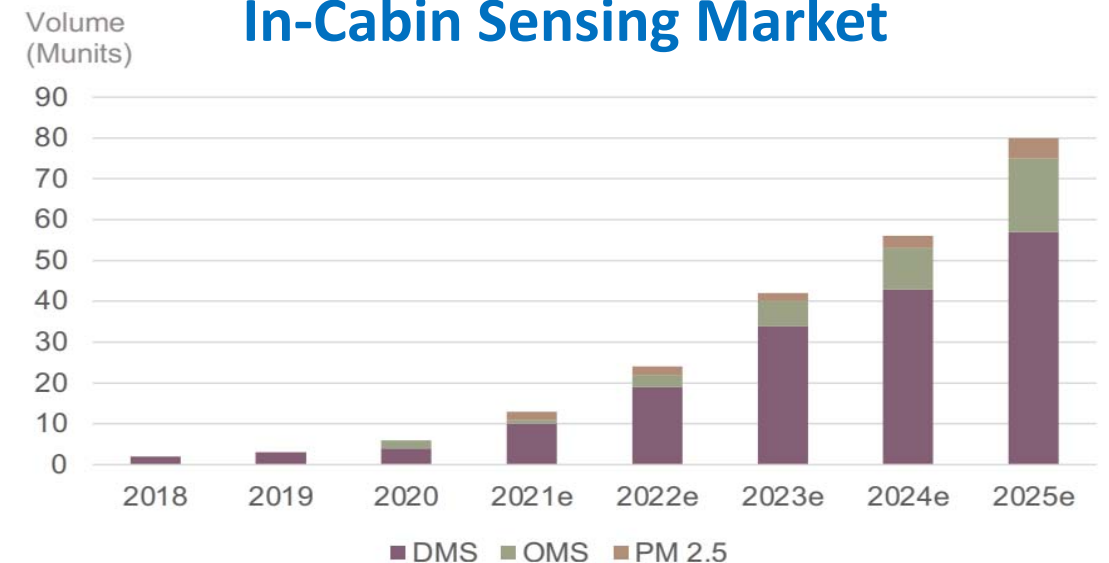
Global Radar Sensor Market is expected to reach **\$33.14 Billion** by 2030

Growing at a **CAGR of 13.10%** (2021-2030)



1. Consumer, Home appliance - 56% growth from 2020 to 2025
2. In-Cabin sensing - 72% growth from 2020 to 2025

In-Cabin Sensing Market



Source: Verified market research, Allied market reserach and Yole developpement website

Product with Richwave sensor

Home Appliance



Energy saving –
Presence detection with
distance information

Car Security



When it detects an event, such as a
bump, break-in, tow-away or an
attempt to open the door.

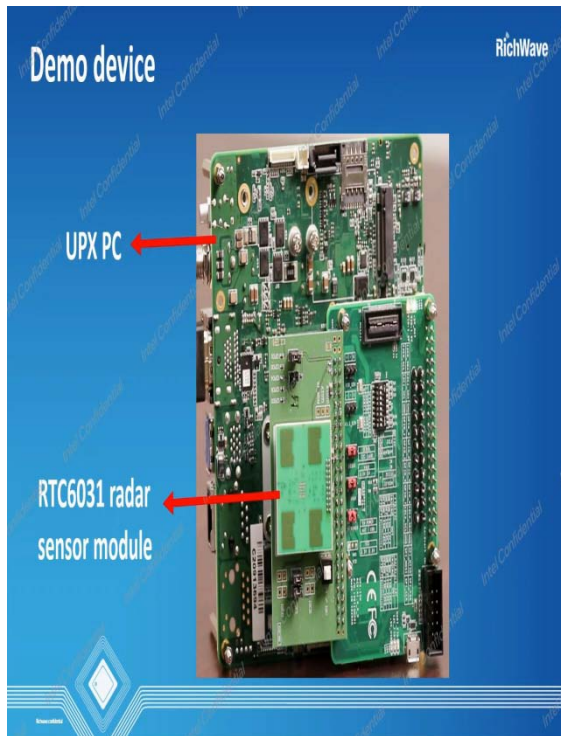
Smart Lighting



RichWave

More projects on-going with partners (Video)

