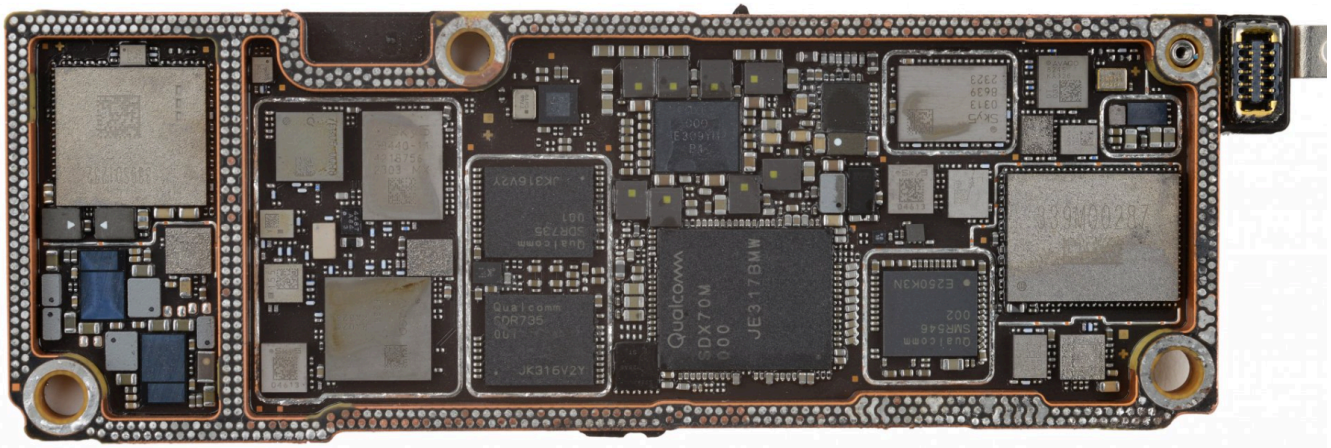
U.S. Patent No. 7,924,802 ("'802 Patent")

Accused Instrumentalities: cellular user equipment (UE) that supports 3GPP carrier aggregation and/or dual connectivity (e.g. EN-DC and NR-DC), including without limitation Apple's iPhone 12, iPhone 12 mini, iPhone 13, iPhone 13 mini, iPhone 13 Pro, iPhone 13 Pro Max, iPhone 14, iPhone 14 Plus, iPhone 14 Pro, iPhone 14 Pro Max, iPhone 15, iPhone 15 Plus, iPhone 15 Pro, iPhone 15 Pro Max, iPhone 16, iPhone 16 Plus, iPhone 16 Pro, iPhone 16 Pro Max, iPhone SE (3rd Gen.), iPad, iPad Air, iPad Mini, and iPad Pro.

Claim 1

Claim 1	Accused Instrumentalities
[1.0] A method of transmitting information in a wireless communication channel comprising:	To the extent the preamble is found to be limiting, the Accused Instrumentalities perform a method of transmitting information in a wireless communication channel. For example, the iPhone 15 supports 3GPP 5G uplink carrier aggregation, and Defendant's customers use the carrier aggregation functionalities of the iPhone 15. For another example, the iPhone 15 supports 3GPP dual connectivity, and Defendant's customers use the dual connectivity functionalities. *See, e.g.*: (https://www.apple.com/iphone-15/specs/)

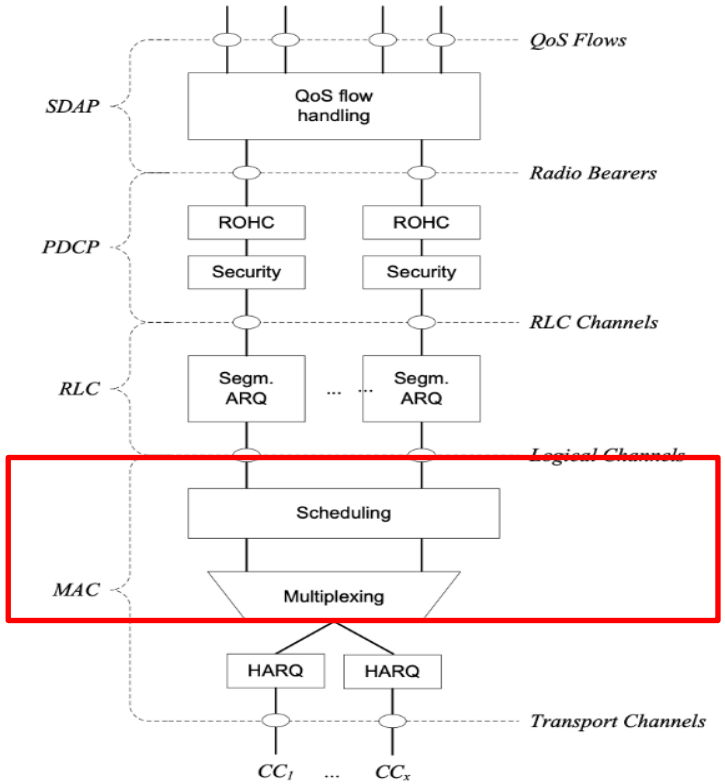
Claim 1	Accused Instrumentalities
	Cellular and Wireless — **Model A2846*** / **Model A2847*** — 5G NR (Bands n1, n2, n3, n5, n7, n8, n12, n14, n20, n25, n26, n28, n29, n30, n38, n40, n41, n48, n53, n66, n70, n71, n75, n76, n77, n78, n79) 5G NR mmWave (Bands n258, n260, n261) FDD-LTE (Bands 1, 2, 3, 4, 5, 7, 8, 12, 13, 14, 17, 18, 19, 20, 25, 26, 28, 29, 30, 32, 66, 71) TD-LTE (Bands 34, 38, 39, 40, 41, 42, 46, 48, 53) UMTS/HSPA+/DC-HSDPA (850, 900, 1700/2100, 1900, 2100 MHz) GSM/EDGE (850, 900, 1800, 1900 MHz) **All models** — 5G (sub-6 GHz and mmWave) with 4x4 MIMO[10] Gigabit LTE with 4x4 MIMO and LAA[10] Wi-Fi 6 (802.11ax) with 2x2 MIMO Bluetooth 5.3 Second-generation Ultra Wideband chip[11] NFC with reader mode Express Cards with power reserve (https://www.apple.com/iphone-15/specs/)

Claim 1	Accused Instrumentalities
	 Sure enough, once we separated the main boards, we can confirm that Apple is using Qualcomm's high end Snapdragon X70 modem. According to Qualcomm, it's powered by AI for beam management and antenna tuning. AI and 5G? We've heard that before! Alas 8K is nowhere to be seen. (https://www.ifixit.com/News/82867/iphone-15-teardown-reveals-software-lockdown)

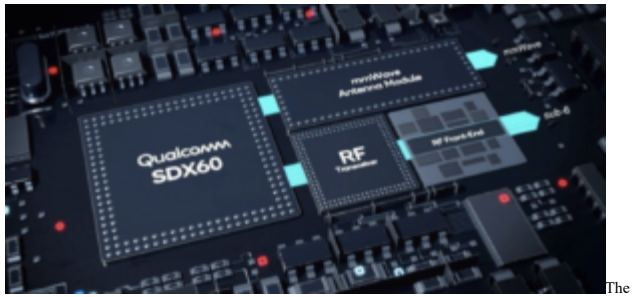
Claim 1	Accused Instrumentalities
	• 3GPP Release 16 support with up to 60% improved power efficiency • Qualcomm 5G Ultra-Low Latency Suite • 5G mmWave-sub6 aggregation • 5G mmWave Stand Alone • 5G global multiSIM including Dual-SIM Dual-Active and mmWave support • mmWave multi-SIM • Comprehensive 4x Carrier Aggregation (CA) support across FDD and TDD (https://www.qualcomm.com/products/technology/modems/snapdragon-x70-modem-rf-system)

Claim 1	Accused Instrumentalities
	Unmatched data speeds, coverage, and latency Snapdragon X70, our 5th generation modem-to-antenna 5G solution, inherits the unrivalled 10 Gigabit 5G peak download speed and packs in new, advanced capabilities such as 5G AI Processor, Qualcomm 5G Ultra-Low Latency Suite and 4X carrier aggregation to achieve unmatched data speeds, coverage, signal quality, and low latency. (https://www.qualcomm.com/products/technology/modems/snapdragon-x70-modem-rf-system) 5.4 Carrier aggregation 5.4.1 Carrier aggregation In Carrier Aggregation (CA), two or more Component Carriers (CCs) are aggregated. A UE may simultaneously receive or transmit on one or multiple CCs depending on its capabilities: - A UE with single timing advance capability for CA can simultaneously receive and/or transmit on multiple CCs corresponding to multiple serving cells sharing the same timing advance (multiple serving cells grouped in one TAG);

Claim 1	Accused Instrumentalities
	- A UE with multiple timing advance capability for CA can simultaneously receive and/or transmit on multiple CCs corresponding to multiple serving cells with different timing advances (multiple serving cells grouped in multiple TAGs). NG-RAN ensures that each TAG contains at least one serving cell; - A non-CA capable UE can receive on a single CC and transmit on a single CC corresponding to one serving cell only (one serving cell in one TAG). CA is supported for both contiguous and non-contiguous CCs. When CA is deployed frame timing and SFN are aligned across cells that can be aggregated, or an offset in multiples of slots between the PCell/PSCell and an SCell is configured to the UE. The maximum number of configured CCs for a UE is 16 for DL and 16 for UL. (3GPP TS 38.300 V17.4.0) ## 6.7 Carrier Aggregation In case of CA, the multi-carrier nature of the physical layer is only exposed to the MAC layer for which one HARQ entity is required per serving cell as depicted on Figures 6.7-1 and 6.7-2 below: - In both uplink and downlink, there is one independent hybrid-ARQ entity per serving cell and one transport block is generated per assignment/grant per serving cell in the absence of spatial multiplexing. Each transport block and its potential HARQ retransmissions are mapped to a single serving cell. (3GPP TS 38.300 V17.4.0)

Claim 1	Accused Instrumentalities
	 **Figure 6.7-2: Layer 2 Structure for UL with CA configured** (3GPP TS 38.300 V17.4.0)

THE BIG FEATURE: ENHANCED 5G CARRIER AGGREGATION ON IPHONE 13



The Qualcomm X60 is the first 5G modem capable of combining different types of 5G signals together.

The additional 5G bands are actually not the biggest cellular change with the iPhone 13.

Assuming the speculation proves true and Apple is indeed using the Qualcomm X60 modem - the real key cellular feature of the iPhone 13 is support for enhanced 5G carrier aggregation.

In addition to being much more power efficient, the big jump between the X55 and X60 modems revolves around improved 5G carrier aggregation - allowing the modem to better combine multiple signals on different frequency bands.

To get deeper into the nitty gritty of why this is (and why we've encouraged many to consider waiting for the X60), see our featured story from June 2021:

5G Industry Update: 5G Routers, Hotspots & Antennas Are Here – But Should You Wait?

In a nutshell - the X60 is just more adept at combining long range and short range 5G signals.

For example, the X60 can combine super short range mmWave with longer range mid-band or low-band 5G, helping to compensate for mmWave's range limitations.

A more specific example: the X60 will allow T-Mobile's long-range low-band band n71 and super-fast mid-band n41 to be used by the modem simultaneously. This will give many T-Mobile customers the range of n71, without sacrificing the speed of n41.

And another example - Verizon or AT&T will be able to combine their upcoming C-Band deployments (n77) with their longer range Sub-6 GHz 5G signals in ways that the X55 is just not capable of.
(https://www.rvmobileinternet.com/apples-fall-2021-cellular-updates-new-iphone-13-modem-analysis-ipad-mini-goes-5g/#The_Big_Feature_Enhanced_5G_Carrier_Aggregation_on_iPhone_13)

Verizon, T-Mobile Advance 5G Strategy with CBRS, Carrier Aggregation

Moves

Posted on June 14, 2022 1:23pm by Joan Engebretson

The highly competitive nature of the U.S. mobile wireless business continues as Verizon announced today that it is deploying 5G in the CBRS spectrum band and T-Mobile said it achieved speeds above 3 Gbps on a production network using 5G carrier aggregation.

Verizon 5G in CBRS Band

Verizon said it worked with Ericsson to complete a 5G data session using CBRS General Authorized Access (GAA) spectrum, which is mid-band spectrum that is essentially available on an unlicensed basis. The company will be able to use the spectrum to augment the licensed spectrum that it has in the same band. Verizon was a big winner in the CBRS auction of 2020.

Verizon's plan is to use CBRS spectrum for Ultra Wideband 5G, which is the term the company uses for the higher-speed 5G service that it has deployed using millimeter wave spectrum and in the company's C-band spectrum, which is considered mid-band.

The latest CBRS test paves the way for Verizon to deploy 5G in the band, said Kyle Malady, Verizon EVP and president of Global Networks and Technology, in a press release.

Deploying 5G in the CBRS band "further strengthens our already robust spectrum portfolio and will lead to an even better customer experience when using Verizon 5G Ultra Wideband," he said.

T-Mobile 5G Carrier Aggregation

T-Mobile said its 5G carrier aggregation achievement was only possible using the company's standalone 5G network.

The company merged three channels of mid-band spectrum – two channels in the 2.5 GHz band and one channel of 1900 MHz spectrum – to create what was essentially a single 210 MHz channel. The test used a Samsung Galaxy S22 device powered by Snapdragon 8 Gen 1 Mobile Platform with Snapdragon X65 Modem-RF System.

In a press release, T-Mobile said it already uses carrier aggregation to combine two 2.5 GHz 5G channels for "greater speeds, performance and capacity." The company expects to begin adding a third 1900 MHz 5G channel later this year.

Initially customers will require the Samsung Galaxy S22 to get the benefits of three-carrier 5G aggregation but later this year, T-Mobile expects additional devices to support that capability.

(Verizon, T-Mobile Advance 5G Strategy with CBRS, Carrier Aggregation Moves (telecompetitor.com))

T-Mobile, Ericsson, Qualcomm Report Record 5G Uplink Speeds

By George Winslow published November 6, 2024

They leveraged 5G Dual Connectivity to combine mid-band spectrum with mmWave, reaching peak uplink speeds over 2.2 Gbps

BELLEVUE, Wash.—T-Mobile said that working with Ericsson and Qualcomm Technologies, it has broken another world record with its 5G standalone (SA) network reaching peak uplink speeds of over 2.2 Gigabits per second.

The test is an important development for broadcast crews needing fast uplink speeds to send content from sports venues, T-Mobile said.

The speeds were achieved by leveraging an emerging feature called New Radio Dual Connectivity (5G DC). With 5G DC, T-Mobile was able to massively increase uplink throughput and capacity, reaching peak speeds of 2.2 Gbps in a demo that demonstrates the technology's potential to create serious efficiencies in how data is transmitted from devices to the network, the companies said.

5G DC enabled T-Mobile to aggregate 2.5 GHz and mmWave spectrum, allowing for a massive improvement in uplink throughput and capacity. In this test, T-Mobile was able to allocate 60% of the mmWave radio resources for uplink, whereas previous use cases typically allowed up to 20%. The test was completed on T-Mobile's 5G SA production network in SoFi Stadium in Inglewood, California, with equipment and 5G DC solution from Ericsson and a mobile test smartphone powered by a flagship Snapdragon X80 5G Modem-RF System from Qualcomm.

"With 5G DC, T-Mobile is pushing the boundaries of what's possible to create better experiences in the places that matter most to our customers," T-Mobile President of Technology Ulf Ewaldsson said. "This accomplishment is a testament to the network we've built over the last five years and our ability to deliver unparalleled capabilities that extend beyond the devices in our pockets."

Download speeds typically reign as the top network performance metric, but with recent strides in uplink capabilities and increasingly demanding tasks, upload speed is becoming more important than ever, especially for live events, mobile gaming and extended reality applications, the companies said.

Because of this, SoFi Stadium served as the perfect test site for 5G DC. Every year, millions of people flock to the stadium for football games or to catch their favorite artists in concert. Naturally, all these people want to post, livestream and share their experiences in real time, which can sometimes be a challenge at crowded events with limited capacity.

(T-Mobile, Ericsson, Qualcomm Report Record 5G Uplink Speeds | TV Tech (tvtechnology.com))

April 18, 2023

Taking 5G to the Next Level with Standalone 5G

By Jason Sikes, AVP Device Architecture

Claim 1	Accused Instrumentalities
	AT&T Labs makes industry-first 5G SA Uplink 2-CA data connection in the U.S. to improve upload speeds, with additional speed and other upgrades in the works AT&T is architecting tomorrow's wireless network to ***connect people to greater possibility***. As engineers, we design, build, test, refine and repeat so that you can get more out of your 5G connection and developers can build and deploy the next generation of apps and services. A key part of this evolution is the critical transition phase we are entering in scaling from 5G non-standalone (NSA) to 5G standalone (SA). **How does Standalone take 5G to the next level?** Unlike 5G NSA that still relies on a 4G LTE core, 5G SA uses a dedicated 5G core that can unlock capabilities like faster upload speeds, ultra-low latency, ultra-high reliability and edge functions. This technology will be key to business opportunities like the next generation of connected cars. We have said that we plan to deploy Standalone 5G when the ecosystem is ready, and AT&T is charging forward to advance SA ecosystem readiness. Businesses and developers will be some of the first to take advantage of the new technologies standalone 5G enables as we continue to move from research & development to their deployment. **Uplink: where challenge meets opportunity** This new age of connectivity is not only about consuming more content but also generating more content than ever before. Demand for uplink capacity and speed continues to increase, about 30% a year in AT&T's mobility network. Whether you are uploading large files, on a video call with family, live streaming, cloud gaming or using extended reality applications, the network is facing surging upstream traffic demands it never has before. Our latest network innovations are complex but are all about helping meet this new demand. Just a few weeks ago, we completed the **first 5G SA Uplink 2-carrier aggregation data call in the U.S.** Carrier aggregation (CA) means we are combining or "aggregating" different frequency bands to give you more bandwidth and capacity. For you, this means faster uplink transmission speeds. *Think of this as adding more lanes in the network traffic highway.* No one in the U.S market has successfully aggregated two carriers in 5G SA uplink – until now. This is part of our ongoing effort to provide greater reliability for our customers. The test was conducted in our labs with Nokia's 5G AirScale portfolio and MediaTek's 5G M80 mobile test platform. We aggregated our low-band n5 and our mid-band n77 spectrum. Compared to our low-band n5 alone, we saw a 100% increase in uplink throughput by aggregating our low-band n5 with 40MHz of our mid-band n77. Taking it a step further, we achieved a 250% increase aggregating 100MHz of n77. The bottom line? We achieved incredible upload speeds of over 70 Mbps on n5 with 40MHz of n77 and over 120 Mbps on n5 with 100MHz of n77. While carrier aggregation is like adding more traffic lanes in the highway, adding another vehicle to carry traffic is another way we are managing surging uplink demand. We are doing this via a **two-layer uplink MIMO** on time division duplex (TDD) in our mid-band

Claim 1	Accused Instrumentalities
	n77. MIMO combines signals and data streams from multiple antennas ("vehicles") to improve signal quality and data rates. This feature will not only improve uplink throughput but also enhance cell capacity and spectrum efficiency. **Network design and device readiness go hand in hand** Although we continue to make progress in enhancing uplink coverage, we haven't forgotten about the downlink. Enhanced downlink and uplink carrier aggregation capabilities work together to bring the 5G SA performance today's technologies need. Last fall, we completed a **5G SA four component carrier downlink** call by combining two FDD carriers and two TDD carriers. These capabilities allow AT&T devices to aggregate our mid-band n77 in the C-Band and 3.45GHz spectrum ranges. Compared with low band and mmWave spectrum, mid-band n77 provides a good balance between coverage and speed. This follows the **5G SA three component carrier downlink feature** that we introduced last year to 2022 AT&T Flagship devices which combines one frequency division duplex (FDD) carrier and two TDD carriers. In the coming months, AT&T will also enable **5G New Radio Dual Connectivity (NR-DC)**, aggregating our low and mid-band spectrum with our high-band mmWave spectrum on 5G SA. Our labs have achieved 5G NR-DC downlink throughput speeds of up to 5.3Gbps and uplink throughput speeds of up to 670Mbps. This technology will help provide high-speed mobile broadband for both downlink and uplink in stadiums, airports, and other high-density venues. (AT&T is Taking 5G to the Next Level with Standalone 5G (att.com)) **T-Mobile Supercharges 5G Standalone Uplink Speeds with Carrier Aggregation First** **BELLEVUE, Wash. — May 4, 2023** **What's the news:** T-Mobile worked with Nokia and Qualcomm to reach uplink speeds topping 200 Mbps in a 5G data call leveraging uplink carrier aggregation – the first-ever on a live commercial 5G standalone network in the U.S. **Why it matters:** Increased uplink speeds allow greater amounts of data to be transmitted from customer devices at a quicker rate, enhancing applications like video livestreaming/calling, gaming and Extended Reality (XR). **Who it's for: T-Mobile T-Mobile Hits Nearly 5 Gbps with Another 5G First** 5G customers nationwide.

Claim 1	Accused Instrumentalities
	Speed … UP! T-Mobile (NASDAQ: TMUS) announced today it achieved another 5G U.S. first by leveraging uplink (UL) carrier aggregation in the field on the country's only nationwide 5G standalone (SA) network. Working with Nokia and a test smartphone powered by Snapdragon® 5G Modem-RF System from Qualcomm Technologies, Inc., the Un-carrier hit a top UL speed of 207 Mbps in the test – the ***fastest ever*** recorded using sub-6 GHz spectrum! This comes just weeks after T-Mobile made the same move in the lab, hitting similar speeds. "T-Mobile has led the industry with 5G standalone since 2020, and we're continuing to drive breakthroughs that advance 5G technology around the globe," said Ulf Ewaldsson, President of Technology at T-Mobile. "We're building the most advanced 5G network in the world, opening the door for massive innovation and laying the foundation for new capabilities that will transform the world around us." 5G carrier aggregation allows T-Mobile to combine multiple channels (or carriers) to deliver greater speed and performance. In this test, the Un-carrier merged two 5G channels of mid-band spectrum – 2.5 GHz Ultra Capacity 5G and 1900 MHz. That's like taking two separate highways and turning them into a superhighway where traffic can zoom faster than before. Customers with compatible devices will begin taking advantage of UL 5G carrier aggregation early next year when T-Mobile begins rolling it out. This is just the latest in a series of important 5G SA milestones for T-Mobile. The Un-carrier was the first in the world to launch a nationwide 5G SA network in 2020 – one that remains the ONLY nationwide 5G SA network in the U.S. Since then, T-Mobile has been driving toward a true 5G-only experience for customers by spearheading advancements like carrier aggregation and VoNR. T-Mobile is the leader in 5G, delivering the country's largest, fastest and most awarded 5G network. The Un-carrier's 5G network covers 326 million people across 2 million square miles – more than AT&T and Verizon combined. 275 million people nationwide are covered by T-Mobile's super-fast Ultra Capacity 5G, and the Un-carrier plans to reach 300 million people with Ultra Capacity – nearly everyone in the country – this year. (T-Mobile Supercharges 5G Standalone Uplink Speeds with Carrier Aggregation First - T-Mobile Newsroom (t-mobile.com)) **T-Mobile Hits Nearly 5 Gbps with Another 5G First** November 04, 2021 In first-ever New Radio Dual Connectivity call on a Standalone 5G network, the Un-carrier hit speeds of 4950 Mbps Standalone 5G is the future of wireless, and we are leading the charge! T-Mobile recently pulled off the world's first 5G standalone (SA) New Radio Dual Connectivity (NR DC) data call on a commercial network. If you need help translating all that (this writer sure did), it means we combined the power of 2.5 GHz spectrum (n41) with millimeter wave (n260) to boost download speeds to nearly 5 Gbps (mind-blowing fast – like download an HD movie in the blink of an eye fast)! Our team made it all happen on the only nationwide commercial SA 5G network in the U.S. This is just the latest in a series of 5G firsts. Among them, last year, we launched the first nationwide SA 5G network in the world. With this industry-leading network, we are paving the way for supercharged applications that require super-fast speeds, real-time responses, and massive connectivity. SA, especially when coupled with core network slicing in the future, will lead to an environment where transformative applications are made possible — things like connected self-driving vehicles, supercharged IoT, real-time translation … and things we haven't even dreamed of yet.

Claim 1	Accused Instrumentalities
	T-Mobile is the leader in 5G with the country's largest and fastest nationwide 5G network, covering 308 million people across 1.7 million square miles. 190 million of those people are covered by Ultra Capacity 5G, which can deliver blazing-fast speeds to more people than any other provider. Ultra Capacity 5G is widely available today, and we are on track to deploy it nationwide, covering 200 million people by the end of this year.

