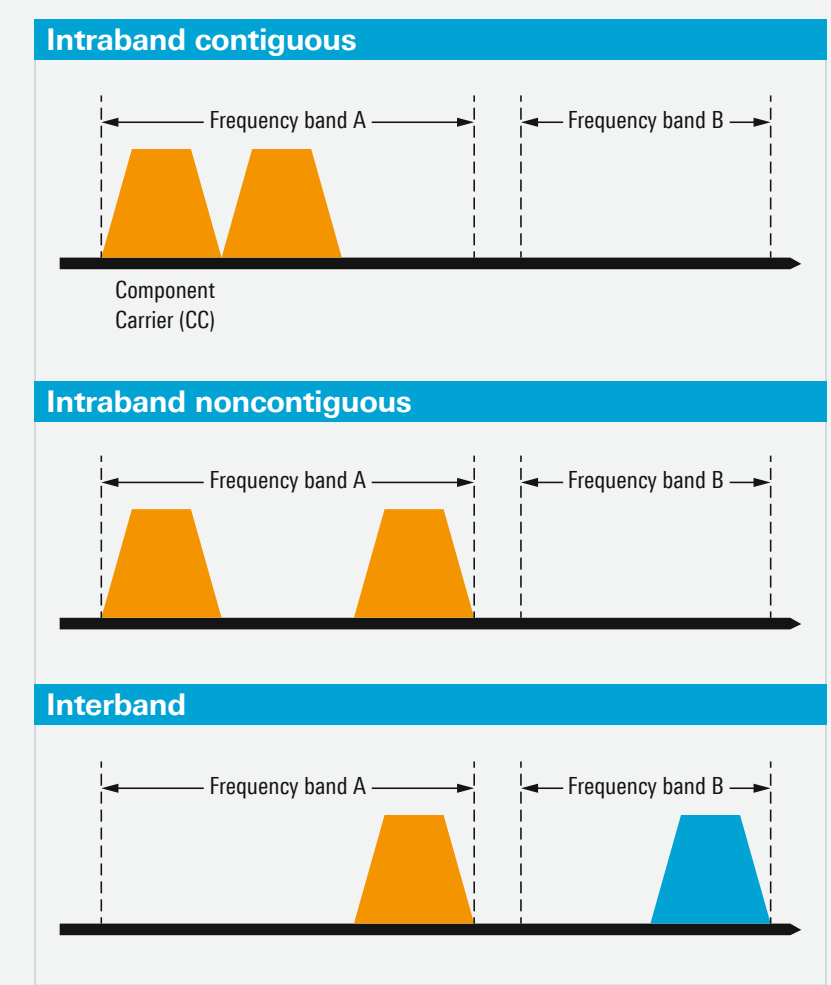


Evolution of Carrier Aggregation (3GPP Releases 10 to 13)

Carrier aggregation (CA) is by far the most demanded feature of the feature set standardized in 3GPP Release 10 and known as LTE-Advanced (LTE-A). The high interest from the mobile industry and network operators in particular has led to a continuous evolution of the original CA definition in subsequent releases of the relevant technical specification. The number of frequency band combinations to aggregate spectrum assets are constantly evolving, as are the achievable data rates. New device categories are required to support these higher data rates. The constantly increasing mobile data consumption forces service providers worldwide to look for alternatives to increase their spectrum holdings. A promising solution is to use carrier aggregation to expand into unlicensed spectrum. Future evolution might require a fundamental change leading to an increased number of carriers to be aggregated. This poster provides an overview of the CA evolution throughout 3GPP Releases 10 to 13.

Test solutions from Rohde & Schwarz evolve in line with the carrier aggregation feature. From infrastructure to chipset and device testing, and from component testing to network optimization and benchmarking, Rohde & Schwarz is the right partner for your CA testing needs.

