

# News



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## Carrier aggregation – (one) key enabler for LTE-Advanced



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Analysts anticipate that by the end of 2012, 152 LTE networks will be on air in 68 countries worldwide. Compared to previous technology rollouts (2G, 3G, 3.5G), this is by far the fastest adaptation that the wireless industry has seen to date. But even with all marketing departments of all network operators advertising today's LTE deployments as 4G, speaking strictly technical – they are not. LTE in its definition as of 3GPP Release 8 does not meet all IMT-Advanced requirements as set by ITU to be designated a true 4G mobile communications technology<sup>1)</sup>. 3GPP, short for 3rd Generation Partnership Project and the standardization body behind LTE, is addressing and exceeding these requirements while standardizing LTE-Advanced as part of its Release 10 for all relevant technical specifications. This article describes the most demanded feature within the LTE-Advanced feature set in greater detail: carrier aggregation. It further outlines how leading Rohde & Schwarz test and measurement solutions support carrier aggregation.

## Carrier aggregation and its different types as part of the LTE-Advanced feature set

While the industry is still facing challenges with LTE, e.g. offering circuit-switched services such as SMS and voice via the "All-IP"-based network architecture, including the IP Multimedia Subsystem, standardization has moved on to enhance LTE to meet the IMT-Advanced requirements outlined in Table 1.

The required spectral efficiency and requested peak data rates for downlink (DL), but moreover uplink (UL), can only be achieved in two steps. First, enhancing the multi-antenna capabilities in the downlink (up to 8x8 Single User MIMO<sup>2)</sup>) and allowing multi-antenna support in the uplink (up to 4x4 Single User MIMO). Second, applying carrier

aggregation, which will be discussed in more detail in the following. LTE-Advanced as of 3GPP Release 10 (Rel-10) allows the aggregation of a maximum of five component carriers with up to 20 MHz bandwidth each to attain a total transmission bandwidth of up to 100 MHz. However, 3GPP's RAN Working Group 4 (RAN4), which is responsible for setting performance requirements, currently limits aggregation to two component carriers. Hence the maximum aggregated bandwidth is 40 MHz, which is still in line with IMT-Advanced requirements. To assure backward compatibility, each of these carriers is configured to be compliant with 3GPP Release 8 (Rel-8). Each of the aggregated component carriers could also use a different bandwidth. In fact, one of the six supported bandwidths

<sup>1)</sup> ITU-R M.2134.

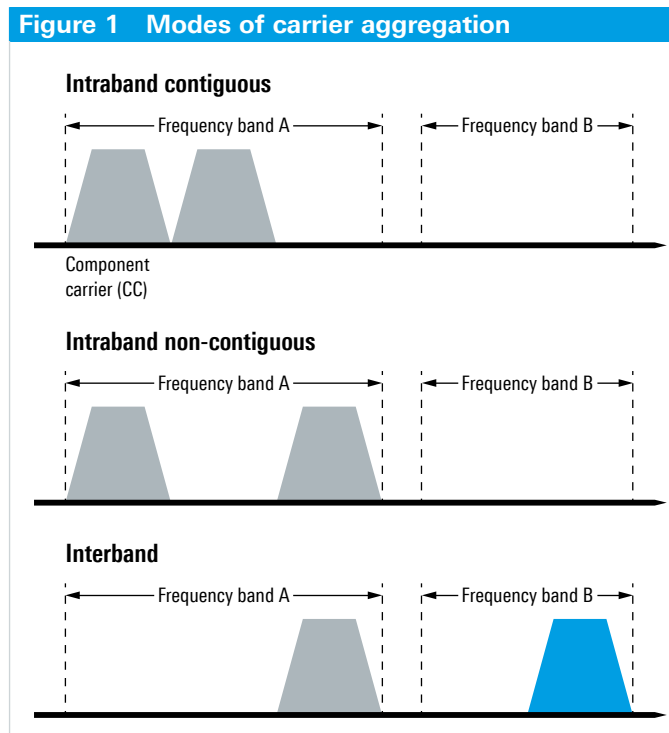
<sup>2)</sup> MIMO: Multiple Input Multiple Output.

**Table 1 IMT-Advanced requirements**

	IMT-Advanced	LTE 3GPP Rel. 8	LTE-Advanced 3GPP Rel. 10
Transmission bandwidth	≤ 40 MHz/≤ 100 MHz	≤ 20 MHz	≤ 100 MHz
Peak data rate (DL/UL)	1000 Mbps (low mobility), 100 Mbps (high mobility)	300 Mbps/75 Mbps	1000 Mbps/500 Mbps
Peak spectral efficiency (in bps/Hz)			
DL (4x4/8x8)	15/–	15/–	16/30
UL (2x2/4x4)	6.75	3.75	8.4/16.8 (FDD), 8.1/16.1 (TDD)
Latency			
User plane	< 10 ms	< 6 ms	< 6 ms
Control plane	< 100 ms	50 ms	50 ms

within LTE: 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz or 20 MHz. This of course depends on the availability of spectrum to each individual network operator. Currently, RAN4 discusses constellations with 5 MHz, 10 MHz, 15 MHz and 20 MHz channel bandwidth. As none of these service providers owns a continuous spectrum of 100 MHz, three different modes of carrier aggregation exist within LTE-Advanced: intraband contiguous, intraband non-contiguous and interband carrier aggregation. Rel-10 already

covers intraband contiguous and interband CA, whereas intraband non-contiguous CA will not be realized until Rel-11. Intraband describes the aggregation of component carriers within the same frequency band in a contiguous or non-contiguous way. For interband carrier aggregation, the two component carriers reside in different frequency bands. Figure 1 shows the different modes being defined for carrier aggregation.