(T-Mobile Hits Nearly 5 Gbps with Another 5G First - T-Mobile Newsroom (t-mobile.com))

Snapdragon® X70 5G Modem-RF System

Features

- Qualcomm® 5G AI Suite includes
  - AI-based channel state feedback and optimization
  - AI-based mmWave beam management
  - AI-based network selection
  - AI-based Signal Boost adaptive antenna tuning
- 3GPP Release 16 support with up to 60%[2] improved power efficiency
- Qualcomm® 5G Ultra-Low Latency Suite
- 5G mmWave-sub6 aggregation
- 5G mmWave Stand Alone
- mmWave multi-SIM
- Comprehensive 4x Carrier Aggregation (CA) support across FDD and TDD
- Switched uplink (FDD-TDD switching in SA mode)
- Advanced power-saving tech
  - Qualcomm® 5G PowerSave Gen 3
  - Qualcomm® QET7100 Wideband Envelope Tracking
- Voice over NR support

Specifications

- 5G Chipset: Snapdragon X70 Modem-RF System
- 5G Spectrum: mmWave-sub6 aggregation, sub-6 carrier aggregation (FDD-TDD, FDD-FDD, TDD-TDD), FDD-TDD support for uplink-CA, Dynamic Spectrum Sharing (DSS)
- 5G Modes: FDD, TDD, SA (standalone), NSA (non-standalone)
- Up to 8CC aggregation in mmWave, up to 4CC aggregation in 5G sub-6GHz
- 8 carriers (mmWave), 800 MHz bandwidth (mmWave), 300 MHz bandwidth (sub-6 GHz)
- 5G Peak Download Speed: 10 Gbps
- 5G Peak Upload Speed: 3.5 Gbps
- 5G global multiSIM including Dual-SIM Dual-Active support
- Cellular Technology: 5G NR, LTE, LAA, WCDMA, GSM / Edge, CBRS, Dynamic Spectrum Sharing (DSS), EN-DC, NR-DC, mmWave, sub-6 GHz

(https://docs.qualcomm.com/bundle/publicresource/87-77347-1_REV_B_Snapdragon_X70_5G_Modem-RF_System_Product_Brief.pdf)

5.4 Carrier aggregation

5.4.1 Carrier aggregation

In Carrier Aggregation (CA), two or more Component Carriers (CCs) are aggregated. A UE may simultaneously receive or transmit on one or multiple CCs depending on its capabilities:

- A UE with single timing advance capability for CA can simultaneously receive and/or transmit on multiple CCs corresponding to multiple serving cells sharing the same timing advance (multiple serving cells grouped in one TAG);
- A UE with multiple timing advance capability for CA can simultaneously receive and/or transmit on multiple CCs corresponding to multiple serving cells with different timing advances (multiple serving cells grouped in multiple TAGs). NG-RAN ensures that each TAG contains at least one serving cell;
- A non-CA capable UE can receive on a single CC and transmit on a single CC corresponding to one serving cell only (one serving cell in one TAG).

CA is supported for both contiguous and non-contiguous CCs. When CA is deployed frame timing and SFN are aligned across cells that can be aggregated, or an offset in multiples of slots between the PCell/PSCell and an SCell is configured to the UE. The maximum number of configured CCs for a UE is 16 for DL and 16 for UL.

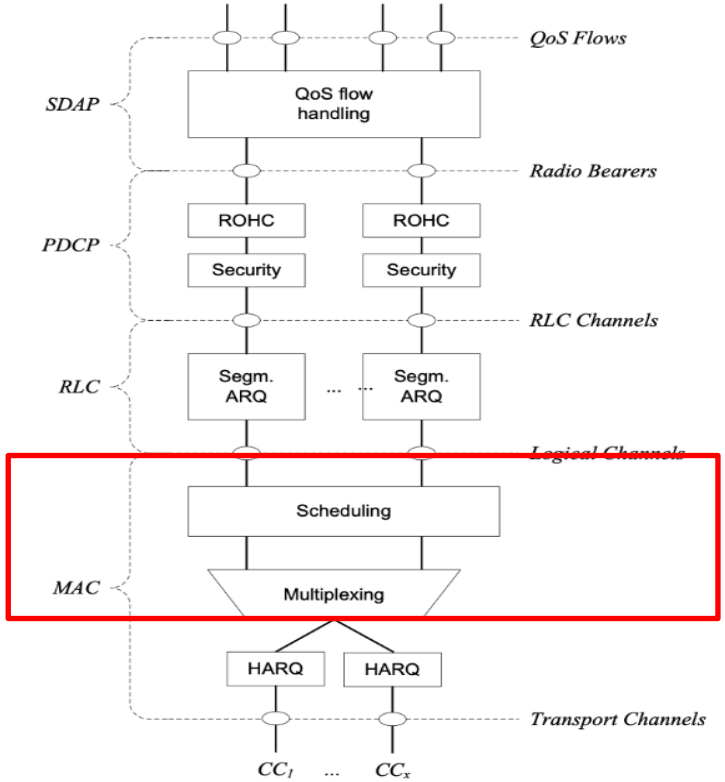
(3GPP TS 38.300 V17.4.0)

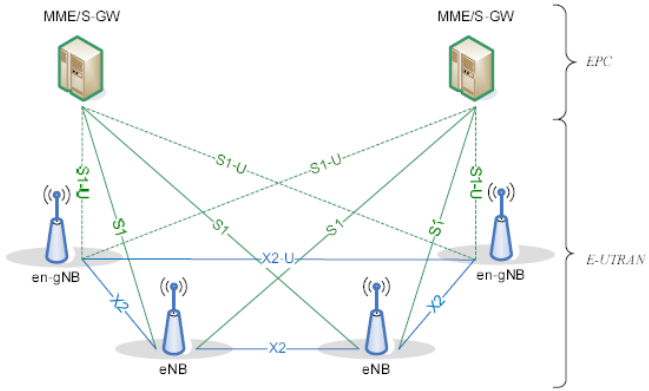
6.7 Carrier Aggregation

In case of CA, the multi-carrier nature of the physical layer is only exposed to the MAC layer for which one HARQ entity is required per serving cell as depicted on Figures 6.7-1 and 6.7-2 below:

- In both uplink and downlink, there is one independent hybrid-ARQ entity per serving cell and one transport block is generated per assignment/grant per serving cell in the absence of spatial multiplexing. Each transport block and its potential HARQ retransmissions are mapped to a single serving cell.

(3GPP TS 38.300 V17.4.0)

Claim 1	Accused Instrumentalities
	 **Figure 6.7-2: Layer 2 Structure for UL with CA configured** (3GPP TS 38.300 V17.4.0)

Claim 1	Accused Instrumentalities
	# 4 Multi-Radio Dual Connectivity ## 4.1 General ### 4.1.1 Common MR-DC principles Multi-Radio Dual Connectivity (MR-DC) is a generalization of the Intra-E-UTRA Dual Connectivity (DC) described in TS 36.300 [2], where a multiple Rx/Tx capable UE may be configured to utilise resources provided by two different nodes connected via non-ideal backhaul, one providing NR access and the other one providing either E-UTRA or NR access. One node acts as the MN and the other as the SN. The MN and SN are connected via a network interface and at least the MN is connected to the core network. The MN and/or the SN can be operated with shared spectrum channel access. All functions specified for a UE may be used for an IAB-MT unless otherwise stated. Similar as specified for UE, the IAB-MT can access the network using either one network node or using two different nodes with EN-DC and NR-DC architectures. In EN-DC, the backhauling traffic over the E-UTRA radio interface is not supported. NOTE 1: MR-DC is designed based on the assumption of non-ideal backhaul between the different nodes but can also be used in case of ideal backhaul. NOTE 2: All MR-DC normative text and procedures in this version of the specification show the aggregated node case. The details about non-aggregated node for MR-DC operation are described in TS 38.401 [7]. ### 4.1.2 MR-DC with the EPC E-UTRAN supports MR-DC via E-UTRA-NR Dual Connectivity (EN-DC), in which a UE is connected to one eNB that acts as a MN and one en-gNB that acts as a SN. The eNB is connected to the EPC via the S1 interface and to the en-gNB via the X2 interface. The en-gNB might also be connected to the EPC via the S1-U interface and other en-gNBs via the X2-U interface. The EN-DC architecture is illustrated in Figure 4.1.2-1 below.  **Figure 4.1.2-1: EN-DC Overall Architecture**

Claim 1	Accused Instrumentalities
	4.1.3 MR-DC with the 5GC **4.1.3.1 E-UTRA-NR Dual Connectivity** NG-RAN supports NG-RAN E-UTRA-NR Dual Connectivity (NGEN-DC), in which a UE is connected to one ng-eNB that acts as a MN and one gNB that acts as a SN. **4.1.3.2 NR-E-UTRA Dual Connectivity** NG-RAN supports NR-E-UTRA Dual Connectivity (NE-DC), in which a UE is connected to one gNB that acts as a MN and one ng-eNB that acts as a SN. **4.1.3.3 NR-NR Dual Connectivity** NG-RAN supports NR-NR Dual Connectivity (NR-DC), in which a UE is connected to one gNB that acts as a MN and another gNB that acts as a SN. In addition, NR-DC can also be used when a UE is connected to a single gNB, acting both as a MN and as a SN, and configuring both MCG and SCG. (TS 137 340 V16.5.0)
[1.1] transmitting first information across a first frequency range using a wireless transmitter, the first frequency range having a first center frequency, a first highest frequency, and a first lowest frequency; and	The Accused Instrumentalities perform a method including transmitting first information across a first frequency range using a wireless transmitter, the first frequency range having a first center frequency, a first highest frequency, and a first lowest frequency. For example, the iPhone 15 transmits uplink information on a first component carrier with a frequency range with a first center frequency (labeled $F_{C,low}$ in the excerpt from 3GPP TS 38.101 V17.9.0 below), first highest frequency (highlighted in red below), and first lowest frequency (highlighted in blue below). This applies in the cases of intra-band contiguous, intra-band non-contiguous, and inter-band CA. *See, e.g.*:

5.3 Uplink

5.3.1 Uplink transmission scheme

Two transmission schemes are supported for PUSCH: codebook based transmission and non-codebook based transmission.

For codebook based transmission, the gNB provides the UE with a transmit precoding matrix indication in the DCI. The UE uses the indication to select the PUSCH transmit precoder from the codebook. For non-codebook based transmission, the UE determines its PUSCH precoder based on wideband SRI field from the DCI.

A closed loop DMRS based spatial multiplexing is supported for PUSCH. For a given UE, up to 4 layer transmissions are supported. The number of code words is one. When transform precoding is used, only a single MIMO layer transmission is supported.

Transmission durations from 1 to 14 symbols in a slot is supported.

Aggregation of multiple slots with TB repetition is supported.

(3GPP TS 38.300 V17.4.0)

5.4 Carrier aggregation

5.4.1 Carrier aggregation

In Carrier Aggregation (CA), two or more Component Carriers (CCs) are aggregated. A UE may simultaneously receive or transmit on one or multiple CCs depending on its capabilities:

- A UE with single timing advance capability for CA can simultaneously receive and/or transmit on multiple CCs corresponding to multiple serving cells sharing the same timing advance (multiple serving cells grouped in one TAG);
- A UE with multiple timing advance capability for CA can simultaneously receive and/or transmit on multiple CCs corresponding to multiple serving cells with different timing advances (multiple serving cells grouped in multiple TAGs). NG-RAN ensures that each TAG contains at least one serving cell;
- A non-CA capable UE can receive on a single CC and transmit on a single CC corresponding to one serving cell only (one serving cell in one TAG).

CA is supported for both contiguous and non-contiguous CCs. When CA is deployed frame timing and SFN are aligned across cells that can be aggregated, or an offset in multiples of slots between the PCell/PSCell and an SCell is configured to the UE. The maximum number of configured CCs for a UE is 16 for DL and 16 for UL.

(3GPP TS 38.300 V17.4.0)

Cobblestone Wireless, LLC
Exhibit 2011, IPR2025-01497
Page 20 of 97

6.7 Carrier Aggregation

In case of CA, the multi-carrier nature of the physical layer is only exposed to the MAC layer for which one HARQ entity is required per serving cell as depicted on Figures 6.7-1 and 6.7-2 below:

- In both uplink and downlink, there is one independent hybrid-ARQ entity per serving cell and one transport block is generated per assignment/grant per serving cell in the absence of spatial multiplexing. Each transport block and its potential HARQ retransmissions are mapped to a single serving cell.

(3GPP TS 38.300 V17.4.0)

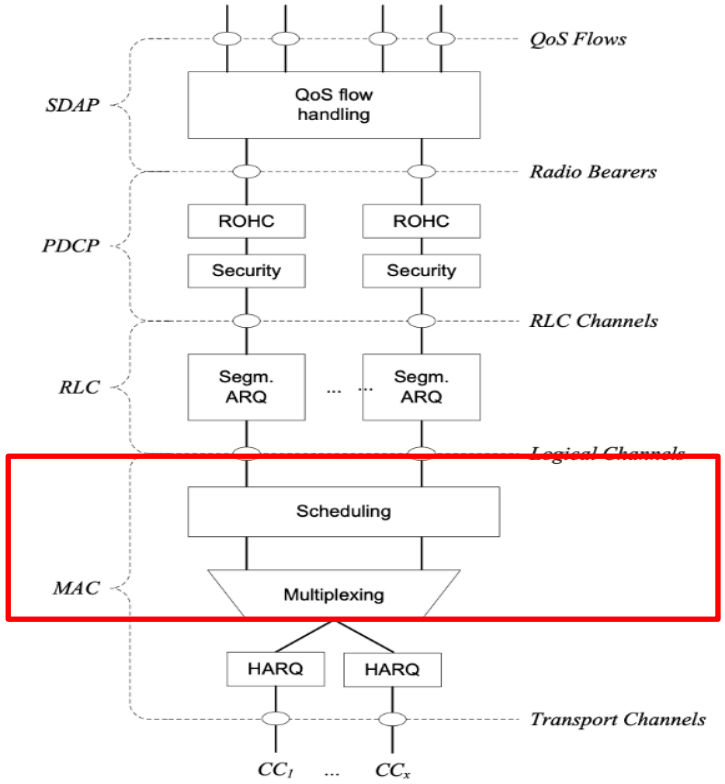


Figure 6.7-2: Layer 2 Structure for UL with CA configured

(3GPP TS 38.300 V17.4.0)

Claim 1	Accused Instrumentalities

5.3A.2 Maximum transmission bandwidth configuration for CA

For carrier aggregation, the maximum transmission bandwidth configuration is defined per component carrier and the requirement is specified in clause 5.3.2.

5.3A.3 Minimum guardband and transmission bandwidth configuration for CA

For intra-band contiguous carrier aggregation, *Aggregated Channel Bandwidth* and *Guard Bands* are defined as follows, see Figure 5.3A.3-1.

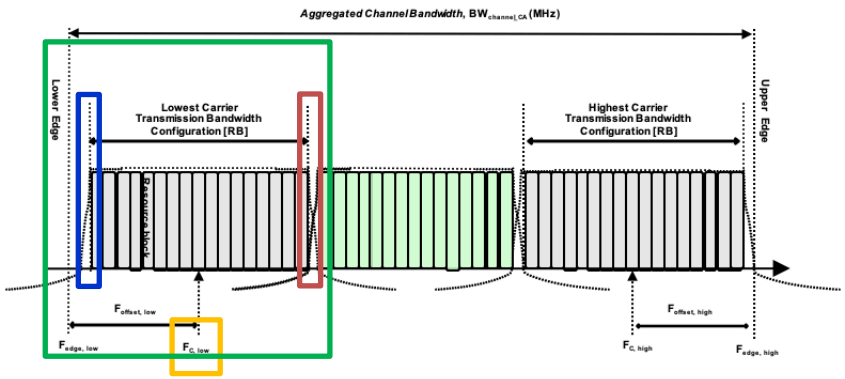


Figure 5.3A.3-1: Definition of *Aggregated Channel Bandwidth* for intra-band carrier aggregation

The *aggregated channel bandwidth*, $BW_{Channel\_CA}$, is defined as

$$BW_{Channel\_CA} = F_{edge,high} - F_{edge,low} \text{ (MHz)}.$$

The lower bandwidth edge $F_{edge,low}$ and the upper bandwidth edge $F_{edge,high}$ of the aggregated channel bandwidth are used as frequency reference points for transmitter and receiver requirements and are defined by

$$F_{edge,low} = F_{C,low} - F_{offset,low}$$

$$F_{edge,high} = F_{C,high} + F_{offset,high}$$

The lower and upper frequency offsets depend on the transmission bandwidth configurations of the lowest and highest assigned edge component carrier and are defined as

$$F_{offset,low} = (N_{RB,low}*12 + 1)*SCS_{low}/2 + BW_{GB} \text{ (MHz)}$$

$$F_{offset,high} = (N_{RB,high}*12 - 1)*SCS_{high}/2 + BW_{GB} \text{ (MHz)}$$

$$BW_{GB} = \max(BW_{GB,Channel(k)})$$

$N_{RB,low}$ and $N_{RB,high}$ are the transmission bandwidth configurations according to Table 5.3.2-1 for the lowest and highest assigned component carrier, SCS_{low} and SCS_{high} are the sub-carrier spacing for the lowest and highest assigned component carrier respectively. SCS_{low}, SCS_{high}, $N_{RB,low}$, $N_{RB,high}$, and $BW_{GB,Channel(k)}$ use the largest μ value among the subcarrier spacing configurations supported in the operating band for both of the channel bandwidths according to Table 5.3.5-1 and $BW_{GB,Channel(k)}$ is the minimum guard band for carrier k according to Table 5.3.3-1 for the said μ value.

In case there is no common μ value for both of the channel bandwidths, μ=1 is used for SCS_{low}, SCS_{high}, $N_{RB,low}$, $N_{RB,high}$ and $BW_{GB,Channel(k)}$.

Claim 1	Accused Instrumentalities

5.5A.1 Configurations for intra-band contiguous CA

Power class 3 is supported for all uplinks. Power classes other than power class 3 are supported as indicated in Table 5.5A.1-1.

Table 5.5A.1-1: NR CA configurations and bandwidth combination sets defined for intra-band contiguous CA

NR CA configuration / Bandwidth combination set								
NR CA configuration	Uplink CA configurations or single uplink carrier[5]	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Maximum aggregated bandwidth (MHz)	Bandwidth combination set
CA_n1B	-	10	10,15				40	0
		15	15,20					
		20	20					
CA_n2B	-	5	15				20	0
		10	10					
CA_n3B	-	5	15, 20, 25, 30				60	0
		10	10, 15, 20, 25, 30					
		15, 20, 25, 30	5, 10, 15, 20, 25, 30					
CA_n5B	CA_n5B	5, 10, 15	5, 10, 15				20	0
CA_n7B	CA_n7B	10	10, 15, 20, 30, 40				50	0
		15	15, 20, 30					
		20	20, 30					
CA_n25B	-	5	15				20	0
		10	10					
CA_n38B	-	5	15, 20, 25				50	0
		10	10, 15, 20, 25					
		15, 20, 25	5, 10, 15, 20, 25					
CA_n40B	-	20	80				100	0
		50	50					
	CA_n40B	10,15, 20, 30, 40, 50, 60, 80	10, 15, 20, 30, 40, 50, 60, 80				100	1
CA_n41B	n41[3] CA_n41B	10, 20, 30, 40, 50	10, 20, 30, 40, 50				100	0
CA_n41C	n41[3,4] CA_n41C[3]	40	80, 100				180	0
		50, 60, 80	60, 80, 100					
		10	100				190	1
		15, 20	90, 100					
		40	80, 90, 100					
		50, 60, 80, 90	60, 80, 90, 100					
		10	100				190	2
		15, 20	90, 100					
		30, 40	80, 90, 100					
		50, 60, 80, 90	60, 80, 90, 100					
		See n41 channel bandwidths in Table 5.3.5-1 for each carrier[2]					190	4 and 5
CA_n46B	-	20, 40, 60	20, 40				100	0
CA_n46C	-	60, 80	60, 80				160	0
CA_n46D	-	60, 80	80	80			240	0
CA_n46M	-	20, 40, 60	20, 40	20, 40			140	0
CA_n46N		Void						0
	-	20, 40, 60	20, 40	20, 40	20, 40		180	1
CA_n46O	-	20, 60	20, 40	20, 40	20, 40	20, 40	220	0
CA_n48B	CA_n48B	5	15, 20				40	0
		10, 15, 20	10, 15, 20					
		15, 20	15, 20					
	-	10	50, 60, 80, 90				100	1

(3GPP TS 38.101 V17.9.0)

Claim 1	Accused Instrumentalities

5.5A.2 Configurations for intra-band non-contiguous CA

Table 5.5A.2-1: NR CA configurations and bandwidth combination sets defined for intra-band non-contiguous CA

NR CA Configuration	Uplink CA Configurations or single uplink carrier[5]	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Maximum Aggregated bandwidth (MHz)	Bandwidth combination set
CA_n1(2A)	-	5, 10, 15, 20	5, 10, 15, 20			40	0
CA_n2(2A)	-	5, 10, 15, 20	5, 10, 15, 20			40	0
CA_n3(2A)	-	5, 10, 15, 20	5, 10, 15, 20			40	0
	-	5, 10, 15, 20, 25, 30	5, 10, 15, 20, 25, 30			60	1
CA_n5(2A)	-	5, 10, 15, 20	5, 10, 15, 20			25	0
CA_n7(2A)	-	5, 10, 15, 20	5, 10, 15, 20			40	0
CA_n12(2A)	-	5	5			10	0
CA_n25(2A)	-	5, 10, 15, 20	5, 10, 15, 20			40	0
		5, 10, 15, 20, 25, 30, 40	5, 10, 15, 20, 25, 30, 40			60	1
		See n25 channel bandwidths in Table 5.3.5-1 for each carrier				60	4 and 5
CA_n25(3A)	-	5, 10, 15, 20, 25, 30, 40	5, 10, 15, 20, 25, 30, 40	5, 10, 15, 20, 25, 30, 40		55	0
		See n25 channel bandwidths in Table 5.3.5-1 for each carrier				55	4 and 5
CA_n41(2A)	n41[3,4] CA_n41(2A)	40, 50, 60, 80, 100	40, 50, 60, 80, 100			180	0
		10, 15, 20, 40, 50, 60, 80, 90, 100	10, 15, 20, 40, 50, 60, 80, 90, 100			190	1
	-	10, 15, 20, 30, 40, 50, 60, 80, 90	15, 20, 30, 40, 50, 60, 80, 90, 100			190	2
		10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100			190	3
		See n41 channel bandwidths in Table 5.3.5-1 for each carrier				190	4 and 5
CA_n41(3A)	n41[3,4]	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100		190	0
		See n41 channel bandwidths in Table 5.3.5-1 for each carrier				190	4 and 5
CA_n41(4A)	n41[3]	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90, 100	190	0
		See n41 channel bandwidths in Table 5.3.5-1 for each carrier				190	4 and 5
CA_n48(2A)		10, 15, 20, 40, 50, 60, 80. 90. 100	10, 15, 20, 40, 50, 60, 80. 90. 100			140[2]	0
		10, 15, 20, 30, 40, 50, 60, 70, 80, 90. 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90. 100			140[2]	1
CA_n48(3A)	-	10, 15, 20, 40,50, 60, 80. 90. 100	10, 15, 20, 40,50, 60, 80. 90. 100	10, 15, 20, 40,50, 60, 80. 90. 100		140[2]	0
		10, 15, 20, 30, 40, 50, 60, 70, 80, 90. 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90. 100	10, 15, 20, 30, 40, 50, 60, 70, 80, 90. 100		140[2]	1

(3GPP TS 38.101 V17.9.0)

Claim 1	Accused Instrumentalities
	4.1.3 MR-DC with the 5GC **4.1.3.1 E-UTRA-NR Dual Connectivity** NG-RAN supports NG-RAN E-UTRA-NR Dual Connectivity (NGEN-DC), in which a UE is connected to one ng-eNB that acts as a MN and one gNB that acts as a SN. **4.1.3.2 NR-E-UTRA Dual Connectivity** NG-RAN supports NR-E-UTRA Dual Connectivity (NE-DC), in which a UE is connected to one gNB that acts as a MN and one ng-eNB that acts as a SN. **4.1.3.3 NR-NR Dual Connectivity** NG-RAN supports NR-NR Dual Connectivity (NR-DC), in which a UE is connected to one gNB that acts as a MN and another gNB that acts as a SN. In addition, NR-DC can also be used when a UE is connected to a single gNB, acting both as a MN and as a SN, and configuring both MCG and SCG. (TS 137 340 V16.5.0)
[1.2] simultaneously transmitting second information across a second frequency range using the same wireless transmitter, the second frequency range having a second center frequency greater than the first center frequency, a second highest frequency, and a second lowest frequency.	The Accused Instrumentalities perform a method including simultaneously transmitting second information across a second frequency range using the same wireless transmitter, the second frequency range having a second center frequency greater than the first center frequency, a second highest frequency, and a second lowest frequency. For example, the iPhone 15 transmits uplink information on a second component carrier with a frequency range with a second center frequency (labeled $F_{C,high}$ in the excerpt from 3GPP TS 38.101 V17.9.0 below), second highest frequency (highlighted in red below), and second lowest frequency (highlighted in blue below). This applies in the cases of intra-band contiguous, intra-band non-contiguous, and inter-band CA. The transmission is performed simultaneously using the same wireless transmitter, as set out in section 5.4 of 3GPP TS 38.300 V17.4.0. *See, e.g.*:

5.3 Uplink

5.3.1 Uplink transmission scheme

Two transmission schemes are supported for PUSCH: codebook based transmission and non-codebook based transmission.

