LTE-Advanced Signal Generation and -Analysis

Application Note

Products:

- R&S®SMU200A
- R&S®SMBV100A
- R&S®AMU200A
- R&S®FSQ
- R&S®FSG
- R&S®FSV

This Application Note describes LTE-Advanced signal generation with spectrum aggregation in numerous configurations using one or more Vector Signal Generators R&S®SMU200A or R&S®SMBV100A. Various examples illustrate how to analyze these signals using the Vector Signal Analyzer R&S®FSQ, R&S®FSG or R&S®FSV.

ROHDE&SCHWARZ

Application Note

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1 Abstract

LTE (Long Term Evolution) standardization within the 3GPP (3rd Generation Partnership Project) has come to a mature state by now where changes in the specification are limited to corrections and bug fixes. LTE mobile communication systems are to be deployed from 2010 onwards.

The ITU (International Telecommunication Union) has coined the term IMT-Advanced to identify mobile systems capabilities going beyond those of IMT-2000. The data rate requirements have been further increased in order to support advanced services and applications. For LTE, these enhancements are being investigated for 3GPP release 10 and beyond (LTE-Advanced or LTE-A). The proposed high peak-data rate targets for LTE-Advanced of 1 Gbps in downlink and 500 Mbps in uplink can only be fulfilled with a further increase of the transmission bandwidth. Therefore transmission bandwidths up to 100 MHz are planned for LTE-Advanced. Being an evolution of LTE, LTE-Advanced shall be backwards compatible. It shall be possible to deploy LTE-Advanced in a spectrum already occupied by LTE with no impact on existing LTE terminals.

This can be achieved with so-called carrier aggregation, where multiple LTE “component carriers” are aggregated on the physical layer to provide the necessary bandwidth.

Details of the LTE-Advanced component carriers are not yet specified. Expected modifications are not assumed to have major influence on LTE-Advanced component tests such as power amplifier tests. With the capability to generate and analyze multiple LTE release 8 component carriers, measurements performed today are transferable to later real LTE-Advanced systems.

This Application Note describes LTE-Advanced signal generation with spectrum aggregation in numerous configurations using one or more Vector Signal Generators R&S®SMU200A or R&S®SMBV100A. Various examples illustrate how to analyze these signals using the Vector Signal Analyzer R&S®FSQ, R&S®FSG or R&S®FSV.

Besides spectrum aggregation, LTE-Advanced comprises further enhancements, including enhanced MIMO (Multiple Input - Multiple Output) schemes and CoMP (Coordinated Multiple Point transmission and reception) which are not covered by this application note. A complete LTE-Advanced technology introduction is provided by application note 1MA169 [3].

The following abbreviations are used in this application note for R&S® test equipment:
The R&S®SMU200A is referred to as the SMU.
The R&S®SMBV100A is referred to as the SMBV.
The R&S®AMU200A is referred to as the AMU.
The R&S®FSQ is referred to as the FSQ.
The R&S®FSB is referred to as the FSG.
The R&S®FSG is referred to as the FSV.
The FSQ, FSV, and FSG are referred to as the FSx.

2 Overview of LTE-Advanced Frequency Bands and Spectrum Deployment

In order to meet the high data rate requirements of IMT-Advanced, LTE-Advanced extends LTE release 8 with support for carrier aggregation: Two or more so called component carriers (CCs) are coupled in order to support wider transmission bandwidths up to 100 MHz. To an LTE terminal, each component carrier will appear as an LTE carrier, while an LTE-Advanced terminal can exploit the total aggregated bandwidth.

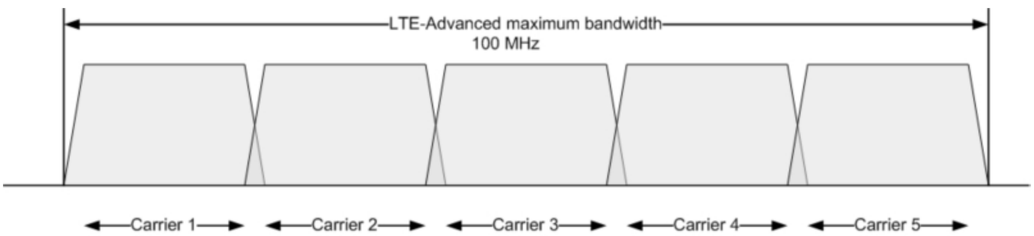


Figure 1: LTE-Advanced maximum bandwidth in contiguous deployment

Spectrum deployment may be either contiguous with adjacent component carriers as illustrated in Figure 1, or non-contiguous with non-adjacent component carriers as illustrated in Figure 2. Data may be sent either in the same frequency band or in different frequency bands in the latter case.

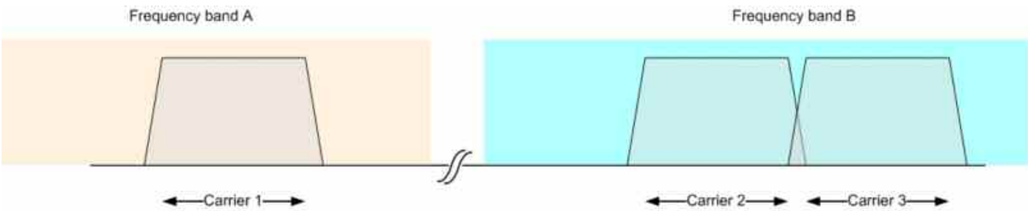


Figure 2: LTE-Advanced non-contiguous spectrum deployment

An LTE-Advanced terminal simultaneously receives one or multiple component carriers (CCs) depending on its capabilities. It will be possible to aggregate a different number of component carriers of possibly different bandwidths in UL and DL.
Deployment scenarios that have been considered for initial investigation within the 3GPP feasibility study for LTE-Advanced [1] are shown in Table 1. Agreed deployment scenarios for initial investigation in order to meet the ITU-R submission timescales are shaded in Table 1.
Latest discussions in 3GPP show that LTE-Advanced release 10 will likely focus on carrier aggregation with 2 component carriers, i.e. the maximum DL/UL bandwidth will be 40MHz for FDD.
This will not preclude a higher number of aggregated carriers to be specified in 3GPP release 11 and/or higher.

Table 1:
Deployment scenarios with the highest priority for the feasibility study (Table 5.1.2.1 of 3GPP TR 36.815 V0.3.0 (2009-10)).
Deployment scenarios for ITU-R submission 1, 2, 7 and 10 are shaded.

Scenario No.	Deployment Scenario	Transmission BWs of LTE-A carriers	No of LTE-A component carriers	Bands for LTE-A carriers	Duplex modes
1	Single-band contiguous spec. alloc. @ 3.5 GHz band for FDD	UL: 40 MHz DL: 80 MHz	UL: Contiguous 2x20 MHz CCs DL: Contiguous 4x20 MHz CCs	3.5 GHz band	FDD
2	Single-band contiguous spec. alloc. @ Band 40 for TDD	100 MHz	Contiguous 5x20 MHz CCs	Band 40 (2.3 GHz)	TDD
3	Single-band contiguous spec. alloc. @ 3.5 GHz band for TDD	100 MHz	Contiguous 5x20 MHz CCs	3.5 GHz band	TDD
4	Single-band, non-contiguous spec. alloc. @ 3.5 GHz band for FDD	UL: 40 MHz DL: 80 MHz	UL: Non-contiguous 20 + 20 MHz CCs DL: Non-contiguous 2x20 + 2x20 MHz CCs	3.5 GHz band	FDD
5	Single-band non-contiguous spec. alloc. @ Band 8 for FDD	UL: 10 MHz DL: 10 MHz	UL/DL: Non-contiguous 5 MHz + 5 MHz CCs	Band 8 (900 MHz)	FDD
6	Single-band non-contiguous spec. alloc. @ Band 38 for TDD	80 MHz	Non-contiguous 2x20 + 2x20 MHz CCs	Band 38 (2.6 GHz)	TDD
7	Multi-band non-contiguous spec. alloc. @ Band 1, 3 and 7 for FDD	UL: 40 MHz DL: 40 MHz	UL/DL: Non-contiguous 10 MHz CC@Band 1 + 10 MHz CC@Band 3 + 20 MHz CC@Band 7	Band 3 (1.8 GHz) Band 1 (2.1 GHz) Band 7 (2.6 GHz)	FDD
8	Multi-band non-contiguous spec. alloc. @ Band 1 and Band 3 for FDD	30 MHz	Non-contiguous 1x15 + 1x15 MHz CCs	Band 1 (2.1 GHz) Band 3 (1.8 GHz)	FDD
9	Multi-band non-contiguous spec. alloc. @ 800 MHz band and Band 8 for FDD	UL: 20 MHz DL: 20 MHz	UL/DL: Non-contiguous 10 MHz CC@UHF + 10 MHz CC@Band 8	800 MHz band Band 8 (900 MHz)	FDD
10	Multi-band non-contiguous spec. alloc. @ Band 39, 34, and 40 for TDD	90 MHz	Non-contiguous 2x20 + 10 + 2x20 MHz CCs	Band 39 (1.8 GHz) Band 34 (2.1 GHz) Band 40 (2.3 GHz)	TDD
11	Single-band Contiguous spec. alloc @ Band 7 for FDD	UL: 20 MHz DL: 40 MHz	UL: 1x20 MHz CCs DL: 2x20 MHz CCs	Band 7 (2.6 GHz)	FDD
12	Multi-band non-contiguous spec. alloc. @ Band 7 and the 3.5 GHz range for FDD	UL: 20 MHz DL: 60 MHz	UL/DL: 20 MHz CCs @ Band 7 DL : Non- contiguous 20 + 20 MHz CCs @ 3.5 GHz band	Band 7 (2.6 GHz) 3.5 GHz band	FDD

Operating bands of LTE-Advanced will involve E-UTRA (LTE) operating bands as well as IMT bands identified by ITU-R. E-UTRA (LTE) operating bands are shown in Table 2.