Interband carrier aggregation has led to a high amount of different band combinations that are in demand by network operators worldwide based on the frequency blocks they are licensing. Especially in the US there is a very competitive situation among all carriers and how much spectrum is available to each one: contiguous, non-contiguous as well as in different frequency bands. Carrier aggregation is clearly seen as the ultimate way to combine these different frequency allocations and is therefore also often referred to as spectrum aggregation. Table 2 shows the band combination that RAN4 is currently working on. As indicated above, the majority of band combinations have been submitted by US-based network operators. Most of these combinations seek aggregation of currently deployed LTE networks at 700 MHz or in general lower frequencies with frequency blocks around 2 GHz, mainly in what is known as the AWS spectrum. AWS stands for Advanced Wireless Services and corresponds in the 3GPP terminology to frequency band 4. AWS frequencies were auctioned off by the Federal Communication Commission (FCC) back in 2006, whereas the 700 MHz frequency band licensing took place in February 2008.

Acronym	Mode	Work item	Work item rapporteur
LTE_CA_B3_B7	FDD	RP-100668	TeliaSonera
LTE_CA_B4_B17	FDD	RP-111750	AT&T
LTE_CA_B4_B13	FDD	RP-111678	Ericsson (Verizon)
LTE_CA_B4_B12	FDD	RP-111316	Cox Communications
LTE_CA_B7_B20	FDD	RP-110403	Huawei (Orange)
LTE_CA_B2_B17	FDD	RP-110432	AT&T
LTE_CA_B4_B5	FDD	RP-110433	AT&T
LTE_CA_B5_B12	FDD	RP-120111	US Cellular
LTE_CA_B5_B17	FDD	RP-110434	AT&T
LTE_CA_B1_B7	FDD	RP-111357	China Telecom
LTE_CA_B3_B5	FDD	RP-111603	SK Telecom
LTE_CA_B4_B7	FDD	RP-111358	Rogers Wireless
LTE_CA_B3_B20	FDD	RP-120372	Vodafone
LTE_CA_B8_B20	FDD	RP-111213	Vodafone
LTE_CA_B11_B18	FDD	RP-111634	KDDI
LTE_CA_B1_B19	FDD	RP-111765	NTT DoCoMo
LTE_CA_B1_B21	FDD	RP-111764	NTT DoCoMo
LTE_CA_B3_B5 with 2 uplink	FDD	RP-120364	SK Telecom
LTE_CA_B3_B8	FDD	RP-120388	KT

## Are all component carriers equal?

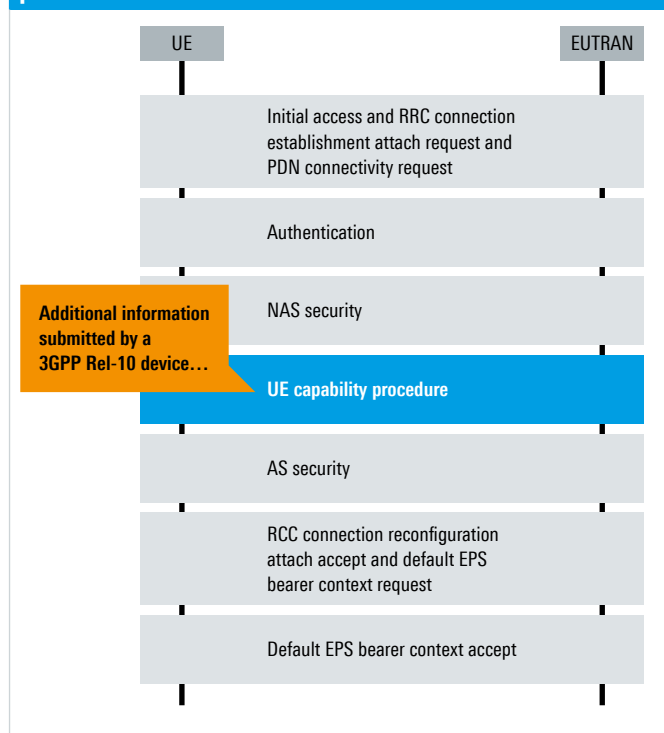
The important question is how carrier aggregation is activated by the network. The answer is simple: only in connected mode. So before this can actually take place, a mobile device that supports Rel-10 needs to execute the generic access procedures that are defined for LTE as of Rel-8: cell search and selection, system information acquisition and initial random access. All these procedures are carried out on the Primary Component Carrier (PCC) for downlink and uplink. Secondary Component Carriers (SCC) – in total up to four, initially two – are seen as additional transmission resources. The basic linkage between the PCC in downlink and uplink is signaled within system information block type 2 (SIB type 2). The PCC is device-specific, not cell-specific. That means, for instance, two terminals belonging to the same network operator could have their PCC on different frequency bands. If we stick with the US-based example mentioned earlier, terminal #1 could have its PCC in the AWS spectrum, whereas terminal #2's PCC is at 700 MHz. However, the most likely initial deployment scenario is that the PCC is configured for 700 MHz since the carriers' initial LTE deployments are in the lower frequency bands. Nevertheless, the network is able to change a terminal's PCC while executing the handover procedure. Besides being used for the initial access, only the PCC in the uplink will carry the Physical Uplink Control Channel (PUCCH) for uplink control information transmission. Any SCC that might be added in the uplink provides only the Physical Uplink Shared Channel (PUSCH). However, even if carrier aggregation in the uplink is defined with Rel-10, it is most likely that initial LTE-Advanced deployments for FDD will only make use of carrier aggregation in the downlink. That means we have an asymmetric aggregation of component carriers, for example two in the downlink and only one in the uplink. Typical TD-LTE carrier aggregation results in a symmetric aggregation. First systems may feature two DL and one UL CA for TDD as well.