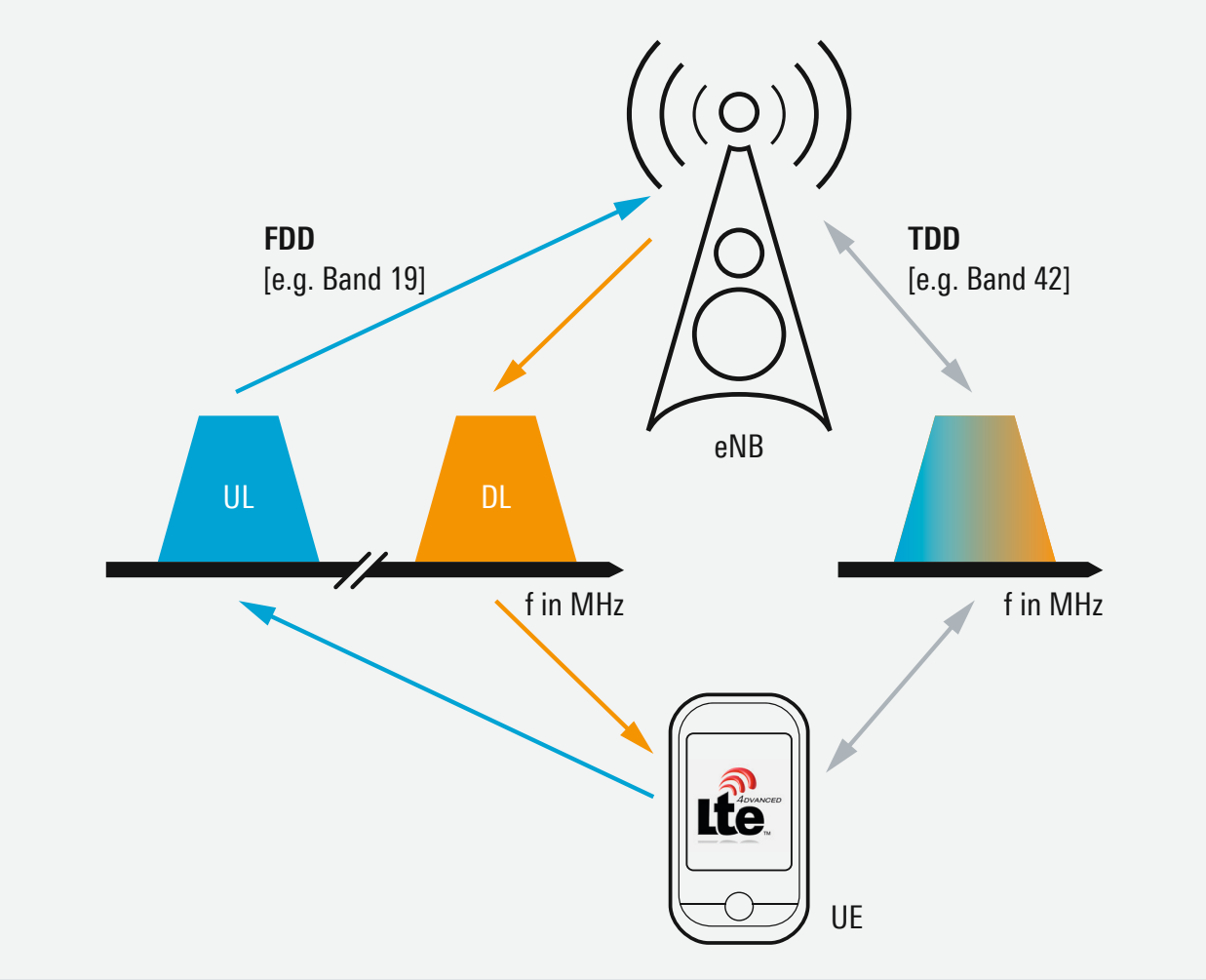
Carrier aggregation modes (Rel. 10) and Rel. 11 enhancements