Table 2: Operating Bands for LTE Advanced

Operating Band	Uplink (UL) operating band BS receive/UE transmit			Downlink (DL) operating band BS transmit /UE receive			Duplex Mode
	F_{UL_low}	–	F_{UL_hig}	F_{DL_low}	–	F_{UL_hig}	
1	1920 MHz	-	1980 MHz	2110 MHz	-	2170 MHz	FDD
2	1850 MHz	-	1910 MHz	1930 MHz	-	1990 MHz	FDD
3	1710 MHz	-	1785 MHz	1805 MHz	-	1880 MHz	FDD
4	1710 MHz	-	1755 MHz	2110 MHz	-	2155 MHz	FDD
5	824 MHz	-	849 MHz	869 MHz	-	894 MHz	FDD
6	830 MHz	-	840 MHz	865 MHz	-	875 MHz	FDD
7	2500 MHz	-	2570 MHz	2620 MHz	-	2690 MHz	FDD
8	880 MHz	-	915 MHz	925 MHz	-	960 MHz	FDD
9	1749.9 MHz	-	1784.9 MHz	1844.9 MHz	-	1879.9 MHz	FDD
10	1710 MHz	-	1770 MHz	2110 MHz	-	2170 MHz	FDD
11	1427.9 MHz	-	1447.9 MHz	1475.9 MHz	-	1495.9 MHz	FDD
12	698 MHz	-	716 MHz	728 MHz	-	746 MHz	FDD
13	777 MHz	-	787 MHz	746 MHz	-	756 MHz	FDD
14	788 MHz	-	798 MHz	758 MHz	-	768 MHz	FDD
15	Reserved			Reserved			-
16	Reserved			Reserved			-
17	704 MHz	-	716 MHz	734 MHz	-	746 MHz	FDD
18	815 MHz	-	830 MHz	860 MHz	-	875 MHz	FDD
19	830 MHz	-	845 MHz	875 MHz	-	890 MHz	FDD
20	832 MHz	-	862 MHz	791 MHz	-	821 MHz	FDD
21	1447.9 MHz	-	1462.9 MHz	1495.9 MHz	-	1510.9 MHz	FDD
22	3410 MHz	-	3500 MHz	3510 MHz	-	3600 MHz	FDD
...							-
33	1900 MHz	-	1920 MHz	1900 MHz	-	1920 MHz	TDD
34	2010 MHz	-	2025 MHz	2010 MHz	-	2025 MHz	TDD
35	1850 MHz	-	1910 MHz	1850 MHz	-	1910 MHz	TDD
36	1930 MHz	-	1990 MHz	1930 MHz	-	1990 MHz	TDD
37	1910 MHz	-	1930 MHz	1910 MHz	-	1930 MHz	TDD
38	2570 MHz	-	2620 MHz	2570 MHz	-	2620 MHz	TDD
39	1880 MHz	-	1920 MHz	1880 MHz	-	1920 MHz	TDD
40	2300 MHz	-	2400 MHz	2300 MHz	-	2400 MHz	TDD
41	3400 MHz	-	3600 MHz	3400 MHz	-	3600 MHz	TDD

3 LTE-Advanced Signal Generation with R&S Signal Generators

R&S signal generators offer many features that are particularly helpful when generating signals with multiple component carriers according to LTE-Advanced requirements. This is especially true for the 2-path concept of the SMU signal generator (Figure 3) which combines up to 2 independent signal generators in one single instrument.

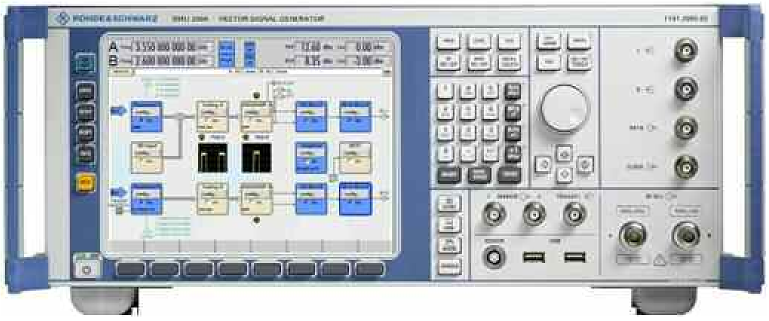


Figure 3: Vector Signal Generator SMU front view

In order to generate LTE-Advanced signals with multiple component carriers according to Table 1, different principles can be used:

- Addition of signals in baseband: Within one SMU signal generator two baseband units can be configured, thus two component carriers can be generated in real-time and added in baseband, either with contiguous or non-contiguous placement. For scenarios with more than two component carriers, with an additional AMU signal generator or a second SMU two extra component carriers can be added in baseband via the digital baseband interface.
- Addition of signals in the RF domain: Of course the signals from different component carriers can be added in the RF domain as well by using an RF power combiner.
- Using the Multi-carrier Arbitrary Waveform capability: This is a very cost-efficient approach available with all R&S signal generators.
- Mixed solutions: Combinations of the above-mentioned approaches may be required or useful for certain scenarios.

The following chapters explain the different approaches in more detail and highlight the benefits and possible limitations of each variant.

3.1 Signal Generation with an SMU

All the advantages of the SMU two-path concept become evident especially when generating LTE-Advanced signals in various configurations. Since the baseband section of the SMU is fully digital, the signals of the two baseband generators can be added to one RF output without synchronization problems and without an external coupler or additional equipment being required. Each signal's frequency offset and relative power can be set accurately. Both baseband generators can generate a single component carrier in real-time. The signals can then be added in the digital domain with a frequency offset, in contiguous placement or non-contiguous placement.

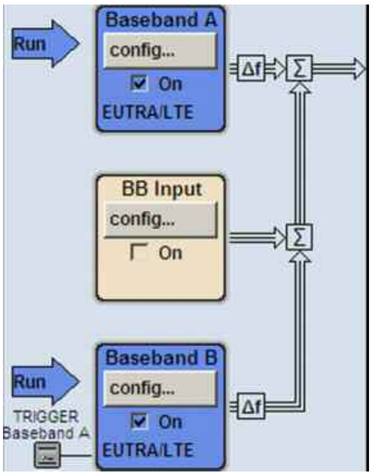


Figure 4: Baseband A and B are combined to path A with adjustable frequency offsets

Due to the SMU baseband generator's 80 MHz real-time bandwidth two component carriers with 20 MHz bandwidth each can be placed with a maximum frequency offset of ± 30 MHz. Thus a maximum gap of 40 MHz is possible with 2 x 20 MHz component carriers in non-contiguous placement, see Figure 5.

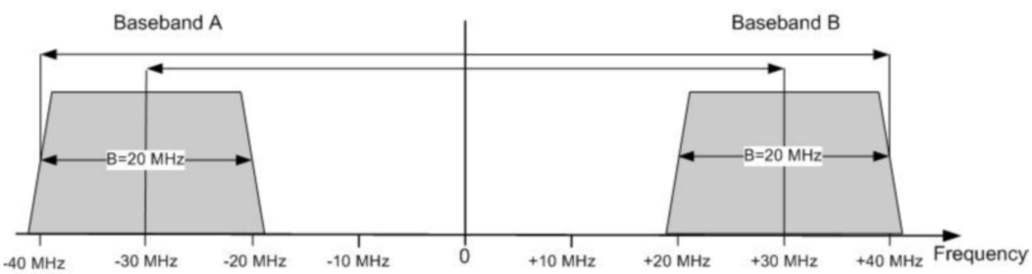


Figure 5: Two component carriers with 40 MHz gap

Figure 6 shows a resulting test setup with one SMU and a signal analyzer that is used to investigate the spectrum of the LTE-Advanced signal.

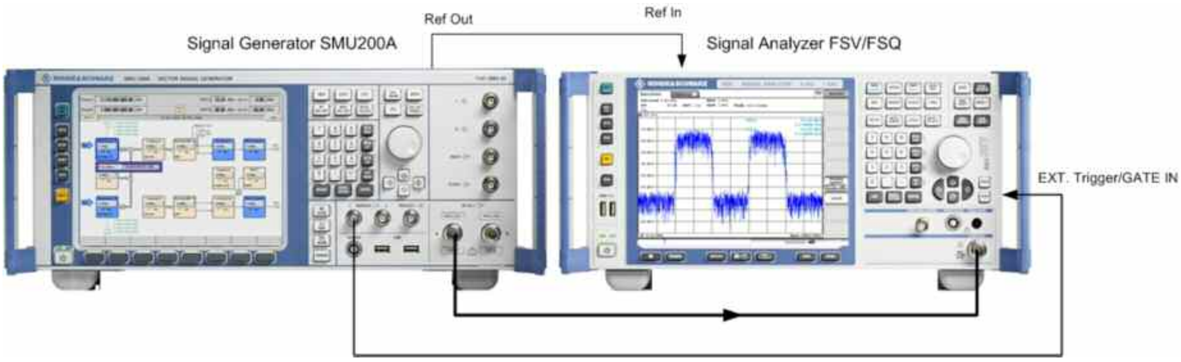


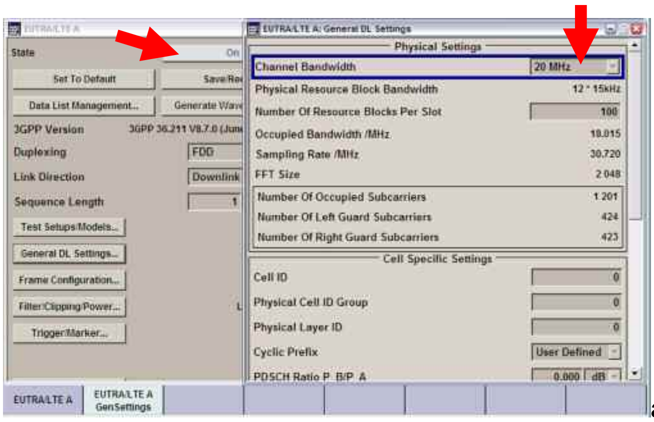
Figure 6: Test setup for generating a 2-carrier LTE-Advanced signal in contiguous or non-contiguous mode (addition in baseband)

<u>*Note:*</u>
All following pictures of the SMU show the model with 2 RF and 2 baseband channels, even if only one channel is used.