So in FDD systems, which are the majority of current deployments, symmetric carrier aggregation with up to five CCs, as shown in Figure 2, as well as intraband non-contiguous CA is supposed to be rolled out in a

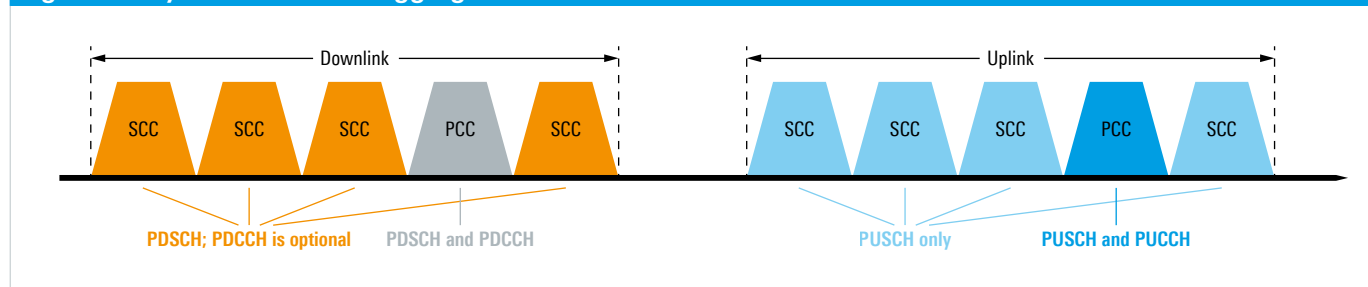
second step. The reasons are quite simple. Uplink carrier aggregation for interband requires a second transmit chain [Ref.01], which leads to a more complex device design and of course higher power consumption. In addition, things like power control per (uplink) component carrier, related power head room reporting, buffer status reports and timing advance are more challenging to implement, and need to be thoroughly tested and verified, resulting in a longer time to market. This would not be in line with the aggressive roadmaps of some, not only US-based, network operators in terms of carrier aggregation. Therefore this two step deployment approach seems to be plausible and is backed up with the work items submitted (WI) to RAN4, where only one network operator requested inter-band carrier aggregation for FDD including aggregation of two uplink component carriers<sup>3)</sup>.

<sup>3)</sup> RP-120364, Rapporteur: SK Telecom (South Korea).

**Figure 3 Default EPS bearer establishment procedure**



**Figure 2 Symmetric carrier aggregation**



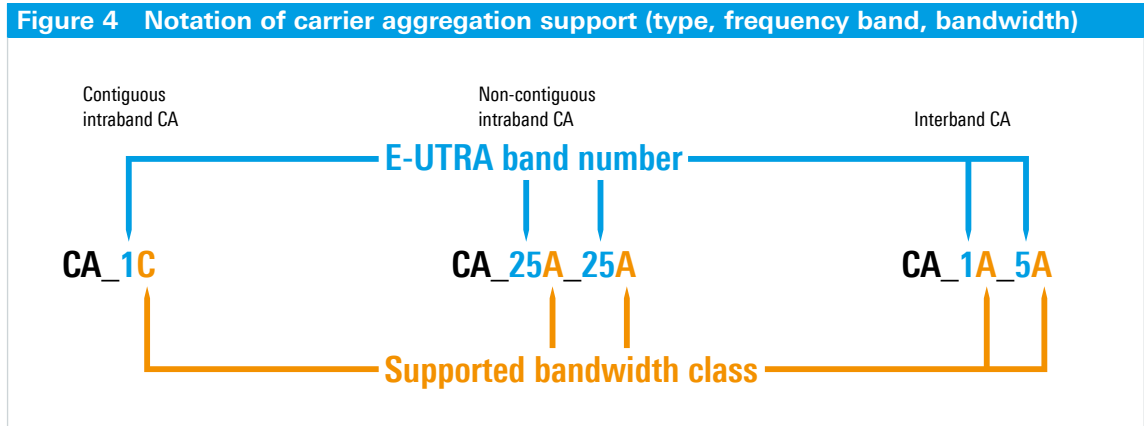
### What type(s) of carrier aggregation does a device support?

At this point it is important to note that there are certain limitations as to what band combinations a Rel-10-capable terminal can support. A multitechnology device enabled for global roaming has to support at least four GSM frequency bands, five 3G/WCDMA frequency bands and three LTE bands, if we just consider 3GPP-defined technology support. Not to mention the support of GPS, FM, Bluetooth® and WLAN standards, and eventually NFC<sup>4)</sup>. Each technology requires its own transmit-receive (TRX) chain, and space is limited due to the form factor and size of today’s smartphones. And the more TRX elements, the higher the power consumption. Due to these limitations, a device that supports LTE-Advanced will submit additional information to the network during the UE capability procedure. The UE capability transfer is part of the Default EPS Bearer establishment – shown in Figure 3 – that takes place after contention resolution of the initial random access procedure. The submitted UE capabilities, already enhanced with Rel-9, have once again been extended for Rel-10. With regards to the supported band combinations, the *RF-Parameters-v1020* information element provides this important detail to the network. The capabilities are signaled per frequency band, separately for downlink and uplink. Furthermore, bandwidth classes are indicated on a per band basis, including the support of either intraband (contiguous or non-contiguous) and