For codebook based transmission, the gNB provides the UE with a transmit precoding matrix indication in the DCI. The UE uses the indication to select the PUSCH transmit precoder from the codebook. For non-codebook based transmission, the UE determines its PUSCH precoder based on wideband SRI field from the DCI.

A closed loop DMRS based spatial multiplexing is supported for PUSCH. For a given UE, up to 4 layer transmissions are supported. The number of code words is one. When transform precoding is used, only a single MIMO layer transmission is supported.

Transmission durations from 1 to 14 symbols in a slot is supported.

Aggregation of multiple slots with TB repetition is supported.

(3GPP TS 38.300 V17.4.0)

5.4 Carrier aggregation

5.4.1 Carrier aggregation

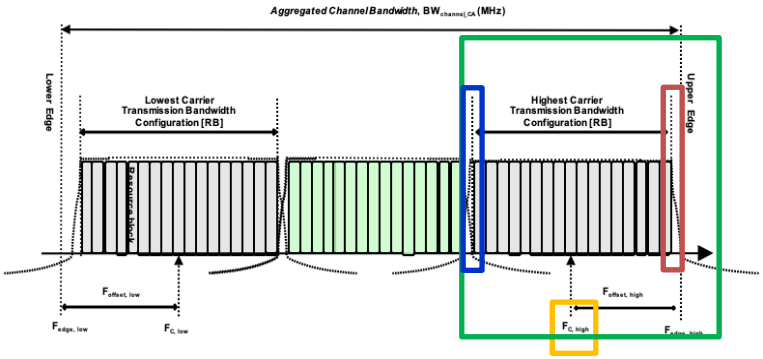
In Carrier Aggregation (CA), two or more Component Carriers (CCs) are aggregated. A UE may simultaneously receive or transmit on one or multiple CCs depending on its capabilities:

- A UE with single timing advance capability for CA can simultaneously receive and/or transmit on multiple CCs corresponding to multiple serving cells sharing the same timing advance (multiple serving cells grouped in one TAG);
- A UE with multiple timing advance capability for CA can simultaneously receive and/or transmit on multiple CCs corresponding to multiple serving cells with different timing advances (multiple serving cells grouped in multiple TAGs). NG-RAN ensures that each TAG contains at least one serving cell;
- A non-CA capable UE can receive on a single CC and transmit on a single CC corresponding to one serving cell only (one serving cell in one TAG).

CA is supported for both contiguous and non-contiguous CCs. When CA is deployed frame timing and SFN are aligned across cells that can be aggregated, or an offset in multiples of slots between the PCell/PSCell and an SCell is configured to the UE. The maximum number of configured CCs for a UE is 16 for DL and 16 for UL.

(3GPP TS 38.300 V17.4.0)

	## 6.7 Carrier Aggregation In case of CA, the multi-carrier nature of the physical layer is only exposed to the MAC layer for which one HARQ entity is required per serving cell as depicted on Figures 6.7-1 and 6.7-2 below: - In both uplink and downlink, there is one independent hybrid-ARQ entity per serving cell and one transport block is generated per assignment/grant per serving cell in the absence of spatial multiplexing. Each transport block and its potential HARQ retransmissions are mapped to a single serving cell. (3GPP TS 38.300 V17.4.0)

Claim 1	Accused Instrumentalities
	5.3A.2 Maximum transmission bandwidth configuration for CA For carrier aggregation, the maximum transmission bandwidth configuration is defined per component carrier and the requirement is specified in clause 5.3.2. 5.3A.3 Minimum guardband and transmission bandwidth configuration for CA For intra-band contiguous carrier aggregation, *Aggregated Channel Bandwidth* and *Guard Bands* are defined as follows, see Figure 5.3A.3-1.  **Figure 5.3A.3-1: Definition of *Aggregated Channel Bandwidth* for intra-band carrier aggregation** The *aggregated channel bandwidth*, $BW_{Channel\_CA}$, is defined as $BW_{Channel\_CA} = F_{edge,high} - F_{edge,low}$ (MHz). The lower bandwidth edge $F_{edge,low}$ and the upper bandwidth edge $F_{edge,high}$ of the aggregated channel bandwidth are used as frequency reference points for transmitter and receiver requirements and are defined by $F_{edge,low} = F_{C,low} - F_{offset,low}$ $F_{edge,high} = F_{C,high} + F_{offset,high}$ The lower and upper frequency offsets depend on the transmission bandwidth configurations of the lowest and highest assigned edge component carrier and are defined as $F_{offset,low} = (N_{RB,low}*12 + 1)*SCS_{low}/2 + BW_{GB}$ (MHz) $F_{offset,high} = (N_{RB,high}*12 - 1)*SCS_{high}/2 + BW_{GB}$ (MHz) $BW_{GB} = \max(BW_{GB,Channel(k)})$ $N_{RB,low}$ and $N_{RB,high}$ are the transmission bandwidth configurations according to Table 5.3.2-1 for the lowest and highest assigned component carrier, SCS_{low} and SCS_{high} are the sub-carrier spacing for the lowest and highest assigned component carrier respectively. SCS_{low}, SCS_{high}, $N_{RB,low}$, $N_{RB,high}$, and $BW_{GB,Channel(k)}$ use the largest μ value among the subcarrier spacing configurations supported in the operating band for both of the channel bandwidths according to Table 5.3.5-1 and $BW_{GB,Channel(k)}$ is the minimum guard band for carrier k according to Table 5.3.3-1 for the said μ value. In case there is no common μ value for both of the channel bandwidths, μ=1 is used for SCS_{low}, SCS_{high}, $N_{RB,low}$, $N_{RB,high}$ and $BW_{GB,Channel(k)}$. (3GPP TS 38.101 V17.9.0)

Claim 1	Accused Instrumentalities

5.5A.1 Configurations for intra-band contiguous CA

Power class 3 is supported for all uplinks. Power classes other than power class 3 are supported as indicated in Table 5.5A.1-1.

Table 5.5A.1-1: NR CA configurations and bandwidth combination sets defined for intra-band contiguous CA

NR CA configuration / Bandwidth combination set								
NR CA configuration	Uplink CA configurations or single uplink carrier[5]	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Maximum aggregated bandwidth (MHz)	Bandwidth combination set
CA_n1B	-	10	10,15				40	0
		15	15,20					
		20	20					
CA_n2B	-	5	15				20	0
		10	10					
CA_n3B	-	5	15, 20, 25, 30				60	0
		10	10, 15, 20, 25, 30					
		15, 20, 25, 30	5, 10, 15, 20, 25, 30					
CA_n5B	CA_n5B	5, 10, 15	5, 10, 15				20	0
CA_n7B	CA_n7B	10	10, 15, 20, 30, 40				50	0
		15	15, 20, 30					
		20	20, 30					
CA_n25B	-	5	15				20	0
		10	10					
CA_n38B	-	5	15, 20, 25				50	0
		10	10, 15, 20, 25					
		15, 20, 25	5, 10, 15, 20, 25					
CA_n40B	-	20	80				100	0
		50	50					
	CA_n40B	10,15, 20, 30, 40, 50, 60, 80	10, 15, 20, 30, 40, 50, 60, 80				100	1
CA_n41B	n41[3] CA_n41B	10, 20, 30, 40, 50	10, 20, 30, 40, 50				100	0
CA_n41C	n41[3,4] CA_n41C[3]	40	80, 100				180	0
		50, 60, 80	60, 80, 100					
		10	100				190	1
		15, 20	90, 100					
		40	80, 90, 100					
		50, 60, 80, 90	60, 80, 90, 100					
		10	100				190	2
		15, 20	90, 100					
		30, 40	80, 90, 100					
		50, 60, 80, 90	60, 80, 90, 100					
		See n41 channel bandwidths in Table 5.3.5-1 for each carrier[2]					190	4 and 5
CA_n46B	-	20, 40, 60	20, 40				100	0
CA_n46C	-	60, 80	60, 80				160	0
CA_n46D	-	60, 80	80	80			240	0
CA_n46M	-	20, 40, 60	20, 40	20, 40			140	0
CA_n46N		Void						0
	-	20, 40, 60	20, 40	20, 40	20, 40		180	1
CA_n46O	-	20, 60	20, 40	20, 40	20, 40	20, 40	220	0
CA_n48B	CA_n48B	5	15, 20				40	0
		10, 15, 20	10, 15, 20					
		15, 20	15, 20					
	-	10	50, 60, 80, 90				100	1

(3GPP TS 38.101 V17.9.0)

Claim 1	Accused Instrumentalities

5.5A.2 Configurations for intra-band non-contiguous CA

Table 5.5A.2-1: NR CA configurations and bandwidth combination sets defined for intra-band non-contiguous CA

NR CA configuration / Bandwidth combination set								
NR CA configuration	Uplink CA configurations or single uplink carrier[5]	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Maximum aggregated bandwidth (MHz)	Bandwidth combination set
CA_n1B	-	10	10,15				40	0
		15	15,20					
		20	20					
CA_n2B	-	5	15				20	0
		10	10					
CA_n3B	-	5	15, 20, 25, 30				60	0
		10	10, 15, 20, 25, 30					
		15, 20, 25, 30	5, 10, 15, 20, 25, 30					
CA_n5B	CA_n5B	5, 10, 15	5, 10, 15				20	0
CA_n7B	CA_n7B	10	10, 15, 20, 30, 40				50	0
		15	15, 20, 30					
		20	20, 30					
CA_n25B	-	5	15				20	0
		10	10					
CA_n38B	-	5	15, 20, 25				50	0
		10	10, 15, 20, 25					
		15, 20, 25	5, 10, 15, 20, 25					
CA_n40B	-	20	80				100	0
		50	50					
	CA_n40B	10,15, 20, 30, 40, 50, 60, 80	10, 15, 20, 30, 40, 50, 60, 80				100	1
CA_n41B	n41[3] CA_n41B	10, 20, 30, 40, 50	10, 20, 30, 40, 50				100	0
CA_n41C	n41[3,4] CA_n41C[3]	40	80, 100				180	0
		50, 60, 80	60, 80, 100					
		10	100				190	1
		15, 20	90, 100					
		40	80, 90, 100					
		50, 60, 80, 90	60, 80, 90, 100					
		10	100				190	2
		15, 20	90, 100					
		30, 40	80, 90, 100					
		50, 60, 80, 90	60, 80, 90, 100					
		See n41 channel bandwidths in Table 5.3.5-1 for each carrier[2]					190	4 and 5
CA_n46B	-	20, 40, 60	20, 40				100	0
CA_n46C	-	60, 80	60, 80				160	0
CA_n46D	-	60, 80	80	80			240	0
CA_n46M	-	20, 40, 60	20, 40	20, 40			140	0
CA_n46N		Void						0
	-	20, 40, 60	20, 40	20, 40	20, 40		180	1
CA_n46O	-	20, 60	20, 40	20, 40	20, 40	20, 40	220	0
CA_n48B	CA_n48B	5	15, 20				40	0
		10, 15, 20	10, 15, 20					
		15, 20	15, 20					
	-	10	50, 60, 80, 90				100	1

(3GPP TS 38.101 V17.9.0)

5.4 Carrier aggregation

5.4.1 Carrier aggregation

In Carrier Aggregation (CA), two or more Component Carriers (CCs) are aggregated. A UE may simultaneously receive or transmit on one or multiple CCs depending on its capabilities:

- A UE with single timing advance capability for CA can simultaneously receive and/or transmit on multiple CCs corresponding to multiple serving cells sharing the same timing advance (multiple serving cells grouped in one TAG);
- A UE with multiple timing advance capability for CA can simultaneously receive and/or transmit on multiple CCs corresponding to multiple serving cells with different timing advances (multiple serving cells grouped in multiple TAGs). NG-RAN ensures that each TAG contains at least one serving cell;
- A non-CA capable UE can receive on a single CC and transmit on a single CC corresponding to one serving cell only (one serving cell in one TAG).

CA is supported for both contiguous and non-contiguous CCs. When CA is deployed frame timing and SFN are aligned across cells that can be aggregated, or an offset in multiples of slots between the PCell/PSCell and an SCell is configured to the UE. The maximum number of configured CCs for a UE is 16 for DL and 16 for UL.

(3GPP TS 38.300 V17.4.0)

Claim 1	Accused Instrumentalities

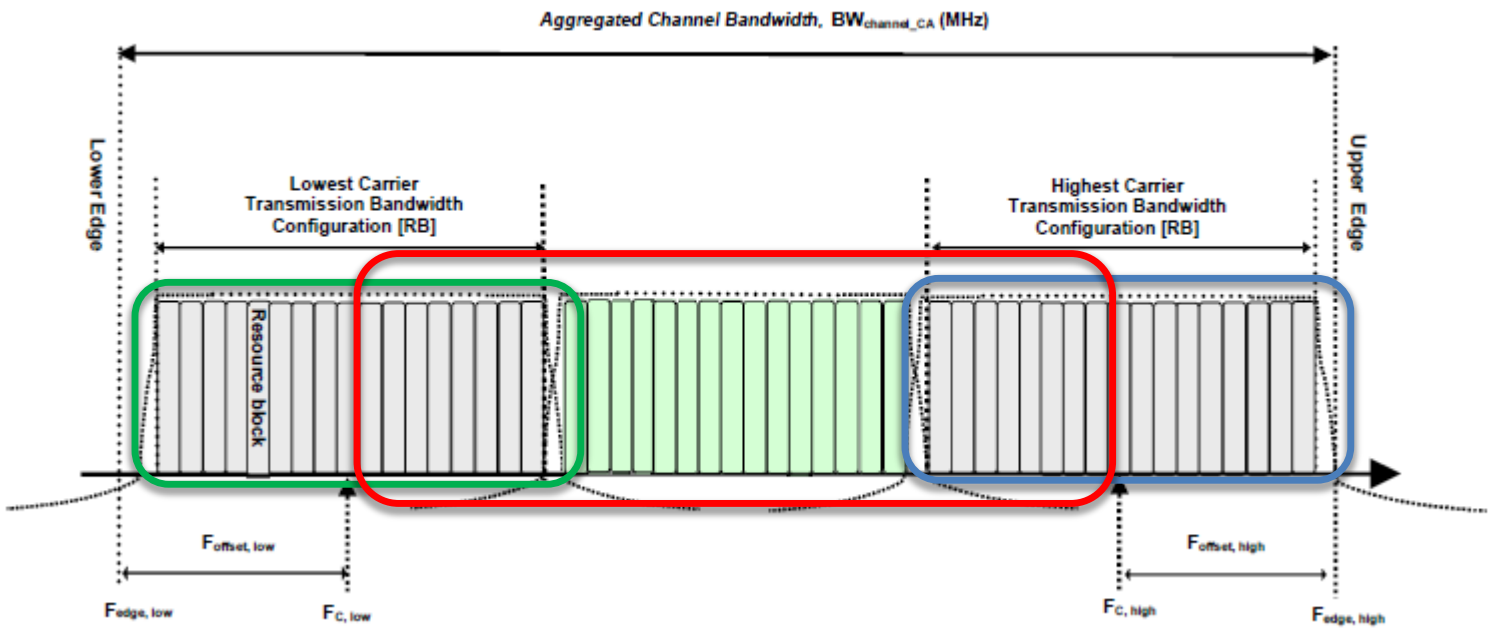
NR CA configuration / Bandwidth combination set

NR CA configuration	Uplink CA configurations or single uplink carrier[5]	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Channel bandwidths for carrier (MHz)	Maximum aggregated bandwidth (MHz)	Bandwidth combination set
CA_n1B	-	10	10,15				40	0
		15	15,20					
		20	20					
CA_n2B	-	5	15				20	0
		10	10					
CA_n3B	-	5	15, 20, 25, 30				60	0
		10	10, 15, 20, 25, 30					
		15, 20, 25, 30	5, 10, 15, 20, 25, 30					
CA_n5B	CA_n5B	5, 10, 15	5, 10, 15				20	0
CA_n7B	CA_n7B	10	10, 15, 20, 30, 40				50	0
		15	15, 20, 30					
		20	20, 30					
CA_n25B	-	5	15				20	0
		10	10					
CA_n38B	-	5	15, 20, 25				50	0
		10	10, 15, 20, 25					
		15, 20, 25	5, 10, 15, 20, 25					
CA_n40B	-	20	80				100	0
		50	50					
	CA_n40B	10,15, 20, 30, 40, 50, 60, 80	10, 15, 20, 30, 40, 50, 60, 80				100	1
CA_n41B	n41[3] CA_n41B	10, 20, 30, 40, 50	10, 20, 30, 40, 50				100	0
CA_n41C	n41[3,4] CA_n41C[3]	40	80, 100				180	0
		50, 60, 80	60, 80, 100					
		10	100				190	1
		15, 20	90, 100					
		40	80, 90, 100					
		50, 60, 80, 90	60, 80, 90, 100					
		10	100				190	2
		15, 20	90, 100					
		30, 40	80, 90, 100					
		50, 60, 80, 90	60, 80, 90, 100					
		See n41 channel bandwidths in Table 5.3.5-1 for each carrier[2]					190	4 and 5
CA_n46B	-	20, 40, 60	20, 40				100	0
CA_n46C	-	60, 80	60, 80				160	0
CA_n46D	-	60, 80	80	80			240	0
CA_n46M	-	20, 40, 60	20, 40	20, 40			140	0
CA_n46N		Void						0
	-	20, 40, 60	20, 40	20, 40	20, 40		180	1
CA_n46O	-	20, 60	20, 40	20, 40	20, 40	20, 40	220	0
CA_n48B	CA_n48B	5	15, 20				40	0
		10, 15, 20	10, 15, 20					
		15, 20	15, 20					
	-	10	50, 60, 80, 90				100	1

Claim 1	Accused Instrumentalities
	4.1.3 MR-DC with the 5GC **4.1.3.1 E-UTRA-NR Dual Connectivity** NG-RAN supports NG-RAN E-UTRA-NR Dual Connectivity (NGEN-DC), in which a UE is connected to one ng-eNB that acts as a MN and one gNB that acts as a SN. **4.1.3.2 NR-E-UTRA Dual Connectivity** NG-RAN supports NR-E-UTRA Dual Connectivity (NE-DC), in which a UE is connected to one gNB that acts as a MN and one ng-eNB that acts as a SN. **4.1.3.3 NR-NR Dual Connectivity** NG-RAN supports NR-NR Dual Connectivity (NR-DC), in which a UE is connected to one gNB that acts as a MN and another gNB that acts as a SN. In addition, NR-DC can also be used when a UE is connected to a single gNB, acting both as a MN and as a SN, and configuring both MCG and SCG. (TS 137 340 V16.5.0)

Claim 2

Claim 2	Accused Instrumentalities
[2] The method of claim 1 wherein frequency difference between the first center frequency and the second center frequency is greater than the sum of one-half the first frequency range and one-half the second frequency	The Accused Instrumentalities perform a method wherein the frequency difference between the first center frequency and the second center frequency is greater than the sum of one-half the first frequency range and one-half the second frequency range. For example, the bandwidth from the center of the first carrier component ("first frequency") to the second carrier component ("second frequency") comprising half of the first carrier component and half of the second carrier component plus the guard band between the two carrier component, is greater than the half of the first frequency and half of the second frequency. (3GPP TS 38.101-1 V17.5.0)

Claim 2	Accused Instrumentalities
range.	**5.3A.2 Maximum transmission bandwidth configuration for CA** For carrier aggregation, the maximum transmission bandwidth configuration is defined per component carrier and the requirement is specified in clause 5.3.2. **5.3A.3 Minimum guardband and transmission bandwidth configuration for CA** For intra-band contiguous carrier aggregation, *Aggregated Channel Bandwidth* and *Guard Bands* are defined as follows, see Figure 5.3A.3-1.  **Figure 5.3A.3-1: Definition of *Aggregated Channel Bandwidth* for intra-band carrier aggregation** BWChannel_CA = Fedge,high - Fedge,low (MHz).

Claim 2	Accused Instrumentalities
	The lower bandwidth edge $F_{edge,\ low}$ and the upper bandwidth edge $F_{edge,high}$ of the aggregated channel bandwidth are used as frequency reference points for transmitter and receiver requirements and are defined by $$F_{edge,low} = F_{C,low} - F_{offset,low}$$ $$F_{edge,high} = F_{C,high} + F_{offset,high}$$ The lower and upper frequency offsets depend on the transmission bandwidth configurations of the lowest and highest assigned edge component carrier and are defined as $$F_{offset,low} = (N_{RB,low}*12 + 1)*SCS_{low}/2 + BW_{GB}\ (MHz)$$ $$F_{offset,high} = (N_{RB,high}*12 - 1)*SCS_{high}/2 + BW_{GB}\ (MHz)\ BW_{GB} = \max(BW_{GB,Channel(k)})$$ $N_{RB,low}$ and $N_{RB,high}$ are the transmission bandwidth configurations according to Table 5.3.2-1 for the lowest and highest assigned component carrier, SCS_{low} and SCS_{high} are the sub-carrier spacing for the lowest and highest assigned component carrier respectively. SCS_{low}, SCS_{high}, $N_{RB,low}$, $N_{RB,high}$, and $BW_{GB,Channel(k)}$ use the largest μ value among the subcarrier spacing configurations supported in the operating band for both of the channel bandwidths according to Table 5.3.5-1 and $BW_{GB,Channel(k)}$ is the minimum guard band for carrier k according to Table 5.3.3-1 for the said μ value. In case there is no common μ value for both of the channel bandwidths, μ=1 is used for SCS_{low}, SCS_{high}, $N_{RB,low}$, $N_{RB,high}$, and $BW_{GB,Channel(k)}$.

Claim 3

Claim 3	Accused Instrumentalities
[3] The method of claim 1 wherein the first and second information are transmitted	The Accused Instrumentalities perform a method wherein the first and second information are transmitted using the same power amplifier in said wireless transmitter.

Claim 3	Accused Instrumentalities
using the same power amplifier in said wireless transmitter.	For example: (3GPP TR 36.912 version 15.0.0 Release 15) **11.3.2.1 Transmitter architecture** Figure 11.3.2.1-1 illustrates various TX architectures options according to where the component carriers are combined, i.e., at digital baseband, or in analog waveforms before RF mixer, or after mixer but before the PA, or after the PA. Option A - In an adjacent *contiguous common carrier* aggregation scenario, the UE very likely has one PA. Connected to the PA can be a single RF chain (a zero-IF mixer, a wideband DAC, and a wideband IFFT) Option-B - Combines analog baseband waveforms from component Carrier first (e.g., via a mixer operating at an IF of roughly the bandwidth of the other component carrier in the example of 2-component carrier aggregation). Then the resulting wideband signal is up-converted to RF. Option-C - Does ZIF up-conversion of each component carrier before combining and feeding into a single PA. Option-D - Employs multiple RF chains and multiple PAs after which the high-power signals are combined and fed into a single antenna. PA coupling at the UE can be challenging for option-D.