3.1.1 Contiguous Placement of 2 LTE Signals with 20 MHz Bandwidth (Addition in Baseband)

This chapter explains how to generate an LTE-Advanced signal in line with downlink scenario 11 of table 1 as an example.

Select an LTE Signal in baseband A and set Channel Bandwidth to 20 MHz as seen below. Do the same in baseband B.



a

Figure 7: Generating an LTE Signal with 20 MHz bandwidth

Set baseband A to a frequency offset of -10 MHz shifting the SMU output signal to 10 MHz below the selected RF Frequency (2.17 GHz).
Set baseband B to a frequency offset of +10 MHz shifting the SMU output signal to 10 MHz above the selected RF frequency.
Root baseband B to path A to combine it with baseband A to a contiguously placed LTE-Advanced signal containing two 20 MHz component carriers as seen in Figure 8 and Figure 9.

Hint:
It is recommended to set symmetrical offsets for baseband A and B. Thus the carrier feed through (as seen mid of Figure 13) will not affect the combined carriers. Intermodulation products are also minimized.

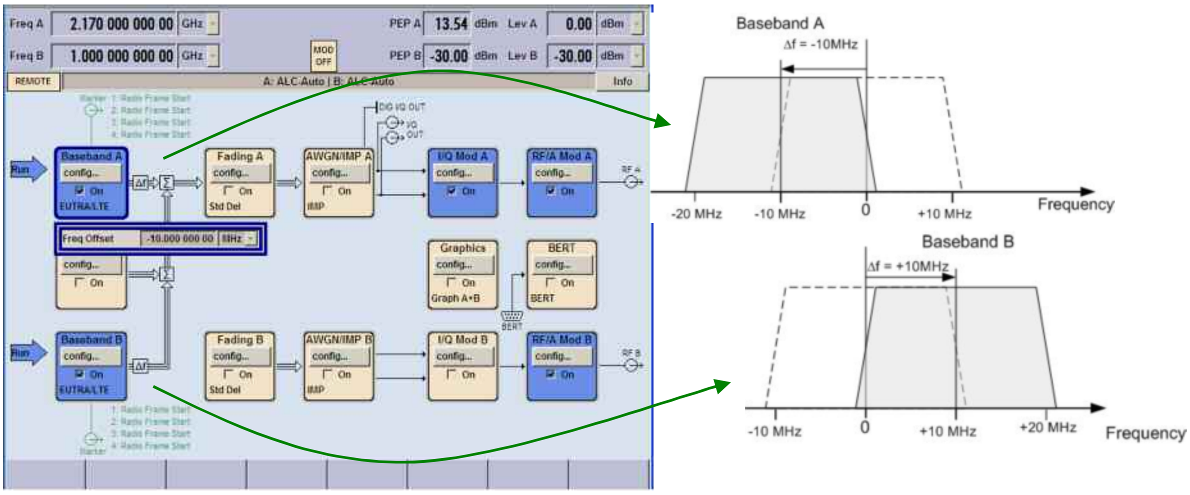


Figure 8: Baseband A is set to a frequency offset of -10 MHz, baseband B to a frequency offset of + 10MHz.

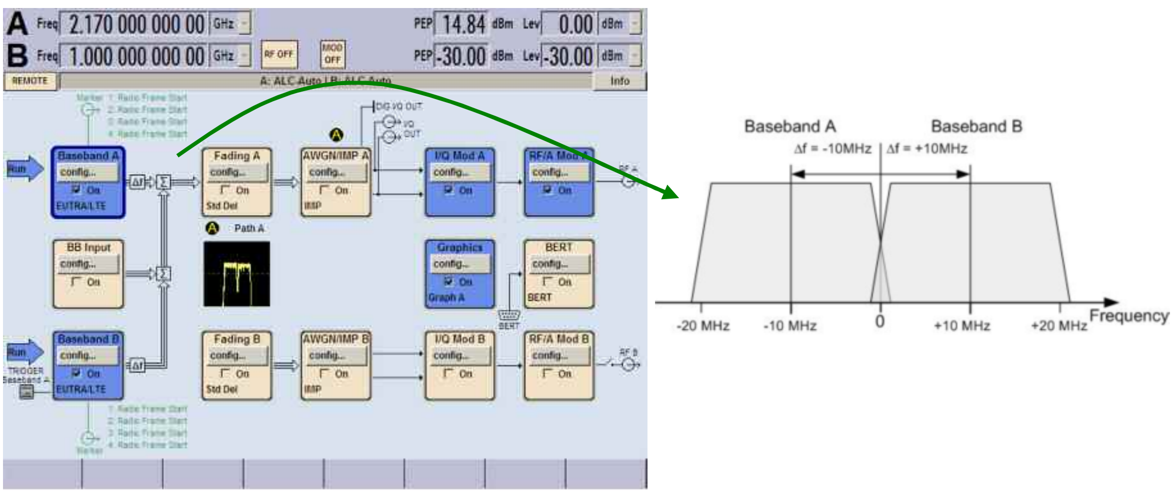


Figure 9: Baseband B is routed to baseband A to produce a contiguously placed LTE-Advanced signal containing two component carriers with 20 MHz bandwidth each.

To start the component carriers produced by baseband A and B synchronously, set the trigger source of baseband B to *Internal (Baseband A)* in Mode *Armed Auto* as seen in Figure 10. Switch baseband A off and on afterwards to run baseband B.

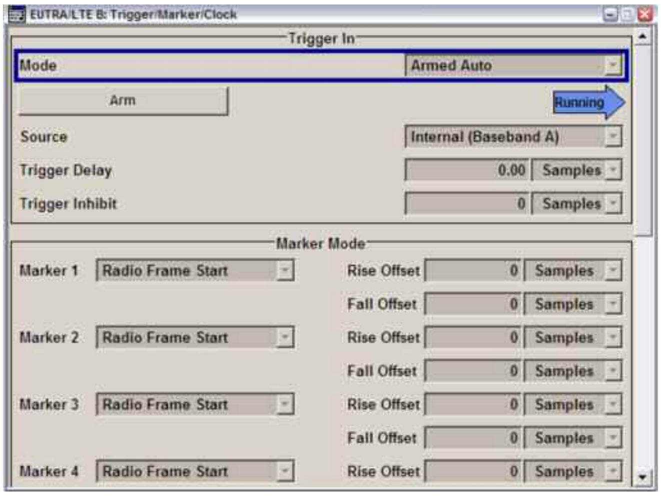


Figure 10: Trigger In of baseband B is set to trigger source Internal (baseband A) in mode Armed Auto, to start baseband A and B synchronously.

Figure 11 shows the output spectrum generated by an SMU as described above measured with an FSV.

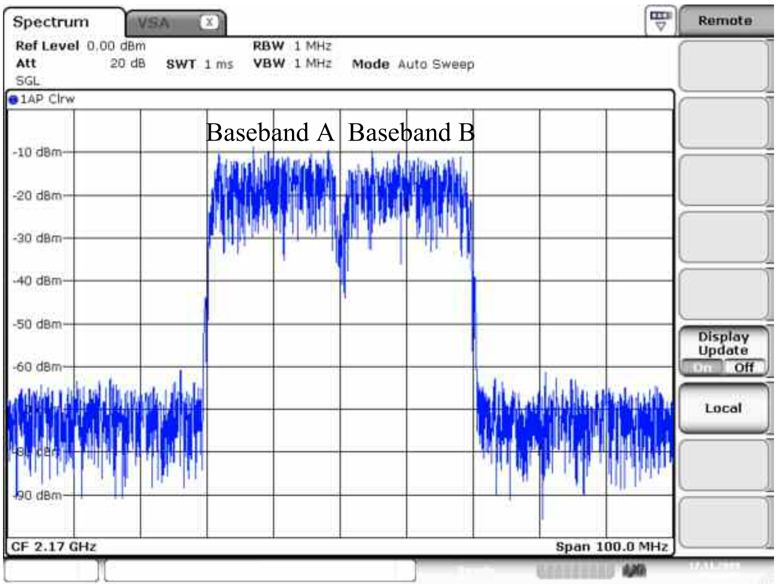


Figure 11: Spectrum of two contiguously placed 20 MHz LTE Signals similar to scenario 11 of Table 1 generated by an SMU as described above.

3.1.2 Non-Contiguous Placement of Two LTE Signals (Addition in Baseband)

Due to the large real-time bandwidth of 80 MHz, two LTE signals with 20 MHz bandwidth each can be placed non-contiguously with a maximum offset up to 60 MHz (each baseband + or - 30 MHz). Setups for smaller bandwidths or offsets can be derived easily from this scenario.

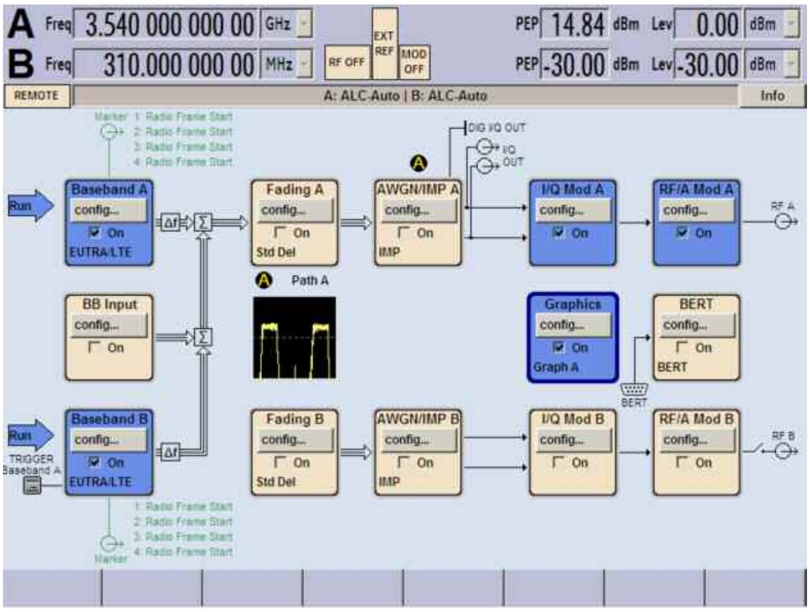


Figure 12: SMU Screen: Combining 2 baseband signals non-contiguously in an SMU (addition in baseband)

Set the SMU's center frequency to 3.54 GHz and the offsets of baseband A to -30 MHz and baseband B to +30 MHz to generate two 2 uplink component carriers at 3.51 GHz and 3.57 GHz according to uplink scenario 4 of Table 1.