interband carrier aggregation. Table 3 shows supported bandwidth classes for LTE-Advanced as defined in the actual version of the related 3GPP specification. Figure 4 provides an example of the terminology used by the device to indicate its support of carrier aggregation for a particular frequency band or band combination<sup>5)</sup>. Let’s take the intraband, non-contiguous case using CA\_25A\_25A as an example. It tells the network that this device is able to receive (or transmit) two separate carriers in frequency band 25, each one with a maximum bandwidth of 100 RB, i.e. 20 MHz. If this device would be able to aggregate two carriers in that frequency band, but continuously, the acronym would change to CA\_25C. Bandwidth class C defines an aggregated transmission bandwidth between 100 RB and 200 RB, allocated to two component carriers. As can be seen, 3GPP still has work to do for bandwidth classes D, E and F as these are marked FFS – For Further Studies. Therefore it’s a fair conclusion that we will have initially an aggregated bandwidth of maximum 200 RB, equal to 40 MHz as required by IMT-Advanced, using two separate carriers. So as soon as the network is aware of the carrier aggregation capabilities of the device, it can add, modify or release SCC by means of the *RRCConnectionReconfiguration* message that has been enhanced with Rel-10. But, let’s take a step back before going into further details.

<sup>4)</sup> NFC: Near Field Communication.

<sup>5)</sup> R4-122764, CA configuration acronyms for non-contiguous intraband CA, Nokia Corp.



CA bandwidth class	Aggregated transmission bandwidth configuration	Maximum number of CC	Nominal guard band BW <sub>GB</sub>
A	$N_{RB,agg} \leq 100$	1	$0.05 BW_{Channel(1)}$
B	$N_{RB,agg} \leq 100$	2	FFS
C	$100 < N_{RB,agg} \leq 200$	2	$0.05 \max(BW_{Channel(1)}, BW_{Channel(2)})$
D	$200 < N_{RB,agg} \leq [300]$	FFS	FFS
E	$[300] < N_{RB,agg} \leq [400]$	FFS	FFS
F	$[400] < N_{RB,agg} \leq [500]$	FFS	FFS

BW<sub>Channel(1)</sub> and BW<sub>Channel(2)</sub> are channel bandwidths of two E-UTRA component carriers according to Table 5.6-1.

## Impact of carrier aggregation on LTE signaling procedures

Generally speaking, the signaling for carrier aggregation affects only certain layers, not the entire protocol stack. For instance, the device is permanently connected via its PCC to the serving Primary Cell (PCell). Non-Access Stratum (NAS) functionality such as security key exchange and mobility information are provided by the PCell. All secondary component carriers, or secondary cells, are understood as additional transmission resources. For the Packet Data Convergence Protocol (PDCP) and Radio Link Control (RLC) layer, carrier aggregation signaling is transparent. Compared to Rel-8, the RLC layer only needs to support the higher data rates by having a larger buffer size. The buffer size is defined by the UE category that a device belongs to. With Rel-10, three new categories have been added (see Table 4), however carrier aggregation is not limited to these new categories. Rel-8 device categories 2 to 5 can also be capable of carrier aggregation. A terminal is configured on the Radio Resource Control (RRC) layer to handle secondary component carriers, provided by secondary cells. Moreover, on RRC the parameters of the SCell(s) are set, i.e. configured. The Medium Access Control (MAC) layer acts as a multiplexing entity for the aggregated component carriers as they are activated or deactivated by MAC control elements. If activation is in

subframe  $n$ , then 8 subframes (8 ms) later the resources are available to the device and it can check for scheduling assignments. At this point in time, a newly introduced timer<sup>6)</sup> will also be started. Assuming an SCC has been configured for a device using RRC signaling and has been activated via MAC, but in a certain period no scheduling information via the PDCCH is received, this SCell will be deactivated on MAC after the timer expires. The timer can be overridden by setting it to infinity, the maximum setting. When the MAC acts as a multiplexer, each component carrier has its own Physical Layer (PHY) entity, providing channel coding, HARQ, data modulation and resource mapping. On the primary and each secondary component carrier, both types of synchronization signals are transmitted to allow device detection and synchronization. Figure 5 shows the control plane signaling, highlighting the layers that are involved in activating carrier aggregation for a particular handset. Coming back to the extension of the previously mentioned *RRConnectionReconfiguration* message at the RRC layer. With the help of this message extension, a maximum of four secondary cells can be activated. For each cell, its physical cell identity is sent, including the explicit downlink carrier frequency as an Absolute Radio Frequency Channel Number (ARFCN)

<sup>6)</sup> sCellDeactivationTimer-r10.