NB Application



- RichWave UWB sensor driver ready to support Intel sensor hub

Level Detection



More project on-going with Partners

Presence Detection



採用雷達技術，新款Nest Thermostat藉由感測是否有人靠近，並且喚醒裝置顯示當前溫度，



ACCURATE RADAR SENSE
精準微波掀蓋/人體感應
便蓋自動開啟/關閉

精準微波技術，將微波回波訊號轉化為電信號，準確的感知動作，實現厘米級的辨識。如輕微手指揮動，即能感知，相比常規技術更精確感知並辨識出人過來、人存在、人離開的狀態，實現來去皆自如。

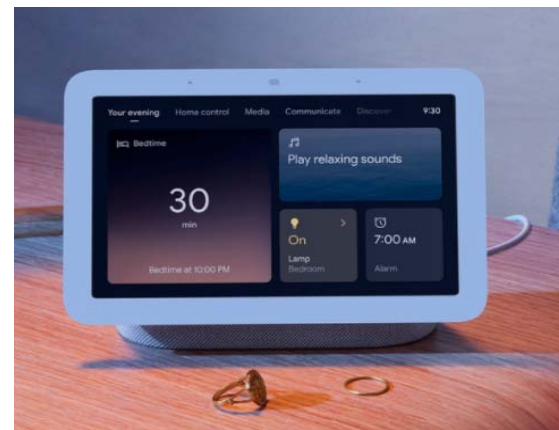
RADAR SENSE
微波掀蓋/人體感應
便蓋自動開啟/關閉

感知人過來、人存在、人離開的狀態，自動開啟與關閉便蓋，實現來去皆自如。離座後自動沖水。

Vital Sensing



Column: Amazon wants to use radar so
Alexa can watch as you sleep

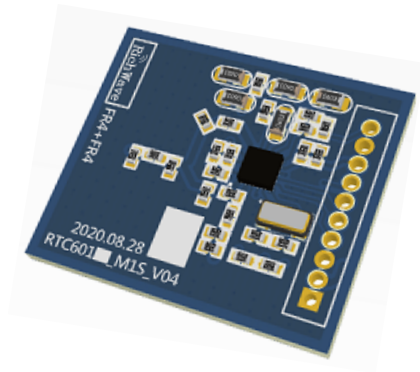


Google 新一代的 Nest Hub 能靠雷達
來記錄你的睡眠狀態

*FCC issued approval

RichWave Microwave Sensor Roadmap

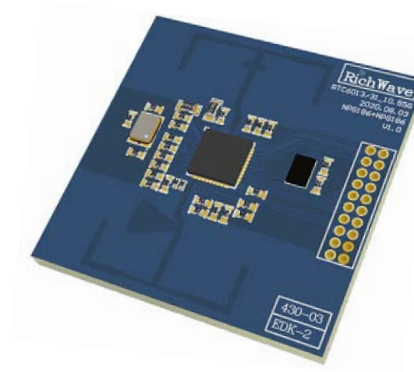
2020



5.8GHz Sensor
(RTC6012)

- QFN2.2x2.2
- Single antenna
- Very low operation current (50uA)
- Motion detection

2021



UWB Radar Sensor
(RTC6013/6022/6031)

- QFN 5x5
- 1 TX antenna, 1 RX antenna
- DSP with Algorithm
- Motion + Range detection

2022



60GHz mmWave Sensor (AiP)



Global UWB Radar Sensor
(1T2R,AoA) 