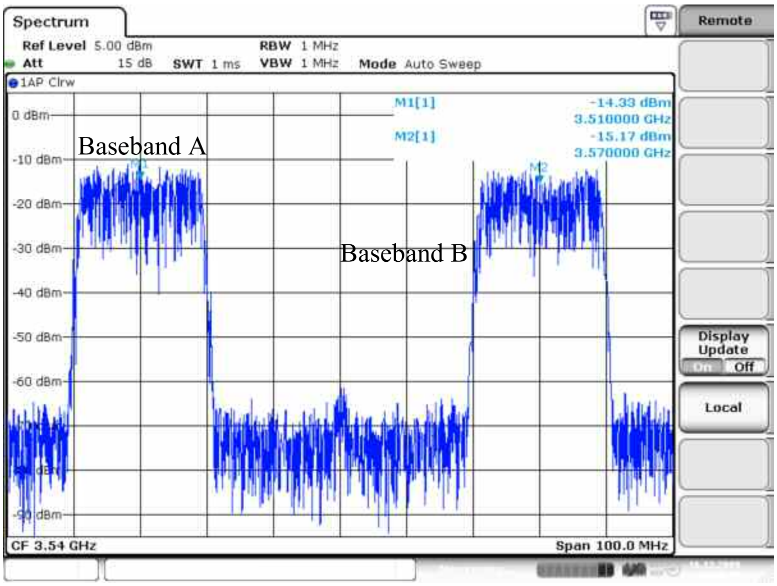


Figure 13: Non-contiguous placement of 2 LTE CCs with 20 MHz bandwidth each within the LTE frequency band 3.5 GHz (uplink scenario 4 of Table 1, addition in baseband).

3.1.3 Contiguous or Non-Contiguous Placement of 2 LTE Signals (Addition in the RF Domain)

By using an SMU with 2 baseband and 2 RF channels 2 LTE signals can also be added in the RF domain with an RF power combiner as illustrated in Figure 14.

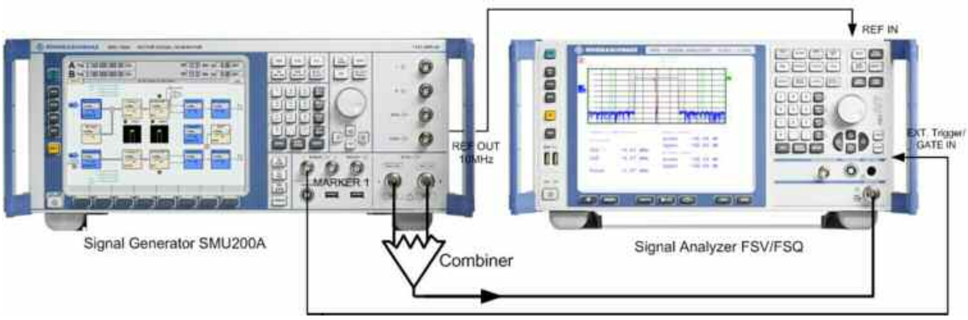


Figure 14: Adding 2 RF channels of an SMU externally with a power combiner to generate 2 LTE component carriers

Since there is no limitation by the real-time bandwidth of the SMU baseband section any longer, this configuration is also suitable for multi-band non-contiguous placement. Use an appropriate non-resistive power combiner with good isolation for optimum results.
This configuration exhibits best spectral performance, for example for critical ACLR tests on power amplifiers.

Setup SMU similar to chapter 3.1.1 but set the frequency offsets of baseband A and baseband B to 0 Hz. Set RF frequency A and B to the center frequencies of the wanted component carriers, see also Figure 15.

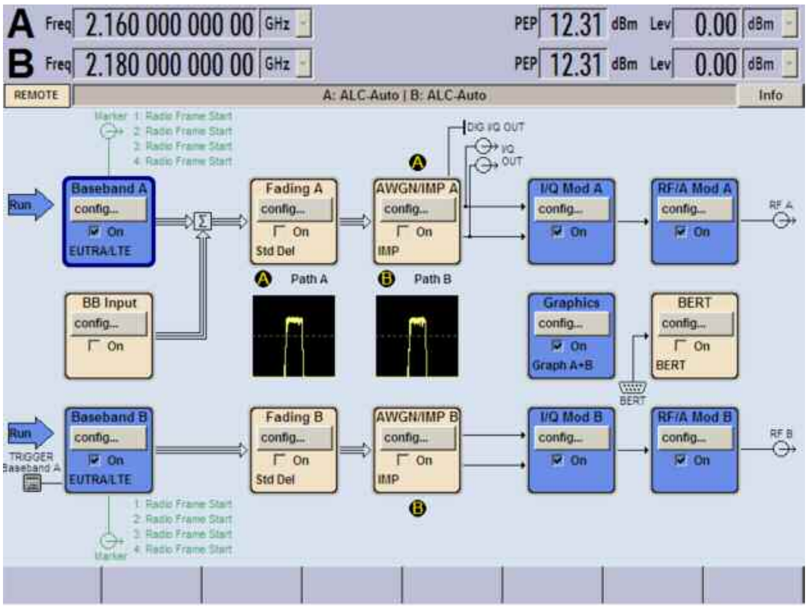


Figure 15: SMU configuration for adding 2 LTE component carriers at RF A and RF B externally with an RF power combiner.

Typical ACLR performance of a 2 carrier signal generated in this manner measured with an FSQ is shown in Figure 14. The ACLR values of -62 dB in the adjacent Channels and -63 dB in the alternate channels are approximately 3 – 4 dB better as of a signal generated according to chapter 3.1.1.

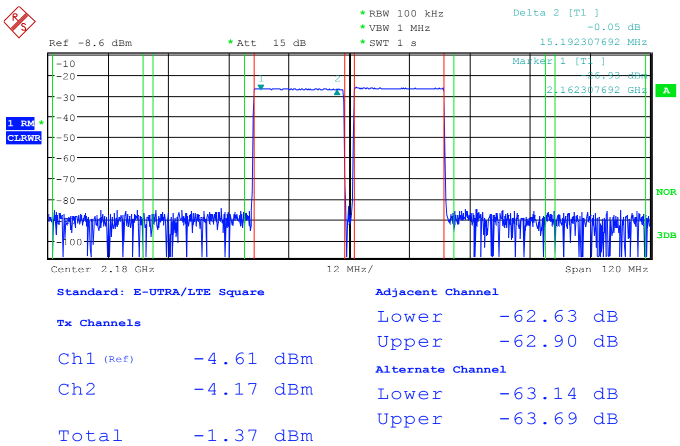


Figure 16: ACLR performance of 2 contiguously placed component carriers with 20 MHz bandwidth each, measured with an FSQ.

3.2 Signal Generation with an SMU and Additional AMU or SMU (Addition in baseband)

A 3rd and 4th LTE baseband can be superimposed to the RF A output signal of the SMU via the digital baseband input. A Baseband Signal Generator AMU200A or a 2nd Vector Signal Generator SMU delivers these additional baseband signals.
Up to 4 component carriers with 20 MHz bandwidth each are combined to the SMU's RF output A aggregating a total bandwidth of 80 MHz which fits in the 80 MHz real-time bandwidth of the SMU. The setup is shown in Figure 17.

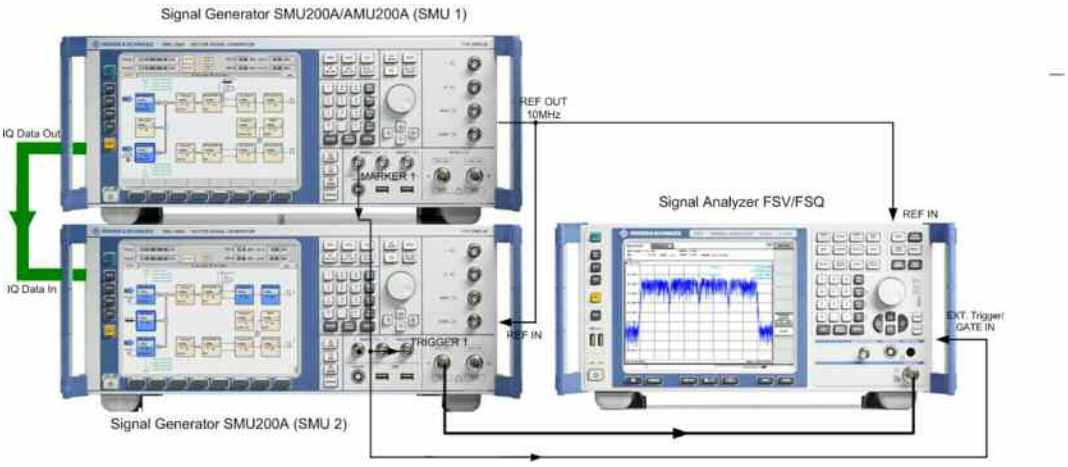


Figure 17: Combining the digital baseband output signal of a second generator

The upper AMU or SMU (SMU1 in Figure 17) is configured like in chapter 3.1.1 but rooted to Digital I/Q Out. Switch on the Digital I/Q Output as seen in Figure 18.