There are two types of CA: interband, and intraband with its two submodes intraband contiguous and intraband noncontiguous. Intraband means that the aggregated component carriers reside in the same frequency band; the carriers are not co-located in the case of noncontiguous. Interband means the aggregated carriers are in different frequency bands. The initial definition was a maximum of five carriers and a total bandwidth of 100 MHz, with a maximum bandwidth of 20 MHz for each component carrier to ensure backward compatibility. Each component carrier can have any of the six bandwidths defined for LTE. Therefore the total aggregated bandwidth highly depends on the network operator's spectrum holdings. The first rollout phase applies CA only in the downlink, with typically two aggregated frequency bands. One component carrier resides in a low frequency band (below 2 GHz) and one in a high band. The next step is triband CA in the downlink and CA in the uplink. In the third phase, four carriers are aggregated, where the two CA types can also be combined: component carriers reside in two or more frequency bands, with some carriers in the same frequency band and deployed in a contiguous or noncontiguous fashion. Release 11 defines some CA enhancements, such as multiple timing advance groups. These enable component carriers (CC) on cells served by antennas that are geographically separated from the primary CC. CA with TDD also gains more flexibility by allowing TDD CC combinations with different UL/DL configurations as long as they operate in different frequency bands.

LTE FDD/TDD joint operation (Rel. 12)

Example of paired (FDD) and unpaired (TDD) spectrum aggregation



When spectrum is auctioned off by local regulators, FDD and TDD spectrum licenses are typically bundled. Hence, most service providers worldwide hold licenses for paired spectrum (FDD) and unpaired spectrum (TDD). With the ability to aggregate spectrum using carrier aggregation and due to constantly increasing mobile data consumption by their subscribers, network operators requested the ability to also aggregate FDD and TDD spectrum, which 3GPP added in Release 12.

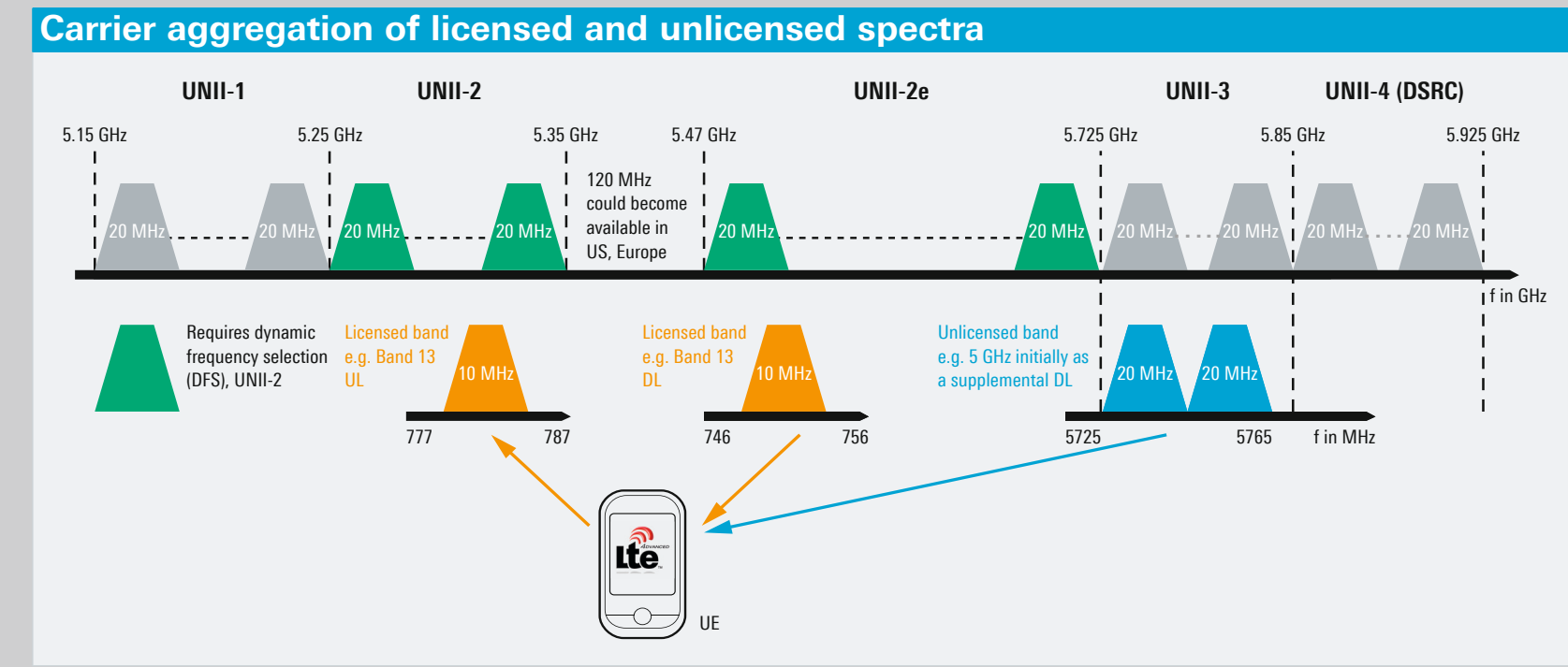
Frequency bands (example for 4 DL/1 UL, Rel. 13)