2D Dynamic Tracking Demo



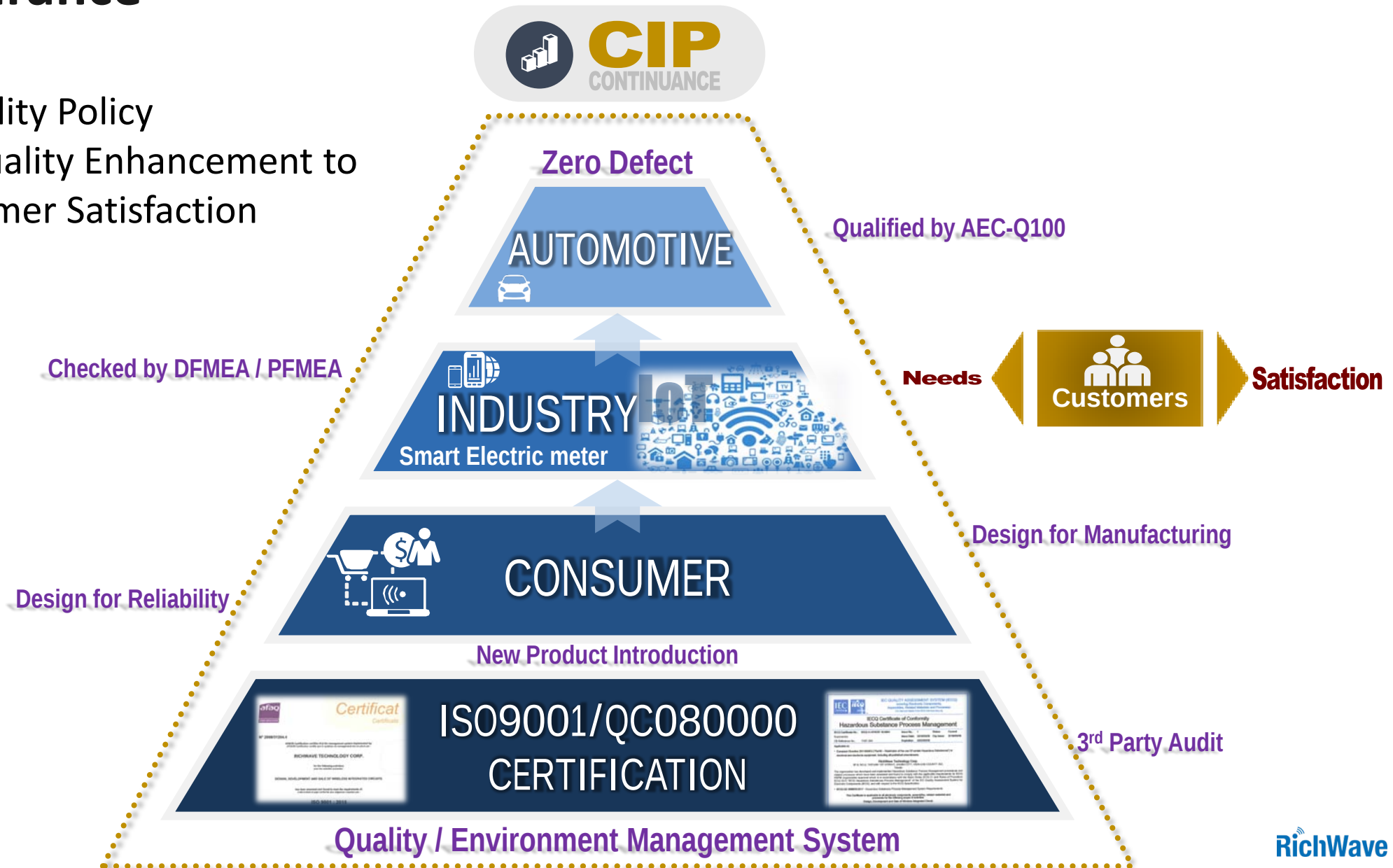
Quality and Production

TS Liou

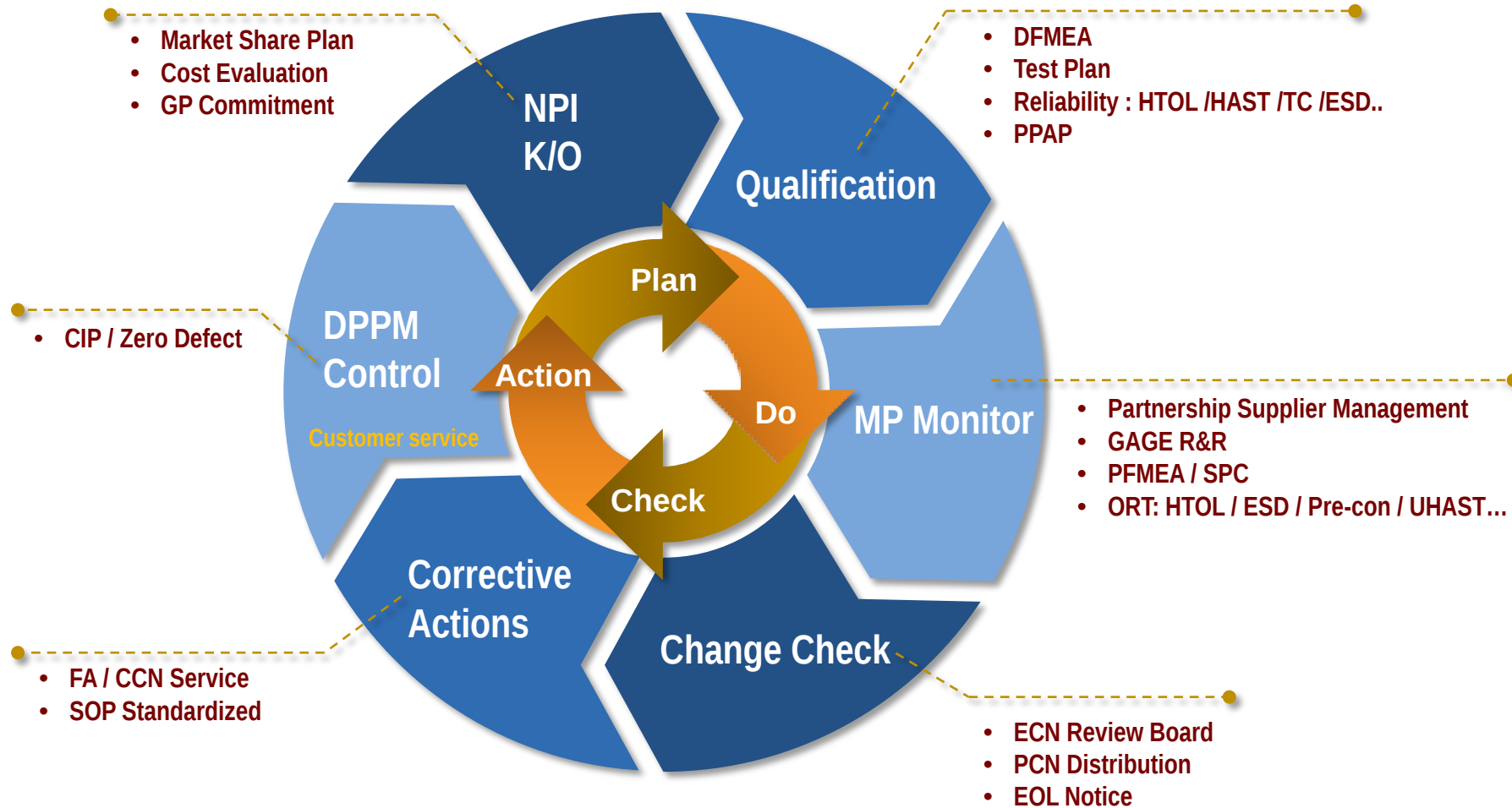
Dec. 2021

Quality Assurance

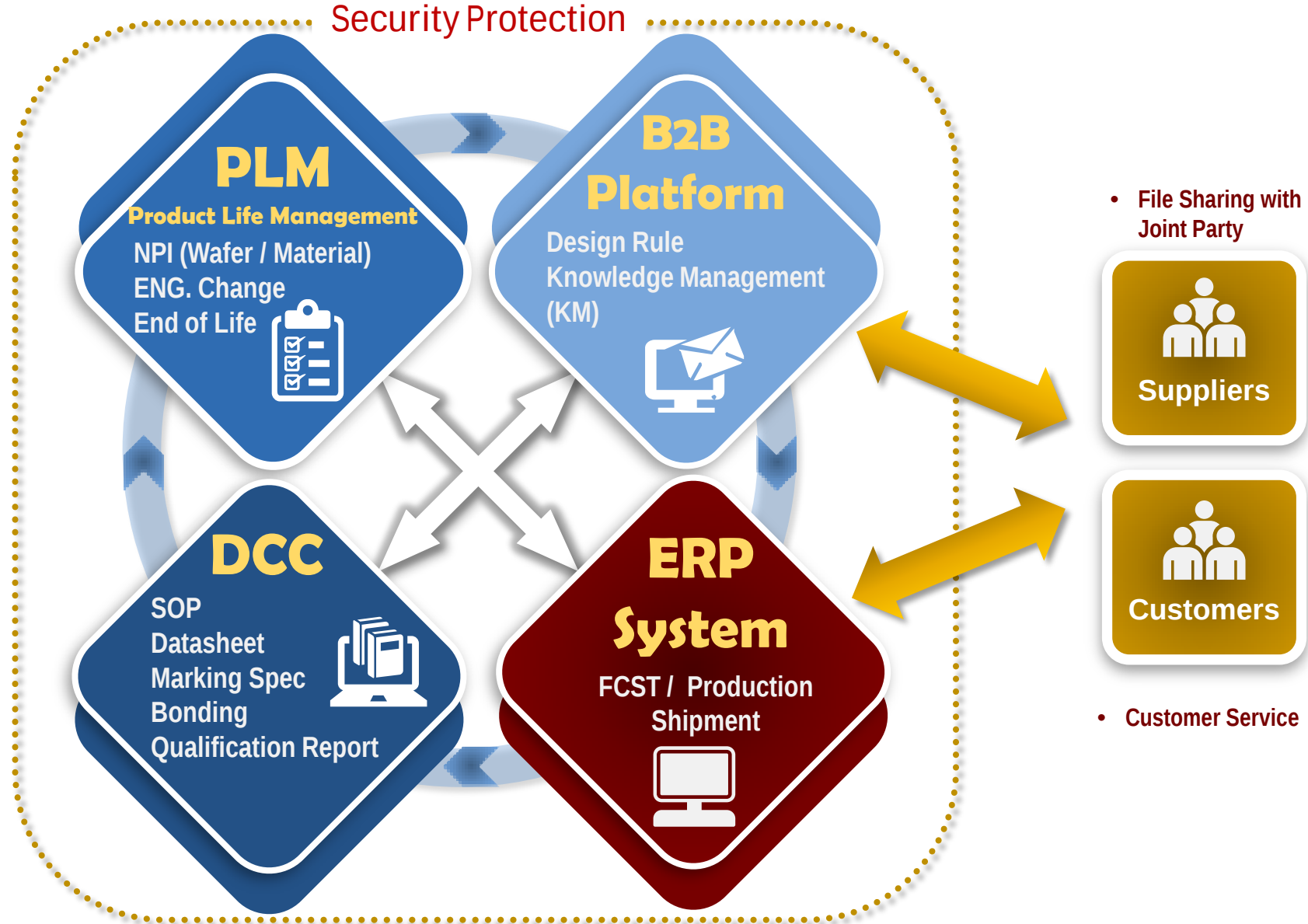
- RichWave Quality Policy
Continuous Quality Enhancement to
Achieve Customer Satisfaction



PDCA Oriented Quality Management System



Good Efficiency and Protection for Quality Guarantee



Process / Material / Package Roadmap

	2021		2022	
Active-TX	PA	PA	PA	PA
	- GaAs - SiGe	- GaAs - SiGe	- GaAs - SiGe - GaN	- GaAs - SiGe - GaN
Active-RX				
	- GaAs - CMOS/SOI	- GaAs - CMOS/SOI	- CMOS/SOI - GaAs	- CMOS/SOI - GaAs
Passive				
	- IPD - SAW	- IPD - SAW - BAW	- IPD/wafer & Substrate type - SAW - BAW	
Package				