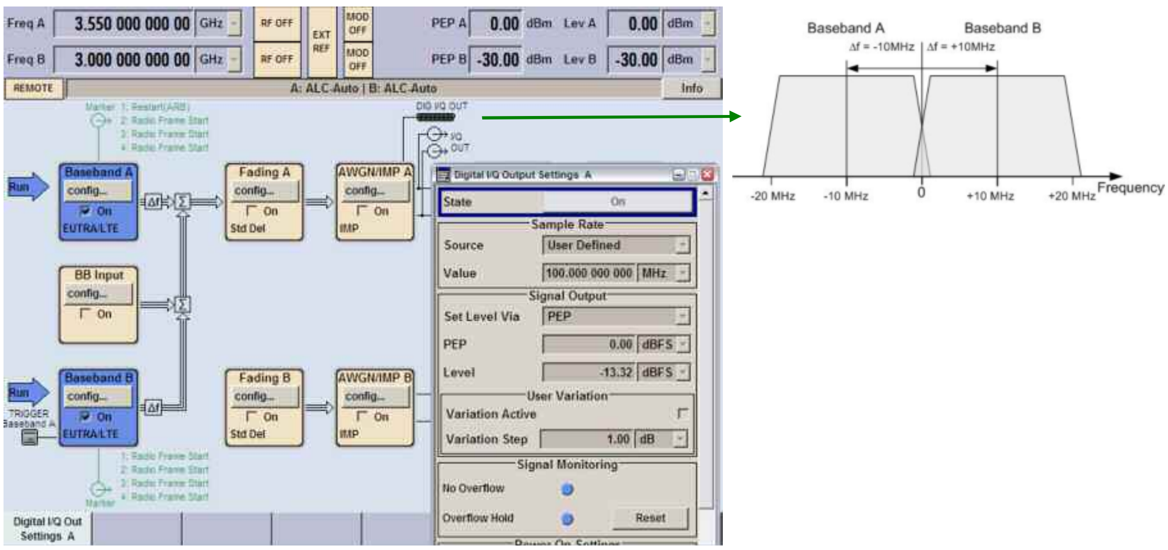


Figure 18: Upper SMU Screen: baseband A&B are combined and output at Digital IQ Out.

The Marker 1 of baseband A in SMU1 is setup to *Restart(ARB)* to get a trigger signal for the lower SMU.

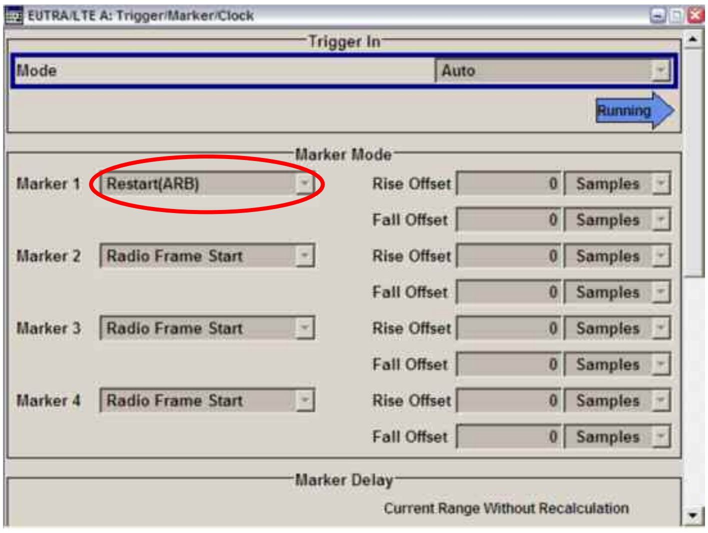


Figure 19: Marker/Trigger Settings of SMU1. Marker 1 is set to Restart(Arb) to get a trigger signal for SMU2 of Figure 17.

Switch on the Digital Baseband Input of the lower SMU (SMU2) and set Sample Rate to *User Defined 100 MHz* as seen in Figure 20.

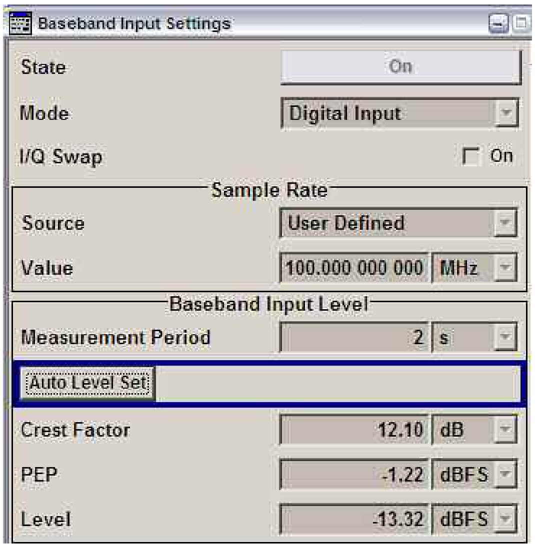


Figure 20: Baseband input settings of SMU2. The sample rate is set to 100 MHz.

Switch on the LTE Signal in SMU2 baseband A & B, set Channel Bandwidth to 20 MHz for both basebands.
Set baseband A to frequency offset -30 MHz shifting the SMU output signal to 30 MHz below the set RF Frequency. Set baseband B to a frequency offset of +30 MHz shifting the SMU output signal to 30 MHz above the set RF frequency. Root baseband B to path A to combine it with baseband A.

Figure 21: The SMU2 digital baseband input receives the digital baseband signal of SMU1 and combines it with its own baseband A and B to a signal with 4 contiguously placed component carriers.

Baseband A and B are triggered by SMU1 Marker1 Output (set to *Restart (ARB))* signal to achieve a synchronous start of all 4 LTE signals. A trigger delay of approximately 243 samples must be set for a synchronous start of all 4 baseband signals. (Measured with FSx and LTE Analysis Software, see Figure 39).

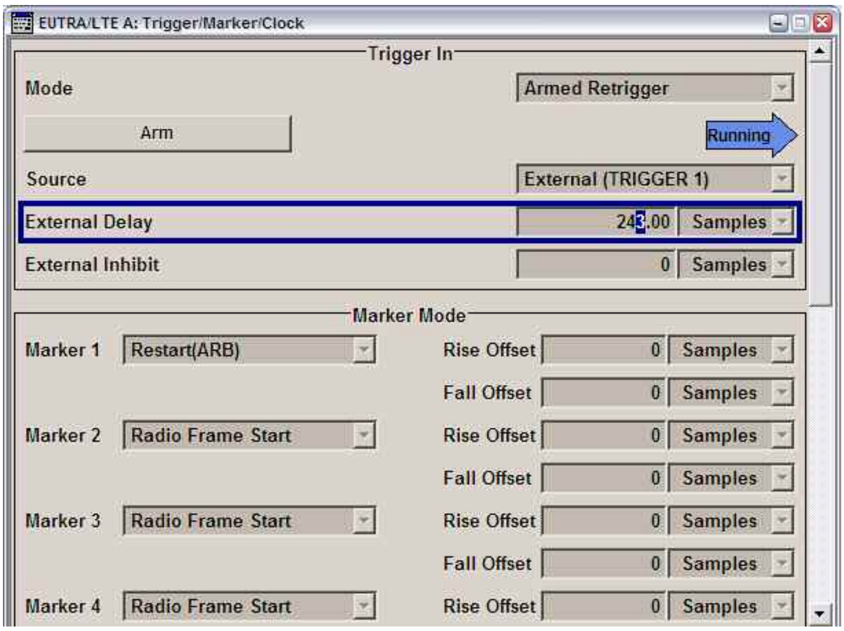


Figure 22: Trigger Settings of SMU2. Adjust External Delay to the same Trigger to Frame Start Offset as the SMU1 signal has.

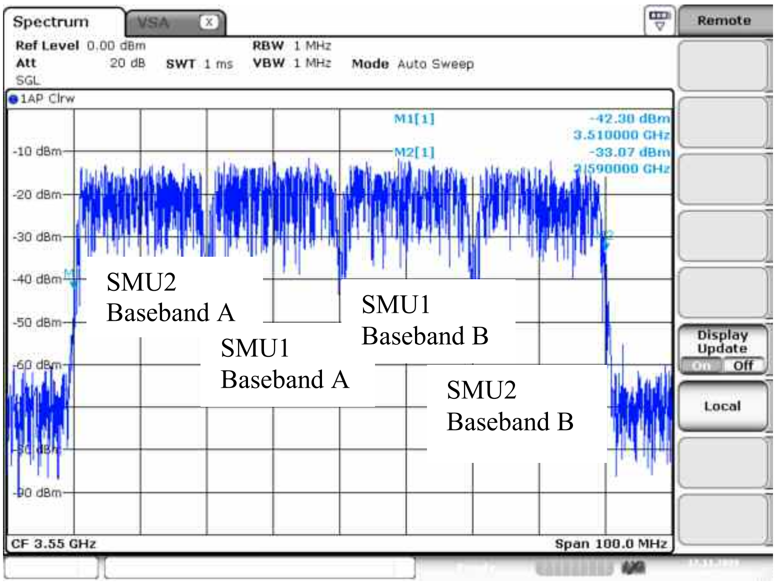


Figure 23: Example downlink carrier aggregation in operating band 24 (scenario 1 of Table 1).Up to 4 LTE CCs with 20 MHz bandwidth each are combined to the SMU's RF A output.

3.3 Using Multi-carrier Arbitrary Waveform

Besides its universal possibilities to create real-time digital modulated signals in different mobile radio standards, the R&S Vector Signal Generators contain a powerful arbitrary waveform generator allowing playback of pre-calculated waveforms. An SMU or SMJ with a waveform memory (up to 128 Msamples) and a clock-rate of 100 MHz is capable of generating pre-calculated complex modulated multi-carrier waveforms with a total RF bandwidth up to 80 MHz. Up to 4 contiguously deployed component carriers with 20 MHz bandwidth each can therefore be created with a single 1 channel SMU. The SMBV even has more waveform memory and a higher clock-rate. Its total RF bandwidth of 120 MHz is also wide enough for the proposed contiguously deployed 100 MHz bandwidth. Also non-contiguously spaced component carriers can be generated as long as the total RF bandwidth of 80 or 120 MHz respectively is not exceeded.
Using the Multi-carrier ARB mode is a cost-efficient way to generate LTE-Advanced signals. A single SMBV or SMJ or a one-channel SMU is sufficient. However, changing of the configuration of the different component carriers may be more time consuming compared to the other approaches described before.