**Table 4**

UE category	Maximum number of DL-SCH transport block bits received within a TTI	Maximum number of bits of a DL-SCH transport block received within a TTI	Total number of soft channel bits	Maximum number of supported layers for spatial multiplexing in DL
...	...	...	...	...
<b>Category 6</b>	301 504	149 776 (4 layers), 75 376 (2 layers)	3 654 144	2 or 4
<b>Category 7</b>	301 504	149 776 (4 layers), 75 376 (2 layers)	3 654 144	2 or 4
<b>Category 8</b>	2 998 560	299 856	35 982 720	8

≈ 3 Gbps peak DL data rate for 8x8 MIMO, 64QAM

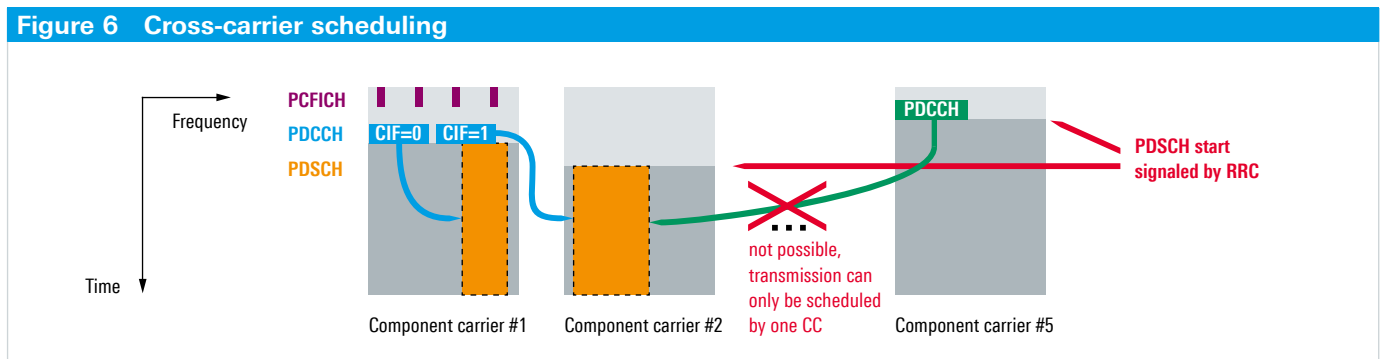
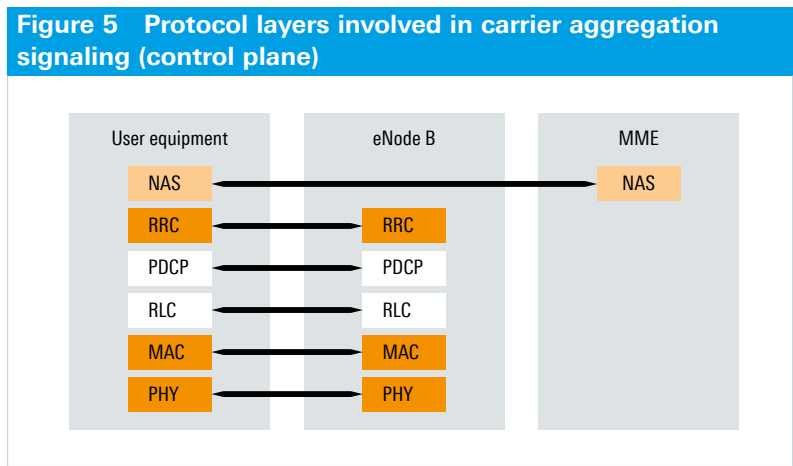
UE category	Maximum number of UL-SCH transport block bits transmitted within a TTI	Maximum number of bits of an UL-SCH transport block transmitted within a TTI	Support for 64QAM in UL	Total layer 2 buffer size
...	...	...	...	...
<b>Category 6</b>	51 024	51 024	no	3 300 000 bytes
<b>Category 7</b>	102 048	51 024	no	3 800 000 bytes
<b>Category 8</b>	1 497 760	149 776	yes	42 200 000 bytes

≈ 1.5 Gbps peak, UL data rate, for 4x4 MIMO, 64QAM

as well as common and dedicated information. For the common and dedicated information, the transferred information is separated for downlink and uplink. Common information means it is applicable to all devices that this carrier will be added to, including for instance its bandwidth, PHICH and PDSCH configuration and, in the case of TD-LTE, the UL-DL configuration and special subframe configuration. Further, the MBSFN subframe configuration is part of the downlink information. With Rel-9, broadcast/multicast capabilities have been fully defined for LTE and summarized as enhanced Multimedia Broadcast Multicast Services (eMBMS). With this feature, mixed mode is possible, where certain subframes out of an LTE radio frame are used for broadcast purposes. In terms of carrier aggregation, this is important information for the device, as it does not need to check subframes that are assigned to MBSFN. For the uplink carrier, frequency and bandwidth information, power control related information and the uplink channel configuration (PRACH, PUSCH) are signaled.

Dedicated information that is only applicable to this particular terminal includes, for instance, the activation and use of cross-carrier scheduling. Cross-carrier scheduling is an optional device feature. Its support is also indicated to the network during the UE capability transfer procedure. The use of cross-carrier scheduling is linked to Heterogeneous

Network (HetNet) deployment scenarios with carrier aggregation, where it is used to reduce interference. In brief, HetNets aim to improve spectral efficiency per unit area using a mixture of macro-cell, pico-cell, and femto-cell base stations and further relays. In these deployment scenarios, interference control and management is introduced. The question that remains is how to schedule resources when carrier aggregation is being activated for a device. The answer is in the definition of cross-carrier scheduling. Instead of decoding the Physical Downlink Control Channel (PDCCH) on each associated component carrier, the device only has to decode the PDCCH on one carrier, presumably the PCC, to also identify allocated resources on associated SCC. For this purpose, the Downlink Control Information (DCI) formats carrying the scheduling assignment will be extended by a Carrier Indicator Field (CIF). This new 3-bit field enables the terminal to clearly identify the component carrier that the decoded scheduling decision is meant for. Figure 6 shows the described principle. As explained, cross-carrier scheduling is enabled by RRC signaling. Since the terminal is not decoding the PCFICH on the associated (secondary) component carrier anymore, it does not know how many OFDM symbols in the beginning of each subframe are used for control data.