	- QFN / DFN (thin) - LGA + CSP - WLCSP	- QFN / DFN (thin) - LGA + CSP - WLCSP	- QFN / DFN (thin) - LGA + CSP (thin) - AiP/AoP - WLCSP	- QFN / DFN (thin) - LGA + CSP (thin) - AiP/AoP - WLCSP

Testing Roadmap

2021



NI PXI



NI STS T1



NI STS T4

2022

Flexibility & Compliance

SoC and Wi-Fi 6E/7 (Low EVM noise floor)

Radar Sensors

Industrial, Automotive Certification

Advance Testing Platform

SG9000, GS I2C, NI STS T4, RedDragon

Low/High temperature characterization

High Quality & High Efficiency Cost Competiveness

Dual/Quad-site production



Cohu



ESG - Supply Chain Management

- During recent years, in addition to Revenue and Profit, RichWave has paid more attention to sustainability goals and strengthened three sustainable management capabilities, including environmental sustainability (Environment) 、 social responsibility (Social) and corporate governance (Governance). A Sustainable Project Team was established this year, the Quality Assurance Department of the Supplier Cooperation Unit is responsible for monitoring the environmental protection, occupational safety and health, labor and human rights of the supply chain to ensure compliance with legal requirements and fulfill social responsibilities. In 2021, RichWave conducted a comprehensive audit of 23 major suppliers focusing on three major supply chains including wafers, packaging, and testing, with an audit coverage rate of 100%, and found the suppliers who has completed our audits are facing the challenge of ESG positively and aggressively.