Following steps are necessary to generate a multi-carrier arbitrary waveform:

1. Setup a real-time LTE component carrier with the desired configuration, then generate and store the waveform file.
2. Repeat step 1 if different configurations are needed in the various component carriers.
3. Select the Multi-carrier menu within the Arbitrary Waveform Modulation functionality in the baseband generator.
4. Combine the (optionally different) waveform files to a multi-carrier waveform file by filling the ARB multi-carrier table.
5. Press *Create and Load*.

These steps are illustrated in more detail in the following.

3.3.1 Generating 4 Component Carriers with Contiguous Allocation with an SMU200A or SMBV100A

Setup a real-time LTE component carrier with the wanted configuration, generate a waveform file and store it under a meaningful name (in this example *LTE DL BW20MHz*).

Figure 24: The currently setup LTE signal is saved as an arbitrary waveform file via the softkey "Generate Waveform File…"

Select ***MENU****:ARB:Multicarrier* and set *Number of Carriers* and *Carrier Spacing* like in Figure 25. Then select *Carrier Table.*

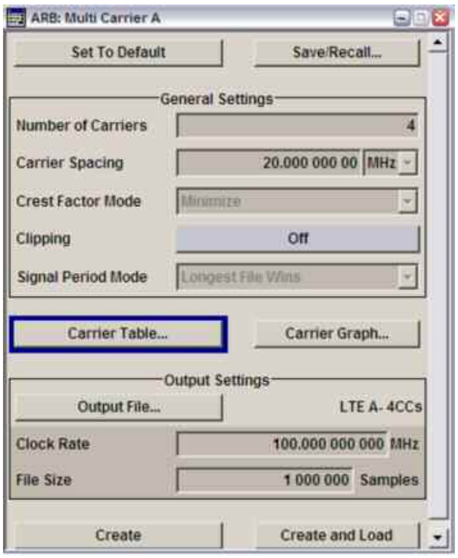


Figure 25:SMU/SMBV screen detail: setup the multi-carrier signal with 4 carriers with a spacing of 20 MHz

Fill the multi-carrier table as shown in Figure 26. Within the column *File* the appropriate waveform files are referenced (different files could be set for different carriers if necessary). Each carrier can be switched on or off in the column *State.* Optionally also different levels, phases and delays can be set for the different carriers via *Gain[dB*], *Phase[deg]* and *Delay[ns]*.
Press ***Escape*** after completing the multi-carrier table.

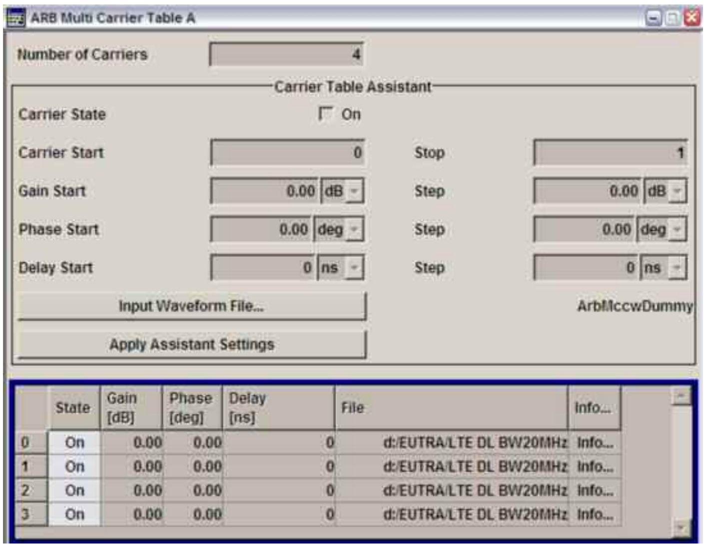


Figure 26: SMU/SMBV Screen Detail: multi-carrier table configuration

Set Output File name (via *Output File ….)* for a later reload of the multi-carrier waveform, then press *Create and Load:*

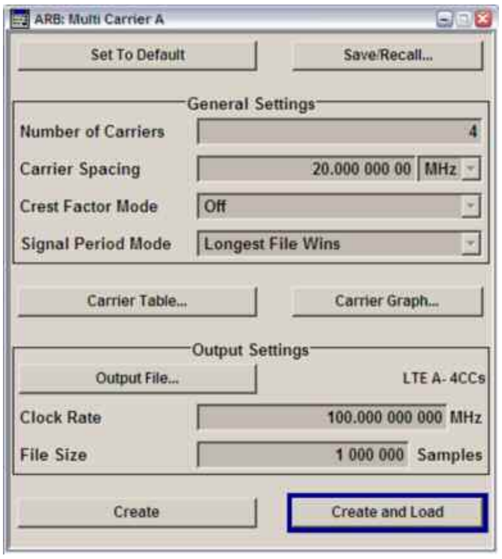


Figure 27: SMU/SMBV Screen detail: The 4-carrier signal is created and loaded via "Create and Load"

The multi-carrier waveform file is now generated.

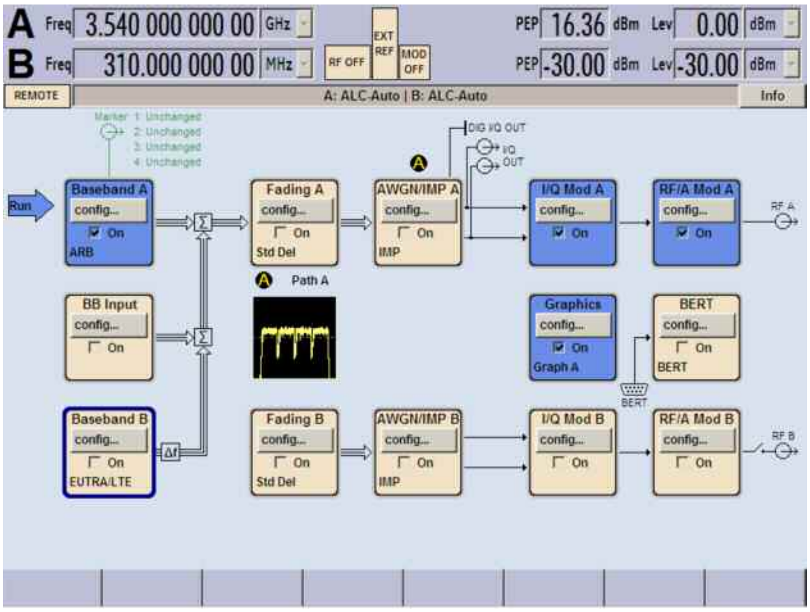


Figure 28: SMU Screen: LTE-Advanced signal with 4 contiguously placed component carriers, each with 20 MHz bandwidth using the Multi-carrier Arbitrary Waveform mode.

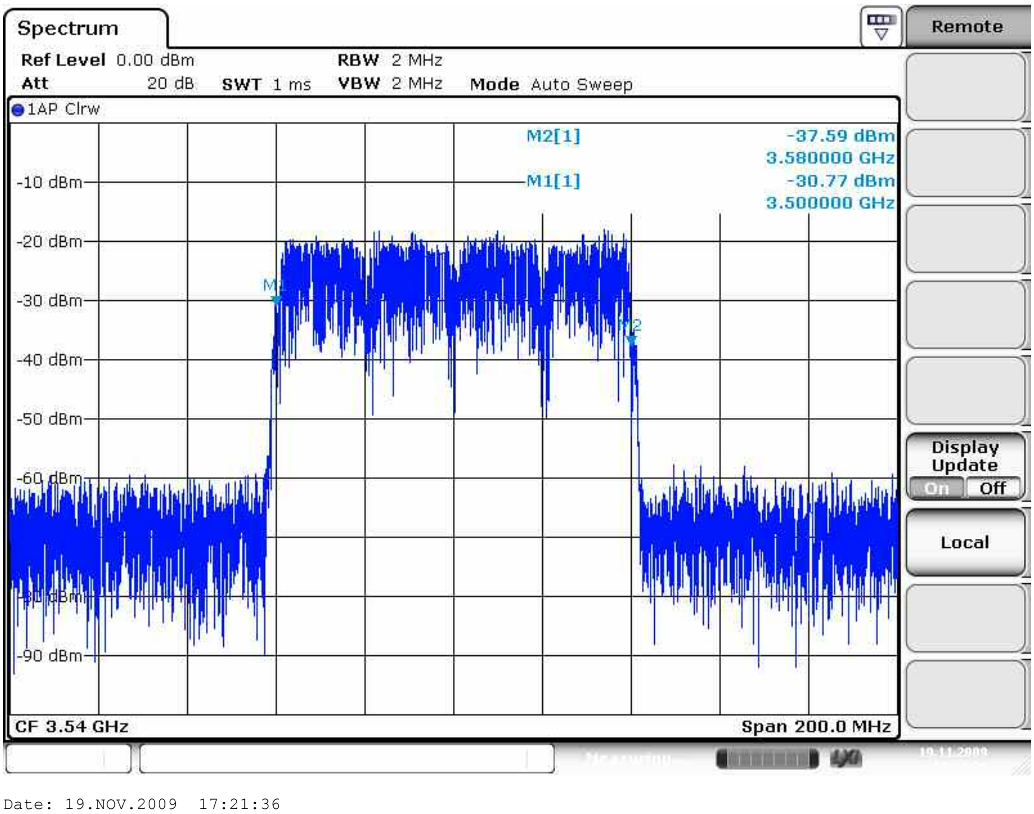


Figure 29: Contiguous placement of 4 x20 MHz carriers (Multi-carrier Arbitrary Waveform mode), DL-Scenario 1 of Table 1.

3.3.2 Generating 5 Component Carriers with Contiguous Allocation with an SMU200A or SMBV100A

There are 2 recommendable ways for generating a contiguous transmission bandwidth of 100 MHz (5x 20 MHz LTE Component Carriers, deployment scenarios No. 2 & 3 of Table 1):

⇒ By using a 2-channel SMU (with 2 RF and 2 baseband modules) and combining RF A and RF B outputs externally via combiner (only scenario 2 is supported by this setup because RF output B is limited to 3 GHz).