Claim 3	Accused Instrumentalities

Tx Characteristics

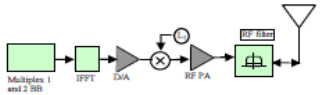
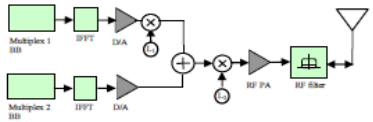
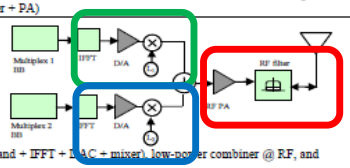
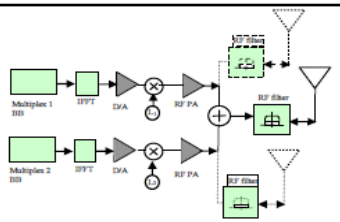
Option	Description (Tx architecture)	Intra Band aggregation		Inter Band aggregation
		Contiguous (CC)	Non contiguous (CC)	Non contiguous (CC)
A	 Single (baseband + IFFT + DAC + mixer + PA)	Yes		
B	 Multiple (baseband + IFFT + DAC), single (stage-1 IF mixer + combiner @ IF + stage-2 RF mixer + PA)	Yes	Yes	
C	 Multiple (baseband + IFFT + DAC + mixer), low-power combiner @ RF, and single PA	Yes	Yes	
D	 Multiple (baseband + IFFT + DAC + mixer + PA), high-power combiner to single antenna OR dual antenna	Yes	Yes	Yes + (depending on the specific EUTRA bands being aggregated),
X	*OTHERS*			

Figure 11.3.2.1-1: Possible UE Architectures in three aggregation scenarios

Claim 3	Accused Instrumentalities
	Qualcomm Introduces Sub-6 GHz and mmWave Modules for 5G Smartphones *July 23, 2018* The Qualcomm® QPM56xx sub-6 GHz RF module family and QTM052 mmWave antenna module family pair with Qualcomm's Snapdragon™ X50 5G modem to deliver modem-to-antenna functionality across multiple 5G bands in a compact footprint suited for mobile devices. **Sub-6 GHz Modules** The QPM56xx module family — the QPM5650, QPM5651, QDM5650 and QDM5652 — works with the Snapdragon X50 5G modem to support the sub-6 GHz 5G NR bands. The QPM5650 and QPM5651 integrate the power amplifier (PA), low noise amplifier (LNA), switch and filtering. For diversity and MIMO, the QDM5650 and QDM5652 integrate the LNA, switch and filtering. All four modules offer integrated sounding reference signal (SRS) switching, required for optimum massive MIMO applications, and support the 3.3 to 4.2 GHz (n77), 3.3 to 3.8 GHz (n78) and 4.4 to 5.0 GHz (n79) bands. **mmWave Antenna Modules** The QTM052 mmWave antenna modules also interface with the Snapdragon X50 5G modem to provide a comprehensive system that supports advanced beam forming, beam steering and beam tracking, which improve the range and reliability of mmWave links. The system comprises an integrated 5G NR radio transceiver, power management IC, RF front-end components and phased array antenna. The QTM052 handles up to 800 MHz bandwidth in the 26.5 to 29.5 GHz (n257) band and the entire 27.5 to 28.35 GHz (n261) and 37 to 40 GHz (n260) bands. The QTM052 modules integrate these capabilities in a compact footprint, enabling four modules to fit in a smartphone. The small size allows phone manufacturers to incorporate the mmWave bands without sacrificing the attractive industrial designs of their mobile devices. Qualcomm said availability of the mmWave modules will support smartphone launches as early as the first half of 2019. (https://www.microwavejournal.com/articles/30752-qualcomm-introduces-sub-6-ghz-and-mmwave-modules-for-5g-smartphones)

Claim 4

Claim 4	Public Documentation
[4] The method of claim 3 wherein the bandwidth of said power amplifier is greater than the difference between the first lowest frequency and the second highest frequency.	The Accused Instrumentalities perform a method wherein the bandwidth of said power amplifier is greater than the difference between the first lowest frequency and the second highest frequency. For example , as shown below, the bandwidth of an exemplary power amplifier meets the claimed conditions.

Claim 4	Public Documentation
	Qualcomm Introduces Sub-6 GHz and mmWave Modules for 5G Smartphones *July 23, 2018* The Qualcomm® QPM56xx sub-6 GHz RF module family and QTM052 mmWave antenna module family pair with Qualcomm's Snapdragon™ X50 5G modem to deliver modem-to-antenna functionality across multiple 5G bands in a compact footprint suited for mobile devices. **Sub-6 GHz Modules** The QPM56xx module family — the QPM5650, QPM5651, QDM5650 and QDM5652 — works with the Snapdragon X50 5G modem to support the sub-6 GHz 5G NR bands. The QPM5650 and QPM5651 integrate the power amplifier (PA), low noise amplifier (LNA), switch and filtering. For diversity and MIMO, the QDM5650 and QDM5652 integrate the LNA, switch and filtering. All four modules offer integrated sounding reference signal (SRS) switching, required for optimum massive MIMO applications, and support the 3.3 to 4.2 GHz (n77), 3.3 to 3.8 GHz (n78) and 4.4 to 5.0 GHz (n79) bands. **mmWave Antenna Modules** The QTM052 mmWave antenna modules also interface with the Snapdragon X50 5G modem to provide a comprehensive system that supports advanced beam forming, beam steering and beam tracking, which improve the range and reliability of mmWave links. The system comprises an integrated 5G NR radio transceiver, power management IC, RF front-end components and phased array antenna. The QTM052 handles up to 800 MHz bandwidth in the 26.5 to 29.5 GHz (n257) band and the entire 27.5 to 28.35 GHz (n261) and 37 to 40 GHz (n260) bands. The QTM052 modules integrate these capabilities in a compact footprint, enabling four modules to fit in a smartphone. The small size allows phone manufacturers to incorporate the mmWave bands without sacrificing the attractive industrial designs of their mobile devices. Qualcomm said availability of the mmWave modules will support smartphone launches as early as the first half of 2019. (https://www.microwavejournal.com/articles/30752-qualcomm-introduces-sub-6-ghz-and-mmwave-modules-for-5g-smartphones)

Claim 6

Claim 6	Accused Instrumentalities
[6] The method of claim 1 wherein the first information corresponds to a first wireless protocol and the second information corresponds to a second wireless protocol.	The Accused Instrumentalities perform a method wherein the first information corresponds to a first wireless protocol and the second information corresponds to a second wireless protocol. For example: Cellular operators, for example T-MO, have deployed carrier aggregation in mid band (2.5 GHz, 3.5 GHz), in 1900 MHz PCS band as well as the 600 MHz band. In the mid band such as the 2.5 GHz or 3.5 GHz TDD protocol has been deployed. In the PCS 1900 MHz and 600 MHz bands, FDD 5G and LTE protocols have been deployed. Two protocols, FDD and TDD, are used in these carrier aggregation deployments. The carrier aggregation tested by Galaxy 22 and Galaxy 23 on T-MO network supported both TDD and FDD protocols. https://www.rcrwireless.com/20220111/test-and-measurement/srg-tests-t-mos-fdd-tdd-ca-you-can-have-your-cake-and-eat-it-too SRG tests T-Mo's FDD-TDD CA: 'You can have your cake and eat it too' January 11, 2022 The aggregation of 600 MHz + 2.5 GHz uses low-band, FDD spectrum to improve performance The aggregation of low and mid-band carriers in both Frequency Division Duplex (FDD) and Time Division Duplex (TDD) spectrum improves cell edge performance in T-Mobile US' network, according to recent testing by Signals Research Group. SRG tested the FDD+TDD carrier aggregation (CA) in T-Mobile US' commercial network. The testing was conducted during the first week of December, at a large cluster of Ericsson sites in a 180-square-kilometer swath of the suburban Maryland/Washington, D.C. area. "A few mobile operators have already launched TDD-TDD CA in other parts of the world but to the best of our knowledge T-Mobile is the first operator in the world to deploy FDD-TDD CA functionality in a commercial network," SRG noted.

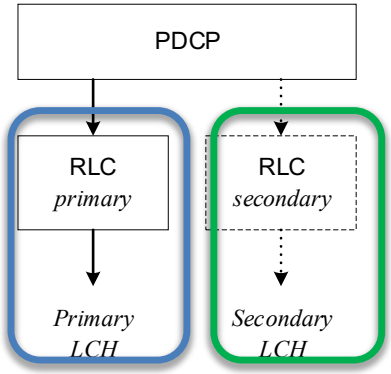
Claim 6	Accused Instrumentalities
	SRG said that T-Mobile US provided the test SIMs and insight into the cluster where the testing was conducted, as well as two Galaxy S21 smartphones — one with pre-commercial software on it that allowed the consulting group to test some of the features it was interested in. Intriguingly, however, SRG found that both devices appeared to support much the same functionality, with a bit of finessing of "hidden" menu options to force the smartphones into the modes of operation that it wanted to test. SRG used test tools from Accuver Americas and Spirent Communications to conduct the study. The firm said that the cell cluster supported a "wide range of different technologies," including both NSA and SA 5G, using T-Mo's 600 MHz (FDD) and/or 2.5 GHz (TDD) spectrum. In terms of 5G New Radio CA, the sites either used two 5G NR carriers at 2.5 GHz, leveraging T-Mo's deep midband holdings for TDD-TDD carrier aggregation; or they paired a single radio channel of 600 MHz spectrum with a single channel of 2.5 GHz — the FDD-TDD CA that SRG sought to test. https://www.rcrwireless.com/20220615/5g/t-mobile-us-tops-3-gbps-standalone-5g- T-MOBILE US USED THE SAMSUNG GALAXY S22 PHONE POWERED BY SNAPDRAGON 8 GEN 1 MOBILE PLATFORM T-Mobile US said it was able to aggregate three channels of mid-band 5G spectrum, reaching speeds over 3 Gbps on its standalone 5G network. The carrier used the Samsung Galaxy S22 phone powered by Snapdragon 8 Gen 1 Mobile Platform with Snapdragon X65 Modem-RF System on a live production network. "This test demonstrates the incredible power of mid-band spectrum and represents another huge step forward for standalone 5G," said Neville Ray, president of Technology at T-Mobile. "Only T-Mobile is delivering a nationwide standalone 5G network to customers today, and we're blazing a trail with new performance-boosting capabilities that generate incredible speeds and deliver on our vision to create the highest capacity network in the country." T-Mobile US noted that 5G Carrier Aggregation (NR CA) allows the combination of multiple 5G channels to improve speed and performance. In this test, the carrier merged three 5G channels — two channels of 2.5 GHz Ultra Capacity 5G and one channel of 1900 MHz spectrum — to create an effective 210 MHz 5G channel. T-Mobile claimed to be the first operator in the world to launch a nationwide SA 5G network nearly two years ago.

Claim 6	Accused Instrumentalities
	NR CA is already live in parts of T-Mobile's network combining two 2.5 GHz 5G channels. The telco said that those customers with the Samsung Galaxy S22 will be among the first to experience a third 1900 MHz 5G channel later this year. This capability will expand across the carrier's network and to additional devices in the near future. Earlier this month, T-Mobile U.S. announced that customers in limited areas of Portland and Salt Lake City who have the Samsung Galaxy S21 5G now have access to Voice Over New Radio (VoNR) services. The carrier said additional cities will be added to the list throughout the remainder of this year. According to T-Mobile US, VoNR brings the promise of Standalone (SA) 5G "one step closer" by enabling advanced capabilities like network slicing that rely on a continuous connection to a 5G core. At the recent Big 5G Event in Austin, Texas, Ray told *RCR Wireless News* that in addition to ultimately supporting 5G voice calls, VoNR, without a Non-Standalone 5G or LTE anchor, sees its investment in low-band as the "foundation" of the company's network. The carrier's Extended Range 5G (low-band 600 MHz spectrum) covers 315 million people across 1.8 million square miles, while 225 million people nationwide are covered with its Ultra Capacity 5G (2.5 GHz spectrum). The carrier expects to cover 260 million in 2022 and 300 million next year. https://www.t-mobile.com/news/network/t-mobile-revs-up-5g-with-four-carrier-aggregation # Taking 5G to the Next Level with Standalone 5G By Jason Sikes, AVP Device Architecture *AT&T Labs makes industry-first 5G SA Uplink 2-CA data connection in the U.S. to improve upload speeds, with additional speed and other upgrades in the works* AT&T is architecting tomorrow's wireless network to ***connect people to greater possibility***. As engineers, we design, build, test, refine and repeat so that you can get more out of your 5G connection and developers can build and deploy the next generation of apps and services. A key part of this evolution is the critical transition phase we are entering in scaling from 5G non-standalone (NSA) to 5G standalone (SA). **How does Standalone take 5G to the next level?** Unlike 5G NSA that still relies on a

Claim 6	Accused Instrumentalities
	4G LTE core, 5G SA uses a dedicated 5G core that can unlock capabilities like faster upload speeds, ultra-low latency, ultra-high reliability and edge functions. This technology will be key to business opportunities like the next generation of connected cars. We have said that we plan to deploy Standalone 5G when the ecosystem is ready, and AT&T is charging forward to advance SA ecosystem readiness. Businesses and developers will be some of the first to take advantage of the new technologies standalone 5G enables as we continue to move from research & development to their deployment. **Uplink: where challenge meets opportunity** This new age of connectivity is not only about consuming more content but also generating more content than ever before. Demand for uplink capacity and speed continues to increase, about 30% a year in AT&T's mobility network. Whether you are uploading large files, on a video call with family, live streaming, cloud gaming or using extended reality applications, the network is facing surging upstream traffic demands it never has before. Our latest network innovations are complex but are all about helping meet this new demand. Just a few weeks ago, we completed the **first 5G SA Uplink 2-carrier aggregation data call in the U.S.** Carrier aggregation (CA) means we are combining or "aggregating" different frequency bands to give you more bandwidth and capacity. For you, this means faster uplink transmission speeds. *Think of this as adding more lanes in the network traffic highway.* No one in the U.S market has successfully aggregated two carriers in 5G SA uplink – until now. This is part of our ongoing effort to provide greater reliability for our customers. The test was conducted in our labs with Nokia's 5G AirScale portfolio and MediaTek's 5G M80 mobile test platform. We aggregated our low-band n5 and our mid-band n77 spectrum. Compared to our low-band n5 alone, we saw a 100% increase in uplink throughput by aggregating our low-band n5 with 40MHz of our mid-band n77. Taking it a step further, we achieved a 250% increase aggregating 100MHz of n77. The bottom line? We achieved incredible upload speeds of over 70 Mbps on n5 with 40MHz of n77 and over 120 Mbps on n5 with 100MHz of n77. While carrier aggregation is like adding more traffic lanes in the highway, adding another vehicle to carry traffic is another way we are managing surging uplink demand. We are doing this via a **two-layer uplink MIMO** on time division duplex (TDD) in our mid-band n77. MIMO combines signals and data streams from multiple antennas ("vehicles") to improve signal quality and data rates. This feature will not only improve uplink throughput but also enhance cell capacity and spectrum efficiency. **Network design and device readiness go hand in hand** Although we continue to make progress in enhancing uplink coverage, we haven't forgotten about the downlink. Enhanced downlink and uplink carrier aggregation capabilities work together to bring the 5G SA performance today's technologies need.

Claim 6	Accused Instrumentalities
	Last fall, we completed a **5G SA four component carrier downlink** call by combining two FDD carriers and two TDD carriers. These capabilities allow AT&T devices to aggregate our mid-band n77 in the C-Band and 3.45GHz spectrum ranges. Compared with low band and mmWave spectrum, mid-band n77 provides a good balance between coverage and speed. This follows the **5G SA three component carrier downlink feature** that we introduced last year to 2022 AT&T Flagship devices which combines one frequency division duplex (FDD) carrier and two TDD carriers. In the coming months, AT&T will also enable **5G New Radio Dual Connectivity (NR-DC)**, aggregating our low and mid-band spectrum with our high-band mmWave spectrum on 5G SA. Our labs have achieved 5G NR-DC downlink throughput speeds of up to 5.3Gbps and uplink throughput speeds of up to 670Mbps. This technology will help provide high-speed mobile broadband for both downlink and uplink in stadiums, airports, and other high-density venues. (https://about.att.com/blogs/2023/standalone-5g-innovations.html)

Claim 7

Claim 7	Accused Instrumentalities
[7] The method of claim 1 wherein the first information and the second information are the same data transmitted across two different frequencies.	The Accused Instrumentalities perform a method wherein the first information and the second information are the same data transmitted across two different frequencies. For example, the packet duplication feature of 5G release 15 transmits the same data on two carrier components of carrier aggregation transmission method, i.e., the first and second data destined to two carriers are the same. (3GPP TS 38.300 version 16.2.0) **16.1.3 Packet Duplication** When duplication is configured for a radio bearer by RRC, at least one secondary RLC entity is added to the radio bearer to handle the duplicated PDCP PDUs as depicted on Figure 16.1.3-1, where the logical channel corresponding to the primary RLC entity is referred to as *the primary logical channel*, and the logical channel corresponding to the secondary RLC entity(ies), the *secondary logical channel(s)*. All RLC entities have the same RLC mode. Duplication at PDCP therefore consists in submitting the same PDCP PDUs multiple times: once to each activated RLC entity for the radio bearer. With multiple independent transmission paths, packet duplication therefore increases reliability and reduces latency and is especially beneficial for URLLC services.  **Figure 16.1.3-1: Packet Duplication** When configuring duplication for a DRB, RRC also sets the state of PDCP duplication (either activated or deactivated) at the time of (re-)configuration. After the configuration, the PDCP duplication state can then be

Claim 7	Accused Instrumentalities
	dynamically controlled by means of a MAC control element and in DC, the UE applies the MAC CE commands regardless of their origin (MCG or SCG). When duplication is configured for an SRB the state is always active and cannot be dynamically controlled. When configuring duplication for a DRB with more than one secondary RLC entity, RRC also sets the state of each of them (i.e. either activated or deactivated). Subsequently, a MAC CE can be used to dynamically control whether each of the configured secondary RLC entities for a DRB should be activated or deactivated, i.e. which of the RLC entities shall be used for duplicate transmission. Primary RLC entity cannot be deactivated. When duplication is deactivated for a DRB, all secondary RLC entities associated to this DRB are deactivated. When a secondary RLC entity is deactivated, it is not re-established, the HARQ buffers are not flushed, and the transmitting PDCP entity should indicate to the secondary RLC entity to discard all duplicated PDCP PDUs. When activating duplication for a DRB, NG-RAN should ensure that at least one serving cell is activated for each logical channel of the DRB; and when the deactivation of SCells leaves no serving cells activated for a logical channel of the DRB, NG-RAN should ensure that duplication is also deactivated. When duplication is activated, the original PDCP PDU and the corresponding duplicate(s) shall not be transmitted on the same carrier. The primary and secondary logical channels can either belong to the same MAC entity (referred to as CA duplication) or to different ones (referred to as DC or DC+CA duplication). CA duplication can be configured together with DC duplication when duplication over more than two legs is configured in the UE. In CA duplication, logical channel mapping restrictions are used in MAC to ensure that the primary and secondary logical channels are not sent on the same carrier. When CA duplication is configured for an SRB, one of the logical channels associated to the SRB is mapped to SpCell. When CA duplication is deactivated for a DRB, the logical channel mapping restrictions of the primary and secondary logical channels are lifted for as long as duplication remains deactivated. When an RLC entity acknowledges the transmission of a PDCP PDU, the PDCP entity shall indicate to the other RLC entity(ies) to discard it. In addition, in case of CA duplication, when an RLC entity restricted to only SCell(s) reaches the maximum number of retransmissions for a PDCP PDU, the UE informs the gNB but does not trigger RLF.

Claim 8

Claim 8	Accused Instrumentalities

[8] The method of claim 1 wherein the first information and the second information are from the same data stream.	The Accused Instrumentalities perform a method wherein the first information and the second information are from the same data stream.
	
	For example, the packet duplication may be deactivated. When packet duplication is deactivated, the same data stream is multiplexed onto the multiple component carriers (CCs) of carrier aggregation method. The data transmitted on the first component carrier ("first information") and the data transmitted on the second component carrier ("second information") are from multiplexing the same data stream for transmission onto the two carriers.
	
	5.11.1 ACTIVATION/DEACTIVATION OF PDCP DUPLICATION
	
	For the PDCP entity configured with *pdcp-Duplication*, the transmitting PDCP entity shall:
	- for SRBs:
	  - activate the PDCP duplication;
	- for DRBs:
	  - if the activation of PDCP duplication is indicated for the DRB:
	    - activate the PDCP duplication for the DRB;
	  - if the activation of PDCP duplication is indicated for at least one associated RLC entities:
	    - activate the PDCP duplication for the indicated associated RLC entities;
	    - activate the PDCP duplication for the DRB;
	  - if the deactivation of PDCP duplication is indicated for the DRB:
	    - deactivate the PDCP duplication for the DRB;
	  - if the deactivation of PDCP duplication is indicated for at least one associated RLC entities:
	    - deactivate the PDCP duplication for the indicated associated RLC entities;
	    - if all associated RLC entities other than the primary RLC entity are deactivated for PDCP duplication:
	      - deactivate the PDCP duplication for the DRB.
	
	(3GPP TS 38.323 V17.4.0)
	
	6.7 CARRIER AGGREGATION
	
	In case of CA, the multi-carrier nature of the physical layer is only exposed to the MAC layer for which one HARQ entity is required per serving cell as depicted on Figures 6.7-1 and 6.7-2 below:
	- In both uplink and downlink, there is one independent hybrid-ARQ entity per serving cell and one transport block is generated per assignment/grant per serving cell in the absence of spatial multiplexing. Each transport block and its potential HARQ retransmissions are mapped to a single serving cell.

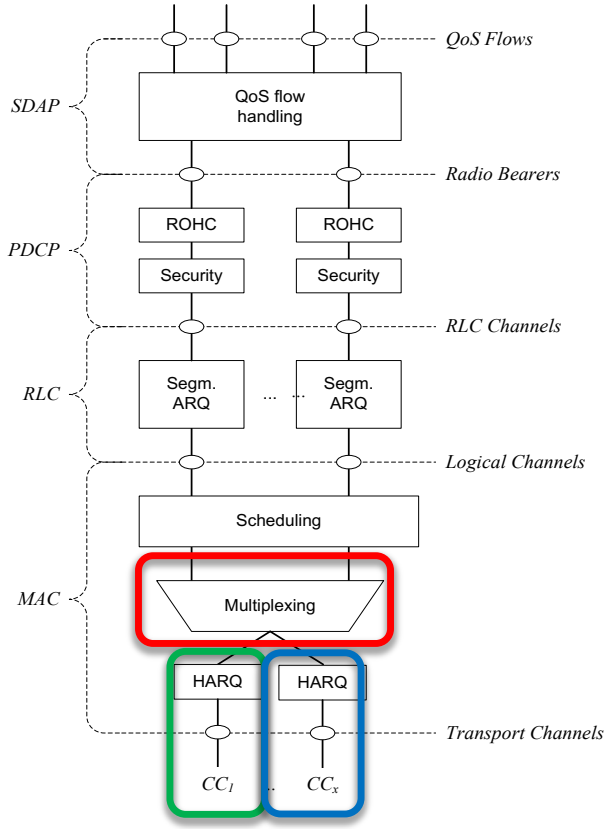
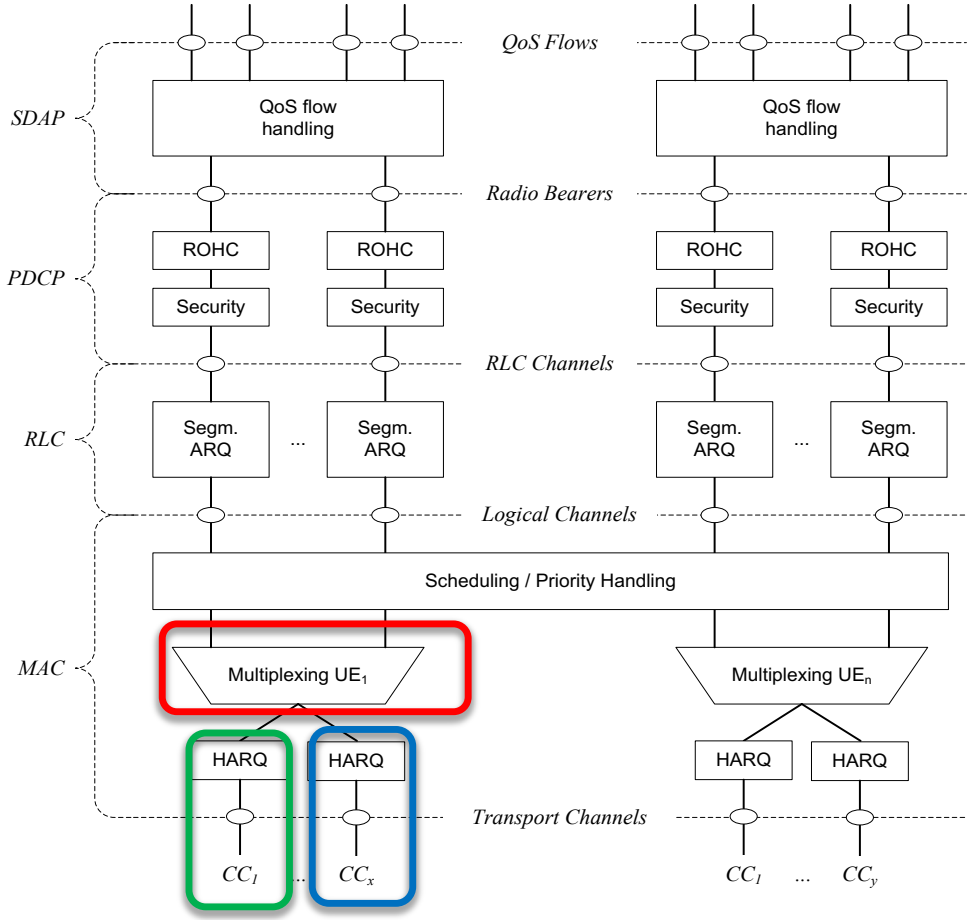


Figure 6.7-2: Layer 2Structure for UL with CA config-

(3GPP TS 38.300 V17.4.0)

Claim 8	Accused Instrumentalities
	 **Figure 6.7-1: Layer 2 Structure for DL with CA configured.**

Claim 9

Claim 9	Accused Instrumentalities
[9] The method of claim 1 wherein first information and second information comprise a plurality of OFDM symbols, wherein a first symbol is transmitted during a first time slot across the first frequency range and a second symbol is trans- mitted during the first time slot across the second frequency range, and wherein a third symbol is transmitted during a second time slot across the first frequency range and a fourth symbol is transmitted during the second time slot across a second frequency range.	The Accused Instrumentalities perform a method wherein first information and second information comprise a plurality of OFDM symbols, wherein a first symbol is transmitted during a first time slot across the first frequency range and a second symbol is transmitted during the first time slot across the second frequency range, and wherein a third symbol is transmitted during a second time slot across the first frequency range and a fourth symbol is transmitted during the second time slot across a second frequency range. For example, the 5G frame structure comprises frames of length 10 msec long, each frame comprises 10 sub-frames, each subframe comprises at least two time slots, and each frame comprises at least 20 time slots. Each time slot comprises a multitude of OFDM symbols. A transport block, data payload, in 5G is divided into a set of code blocks, each code block is transmitted on frequency resources of OFDM symbols that comprise a time slot. In a Carrier Aggregation (CA) method, a data stream is multiplexed onto multiple Component Carriers (CCs), e.g., onto a first and a second data stream. The first and second data ("information") streams are transmitted on a first and a second CC, respectively. The first data stream is transmitted on a first CC, on frequency resources of an OFDM symbol in a time slot of the first CC, and the second data stream is transmitted on a second CC, on frequency resources of an OFDM symbol in the time slot of the second CC. The code blocks of the transport block (payload, data stream) are multiplexed onto the CCs and transmitted in consecutive time slots. **6.7 CARRIER AGGREGATION** In case of CA, the multi-carrier nature of the physical layer is only exposed to the MAC layer for which one HARQ entity is required per serving cell as depicted on Figures 6.7-1 and 6.7-2 below: - In both uplink and downlink, there is one independent hybrid-ARQ entity per serving cell and one transport block is generated per assignment/grant per serving cell in the absence of spatial multiplexing. Each transport block and its potential HARQ retransmissions are mapped to a single serving cell.