This information, referred to as PDSCH-Start<sup>7)</sup>, needs to be signaled to the device during activation of cross-carrier scheduling and is therefore part of the related information element. Depending on the bandwidth of the component carrier, this could be anywhere from 1 to 4 OFDM symbols. For cross-carrier scheduling, it is also important to point out that if resources on a component carrier are scheduled via another carrier, e.g. the PCC, no resources on that SCC for that terminal can be scheduled by any other component carrier.

However, initial deployments with carrier aggregation will utilize resource allocation as of Rel-8. This means the terminal will check, on the PCC as well as on all activated SCC, for the PDCCH to decode the associated DCI format and demodulate the assigned PDSCH resources. HetNets with cross-carrier scheduling will be deployed in a second phase.

### Carrier aggregation and LTE-Advanced support with test solutions from Rohde & Schwarz

Rohde & Schwarz offers a multitude of solutions for testing LTE-Advanced carrier aggregation implementations. The broad offering includes signal generators and analyzers for performing physical layer tests on base stations, mobile devices or components as well as base station emulators for physical layer and protocol tests on all kinds of wireless devices and chipsets.

The Rohde & Schwarz universal hardware platform for multiband, multimode wireless device and chipset development, for R&D, production and service, is the R&S<sup>®</sup>CMW500 wideband radio communication tester.

Today, it already supports a frequency range up to 6 GHz, making it a secure investment for all upcoming future challenges, including LTE-Advanced. With the proper hardware configuration, available today, a standalone R&S<sup>®</sup>CMW500 supports all variances of carrier aggregation: intraband (contiguous, non-contiguous) and interband with two component carriers. As a single instrument, it already supports all 3GPP frequency bands that are or will be utilized for LTE; support of the different combinations for interband carrier aggregation, including 2x2 MIMO, is no problem at all. Different bandwidths per component carrier, up to 20 MHz each, are supported, including asymmetric carrier aggregation, i.e. 2 DL and 1 UL. Carrier aggregation further increases mobile device complexity. The major design challenge is on the transceiver frontend to support multiple band combinations. This requires highly flexible switches, a wideband power amplifier and tunable antenna elements. As described earlier, other aspects are the Physical Layer (PHY) design, RRC signaling and mobility. For testing physical layer aspects of LTE-Advanced, Rohde & Schwarz has created a new test case package, the R&S<sup>®</sup>CMW-KF513. Test cases in a first release focus on carrier aggregation. This package will be continually enhanced to cover all upcoming physical layer aspects for LTE-Advanced. From an RRC signaling and mobility perspective, Rohde & Schwarz has defined multiple test scenarios, which are found in the R&S<sup>®</sup>CMW-KF514 test case package. For flexible mobility testing of carrier aggregation with 2x2 MIMO (intra-frequency or interfrequency), Rohde & Schwarz utilizes its R&S<sup>®</sup>CMW500 multibox setup (Figure 7). This setup is

<sup>7)</sup> The exact label of the information element is *pdsch-Start-r10*, see 3GPP TS 36.331 V10.6.0.



Figure 7 R&S<sup>®</sup>CMW500 multibox setup for testing carrier aggregation mobility with 2x2 MIMO.



used today in many development labs around the world to perform full protocol conformance testing according to the relevant 3GPP specification<sup>8)</sup>. A certain number of test cases require the simulation of multiple cells of different technologies (e.g. LTE, 3G/WCDMA or 2G/GSM) for mobility testing, PLMN and cell selection scenarios or neighbor cell measurements. Investing in a multibox setup will pay off as it will be reused for mobility testing for carrier aggregation, including 2x2 MIMO or even 4x2 MIMO, which is already supported today as defined in LTE as of Rel-8.

Another option for testing the LTE physical layer with a focus on carrier aggregation is the R&S<sup>®</sup>SMU200A vector signal generator. This instrument combines two complete signal generators – each with a baseband section and RF upconversion – in a single unit, making it ideal for all LTE-Advanced interband and intraband carrier aggregation scenarios. With the internal R&S<sup>®</sup>SMU-K85 software option, even complex LTE-Advanced carrier aggregation signals are intuitively configured (see Figure 8). Up to five component carriers with a variable bandwidth of up to 20 MHz can be generated. Each carrier is assigned to one of the two signal generation paths (path A/path B). The paths are mapped to the desired frequency band, e.g. 751 MHz and 1.9 GHz. Via relative frequency offsets for each component carrier, interband, contiguous intraband as well as non-contiguous intraband scenarios are easily and flexibly created. Configuration of cross-carrier scheduling and the PDSCH start offset of the secondary component carriers are also supported. Furthermore, the R&S<sup>®</sup>SMU200A vector signal generator can optionally perform AWGN, fading and MIMO (up to 4x2, 2x4) simulation.

All in all, the R&S<sup>®</sup>SMU200A is the right choice for testing receiver modules and algorithms of LTE-Advanced capable handsets during the initial design phase – for both LTE FDD and TD-LTE.