Thank you

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www.richwave.com.tw



2021, 2022 China Carrier Business Brief

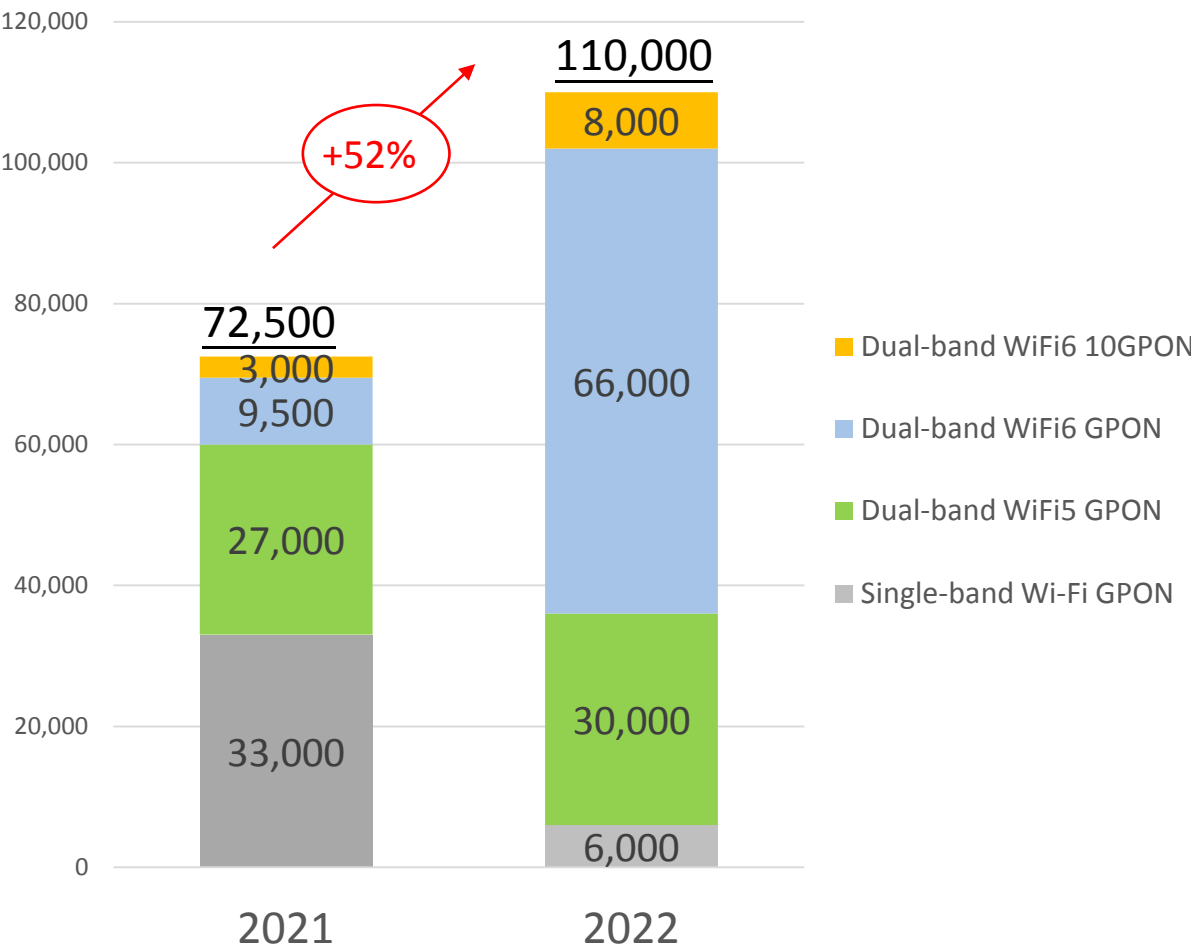
Kick Huang

Dec. 2021

China Gateway Tender Market

Unit: (000s)

Spec	2021	2022	YoY
Single-band Wi-Fi GPON	33,000	6,000	-82%
Dual-band WiFi5 GPON	27,000	30,000	11%
Dual-band WiFi6 GPON	9,500	66,000	595%
Dual-band WiFi6 10GPON	3,000	8,000	167%
Total	72,500	110,000	52%





Thank you

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