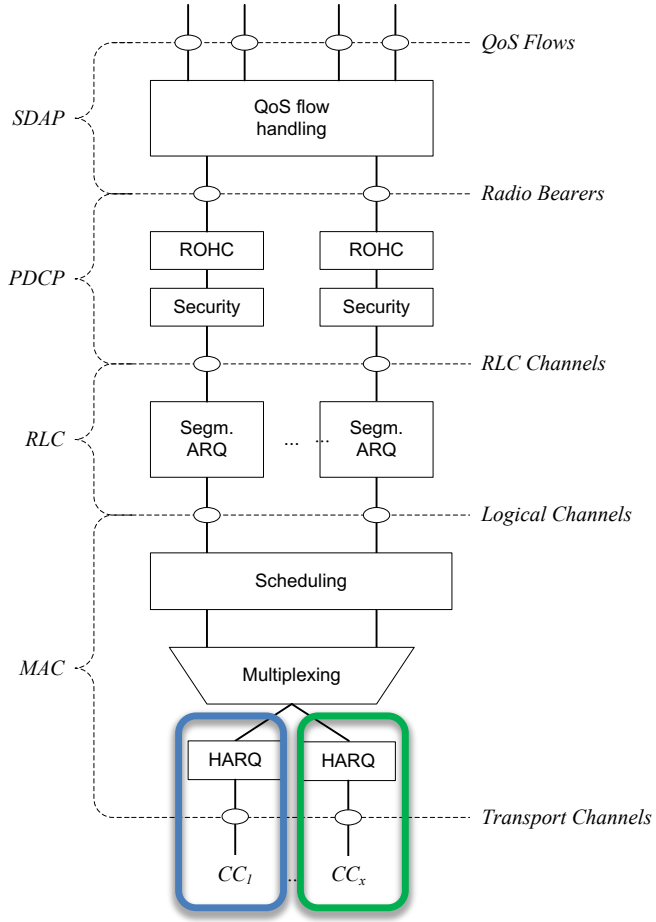


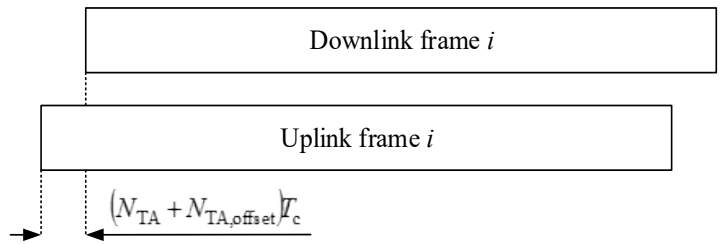
Figure 6.-2: Layer 2 Structure for UL with CA configured.

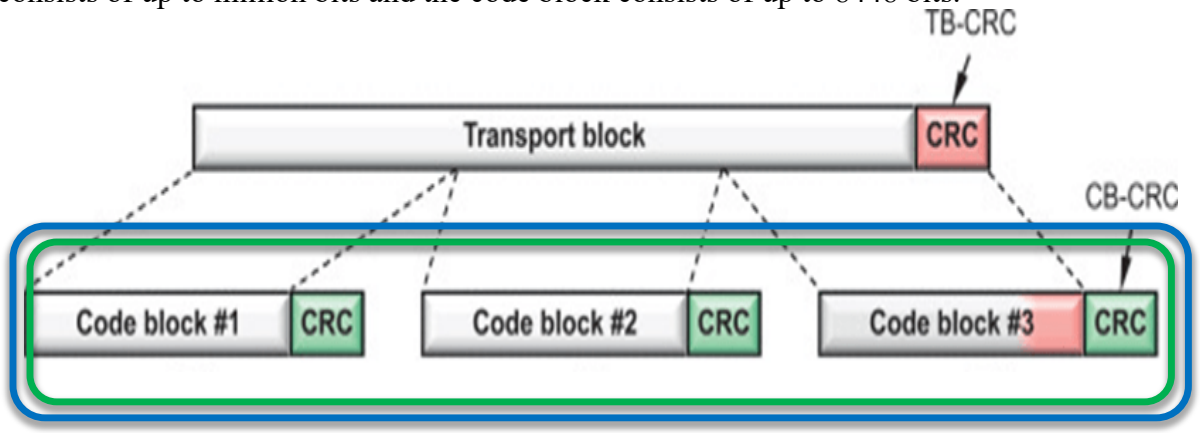
(3GPP TS 38.300 V17.4.0)

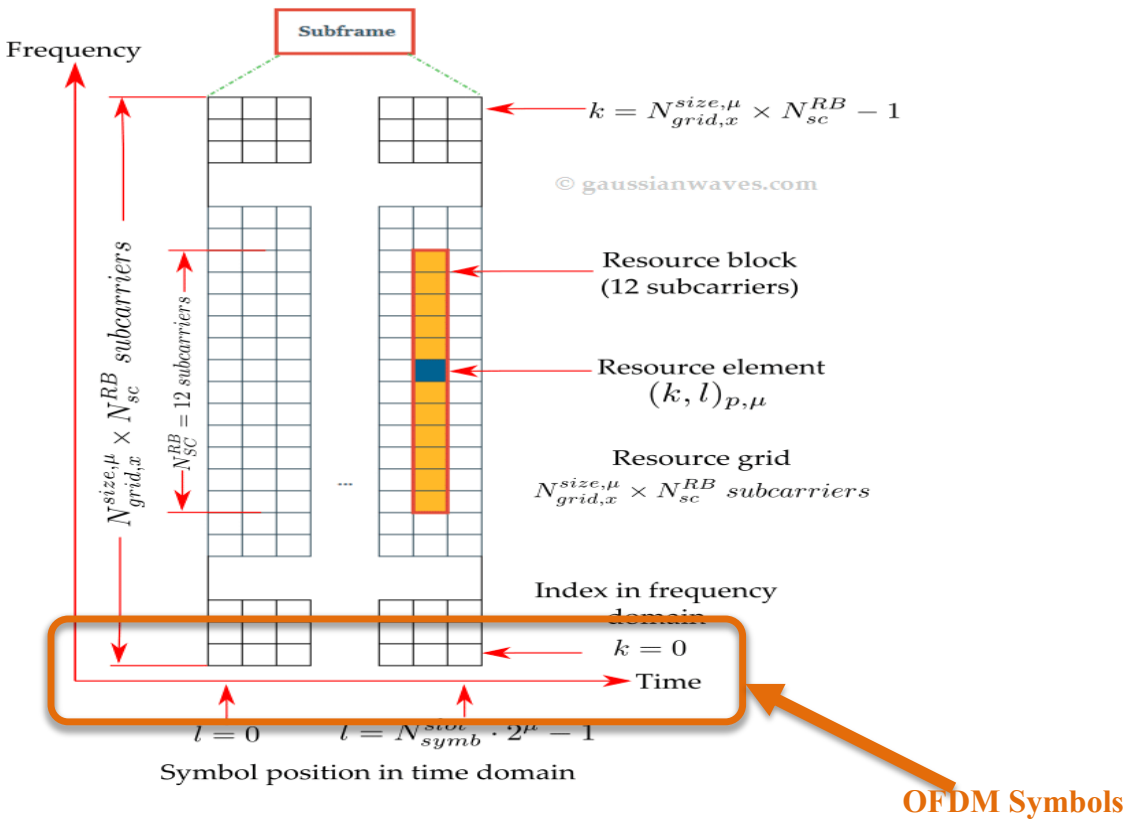
Frame structure and physical resources

4.1 GENERAL

Claim 9	Accused Instrumentalities
	Throughout this specification, unless otherwise noted, the size of various fields in the time domain is expressed in time units $T_c = 1/(\Delta f_{max} \cdot N_f)$ where $\Delta f_{max} = 480 \cdot 10^3$ Hz and $N_f = 4096$. The constant $\kappa = T_s/T_c = 64$ where $T_s = 1/(\Delta f_{ref} \cdot N_{f,ref})$, $\Delta f_{ref} = 15 \cdot 10^3$ Hz and $N_{f,ref} = 2048$. Throughout this specification, unless otherwise noted, statements using the term "UE" in clauses 4, 5, 6, or 7 are equally applicable to the IAB-MT part of an IAB node. **4.2 NUMEROLOGIES** Multiple OFDM numerologies are supported as given by Table 4.2-1 where μ and the cyclic prefix for a downlink or uplink bandwidth part are obtained from the higher-layer parameter *subcarrierSpacing* and *cyclicPrefix*, respectively. **Table 4.2-1: Supported transmission numerologies.** μ | $\Delta f = 2^{\mu} \cdot 15$[kHz] | **Cyclic prefix** 0 | 15 | Normal 1 | 30 | Normal 2 | 60 | Normal, Extended 3 | 120 | Normal 4 | 240 | Normal **4.3 FRAME STRUCTURE** **4.3.1 FRAMES AND SUBFRAMES** Downlink, uplink, and sidelink transmissions are organized into frames with $T_f = (\Delta f_{max} N_f/100) \cdot T_c = 10$ ms duration, each consisting of ten subframes of $T_{sf} = (\Delta f_{max} N_f/1000) \cdot T_c = 1$ ms duration. The number of consecutive OFDM symbols per subframe is $N_{symb}^{subframe,\mu} = N_{symb}^{slot} N_{slot}^{subframe,\mu}$. Each frame is divided into two equally-sized half-frames of five subframes each with half-frame 0 consisting of subframes 0 – 4 and half-frame 1 consisting of subframes 5 – 9. There is one set of frames in the uplink and one set of frames in the downlink on a carrier.

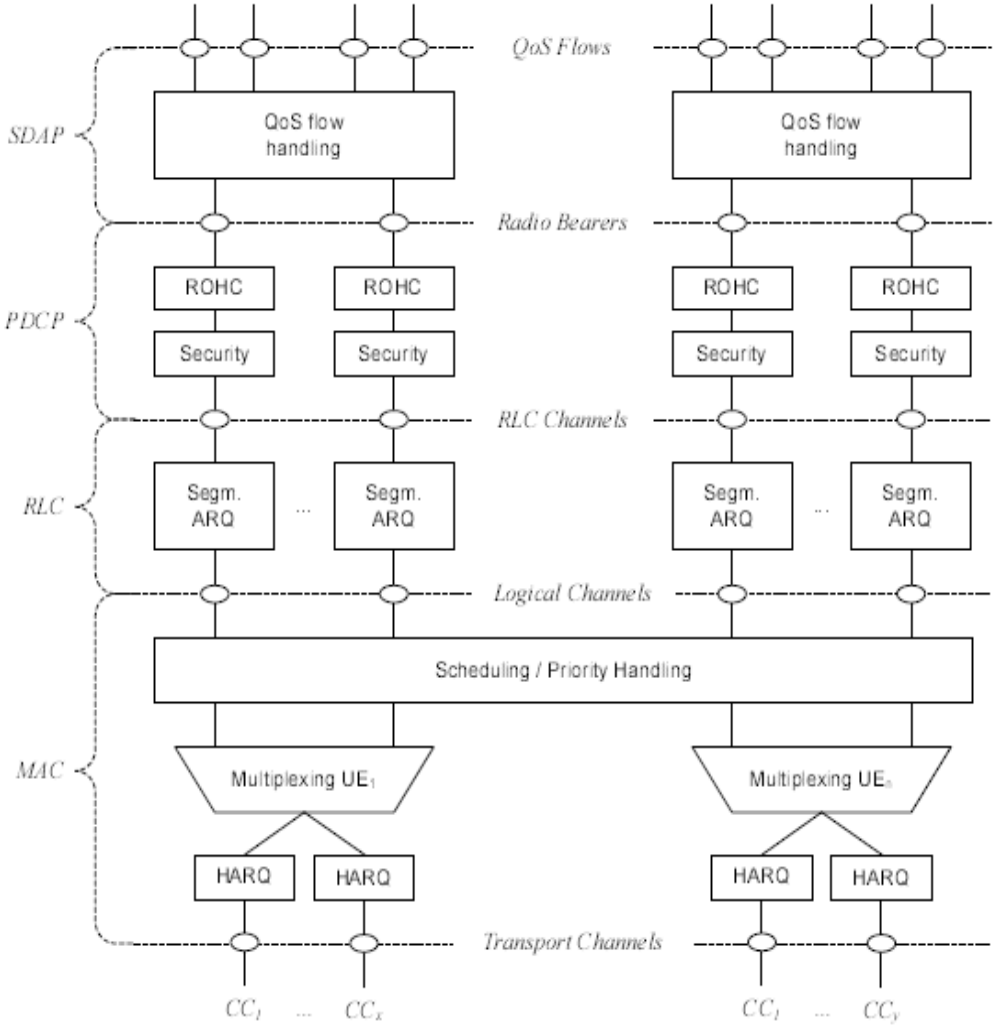
Claim 9	Accused Instrumentalities
	Uplink frame number i for transmission from the UE shall start $T_{TA} = (N_{TA} + N_{TA,offset})T_c$ before the start of the corresponding downlink frame at the UE where $N_{TA,offset}$ is given by [5, TS 38.213], except for msgA transmission on PUSCH where $T_{TA} = 0$ shall be used.  **Figure 4.3.1-1: Uplink-downlink timing relation.** **4.3.2 SLOTS** For subcarrier spacing configuration μ, slots are numbered $n_s^\mu \in \{0, \ldots, N_{slot}^{subframe,\mu} - 1\}$ in increasing order within a subframe and $n_{s,f}^\mu \in \{0, \ldots, N_{slot}^{frame,\mu} - 1\}$ in increasing order within a frame. There are N_{symb}^{slot} consecutive OFDM symbols in a slot where N_{symb}^{slot} depends on the cyclic prefix as given by Tables 4.3.2-1 and 4.3.2-2. The start of slot n_s^μ in a subframe is aligned in time with the start of OFDM symbol $n_s^\mu N_{symb}^{slot}$ in the same subframe. OFDM symbols in a slot in a downlink or uplink frame can be classified as 'downlink', 'flexible', or 'uplink'. Signaling of slot formats is described in clause 11.1 of [5, TS 38.213]. (3GPP TS 38.211 V16.1.0) **5G NR Transport Block Size (TBS) Calculation** August 16, 2020Author3GPP Specification, 5G MAC Layer, 5G NR, 5G Physical Layer Frame structure and physical resources Transport Block in 5G NR, is nothing but the payload, which is passed between the MAC and Phy Layers, specifically for the shared data channel such as PDSCH and PUSCH. A Transport Block undergoes Phy layer

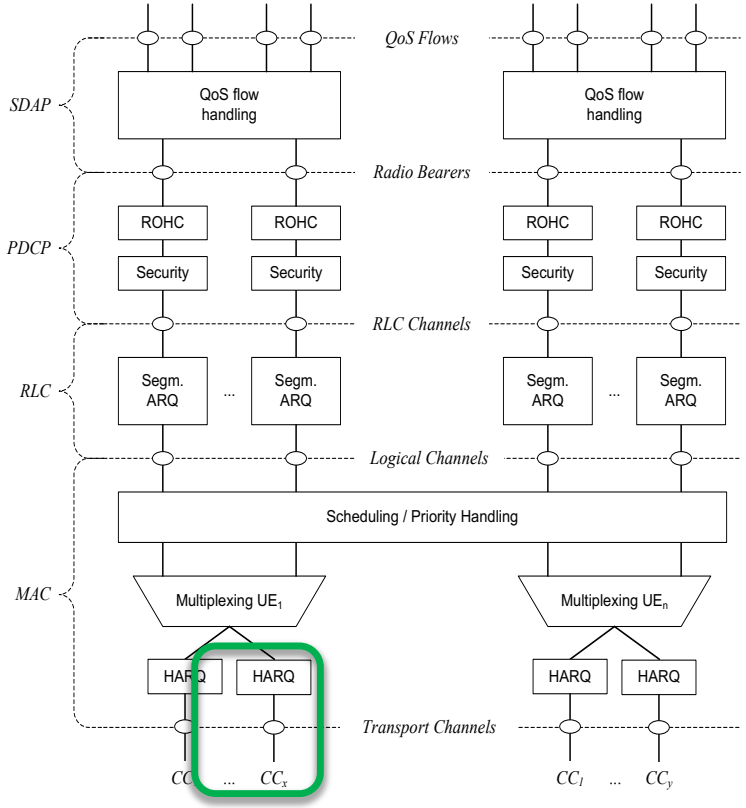
Claim 9	Accused Instrumentalities
	processing at the transmitter before being mapped onto the PDSCH for transmission over the air interface. A Transport block is added with CRC and segmented into code blocks as shown as below. The transport block consists of up to million bits and the code block consists of up to 8448 bits.  https://www.techplayon.com/5g-nr-transport-block-size-tbs-calculatin **TIME-FREQUENCY RESOURCE** A ***resource element*** is the smallest time-frequency resource over one subcarrier of a single OFDM symbol. It is identified as $(k,l)_{p,\mu}$ where k is the index of the subcarrier in the frequency domain, l is the OFDM symbol position in time domain, p is the antenna port and μ is the subcarrier spacing configuration defined in Table 1 above. A ***resource block*** (a.k.a ***physical resource block – PRB***) is a block of $N^{RB}_{sc} = 12$ subcarriers over which the transmissions are scheduled. 5G NR physical layer uses time-frequency resource (***physical resource block***) for transmission.

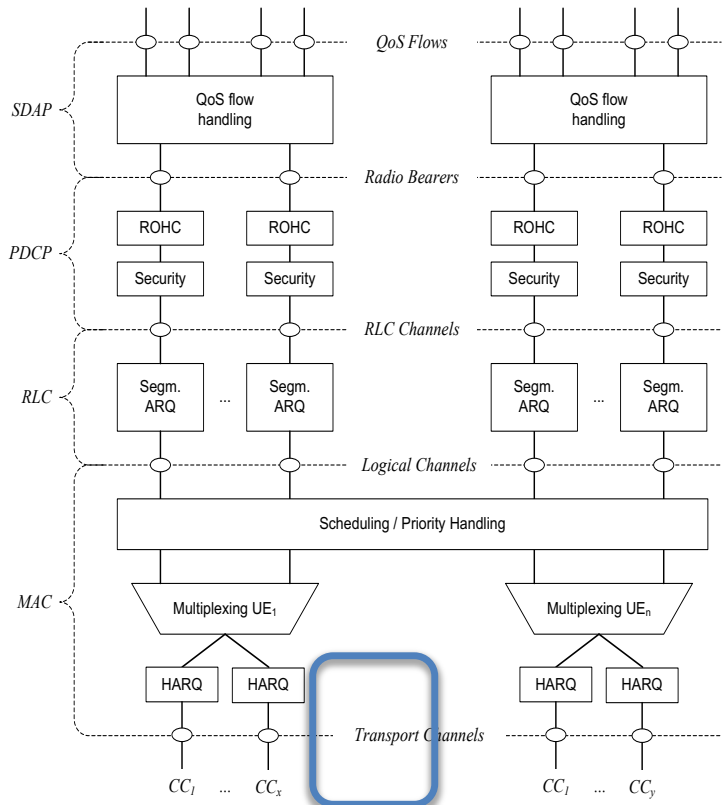
Claim 9	Accused Instrumentalities
	A resource grid consists of $N^{size,\mu}_{grid,x}$ subcarriers and $N^{subframe,\mu}_{symb}$ number of OFDM symbols (***Table 2 and 3***).  ***Figure 3: Resource element, Resource block, Resource grid in 5G NR*** https://www.gaussianwaves.com/2022/02/5g-nr-resource-block

Claim 10

Claim 10	Accused Instrumentalities
[10.0] A method of transmitting information in a wireless communication channel comprising:	To the extent the preamble is found to be limiting, the Accused Instrumentalities perform a method of transmitting information in a wireless communication channel. For example, Defendant's cellular UEs support 3GPP 5G uplink carrier aggregation, and Defendant's customers use the carrier aggregation functionalities. *See* analysis and evidence for [1.0] above.
[10.1] receiving a first digital signal comprising first data to be transmitted;	The Accused Instrumentalities perform a method that includes receiving a first digital signal comprising first data to be transmitted. For example: **6.7 CARRIER AGGREGATION** In case of CA, the multi-carrier nature of the physical layer is only exposed to the MAC layer for which one HARQ entity is required per serving cell as depicted on Figures 6.7-1 and 6.7-2 below: - In both uplink and downlink, there is one independent hybrid-ARQ entity per serving cell and one transport block is generated per assignment/grant per serving cell in the absence of spatial multiplexing. Each transport block and its potential HARQ retransmissions are mapped to a single serving cell. (3GPP TS 38.300 V17.4.0)

Claim 10	Accused Instrumentalities
	 **Figure 6.7-1: Layer 2 Structure for DL with CA configured** (3GPP TS 38.300 V17.4.0)

Claim 10	Accused Instrumentalities
	 **Figure 6.7-2: Layer 2 Structure for UL with CA configured** (3GPP TS 38.300 V17.5.0)
[10.2] receiving a second digital signal comprising second data to be transmitted;	The Accused Instrumentalities perform a method that includes amplifying the combined up-converted signal in a power amplifier resulting in an amplified combined up-converted signal. For example:

Claim 10	Accused Instrumentalities
	6.7 CARRIER AGGREGATION In case of CA, the multi-carrier nature of the physical layer is only exposed to the MAC layer for which one HARQ entity is required per serving cell as depicted on Figures 6.7-1 and 6.7-2 below: -- In both uplink and downlink, there is one independent hybrid-ARQ entity per serving cell and one transport block is generated per assignment/grant per serving cell in the absence of spatial multiplexing. Each transport block and its potential HARQ retransmissions are mapped to a single serving cell. (3GPP TS 38.300 V17.4.0)  **Figure 6.7-2: Layer 2 Structure for UL with CA configured** (3GPP TS 38.300 V17.5.0)

Claim 10	Accused Instrumentalities
[10.3] converting the first digital signal into a first analog signal using a first digital-to-analog converter, the first analog signal carrying the first data across a first frequency range;	The Accused Instrumentalities perform a method that includes converting the first digital signal into a first analog signal using a first digital-to-analog converter, the first analog signal carrying the first data across a first frequency range. For example: **11.3.2.1 Transmitter architecture** Figure 11.3.2.1-1 illustrates various TX architectures options according to where the component carriers are combined, i.e., at digital baseband, or in analog waveforms before RF mixer, or after mixer but before the PA, or after the PA. Option A - In an adjacent *contiguous common carrier* aggregation scenario, the UE very likely has one PA. Connected to the PA can be a single RF chain (a zero-IF mixer, a wideband DAC, and a wideband IFFT) Option-B - Combines analog baseband waveforms from component Carrier first (e.g., via a mixer operating at an IF of roughly the bandwidth of the other component carrier in the example of 2-component carrier aggregation). Then the resulting wideband signal is up-converted to RF. Option-C - Does ZIF up-conversion of each component carrier before combining and feeding into a single PA. Option-D - Employs multiple RF chains and multiple PAs after which the high-power signals are combined and fed into a single antenna. PA coupling at the UE can be challenging for option-D. (3GPP TR 36.912 version 15.0.0 Release 15)