At the beginning of 2015, 32 FDD and 11 TDD bands were specified for LTE deployment. The geographical region and the network operators' spectrum holdings determine which band combinations for interband, intraband contiguous and intraband noncontiguous CA will be added to the standard. A complete overview is available in the relevant 3GPP specification, TS36.101. As an example, the table lists the proposed band combinations for aggregating four component carriers in the downlink, while maintaining only one uplink carrier, which is supposed to be added with 3GPP Release 13. All these frequency bands are used in North America.

E-UTRA CA band	E-UTRA band	Uplink (UL) operating band in MHz	Downlink (DL) operating band in MHz	Duplex
CA_2-2-12-30	2	1850 to 1910	1930 to 1990	FDD
	12	699 to 716	729 to 746	
	30	2305 to 2315	2350 to 2360	
CA_2-2-5-30	2	1850 to 1910	1930 to 1990	
	5	824 to 849	869 to 894	
	30	2305 to 2315	2350 to 2360	
CA_2-2-29-30	2	1850 to 1910	1930 to 1990	
	29	N/A	717 to 728	
	30	2305 to 2315	2350 to 2360	
CA_2-4-12-30	2	1850 to 1910	1930 to 1990	
	4	1710 to 1785	1805 to 1880	
	12	699 to 716	729 to 746	
CA_2-5-12-30	2	1850 to 1910	1930 to 1990	
	5	824 to 849	869 to 894	
	12	699 to 716	729 to 746	
CA_2-5-12-30	2	1850 to 1910	1930 to 1990	
	12	699 to 716	729 to 746	
	30	2305 to 2315	2350 to 2360	
CA_2-4-29-30	2	1850 to 1910	1930 to 1990	
	4	1710 to 1785	1805 to 1880	
	29	N/A	717 to 728	
CA_25-41-41-41	25	1850 to 1915	1930 to 1995	
	41	2496 to 2690	2496 to 2690	
	41	2496 to 2690	2496 to 2690	

Licensed assisted access (LAA) and extension up to 32 component carriers (Rel. 13)

Up to Release 12, all LTE networks use licensed spectrum bands. The ever-increasing demands for more capacity forces network operators worldwide to exploit all possible spectrum accessible to them. Unlicensed spectra such as the industrial, scientific and medical (ISM) bands, primarily at 2.4 GHz and 5 GHz, are considered. The 2.4 GHz band is fairly crowded with Bluetooth and Wi-Fi access points, but the 5 GHz ISM band is still underutilized. Offering more than 500 MHz of additional bandwidth, the upper portion of that frequency band in particular has very low or even no regulatory requirements in several regions worldwide. Local regulators have made some adjustments to exploit the full potential of the 5 GHz band. In addition, the relevant listen before talk (LBT) functionality needs to be standardized to ensure coexistence with other systems, such as 5 GHz Wi-Fi. 3GPP Release 13 will add the LBT functionality as part of LAA and enhance the carrier aggregation functionality to make use of the 5 GHz spectrum based on a fair share principle.