⇒ Or by using the Multi-Carrier Arbitrary Waveform mode of a single SMBV.

3.3.2.1 Using a 2-Channel SMU (Mixed Solution)

Baseband A generates a 4-carrier multi-carrier signal and is routed to the RF A output, baseband B generates a real-time LTE signal and is routed to the RF B output.
RF A and RF B are combined as shown in Figure 30.

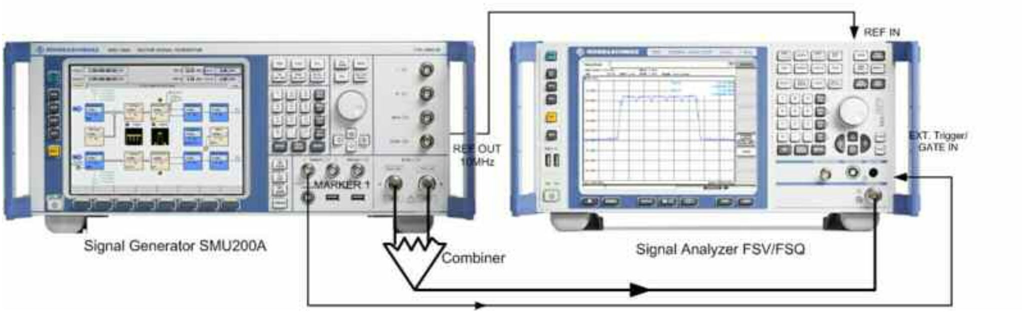


Figure 30: Test setup with a 2-channel SMU200A (2 baseband modules, 2 RF modules)

The multi-carrier signal at baseband A is setup similar to chapter 3.3.1.

Setup a real-time LTE signal at baseband B and set RF frequencies as shown in Figure 31 for the scenario 2 configuration of Table 1.
Trigger baseband B by baseband A with Mode *Armed Auto* for a synchronous start of the different combined carriers.

Hint:
Power of one component carrier dependent on number of component carriers (equal levels of all component carriers assumed)

When more than one LTE-Advanced component carrier of equal bandwidth is generated by the SMU's baseband section and output at RF output, the total power (P_{Tot}) corresponds to the set power (indicated in the SMU's Level display). The power of one component carrier (P_{cc}) is reduced correspondingly. The formula to calculate the power of one component carrier is:

P_{cc} =10 log P_{Tot} /N where N = number of generated component carrier

Power of one component carrier dependent on the number of total generated component carriers :	
Number of component carriers:	**Power of 1 component carrier P_{cc}:**
2	P_{Tot} - 3 dB
3	P_{Tot} – 4.8 dB
4	P_{Tot} - 6 dB
5	P_{Tot} - 7 dB (valid for SMBV, see chapter 3.3.2.2)

Table 3: Power of one component carrier dependent on the number of total generated Component carriers (equal levels of all component carriers assumed).

This means if a single component carrier generated in channel B is added externally to a 4 component carriers signal generated in channel A, the set level in channel B has to be 6 dB lower than the set level in channel A for equal levels of all the 5 component carriers (example of Figure 31).

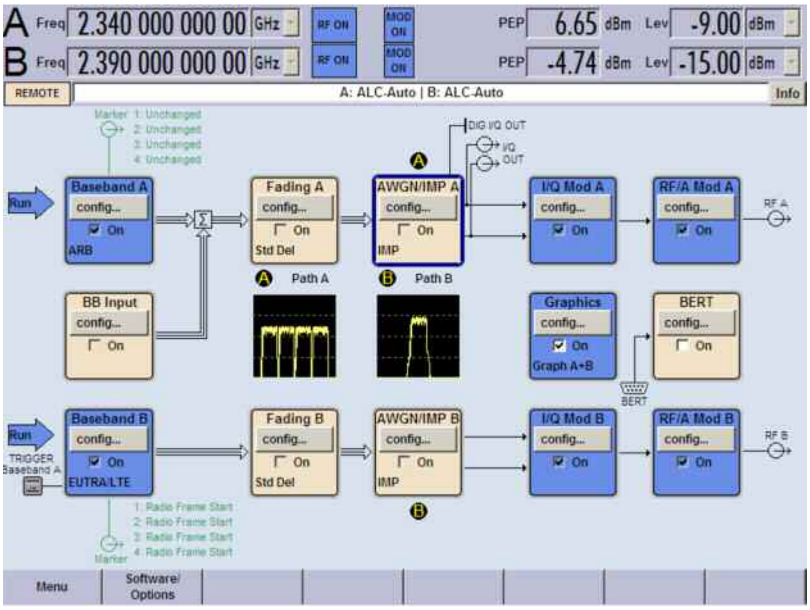


Figure 31: Configuration of a 2-channel SMU for generating 5 x 20 MHz LTE component carriers in band 40 (scenario 2 of table 1)

3.3.2.2 Using an SMBV (Multi-carrier Solution)

The SMBV's internal baseband generator allows 120 MHz bandwidth and is capable of generating 5 x 20 MHz component carriers in multi-carrier arbitrary waveform mode. Thus scenario No. 2 or 3 with 100 MHz transmission bandwidth can be generated with a single SMBV.

Setup the SMBV similar to chapter 3.3.1 but with 5 carriers.

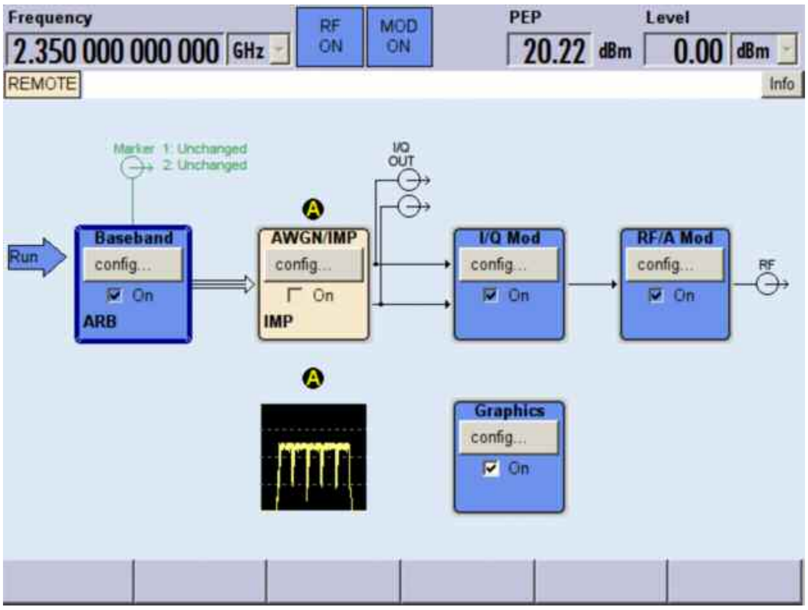


Figure 32: Generating deployment scenario 2 or 3 (5x20 MHz CCs) with a single SMBV using the multi-carrier ARB mode.

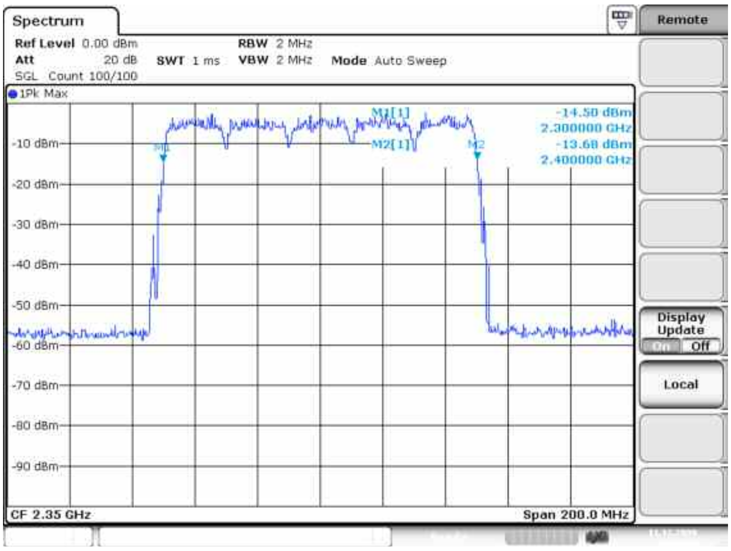


Figure 33: Output spectrum of contiguous 5x20 MHz component carriers (scenario 2 of Table 1)

3.4 Generating Multi-Band LTE-Advanced Signals (Mixed Solutions)

3.4.1 Generating an LTE-Advanced Dual-Band Signal in Non-Contiguous Placement with a Single SMU

Adding dual-band signals has to be done in the RF domain, because of the bandwidth limitation of the baseband generator. Two 2 RF signals must be combined externally via an appropriate RF signal combiner. A 2-channel SMU can provide these 2 RF signal outputs. Alternatively, 2 SMBV's can be used.
For generating scenario 12 of Table 1 with an SMU, path A of the SMU delivers 2x20 MHz component carriers in non-contiguous placement using its multi-carrier ARB function at 3.5 GHz band (similar to chapter 3.3.1). Path B delivers a single real-time modulated 20 MHz component carrier at 2.6 GHz band. RF A and RF B are externally combined with an RF combiner.
Trigger baseband B with baseband A as shown in chapter 3.1.1.