Claim 10	Accused Instrumentalities

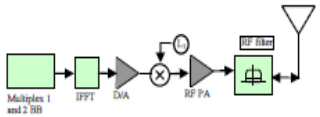
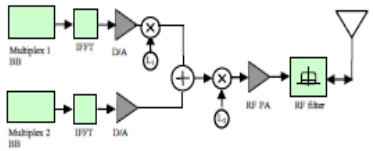
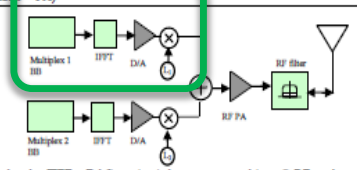
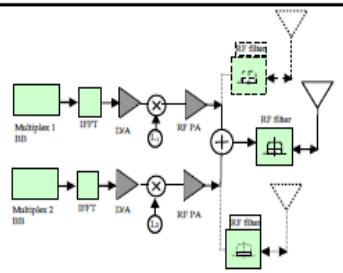
Tx Characteristics				
Option	Description (Tx architecture)	Intra Band aggregation		Inter Band aggregation
		Contiguous (CC)	Non contiguous (CC)	Non contiguous (CC)
A	 Single (baseband + IFFT + DAC + mixer + PA)	Yes		
B	 Multiple (baseband + IFFT + DAC), single (stage-1 IF mixer + combiner @ IF + stage-2 RF mixer + PA)	Yes	Yes	
C	 Multiple (baseband + IFFT + DAC + mixer), low-power combiner @ RF, and single PA	Yes	Yes	
D	 Multiple (baseband + IFFT + DAC + mixer + PA), high-power combiner to single antenna OR dual antenna	Yes	Yes	Yes + (depending on the specific EUTRA bands being aggregated),
X	*OTHERS*			

Figure 11.3.2.1-1: Possible UE Architectures in three aggregation scenarios

(3GPP TR 36.912 version 15.0.0 Release 15)

Claim 10	Accused Instrumentalities
[10.4] converting the second digital signal into a second analog signal using a second digital-to-analog converter, the second analog signal carrying the second data across a second frequency range;	The Accused Instrumentalities perform a method that includes converting the second digital signal into a second analog signal using a second digital-to-analog converter, the second analog signal carrying the second data across a second frequency range. For example:

Tx Characteristics

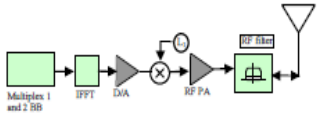
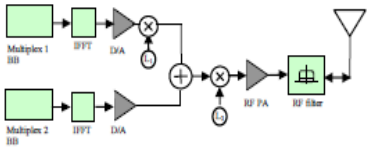
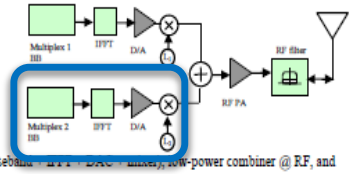
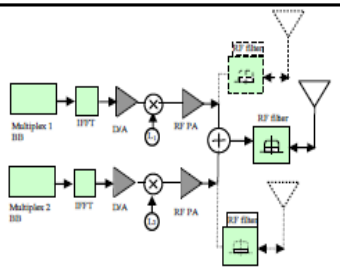
Option	Description (Tx architecture)	Intra Band aggregation		Inter Band aggregation
		Contiguous (CC)	Non contiguous (CC)	Non contiguous (CC)
A	 Single (baseband + IFFT + DAC + mixer + PA)	Yes		
B	 Multiple (baseband + IFFT + DAC), single (stage-1 IF mixer + combiner @ IF + stage-2 RF mixer + PA)	Yes	Yes	
C	 Multiple (baseband + IFFT + DAC + mixer), low-power combiner @ RF, and single PA	Yes	Yes	
D	 Multiple (baseband + IFFT + DAC + mixer + PA), high-power combiner to single antenna OR dual antenna	Yes	Yes	Yes + (depending on the specific EUTRA bands being aggregated),
X	*OTHERS*			

Figure 11.3.2.1-1: Possible UE Architectures in three aggregation scenarios

(3GPP TR 36.912 version 15.0.0 Release 15)

Claim 10	Accused Instrumentalities
[10.5] up-converting the first analog signal to a first RF center frequency to produce a first up-converted analog signal, wherein the first up-converted analog signal comprises a first up-converted frequency range from the first RF center frequency minus one-half the first frequency range to the first RF center frequency plus one-half the first frequency range;	The Accused Instrumentalities perform a method that includes up-converting the first analog signal to a first RF center frequency to produce a first up-converted analog signal, wherein the first up-converted analog signal comprises a first up-converted frequency range from the first RF center frequency minus one-half the first frequency range to the first RF center frequency plus one-half the first frequency range. For example:

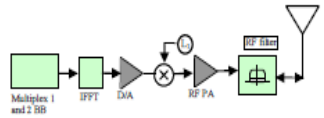
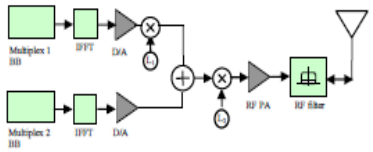
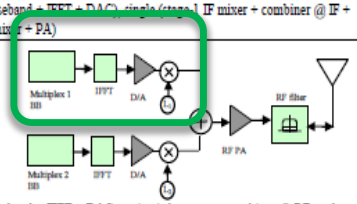
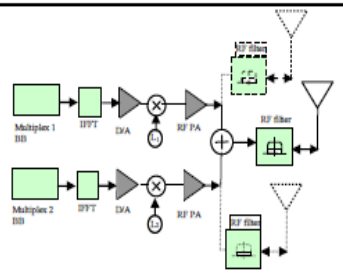
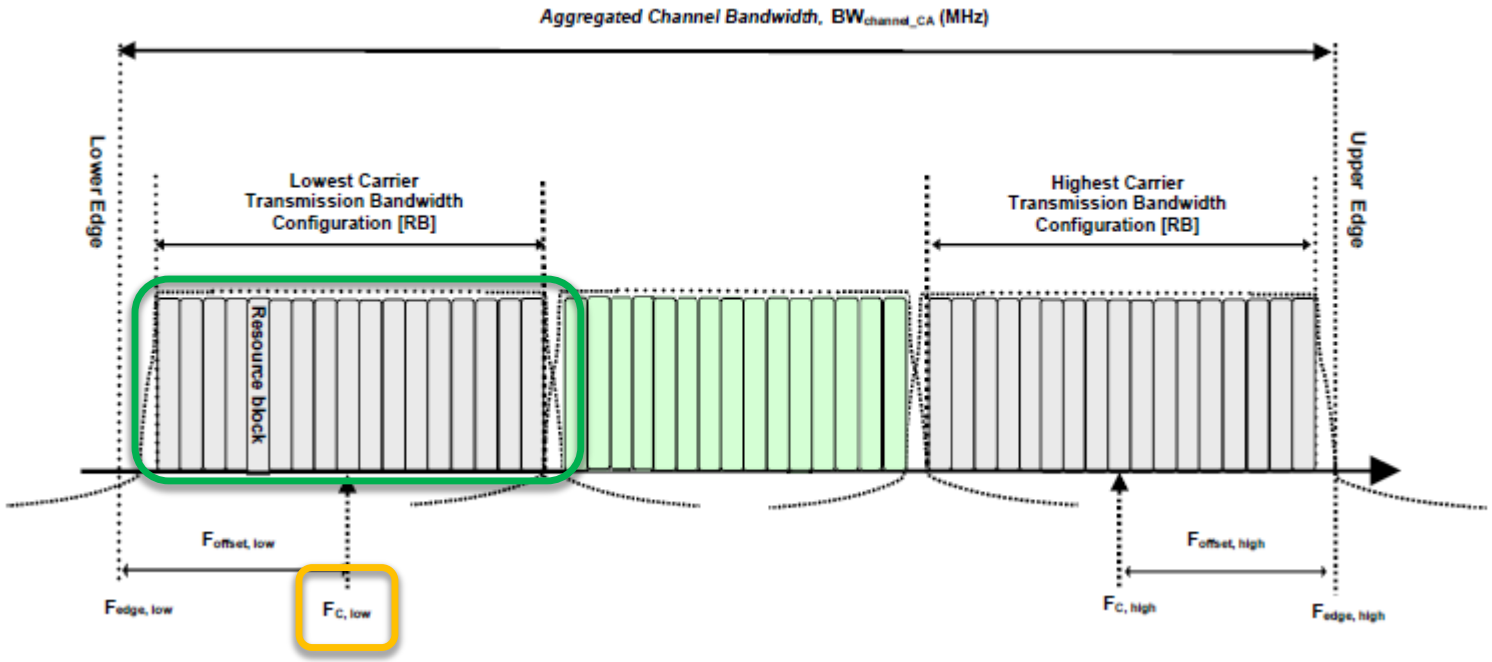
Tx Characteristics				
Option	Description (Tx architecture)	Intra Band aggregation		Inter Band aggregation
		Contiguous (CC)	Non contiguous (CC)	Non contiguous (CC)
A	 Single (baseband + IFFT + DAC + mixer + PA)	Yes		
B	 Multiple (baseband + IFFT + DAC), single (stage-1 IF mixer + combiner @ IF + stage-2 RF mixer + PA)	Yes	Yes	
C	 Multiple (baseband + IFFT + DAC + mixer), low-power combiner @ RF, and single PA	Yes	Yes	
D	 Multiple (baseband + IFFT + DAC + mixer + PA), high-power combiner to single antenna OR dual antenna	Yes	Yes	Yes + (depending on the specific EUTRA bands being aggregated),
X	*OTHERS*			

Figure 11.3.2.1-1: Possible UE Architectures in three aggregation scenarios

(3GPP TR 36.912 version 15.0.0 Release 15)

Claim 10	Accused Instrumentalities
	For carrier aggregation, the maximum transmission bandwidth configuration is defined per component carrier and the requirement is specified in clause 5.3.2. 5.3A.3 Minimum guardband and transmission bandwidth configuration for CA For intra-band contiguous carrier aggregation, *Aggregated Channel Bandwidth* and *Guard Bands* are defined as follows, see Figure 5.3A.3-1.  **Figure 5.3A.3-1: Definition of *Aggregated Channel Bandwidth* for intra-band carrier aggregation**

Claim 10	Accused Instrumentalities
	$BW_{Channel\_CA} = F_{edge,high} - F_{edge,low}$ (MHz). The lower bandwidth edge $F_{edge,low}$ and the upper bandwidth edge $F_{edge,high}$ of the aggregated channel bandwidth are used as frequency reference points for transmitter and receiver requirements and are defined by $F_{edge,low} = F_{C,low} - F_{offset,low}$ $F_{edge,high} = F_{C,high} + F_{offset,high}$ The lower and upper frequency offsets depend on the transmission bandwidth configurations of the lowest and highest assigned edge component carrier and are defined as $F_{offset,low} = (N_{RB,low}*12 + 1)*SCS_{low}/2 + BW_{GB}$ (MHz) $F_{offset,high} = (N_{RB,high}*12 - 1)*SCS_{high}/2 + BW_{GB}$ (MHz) $BW_{GB} = \max(BW_{GB,Channel(k)})$ $N_{RB,low}$ and $N_{RB,high}$ are the transmission bandwidth configurations according to Table 5.3.2-1 for the lowest and highest assigned component carrier, SCS_{low} and SCS_{high} are the sub-carrier spacing for the lowest and highest assigned component carrier respectively. SCS_{low}, SCS_{high}, $N_{RB,low}$, $N_{RB,high}$, and $BW_{GB,Channel(k)}$ use the largest μ value among the subcarrier spacing configurations supported in the operating band for both of the channel bandwidths according to Table 5.3.5-1 and $BW_{GB,Channel(k)}$ is the minimum guard band for carrier k according to Table 5.3.3-1 for the said μ value. In case there is no common μ value for both of the channel bandwidths, μ=1 is used for SCS_{low}, SCS_{high}, $N_{RB,low}$, $N_{RB,high}$, and $BW_{GB,Channel(k)}$. (3GPP TS 38.101-1 V17.5.0)
[10.6] up-converting the second analog signal to a second RF center frequency greater than the first center RF frequency to produce a second up-converted analog signal, wherein the second up-converted analog signal comprises a second up-converted	The Accused Instrumentalities perform a method that includes up-converting the second analog signal to a second RF center frequency greater than the first center RF frequency to produce a second up-converted analog signal, wherein the second up-converted analog signal comprises a second up-converted frequency range from the second RF center frequency minus one-half the second frequency range to the second RF center frequency plus one-half the second frequency range, and wherein a frequency difference between the first RF center frequency and the second RF center frequency is greater than the sum of one-half the first frequency range and one-half the second frequency range. For example:

Claim 10	Accused Instrumentalities
frequency range from the second RF center frequency minus one-half the second frequency range to the second RF center frequency plus one-half the second frequency range, and wherein a frequency difference between the first RF center frequency and the second RF center frequency is greater than the sum of one-half the first frequency range and one-half the second frequency range;	

Tx Characteristics

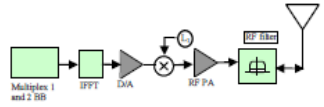
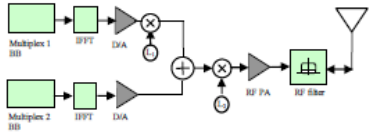
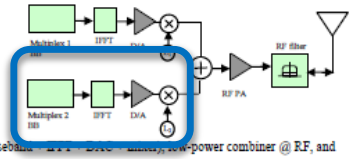
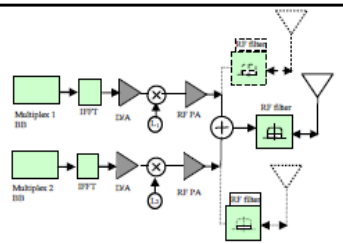
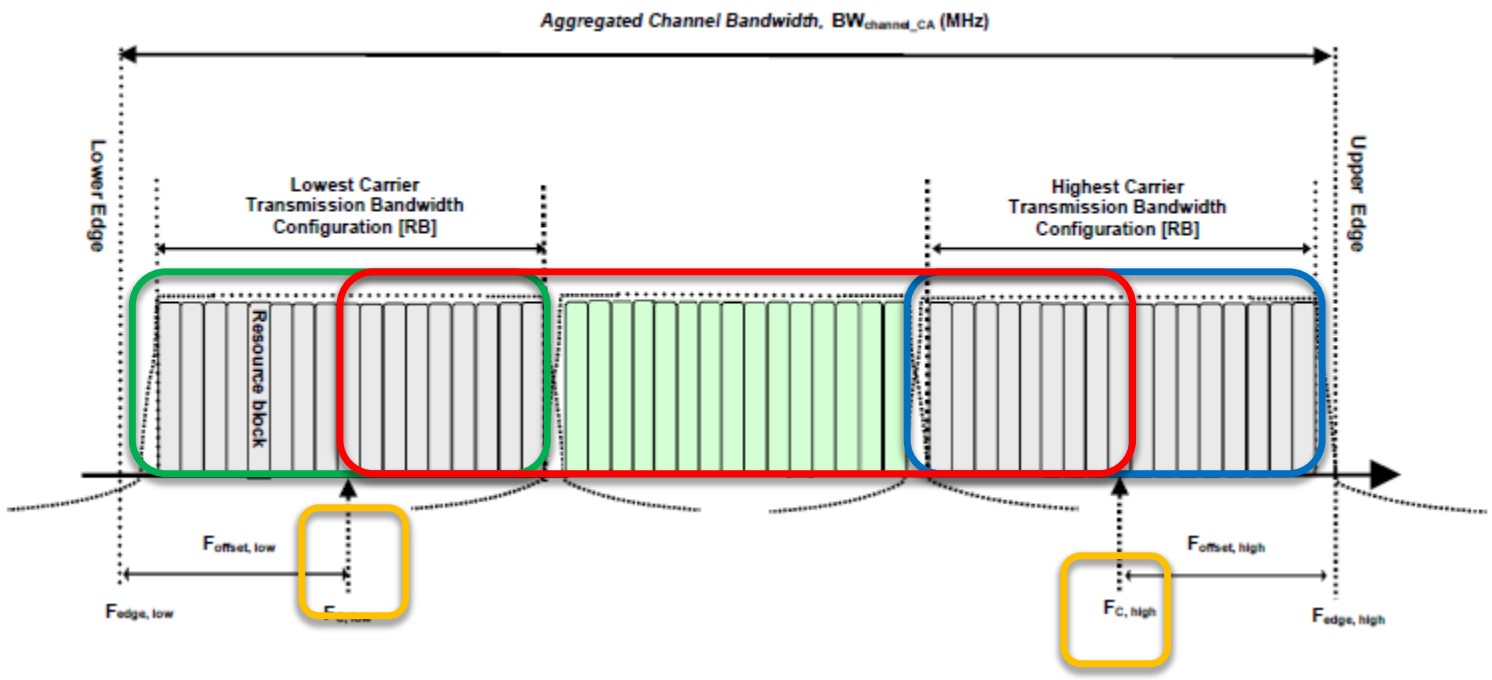
Option	Description (Tx architecture)	Intra Band aggregation		Inter Band aggregation
		Contiguous (CC)	Non contiguous (CC)	Non contiguous (CC)
A	 Single (baseband + IFFT + DAC + mixer + PA)	Yes		
B	 Multiple (baseband + IFFT + DAC), single (stage-1 IF mixer + combiner @ IF + stage-2 RF mixer + PA)	Yes	Yes	
C	 Multiple (baseb[illegible]-power combiner @ RF, and single PA	Yes	Yes	
D	 Multiple (baseband + IFFT + DAC + mixer + PA), high-power combiner to single antenna OR dual antenna	Yes	Yes	Yes + (depending on the specific EUTRA bands being aggregated),
X	*OTHERS*			

Figure 11.3.2.1-1: Possible UE Architectures in three aggregation scenarios

(3GPP TR 36.912 version 15.0.0 Release 15)

For carrier aggregation, the maximum transmission bandwidth configuration is defined per component carrier and the requirement is specified in clause 5.3.2.

5.3A.3 Minimum guardband and transmission bandwidth configuration for

Claim 10	Accused Instrumentalities
	CA For intra-band contiguous carrier aggregation, *Aggregated Channel Bandwidth* and *Guard Bands* are defined as follows, see Figure 5.3A.3-1.  **Figure 5.3A.3-1: Definition of *Aggregated Channel Bandwidth* for intra-band carrier aggregation** (3GPP TS 38.101-1 V17.5.0)
[10.7] combining the first up-converted analog signal and	The Accused Instrumentalities perform a method that includes combining the first up-converted analog signal and the second up-converted analog signal to produce a combined up-converted signal. For example:

Claim 10	Accused Instrumentalities
the second up-converted analog signal to produce a combined up-converted signal;	

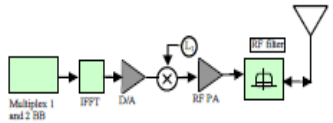
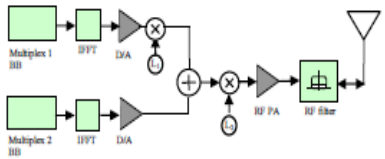
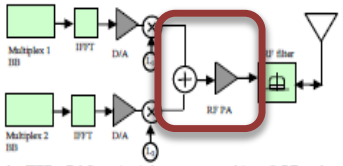
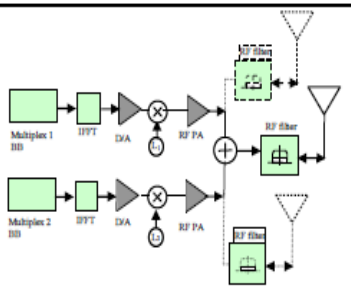
Tx Characteristics				
Option	Description (Tx architecture)	Intra Band aggregation		Inter Band aggregation
		Contiguous (CC)	Non contiguous (CC)	Non contiguous (CC)
A	 Single (baseband + IFFT + DAC + mixer + PA)	Yes		
B	 Multiple (baseband + IFFT + DAC), single (stage-1 IF mixer + combiner @ IF + stage-2 RF mixer + PA)	Yes	Yes	
C	 Multiple (baseband + IFFT + DAC + mixer), low-power combiner @ RF, and single PA	Yes	Yes	
D	 Multiple (baseband + IFFT + DAC + mixer + PA), high-power combiner to single antenna OR dual antenna	Yes	Yes	Yes + (depending on the specific EUTRA bands being aggregated),
X	*OTHERS*			

Figure 11.3.2.1-1: Possible UE Architectures in three aggregation scenarios

(3GPP TR 36.912 version 15.0.0 Release 15)

Claim 10	Accused Instrumentalities
[10.8] amplifying the combined up-converted signal in a power amplifier resulting in an amplified combined up-converted signal; and	The Accused Instrumentalities perform a method that includes receiving a second digital signal comprising second data to be transmitted. For example:

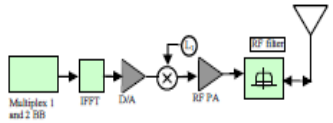
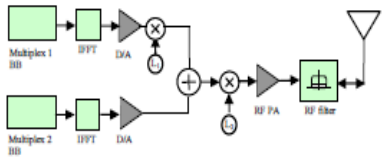
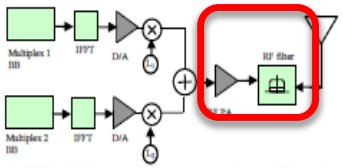
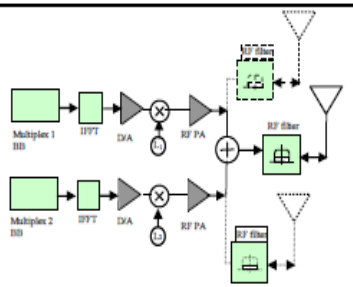
Tx Characteristics				
Option	Description (Tx architecture)	Intra Band aggregation		Inter Band aggregation
		Contiguous (CC)	Non contiguous (CC)	Non contiguous (CC)
A	 Single (baseband + IFFT + DAC + mixer + PA)	Yes		
B	 Multiple (baseband + IFFT + DAC), single (stage-1 IF mixer + combiner @ IF + stage-2 RF mixer + PA)	Yes	Yes	
C	 Multiple (baseband + IFFT + DAC + mixer), low-power combiner @ RF, and single PA	Yes	Yes	
D	 Multiple (baseband + IFFT + DAC + mixer + PA), high-power combiner to single antenna OR dual antenna	Yes	Yes	Yes + (depending on the specific EUTRA bands being aggregated),
X	*OTHERS*			

Figure 11.3.2.1-1: Possible UE Architectures in three aggregation scenarios

Claim 10	Accused Instrumentalities
[10.9] transmitting the amplified combined up-converted signal on a first antenna,	The Accused Instrumentalities perform a method that includes transmitting the amplified combined up-converted signal on a first antenna. For example:

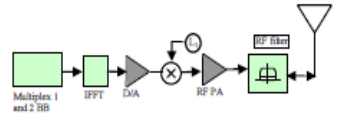
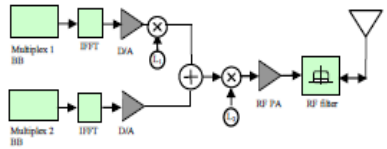
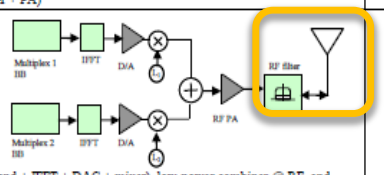
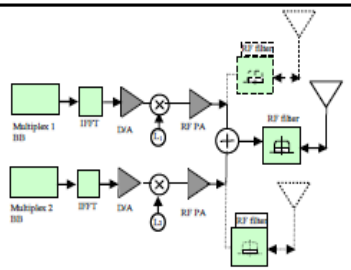
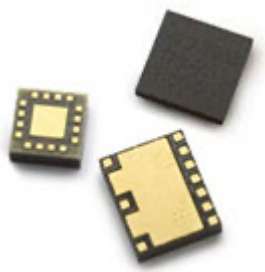
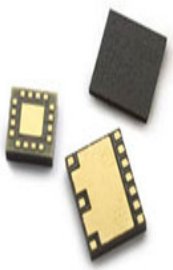
Tx Characteristics				
Option	Description (Tx architecture)	Intra Band aggregation		Inter Band aggregation
		Contiguous (CC)	Non contiguous (CC)	Non contiguous (CC)
A	 Single (baseband + IFFT + DAC + mixer + PA)	Yes		
B	 Multiple (baseband + IFFT + DAC), single (stage-1 IF mixer + combiner @ IF + stage-2 RF mixer + PA)	Yes	Yes	
C	 Multiple (baseband + IFFT + DAC + mixer), low-power combiner @ RF, and single PA	Yes	Yes	
D	 Multiple (baseband + IFFT + DAC + mixer + PA), high-power combiner to single antenna OR dual antenna	Yes	Yes	Yes + (depending on the specific EUTRA bands being aggregated),
X	*OTHERS*			

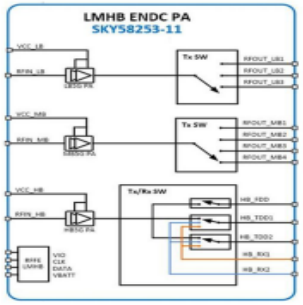
Figure 11.3.2.1-1: Possible UE Architectures in three aggregation scenarios

(3GPP TR 36.912 version 15.0.0 Release 15)

Claim 10	Accused Instrumentalities

[10.10] wherein the bandwidth of said power amplifier is greater than the difference between a lowest frequency in the first up-converted frequency range and a highest frequency in the second up-converted frequency range.	The Accused Instrumentalities perform a method wherein the bandwidth of said power amplifier is greater than the difference between a lowest frequency in the first up-converted frequency range and a highest frequency in the second up-converted frequency range. For example, in power amplifier designs believed to be representative of those used in the Accused Instrumentalities:
	
	Mobile RF FEM
	
	 
	
	Broadcom provides custom RF frond end module (FEM) devices for mobile wireless applications. These devices incorporate multiband power amplifiers (PA), FBAR duplexers and multiplexers, SOI multi-mode LNAs and antenna switch, coupler and MIPI controller, designed to support various carrier aggregation (CA) for both FDD and TDD bands.
	Broadcom has shipped billions of RF FEM devices to the world's leading smartphone manufacturers.
	