The initially defined five component carriers to meet the ITU requirements for IMT-Advanced are no longer sufficient for the CA enhancement to also use unlicensed spectrum. The LTE-A standard could easily be extended to support up to eight carriers, requiring only minor changes to the relevant specification. But the need to be future-viable and the significant amount of unlicensed spectrum require 3GPP to discuss up to 32 component carriers for the CA enhancement.

Evolution of UE categories due to carrier aggregation (Rel. 10 to 12)

UE category		Max. data rate in Mbps		Min. number of DL CCs	DL MIMO layer(s)	Highest modulation scheme	
		DL	UL			DL	UL
Rel. 8	1	~10	~5	1	2	64QAM	16QAM
	2	~50	~25				
	3	~100	~50				
	4	~150	~75				
	5	~300	~150				
Rel. 10	6	~300	~150	1 or 2	2 or 4	64QAM	16QAM
	7	~300	~150				
	8	~3000	~1500				
	9	~450	~225				
	10	~450	~225				
Rel. 11	11	~600	~300	2 or 3	2 or 4	64QAM	16QAM
	12	~600	~300				

LTE Releases 8 to 11 specify a single UE category to describe an overall capability in terms of maximum supported data rate and MIMO support. They only partly refer to single device capabilities. Additional parameter signaling is used to inform about detailed support for individual device capabilities.

Downlink				Uplink		
DL cat. Rel. 12	Max. data rate in Mbps	DL MIMO layer(s)	UL cat. Rel. 12	Max. data rate in Mbps	64QAM support	UE DL cat.
0	~1	1	0	~1	no	0
6	~300	2 or 4	3	~50	no	6
7	~300		5	~75	yes	7
9	~450		7	~100	no	9
10	~450		8	~1500	yes	10
11	~600		13	~150	yes	11
12	~390					12
13	~390					13
14	~3900					14

3GPP Releases 12 and higher decouple DL and UL capabilities. Various combinations of DL and UL categories are specified. DL and UL categories 0 are specifically added to support machine type communications (MTC). To ensure backward compatibility, a device that supports any of the Release 12 DL and UL category combinations also signals the corresponding legacy UE categories (Releases 8 to 11) to the network. This enables Release 8 to Release 11 compliant networks to support Release 12 compliant devices.

Glossary:
3GPP = 3rd Generation Partnership Project, CA = Carrier Aggregation, CC = Component Carrier, DFS = Dynamic Frequency Selection, DL = Downlink, DSRC = Dedicated Short Range Communications, E2E = End-to-End, eNB = Enhanced NodeB, E-UTRA = Evolved Universal Terrestrial Radio Access, FDD = Frequency Division Duplex, IMT = International Mobile Telecommunications, IP = Internet Protocol, ISM = Industrial, Scientific and Medical, ITU = International Telecommunication Union, LAA = Licensed Assisted Access, LBT = Listen Before Talk, LTE = Long Term Evolution, MIMO = Multiple Input Multiple Output, MTC = Machine Type Communications, OAM = Quadrature Amplitude Modulation, TDD = Time Division Duplex, UE = User Equipment, UNII = Unlicensed National Information Infrastructure, UL = Uplink



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R&S*SMW200A vector signal generator and R&S*FSW signal and spectrum analyzer for infrastructure, component and handset testing



R&S*TSMa autonomous mobile network scanner and SwissQual QualiPoc Android drive test software for mobile network testing

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