Infrastructure suppliers also have to perform dedicated tests for carrier aggregation. One of these is the Time Alignment Error (TAE) measurement. As the frames of LTE signals at a base station antenna port are not perfectly aligned, they need to fulfill certain timing requirements. For intraband carrier aggregation, the TAE shall not exceed 155 ns; 285 ns for the non-contiguous case. Interband carrier aggregation allows an error of up to 1325 ns. These requirements are independent of whether TX diversity or MIMO is applied per component carrier. Figure 9 shows the required setup to measure the time alignment error for interband carrier aggregation. In this example, the new high-end R&S<sup>®</sup>FSW signal and spectrum analyzer is acting as master, controlled by a software application. This program, which resides inside the instrument, is used to synchronize the capture of I/Q data from master and slave. Here, the slave is represented by the mid-range R&S<sup>®</sup>FSV signal and spectrum analyzer, the first instrument on the market to offer touchscreen operation. For measuring time alignment error for intraband carrier aggregation, a standalone R&S<sup>®</sup>FSW is sufficient due to its RF analysis bandwidth of 160 MHz. Further details can be found in the related 3GPP specification for LTE base station RF conformance testing [Ref. 02].

<sup>8)</sup> See 3GPP TS 36.523-1.

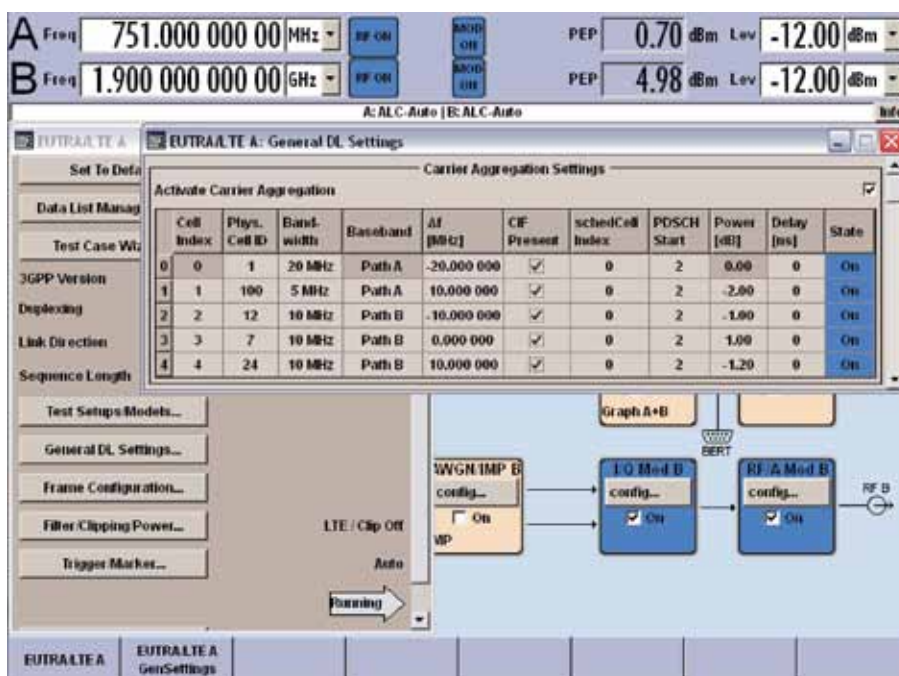
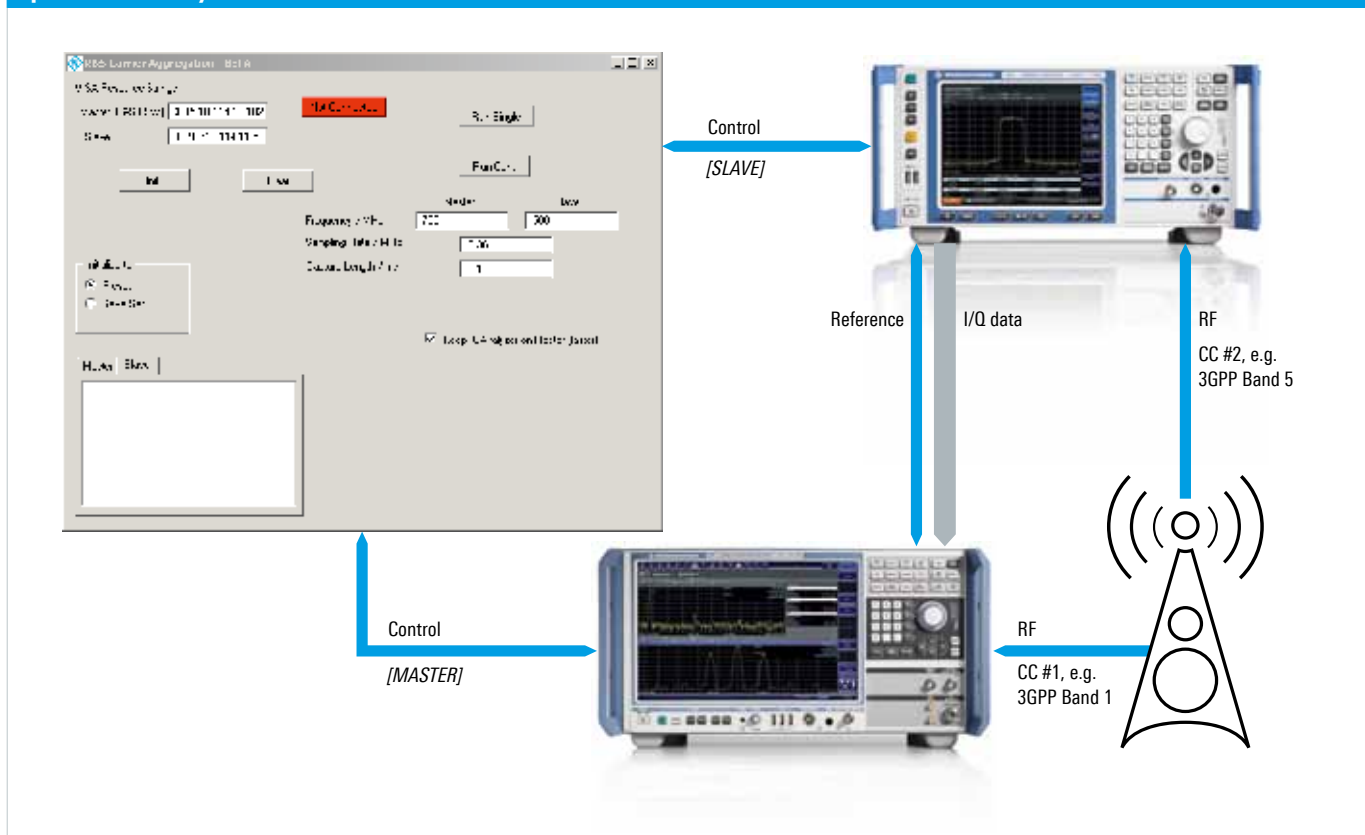