	The Broadcom ACFM-2S13 is a quadplexer device that combines Band 1 and Band 3 duplexers into a single, miniature package. Band 4 duplexer is co-banded. The device features a single antenna connection, eliminating the need for antenna switching. High Isolation between bands enables the use of carrier aggregation.
	
	The ACFM-2S13 is designed with Broadcom's innovative filter capability which makes possible ultra-small, high-Q filters at a fraction of their usual size. Low Tx Insertion Loss of the ACFM-2S13 reduces power amplifier current, extending battery life. The device enhances receiver sensitivity and dynamic range with low Rx Insertion Loss and high rejection of Tx signals at the Rx ports.
	Features
	• Single antenna
	• High cross band isolation
	  • Enables carrier aggregation
	• Band 4 co-banding
	• Miniature size
	  • 2.0 x 2.5 mm footprint
	  • 0.710 mm typ. height
	• High Power Rating
	• Environmental
	  • RoHS 6 Compliant
	  • Halogen Free
	  • TBBPA Free

Claim 10	Accused Instrumentalities
	(https://www.broadcom.com/products/wireless/demo-boards/acfm-2s13) Mobile RF FEM  Broadcom provides custom RF frond end module (FEM) devices for mobile wireless applications. These devices incorporate multiband power amplifiers (PA), FBAR duplexers and multiplexers, SOI multimode LNAs and antenna switch, coupler and MIPI controller, designed to support various carrier aggregation (CA) for both FDD and TDD bands. Broadcom has shipped billions of RF FEM devices to the world's leading smartphone manufacturers. (https://www.broadcom.com/products/wireless/rf-front-end-modules/mobile-rf-fem)

Claim 10	Accused Instrumentalities
	PRODUCT SUMMARY **SKY58253-11 LMH ENDC Multimode/Multiband Power Amplifier Module** **Applications** • 5G NR handsets requiring 5G re-farm bands support for ENDC (E-UTRAN New Radio – Dual Connectivity) • 5G Bands: - LB: n5/8/12/13/14/18/20/26/28/71 - MB: n1/2/3/4/25/34/39/66/70 - HB: n7/30/38/40 (HPUE)/41 (HPUE) • LTE Bands: 1, 2, 3, 4, 5, 7, 8, 9, 12, 13, 14, 17, 18, 20, 25, 26, 28, 30, 66, 70, 71 **Features** • Sky5® NR Power Amplifier Module (PAM) for ENDC applications • APT optimized • Three RF_IN ports (one LB, one MB, and one HB) • 12 RF_OUT ports: - 3 LB: n5/8/12/13/14/18/20/26/28/71 - 4 MB: n1/2/3/4/25/34/39/66/70 - 3 HB: n7/30/38/40/41 - 2 HB Rx • N41, N40 PC2 support at 4.5V • 5G NR Band support for all ENDC Cases • Small, low profile package 4.2 mm x 4.3 mm x 0.70 mm (max) • 32-pad configuration • LGA with conformal shielding Skyworks Green™ products are compliant with all applicable legislation and are halogen-free. For additional information, refer to *Skyworks Definition of Green™*, document number SQ04–0074. **Description** The SKY58253-11 supports 5G handsets and operates in NR mode when ENDC is required. The PAM consists of PA blocks for Low-bands, Mid-bands and High-bands, a logic control block for multiple power control levels, and band enable functions. RF I/O ports are internally matched to 50 Ω to minimize the number of external components. Extremely low leakage current maximizes handset standby time. The InGaP/GaAs PA die, CMOS controller, and SOI switch die and passive components are mounted on a multi-layer laminate substrate and assembly encapsulated in plastic overmold and coated with conformal shielding. **5G NR** The SKY58253-11 meets spectral linearity requirements of NR modulation with DFT and CP OFDM modulations with up to 256 QAM constellations. The PAM supports resource block allocations within 3GPP defined transmission bandwidth with good power-added efficiency.  Figure 1. SKY58253-11 Functional Block Diagram (https://www.skyworksinc.com/-/media/SkyWorks/Documents/Products/3001-3100/SKY58253-11_206595A_PS.pdf)

Claim 10	Accused Instrumentalities
	Qualcomm Introduces Sub-6 GHz and mmWave Modules for 5G Smartphones *July 23, 2018* The Qualcomm® QPM56xx sub-6 GHz RF module family and QTM052 mmWave antenna module family pair with Qualcomm's Snapdragon™ X50 5G modem to deliver modem-to-antenna functionality across multiple 5G bands in a compact footprint suited for mobile devices. **Sub-6 GHz Modules** The QPM56xx module family — the QPM5650, QPM5651, QDM5650 and QDM5652 — works with the Snapdragon X50 5G modem to support the sub-6 GHz 5G NR bands. The QPM5650 and QPM5651 integrate the power amplifier (PA), low noise amplifier (LNA), switch and filtering. For diversity and MIMO, the QDM5650 and QDM5652 integrate the LNA, switch and filtering. All four modules offer integrated sounding reference signal (SRS) switching, required for optimum massive MIMO applications, and support the 3.3 to 4.2 GHz (n77), 3.3 to 3.8 GHz (n78) and 4.4 to 5.0 GHz (n79) bands. **mmWave Antenna Modules** The QTM052 mmWave antenna modules also interface with the Snapdragon X50 5G modem to provide a comprehensive system that supports advanced beam forming, beam steering and beam tracking, which improve the range and reliability of mmWave links. The system comprises an integrated 5G NR radio transceiver, power management IC, RF front-end components and phased array antenna. The QTM052 handles up to 800 MHz bandwidth in the 26.5 to 29.5 GHz (n257) band and the entire 27.5 to 28.35 GHz (n261) and 37 to 40 GHz (n260) bands. The QTM052 modules integrate these capabilities in a compact footprint, enabling four modules to fit in a smartphone. The small size allows phone manufacturers to incorporate the mmWave bands without sacrificing the attractive industrial designs of their mobile devices. Qualcomm said availability of the mmWave modules will support smartphone launches as early as the first half of 2019.

Claim 10	Accused Instrumentalities
	Qualcomm Introduces Sub-6 GHz and mmWave Modules for 5G Smartphones *July 23, 2018* The Qualcomm® QPM56xx sub-6 GHz RF module family and QTM052 mmWave antenna module family pair with Qualcomm's Snapdragon™ X50 5G modem to deliver modem-to-antenna functionality across multiple 5G bands in a compact footprint suited for mobile devices. **Sub-6 GHz Modules** The QPM56xx module family — the QPM5650, QPM5651, QDM5650 and QDM5652 — works with the Snapdragon X50 5G modem to support the sub-6 GHz 5G NR bands. The QPM5650 and QPM5651 integrate the power amplifier (PA), low noise amplifier (LNA), switch and filtering. For diversity and MIMO, the QDM5650 and QDM5652 integrate the LNA, switch and filtering. All four modules offer integrated sounding reference signal (SRS) switching, required for optimum massive MIMO applications, and support the 3.3 to 4.2 GHz (n77), 3.3 to 3.8 GHz (n78) and 4.4 to 5.0 GHz (n79) bands. **mmWave Antenna Modules** The QTM052 mmWave antenna modules also interface with the Snapdragon X50 5G modem to provide a comprehensive system that supports advanced beam forming, beam steering and beam tracking, which improve the range and reliability of mmWave links. The system comprises an integrated 5G NR radio transceiver, power management IC, RF front-end components and phased array antenna. The QTM052 handles up to 800 MHz bandwidth in the 26.5 to 29.5 GHz (n257) band and the entire 27.5 to 28.35 GHz (n261) and 37 to 40 GHz (n260) bands. The QTM052 modules integrate these capabilities in a compact footprint, enabling four modules to fit in a smartphone. The small size allows phone manufacturers to incorporate the mmWave bands without sacrificing the attractive industrial designs of their mobile devices. Qualcomm said availability of the mmWave modules will support smartphone launches as early as the first half of 2019. (https://www.microwavejournal.com/articles/30752-qualcomm-introduces-sub-6-ghz-and-mmwave-modules-for-5g-smartphones)

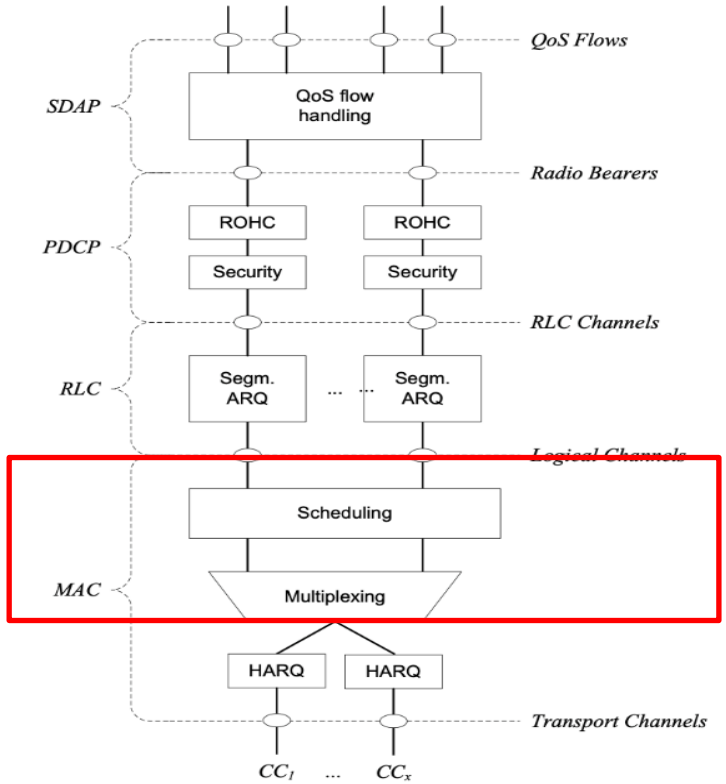
Claim 13

Claim 13	Accused Instrumentalities
[13] The method of claim 10 wherein the first digital signal is encoded using a first wireless protocol and the second digital signal is encoded using a second wireless protocol.	The Accused Instrumentalities perform a method wherein the first digital signal is encoded using a first wireless protocol and the second digital signal is encoded using a second wireless protocol. *See* Claim 6.

Claim 17

Claim 17	Accused Instrumentalities
[17.0] A wireless communication system comprising:	To the extent the preamble is found to be limiting, the Accused Instrumentalities include a wireless communication system. For example, the Accused Instrumentalities support 3GPP carrier aggregation technologies for transmitting uplink information over LTE and/or NR wireless channels. *See, e.g.*: 5.4 Carrier aggregation 5.4.1 Carrier aggregation In Carrier Aggregation (CA), two or more Component Carriers (CCs) are aggregated. A UE may simultaneously receive or transmit on one or multiple CCs depending on its capabilities: - A UE with single timing advance capability for CA can simultaneously receive and/or transmit on multiple CCs corresponding to multiple serving cells sharing the same timing advance (multiple serving cells grouped in one TAG);

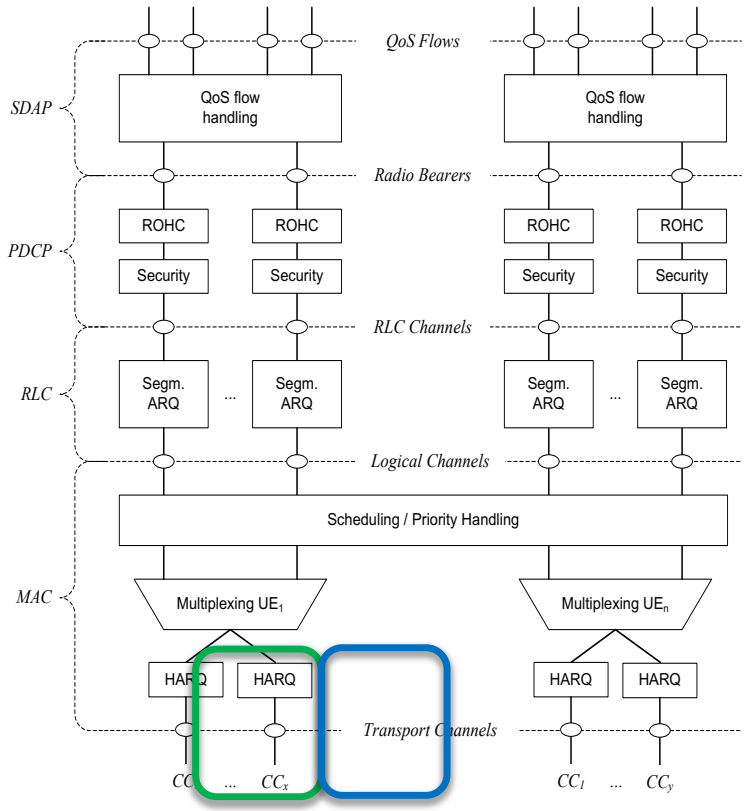
Claim 17	Accused Instrumentalities
	- A UE with multiple timing advance capability for CA can simultaneously receive and/or transmit on multiple CCs corresponding to multiple serving cells with different timing advances (multiple serving cells grouped in multiple TAGs). NG-RAN ensures that each TAG contains at least one serving cell; - A non-CA capable UE can receive on a single CC and transmit on a single CC corresponding to one serving cell only (one serving cell in one TAG). CA is supported for both contiguous and non-contiguous CCs. When CA is deployed frame timing and SFN are aligned across cells that can be aggregated, or an offset in multiples of slots between the PCell/PSCell and an SCell is configured to the UE. The maximum number of configured CCs for a UE is 16 for DL and 16 for UL. (3GPP TS 38.300 V17.4.0) 6.7 Carrier Aggregation In case of CA, the multi-carrier nature of the physical layer is only exposed to the MAC layer for which one HARQ entity is required per serving cell as depicted on Figures 6.7-1 and 6.7-2 below: - In both uplink and downlink, there is one independent hybrid-ARQ entity per serving cell and one transport block is generated per assignment/grant per serving cell in the absence of spatial multiplexing. Each transport block and its potential HARQ retransmissions are mapped to a single serving cell. (3GPP TS 38.300 V17.4.0)

Claim 17	Accused Instrumentalities
	 **Figure 6.7-2: Layer 2 Structure for UL with CA configured** (3GPP TS 38.300 V17.4.0)

Claim 17	Accused Instrumentalities
	5G Carrier Aggregation is set to deliver a significant performance boost to mobile users but what is it and how does it work? The ongoing rollout of commercial 5G networks has significantly improved the experience for mobile subscribers around the world. As the ecosystem matures, a growing number of more advanced 5G Standalone (5G SA) networks will be central to delivering the speed and ultra-low latency to support cutting-edge applications. 5G Carrier Aggregation will play a vital role in underpinning the significant performance boost promised by 5G SA, representing an important milestone in the evolution of wireless infrastructure. Carrier Aggregation is a software functionality in Radio Access Networks and user devices which allows Mobile Network Operators (MNOs) to combine the capabilities of radio cells at distinct frequency allocations to enhance the end user experience. A key technology already in the LTE-Advanced networks, Carrier Aggregation enabled the evolution to Gigabit-LTE, achieving user data rates of more than 1 Gbps. However, in 5G networks, Carrier Aggregation will enable the evolution to multi-Gigabit-5G, reaching user data rates of about 4 Gbps and above. 5G Carrier Aggregation is also capable of improving the geographic availability, more commonly referred to as coverage, of high data rates. (https://www.nokia.com/about-us/newsroom/articles/5g-carrier-aggregation-explained/)

Claim 17	Accused Instrumentalities
	Carrier Aggregation in 5G Networks To accelerate rollout, the initial commercial 5G networks relied on the LTE infrastructure in radio access and the core network, referred to as 5G non-Standalone (5G NSA). 5G NSA allows MNOs to increase the bandwidth available to end users by bundling 4G and 5G carriers through 4G-5G Dual Connectivity. This allowed 5G users to benefit from existing LTE Carrier Aggregation capabilities with up to two 5G carriers aggregated alongside LTE carriers. To unlock the full capability of 5G, including ultra-low latency, reliability, and efficiency, MNOs are introducing 5G Standalone (5G SA) with a dedicated 5G Core and highly efficient 5G air interface, without dependency on existing LTE networks. The number of specified 5G SA Carrier Aggregation band combinations is increasing with each quarterly revision of the 3GPP specifications, enabling further options to achieve multi-Gigabit 5G data rates. These specifications are important to ensure interoperability between user equipment, such as smartphones, and networks. Between 2021 to 2022, the focus of the specifications for Carrier Aggregation in 5G SA in FR1 shifted from two component carriers to three and four component carriers. As the number of 5G frequency bands exceeds that of LTE-A, the possible Carrier Aggregation band combinations are greatly expanded, offering increased deployment options and flexibility for MNOs in different markets. (https://www.nokia.com/about-us/newsroom/articles/5g-carrier-aggregation-explained/)

Claim 17	Accused Instrumentalities
	Key benefits of 5G Carrier Aggregation Improved data speeds and throughput 5G Carrier Aggregation will boost the network performance to meet the requirements of data-hungry applications, such as augmented and virtual reality services, for both industrial and consumer use cases. Greater cell coverage As operators are looking to maximize the use of their available spectrum assets in different FDD and TDD bands, Carrier Aggregation is the key to reaching extended coverage range. This helps reduce the need to deploy new cell sites, bringing cost savings to operators. It also improves mobile user experience with consistent level of service across the network. Enhanced energy efficiency In 2019, the mobile industry made a milestone commitment to transform the sector and reach net zero carbon emissions by 2050. Carrier Aggregation has been demonstrated to reduce overall power consumption levels while increasing throughput and maintaining high service levels. This indicates that the technology could contribute to reducing overall energy usage and the mobile industry's carbon footprint. Improved coverage can also contribute to longer battery life for individual devices, requiring less frequent charging. Greater ROI According to data from GSA, the total amount raised in 2021 from spectrum auctions and assignments reached at least $140.1Bn. Radio spectrum is a finite and extremely valuable resource, representing a considerable financial burden for most MNOs. Therefore, with ever increasing demands for bandwidth, utilising this spectrum in the most efficient way becomes a top operational priority. 5G CA represents one of the most effective methods for MNOs to get the most from their outlay by maximising spectral efficiency. (https://www.nokia.com/about-us/newsroom/articles/5g-carrier-aggregation-explained/)

[17.1] a baseband digital system for providing a first digital signal comprising a first data to be transmitted and a second digital signal comprising a second data to be transmitted;	The Accused Instrumentalities include a baseband digital system for providing a first digital signal comprising a first data to be transmitted and a second digital signal comprising a second data to be transmitted. For example: (3GPP TS 38.300 V17.5.0) **6.7 CARRIER AGGREGATION** In case of CA, the multi-carrier nature of the physical layer is only exposed to the MAC layer for which one HARQ entity is required per serving cell as depicted on Figures 6.7-1 and 6.7-2 below: - In both uplink and downlink, there is one independent hybrid-ARQ entity per serving cell and one transport block is generated per assignment/grant per serving cell in the absence of spatial multiplexing. Each transport block and its potential HARQ retransmissions are mapped to a single serving cell.  **Figure 6.7-2: Layer 2 Structure for UL with CA configured**

Claim 17	Accused Instrumentalities
[17.2] a first digital-to-analog converter for receiving the first digital signal and converting the first digital signal into a first analog signal, the first analog signal carrying the first data across a first frequency range;	The Accused Instrumentalities include a first digital-to-analog converter for receiving the first digital signal and converting the first digital signal into a first analog signal, the first analog signal carrying the first data across a first frequency range. For example: (3GPP TR 36.912 version 15.0.0 Release 15) **11.3.2.1 Transmitter architecture** Figure 11.3.2.1-1 illustrates various TX architectures options according to where the component carriers are combined, i.e., at digital baseband, or in analog waveforms before RF mixer, or after mixer but before the PA, or after the PA. Option A - In an adjacent *contiguous common carrier* aggregation scenario, the UE very likely has one PA. Connected to the PA can be a single RF chain (a zero-IF mixer, a wideband DAC, and a wideband IFFT) Option-B - Combines analog baseband waveforms from component Carrier first (e.g., via a mixer operating at an IF of roughly the bandwidth of the other component carrier in the example of 2-component carrier aggregation). Then the resulting wideband signal is up-converted to RF. Option-C - Does ZIF up-conversion of each component carrier before combining and feeding into a single PA. Option-D - Employs multiple RF chains and multiple PAs after which the high-power signals are combined and fed into a single antenna. PA coupling at the UE can be challenging for option-D.

Claim 17	Accused Instrumentalities

Tx Characteristics

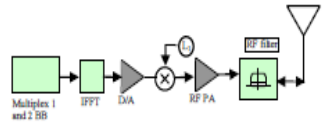
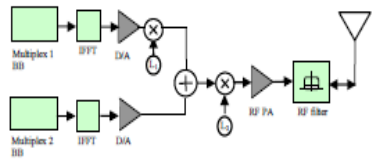
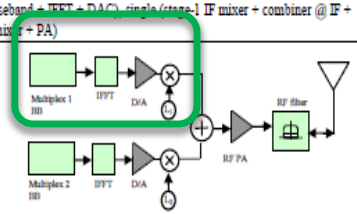
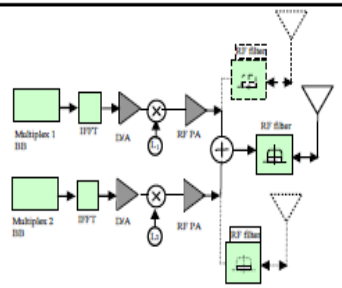
Option	Description (Tx architecture)	Intra Band aggregation		Inter Band aggregation
		Contiguous (CC)	Non contiguous (CC)	Non contiguous (CC)
A	 Single (baseband + IFFT + DAC + mixer + PA)	Yes		
B	 Multiple (baseband + IFFT + DAC), single (stage-1 IF mixer + combiner @ IF + stage-2 RF mixer + PA)	Yes	Yes	
C	 Multiple (baseband + IFFT + DAC + mixer), low-power combiner @ RF, and single PA	Yes	Yes	
D	 Multiple (baseband + IFFT + DAC + mixer + PA), high-power combiner to single antenna OR dual antenna	Yes	Yes	Yes + (depending on the specific EUTRA bands being aggregated),
X	*OTHERS*			

Figure 11.3.2.1-1: Possible UE Architectures in three aggregation scenarios

Claim 17	Accused Instrumentalities
[17.3] a second digital-to-analog converter for receiving the second digital signal and converting the second digital signal into a second analog signal, the second analog signal carrying the second data across a second frequency range;	The Accused Instrumentalities include a second digital-to-analog converter for receiving the second digital signal and converting the second digital signal into a second analog signal, the second analog signal carrying the second data across a second frequency range. For example:

(3GPP TR 36.912 version 15.0.0 Release 15)

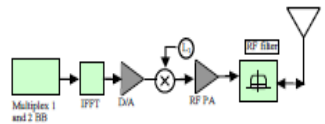
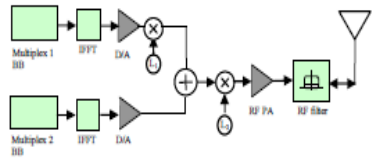
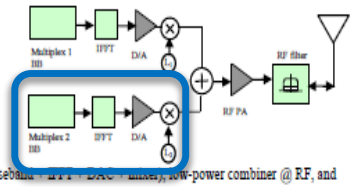
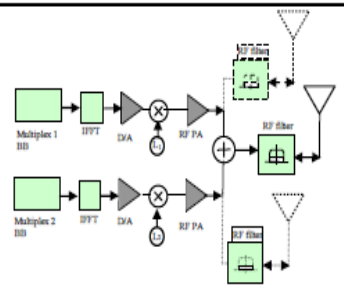
Tx Characteristics				
Option	Description (Tx architecture)	Intra Band aggregation		Inter Band aggregation
		Contiguous (CC)	Non contiguous (CC)	Non contiguous (CC)
A	 Single (baseband + IFFT + DAC + mixer + PA)	Yes		
B	 Multiple (baseband + IFFT + DAC), single (stage-1 IF mixer + combiner @ IF + stage-2 RF mixer + PA)	Yes	Yes	
C	 Multiple (baseband + IFFT + DAC + mixer), low-power combiner @ RF, and single PA	Yes	Yes	
D	 Multiple (baseband + IFFT + DAC + mixer + PA), high-power combiner to single antenna OR dual antenna	Yes	Yes	Yes + (depending on the specific EUTRA bands being aggregated),
X	*OTHERS*			

Figure 11.3.2.1-1: Possible UE Architectures in three aggregation scenarios

[17.4] a first up-converter circuit having a first input coupled to receive the first analog signal and a second input coupled to receive a first modulation signal having a first RF frequency, wherein the first up-converter outputs a first up-converted analog signal comprising a first up-converted frequency range from the first RF frequency minus one-half the first frequency range to the first RF frequency plus one-half the first frequency range;

The Accused Instrumentalities include a first up-converter circuit having a first input coupled to receive the first analog signal and a second input coupled to receive a first modulation signal having a first RF frequency, wherein the first up-converter outputs a first up-converted analog signal comprising a first up-converted frequency range from the first RF frequency minus one-half the first frequency range to the first RF frequency plus one-half the first frequency range. For example:

(3GPP TR 36.912 version 15.0.0 Release 15)

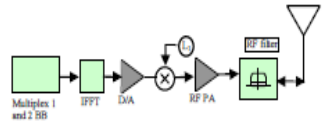
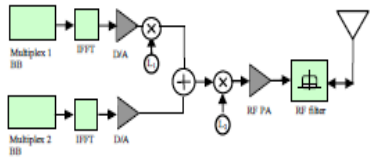
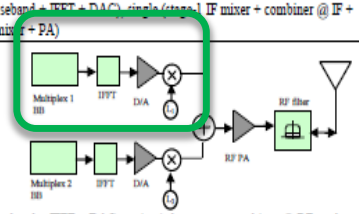
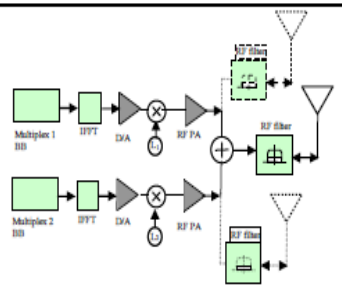
Tx Characteristics				
Option	Description (Tx architecture)	Intra Band aggregation		Inter Band aggregation
		Contiguous (CC)	Non contiguous (CC)	Non contiguous (CC)
A	 Single (baseband + IFFT + DAC + mixer + PA)	Yes		
B	 Multiple (baseband + IFFT + DAC), single (stage-1 IF mixer + combiner @ IF + stage-2 RF mixer + PA)	Yes	Yes	
C	 Multiple (baseband + IFFT + DAC + mixer), low-power combiner @ RF, and single PA	Yes	Yes	
D	 Multiple (baseband + IFFT + DAC + mixer + PA), high-power combiner to single antenna OR dual antenna	Yes	Yes	Yes + (depending on the specific EUTRA bands being aggregated),
X	*OTHERS*			

Figure 11.3.2.1-1: Possible UE Architectures in three aggregation scenarios

(3GPP TS 38.101-1 V17.5.0)

For carrier aggregation, the maximum transmission bandwidth configuration is defined per component carrier and the requirement is specified in clause 5.3.2.

5.3A.3 Minimum guardband and transmission bandwidth configuration for CA

For intra-band contiguous carrier aggregation, *Aggregated Channel Bandwidth* and *Guard Bands* are defined as follows, see Figure 5.3A.3-1.

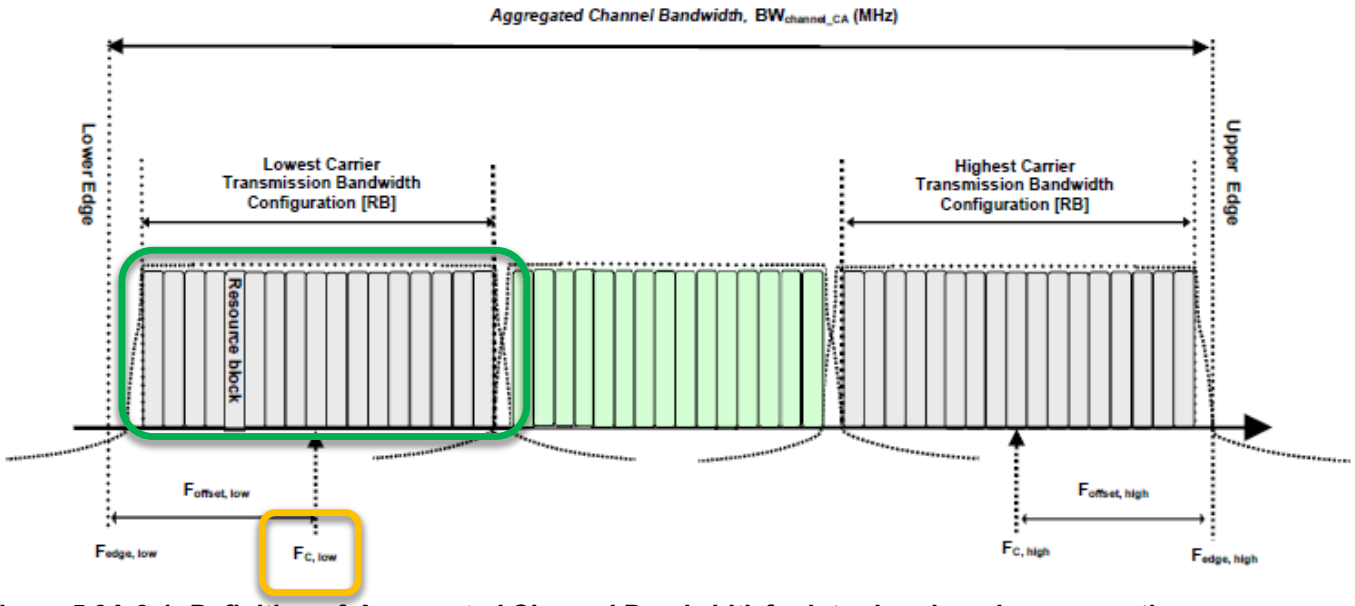


Figure 5.3A.3-1: Definition of *Aggregated Channel Bandwidth* for intra-band carrier aggregation

$$BW_{Channel\_CA} = F_{edge,high} - F_{edge,low} \text{ (MHz).}$$

The lower bandwidth edge $F_{edge,\ low}$ and the upper bandwidth edge $F_{edge,high}$ of the aggregated channel bandwidth are used as frequency reference points for transmitter and receiver requirements and are defined by

$$F_{edge,low} = F_{C,low} - F_{offset,low}$$

$$F_{edge,high} = F_{C,high} + F_{offset,high}$$

The lower and upper frequency offsets depend on the transmission bandwidth configurations of the lowest and highest assigned edge component carrier and are defined as

$$F_{offset,low} = (N_{RB,low}*12 + 1)*SCS_{low}/2 + BW_{GB} \text{ (MHz)}$$

$$F_{offset,high} = (N_{RB,high}*12 - 1)*SCS_{high}/2 + BW_{GB} \text{ (MHz)} \quad BW_{GB} = \max(BW_{GB,Channel(k)})$$

$N_{RB,low}$ and $N_{RB,high}$ are the transmission bandwidth configurations according to Table 5.3.2-1 for the lowest and highest assigned component carrier, SCS_{low} and SCS_{high} are the sub-carrier spacing for the lowest and highest assigned component carrier respectively. SCS_{low}, SCS_{high}, $N_{RB,low}$, $N_{RB,high}$, and $BW_{GB,Channel(k)}$ use the largest μ value among the subcarrier spacing configurations supported in the operating band for both of the channel bandwidths according to Table 5.3.5-1 and $BW_{GB,Channel(k)}$ is the minimum guard band for carrier k according to Table 5.3.3-1 for the said μ value.

In case there is no common μ value for both of the channel bandwidths, μ=1 is used for SCS_{low}, SCS_{high}, $N_{RB,low}$, $N_{RB,high}$, and $BW_{GB,Channel(k)}$.

[17.5] a second up-converter circuit having a first input coupled to receive the second analog signal and a second input coupled to receive a second modulation signal having a second RF frequency, wherein the second up-converter outputs a second up-converted analog signal comprising a second up-converted frequency range from the second RF frequency minus one-half the second frequency range to the second RF frequency plus one-half the second frequency range, and wherein frequency difference between the first RF frequency and the second RF frequency is greater than the sum of one-half the first frequency range and one-half the second frequency range; and	The Accused Instrumentalities include a second up-converter circuit having a first input coupled to receive the second analog signal and a second input coupled to receive a second modulation signal having a second RF frequency, wherein the second up-converter outputs a second up-converted analog signal comprising a second up-converted frequency range from the second RF frequency minus one-half the second frequency range to the second RF frequency plus one-half the second frequency range, and wherein frequency difference between the first RF frequency and the second RF frequency is greater than the sum of one-half the first frequency range and one-half the second frequency range. For example:

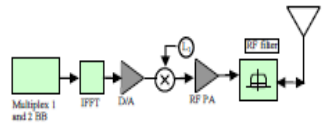
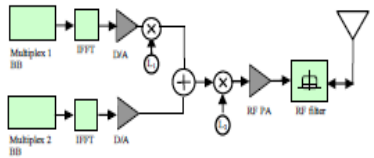
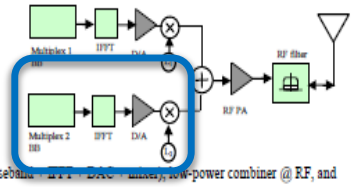
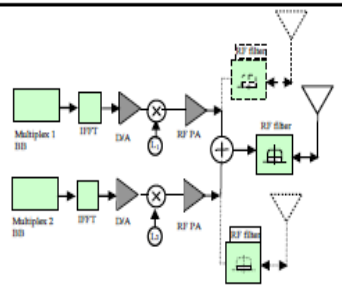
Tx Characteristics				
Option	Description (Tx architecture)	Intra Band aggregation		Inter Band aggregation
		Contiguous (CC)	Non contiguous (CC)	Non contiguous (CC)
A	 Single (baseband + IFFT + DAC + mixer + PA)	Yes		
B	 Multiple (baseband + IFFT + DAC), single (stage-1 IF mixer + combiner @ IF + stage-2 RF mixer + PA)	Yes	Yes	
C	 Multiple (baseband + IFFT + DAC + mixer), low-power combiner @ RF, and single PA	Yes	Yes	
D	 Multiple (baseband + IFFT + DAC + mixer + PA), high-power combiner to single antenna OR dual antenna	Yes	Yes	Yes + (depending on the specific EUTRA bands being aggregated),
X	*OTHERS*			

Figure 11.3.2.1-1: Possible UE Architectures in three aggregation scenarios

(3GPP TS 38.101-1 V17.5.0)

For carrier aggregation, the maximum transmission bandwidth configuration is defined per component carrier and the requirement is specified in clause 5.3.2.

5.3A.3 Minimum guardband and transmission bandwidth configuration for CA

For intra-band contiguous carrier aggregation, *Aggregated Channel Bandwidth* and *Guard Bands* are defined as follows, see Figure 5.3A.3-1.

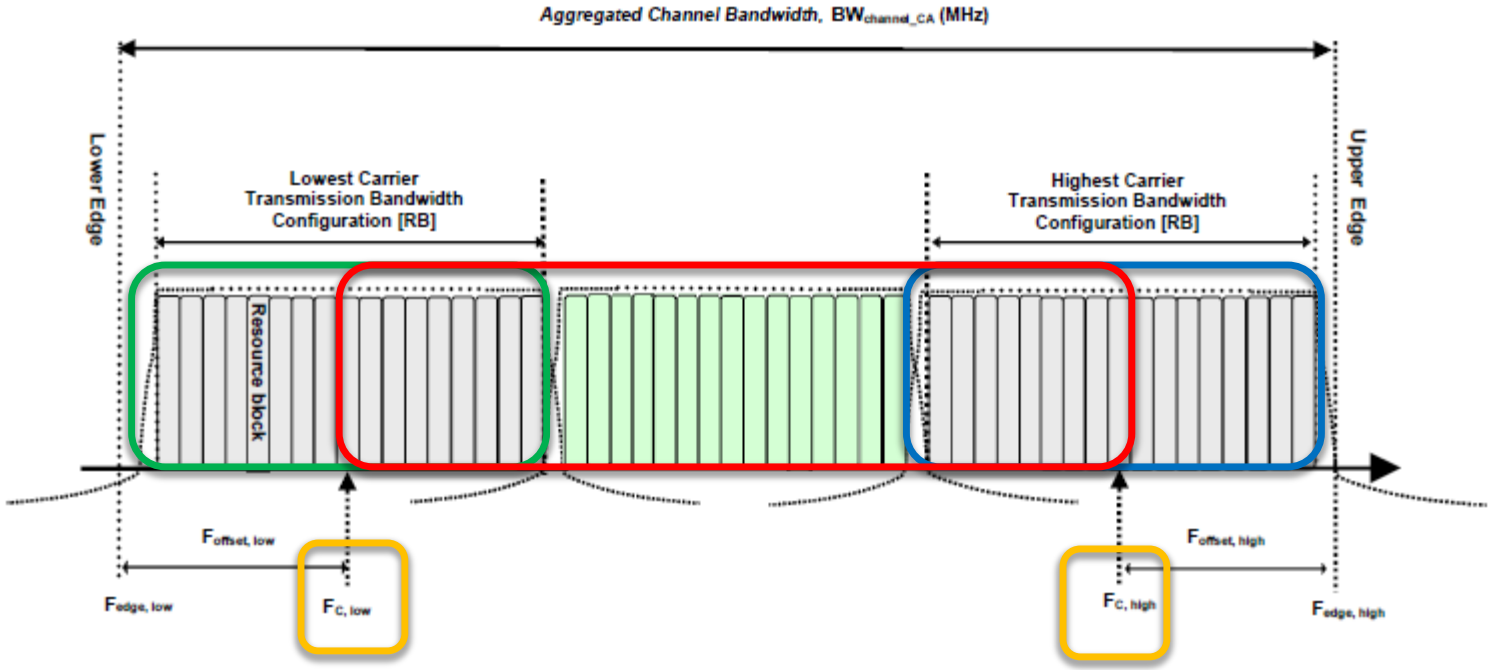


Figure 5.3A.3-1: Definition of *Aggregated Channel Bandwidth* for intra-band carrier aggregation

Claim 17	Accused Instrumentalities
[17.6] a power amplifier coupled to receive the first and second up-converted analog signals, wherein the bandwidth of the power amplifier is greater than the difference between a lowest frequency in the first up-converted frequency range and a highest frequency in the second up-converted frequency range.	The Accused Instrumentalities include a power amplifier coupled to receive the first and second up-converted analog signals, wherein the bandwidth of the power amplifier is greater than the difference between a lowest frequency in the first up-converted frequency range and a highest frequency in the second up-converted frequency range. For example:

(3GPP TR 36.912 version 15.0.0 Release 15)

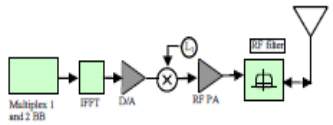
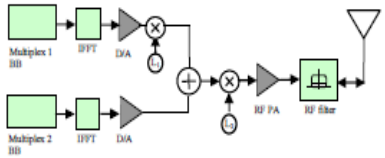
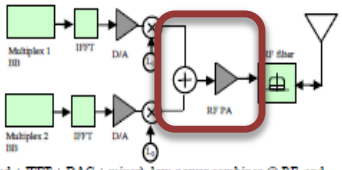
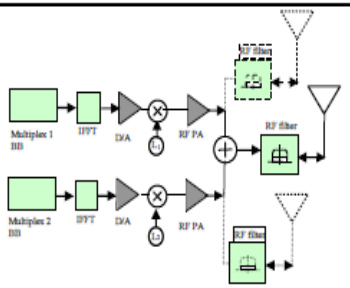
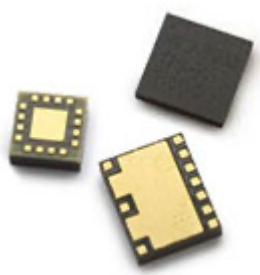
Tx Characteristics				
Option	Description (Tx architecture)	Intra Band aggregation		Inter Band aggregation
		Contiguous (CC)	Non contiguous (CC)	Non contiguous (CC)
A	 Single (baseband + IFFT + DAC + mixer + PA)	Yes		
B	 Multiple (baseband + IFFT + DAC), single (stage-1 IF mixer + combiner @ IF + stage-2 RF mixer + PA)	Yes	Yes	
C	 Multiple (baseband + IFFT + DAC + mixer), low-power combiner @ RF, and single PA	Yes	Yes	
D	 Multiple (baseband + IFFT + DAC + mixer + PA), high-power combiner to single antenna OR dual antenna	Yes	Yes	Yes + (depending on the specific EUTRA bands being aggregated),
X	*OTHERS*			

Figure 11.3.2.1-1: Possible UE Architectures in three aggregation scenarios

Claim 17	Accused Instrumentalities

	As a further example, in power amplifier designs believed to be representative of those used in the Accused Instrumentalities:
	https://www.broadcom.com/products/wireless/rf-front-end-modules/mobile-rf-fem
	
	Mobile RF FEM
	
	 
	Broadcom provides custom RF frond end module (FEM) devices for mobile wireless applications. These devices incorporate multiband power amplifiers (PA), FBAR duplexers and multiplexers, SOI multi-mode LNAs and antenna switch, coupler and MIPI controller, designed to support various carrier aggregation (CA) for both FDD and TDD bands.
	Broadcom has shipped billions of RF FEM devices to the world's leading smartphone manufacturers.
	
	The Broadcom ACFM-2S13 is a quadplexer device that combines Band 1 and Band 3 duplexers into a single, miniature package. Band 4 duplexer is co-banded. The device features a single antenna connection, eliminating the need for antenna switching. High Isolation between bands enables the use of carrier aggregation.
	
	The ACFM-2S13 is designed with Broadcom's innovative filter capability which makes possible ultra-small, high-Q filters at a fraction of their usual size. Low Tx Insertion Loss of the ACFM-2S13 reduces power amplifier current, extending battery life. The device enhances receiver sensitivity and dynamic range with low Rx Insertion Loss and high rejection of Tx signals at the Rx ports.
	Features
	• Single antenna
	• High cross band isolation
	  • Enables carrier aggregation
	• Band 4 co-banding
	• Miniature size
	  • 2.0 x 2.5 mm footprint
	  • 0.710 mm typ. height
	• High Power Rating
	• Environmental
	  • RoHS 6 Compliant
	  • Halogen Free
	  • TBBPA Free
	
	https://www.broadcom.com/products/wireless/demo-boards/acfm-2s13

Claim 17	Accused Instrumentalities

SKYWORKS®

PRODUCT SUMMARY

SKY77786-11 High Band Multimode Multiband Power Amplifier Module Supporting LTE Advanced Applications

Applications

- Multiband 4G / LTE handsets
- FDD LTE Bands 7 and 30
- TDD LTE Band 38, 40, 41

Features

- Two T/R (RX) port and 3 outputs
- Industry-leading PAE for 4G
- Optimized for APT DCDC operation
- Fully programmable Mobile Industry Processor Interface (MIPI) control
- MIPI programmable bias modes optimize best 4G efficiency/linearity performance.
- Small, low profile package:
  - 3.0 x 3.0 x 0.71 mm
  - 20-pad configuration

Skyworks Green™ products are compliant with all applicable legislation and are halogen-free. For additional information, refer to Skyworks *Definition of Green*™, document number SQ04-0074.

Description

Skyworks SKY77786-11 Skyl iTE™ is a multimode multiband (MMMB) Power Amplifier Module (PAM) that supports 4G handsets and operates efficiently in LTE bands from 2.3 GHz to 2.7 GHz. The module is fully programmable through a Mobile Industry Processor Interface (MIPI®).

The PAM consists of a single high band LTE block, a Multi-Function Control (MFC) block, and a T/R switch block. RF input/output ports internally matched to 50 Ω to reduce the number of external components. A CMOS integrated circuit uses standard MIPI controls to provide the internal MFC interface and operation. Extremely low leakage current maximizes handset standby time.

The InGaP die and the silicon die and passive components are mounted on a multi-layer laminate substrate. The assembly is encapsulated in a 3.0 mm x 3.0 mm x 0.71 mm, 20-pad MCM, SMT package which is a more highly manufacturable, low cost solution.

4G: The SKY77786-11 supports 1.4, 3, 5, 10, 15, 20, 30, 35, 40 MHz channel bandwidths. Similar to 3G operation, output power is controlled by varying the input power and V_{CC} is adjusted using a DCDC converter to maximize efficiency for each power level.

4G Modulation scheme includes:

- FDD LTE
- TDD LTE
- Uplink Carrier Aggregation (CA) support for Bands 40/41 (up to 40 MHz)

Claim 17	Accused Instrumentalities
	Elevating Performance with Industry-Leading Primary Path Architectures Skyworks is enabling technology evolutions industry-wide with its advanced cellular transmit solutions for mobile devices. Leveraging decades of systems and module expertise, we architect baseband agnostic solutions that utilize our advanced power amplifier, low noise amplifier, filter and switch technologies. Our portfolio covers 2G, 3G, 4G and 5G applications, addressing specific customer priorities for system efficiency, solution size and total cost. Skyworks' latest modules for 5G from our SKY5® portfolio feature the highest transmit efficiency — optimizing battery life and enhancing thermal benefits — and advanced BAW and TC-SAW technologies in an exceptionally compact form factor, while supporting the maximum combination of carrier aggregation (CA) bands. Our products uniquely provide the best performance at targeted frequency bands, supporting up to 100 MHz wide bandwidth, maximizing data throughput at ultra-fast speeds. https://www.skyworksinc.com/en/System-Solutions/Transmit

Claim 17	Accused Instrumentalities
	Qualcomm Introduces Sub-6 GHz and mmWave Modules for 5G Smartphones *July 23, 2018* The Qualcomm® QPM56xx sub-6 GHz RF module family and QTM052 mmWave antenna module family pair with Qualcomm's Snapdragon™ X50 5G modem to deliver modem-to-antenna functionality across multiple 5G bands in a compact footprint suited for mobile devices. **Sub-6 GHz Modules** The QPM56xx module family — the QPM5650, QPM5651, QDM5650 and QDM5652 — works with the Snapdragon X50 5G modem to support the sub-6 GHz 5G NR bands. The QPM5650 and QPM5651 integrate the power amplifier (PA), low noise amplifier (LNA), switch and filtering. For diversity and MIMO, the QDM5650 and QDM5652 integrate the LNA, switch and filtering. All four modules offer integrated sounding reference signal (SRS) switching, required for optimum massive MIMO applications, and support the 3.3 to 4.2 GHz (n77), 3.3 to 3.8 GHz (n78) and 4.4 to 5.0 GHz (n79) bands. **mmWave Antenna Modules** The QTM052 mmWave antenna modules also interface with the Snapdragon X50 5G modem to provide a comprehensive system that supports advanced beam forming, beam steering and beam tracking, which improve the range and reliability of mmWave links. The system comprises an integrated 5G NR radio transceiver, power management IC, RF front-end components and phased array antenna. The QTM052 handles up to 800 MHz bandwidth in the 26.5 to 29.5 GHz (n257) band and the entire 27.5 to 28.35 GHz (n261) and 37 to 40 GHz (n260) bands. The QTM052 modules integrate these capabilities in a compact footprint, enabling four modules to fit in a smartphone. The small size allows phone manufacturers to incorporate the mmWave bands without sacrificing the attractive industrial designs of their mobile devices. Qualcomm said availability of the mmWave modules will support smartphone launches as early as the first half of 2019. (https://www.microwavejournal.com/articles/30752-qualcomm-introduces-sub-6-ghz-and-mmwave-modules-for-5g-smartphones)

Claim 21

Claim 21	Accused Instrumentalities
[21] The communication system of claim 17 wherein the first data of the first digital signal is encoded using a first wireless protocol and the first data of the second digital signal is encoded using a second wireless protocol.	In the Accused Instrumentalities the first data of the first digital signal is encoded using a first wireless protocol and the first data of the second digital signal is encoded using a second wireless protocol. *See* Claim 6.

Claim 23

Claim 23	Accused Instrumentalities
[23] The communication system of claim 17 wherein first and second data to be transmitted comprise a plurality of OFDM symbols, wherein a first symbol is transmitted during a first time slot across the first up-converted frequency range and a second symbol is transmitted during the first time slot across the second up-converted frequency range, and wherein a third symbol is transmitted during a second time slot across the first up-converted frequency range and a fourth symbol is transmitted during the second time slot across a second up-converted frequency range.	In the Accused Instrumentalities, first and second data to be transmitted comprise a plurality of OFDM symbols, wherein a first symbol is transmitted during a first time slot across the first up-converted frequency range and a second symbol is transmitted during the first time slot across the second up-converted frequency range, and wherein a third symbol is transmitted during a second time slot across the first up-converted frequency range and a fourth symbol is transmitted during the second time slot across a second up-converted frequency range. *See* Claim 9.