Figure 8 Configuration menu for Carrier Aggregation (CA) in R&S<sup>®</sup>SMU200A vector signal generator.

**Figure 9 Setup measuring TAE for interband carrier aggregation with Rohde & Schwarz signal and spectrum analyzer**



### Outlook: carrier aggregation enhancements with 3GPP Releases 11 and 12

While Rel-10 carrier aggregation is currently in the implementation phase, the 3GPP standardization is working on new CA features and enhancements for the next release (Rel-11). The core work item "LTE Carrier Aggregation Enhancements" in all its details will not be finalized before December 2012. Nevertheless, RAN1 has already decided on the basic functionality, features and changes. We present a brief preview here.

The support of multiple timing advance groups (TAGs) is included, i.e. the PCell and the SCell can have different uplink timing if they belong to different TAGs. This is enabled in Rel-11 by the introduction of a random access procedure on SCells, in contrast to Rel-10 where the PCell determines the timing for all aggregated cells. Further, in Rel-10 for TDD CA, the UL/DL configuration on all cells has to be identical. However, in Rel-11, different UL/DL configurations can be used as long as the CCs are located in different bands. This new feature provides more flexibility for CA with TDD. Next, transmit diversity for PUCCH format 1b with channel selection is introduced using the SORTD method for the PUCCH resource allocation. Finally, multicell HARQ-ACK and periodic CSI multiplexing for

PUCCH format 3 is defined in detail for FDD CA with more than two carriers or TDD carrier aggregation. Thus, Rel-11 will bring some innovations. For 3GPP Release 12, even a new carrier type that is not backward compatible is under discussion, which would be a major change.

### Summary

Carrier aggregation is one key enabler of LTE-Advanced to meet the IMT-Advanced requirements in terms of peak data rates. It is a highly demanded feature from a network operator perspective, since it also enables the aggregation of different spectrum fragments and offers a way out of the spectrum crunch. However, the major design challenge is on the terminal side. Support of higher bandwidths and aggregation of carriers in different frequency bands tremendously increase the complexity of transceiver circuits, including component designs like wideband power amplifiers, highly efficient switches and tunable antenna elements. Further, the additional functionality provided in the PHY/MAC layer and the adaptations to the RRC layer need to be thoroughly tested. As a premium supplier of test and measurement solutions to the wireless industry, Rohde & Schwarz already offers today the right tools to guide the design engineer through these challenges.

Andreas Roessler; Meik Kottkamp; Sandra Merkel

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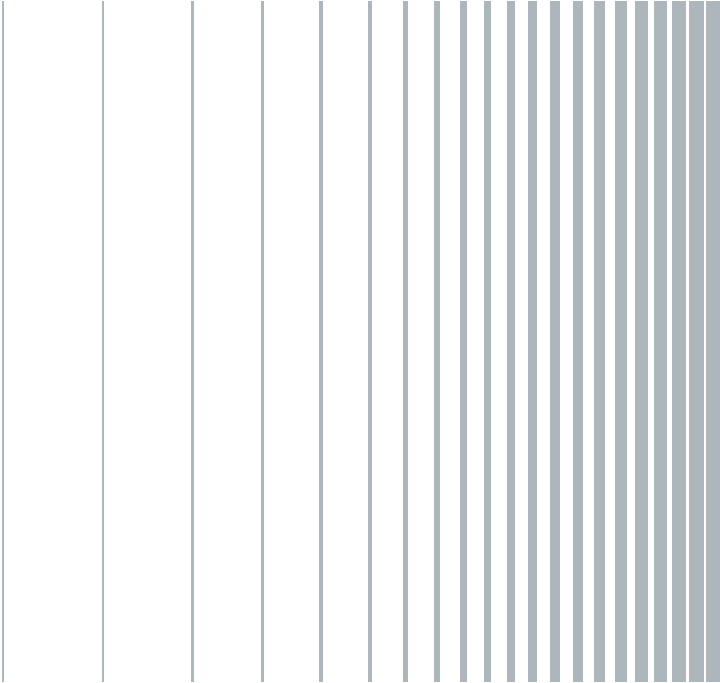
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#### REFERENCES

- [Ref. 01] 3GPP TR 36.815 Further advancements for E-UTRA; LTE-Advanced feasibility studies in RAN WG4, V9.1.0, see section 5.3
- [Ref. 02] 3GPP TS 36.141 E-UTRA Base Station (BS) conformance testing, V11.1.0
- [Ref. 03] 3GPP TS 36.321 Medium Access Control (MAC) protocol specification, V10.5.0
- [Ref. 04] 3GPP TS 36.331 Radio Resource Control (RRC) protocol specification, V10.5.0

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