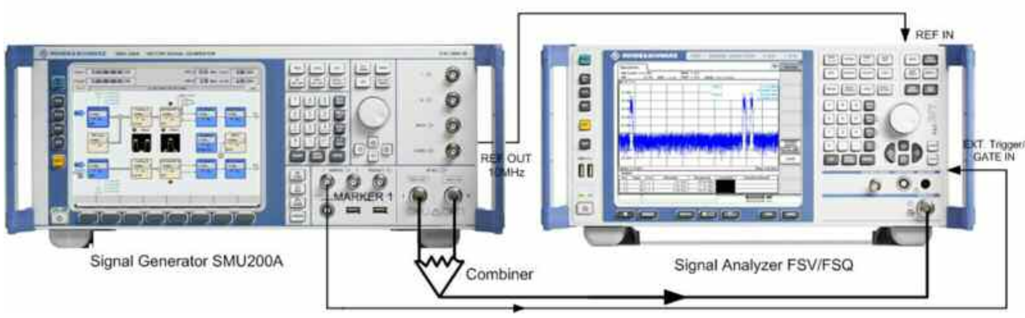


Figure 34: Test setup with a 2-channel SMU200A (2 baseband modules, 2 RF modules)

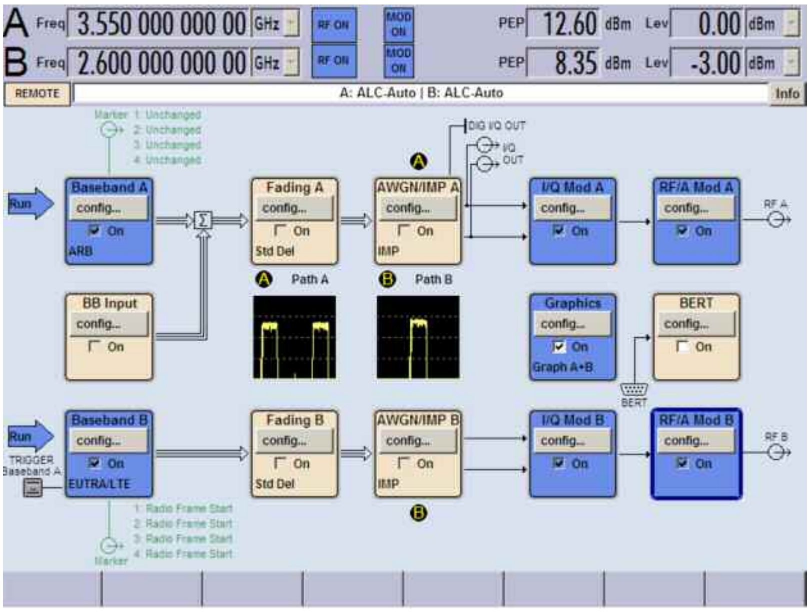


Figure 35: Generating scenario 12 of Table 1 with a 2-path SMU. Path A delivers 2x20 MHz CCs in non-contiguous placement using its multi-carrier ARB function at 3.5 GHz band. Path B delivers a single 20 MHz CC at 2.6 GHz band. RF A and RF B are externally combined.

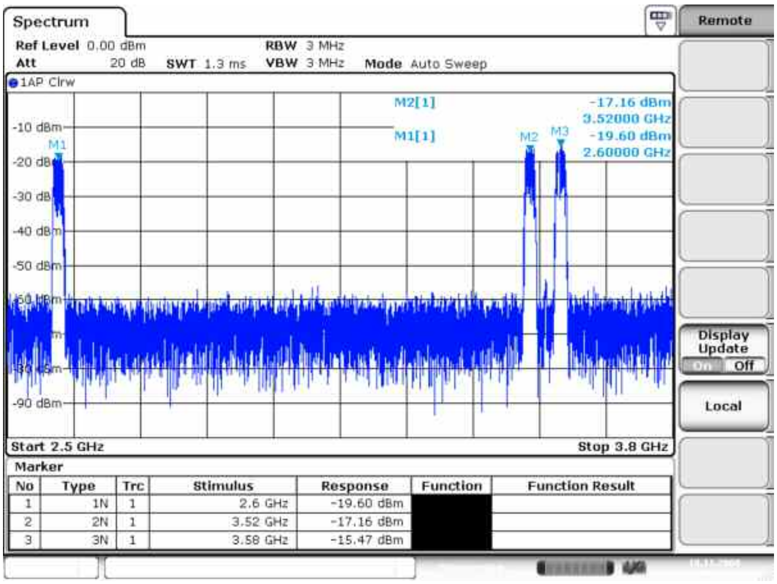


Figure 36: Example multi-band non-contiguous spectrum allocation at band 7 (2.6 GHz) and at 3.5 GHz band (scenario 12 of Table 1) generated with a 2-path SMU.

3.4.2 Generating a 3-band LTE-Advanced Signal in Non-Contiguous Placement

A 3-band LTE-Advanced signal in non-contiguous placement requires 3 RF channels. This can be arranged in the following ways:

a. Using 3 SMBV's combined with an external power combiner
b. Using an SMU with 2 RF channels and 2 baseband units and 1 SMBV
c. Using an SMU with 2 RF channels and 2 baseband units and an SMU with 1 RF channel and 1 baseband unit (as shown in Figure 37)

Each component carrier is generated using real-time modulation as described in chapter 3.1.1. Trigger baseband A and B of signal generator 2 (lower SMU) by signal Generator 1 (upper SMU) via its Marker 1 output similar to the description in chapter 3.2.

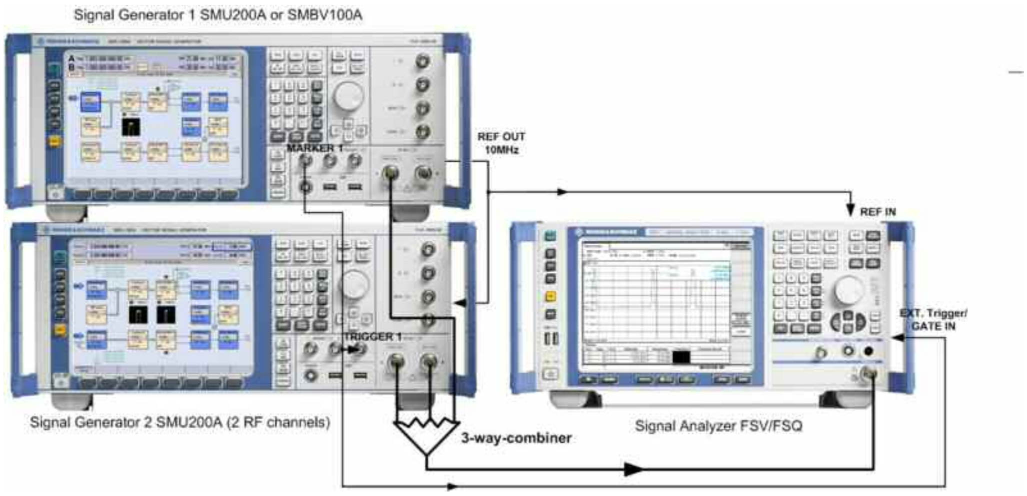


Figure 37: Configuration for multi-band deployment scenarios 7 or 10 of Table 1. Three RF channels are combined externally.

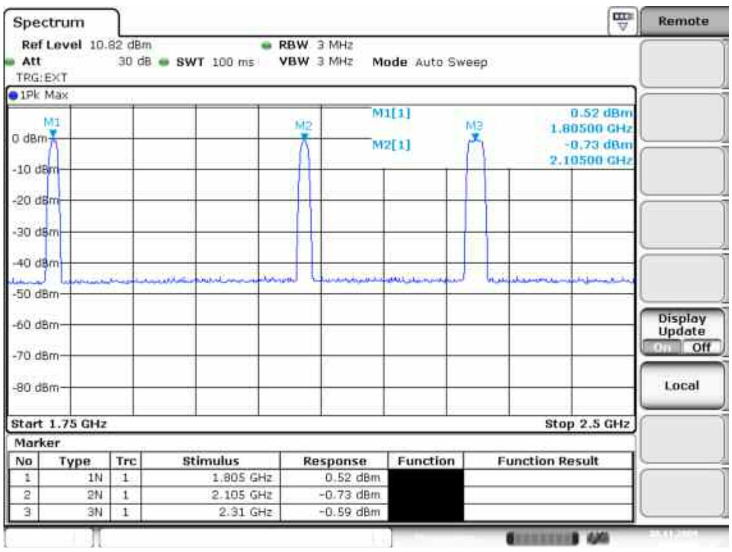


Figure 38: Example spectrum deployment scenario 7 of Table 1

3.5 Overview: Recommended Arrangements for Signal Generation

With one or more R&S signal generators every planned scenario of Table 1 can be generated. Recommended arrangements are listed in Table 4.

Table 4: Recommended arrangements for generation of LTE-A signal scenarios acc. to Table 1

Scenario No.	No of LTE-A component carriers	Bands for LTE-A carriers	Duplex modes	Recommended arrangement	Recommend arrangement (Multi-carrier)
1	UL: Contiguous 2x20 MHz CCs DL: Contiguous 4x20 MHz CCs	3.5 GHz band	FDD	UL: SMU with 2 baseband units DL: 2 SMU with 2 baseband units	UL and DL: 1 single Channel SMU or SMBV
2	Contiguous 5x20 MHz CCs	Band 40 (2.3 GHz)	TDD	1 SMU with 2 RF chan. ext. coupled	1 SMBV
3	Contiguous 5x20 MHz CCs	3.5 GHz band	TDD	1 SMU with 2 RF chan. ext. coupled	1 SMBV
4	UL: Non-contiguous 20 + 20 MHz CCs DL: Non-contiguous 2x20 + 2x20 MHz CCs	3.5 GHz band	FDD	UL: 1 SMU with 2 BB& 2 RF chan. DL: 2 SMU with 2 BB& 2 RF chan. ext coupled	1 SMBV
5	UL/DL: Non-contiguous 5 MHz + 5 MHz CCs	Band 8 (900 MHz)	FDD	1 SMU with 2 BB units and 1 RF unit	1 SMBV or 1 single channel SMU
6	Non-contiguous 2x20 + 2x20 MHz CCs	Band 38 (2.6 GHz)	TDD	UL: 1 SMU with 2 BB& 2 RF chan. DL: 2 SMU with 2 BB& 2 RF chan ext coupled	1 SMBV
7	UL/DL: Non-contiguous 10 MHz CC@Band 1 + 10 MHz CC@Band 3 + 20 MHz CC@Band 7	Band 3 (1.8 GHz) Band 1 (2.1 GHz) Band 7 (2.6 GHz)	FDD	1 SMU with 2 BB units and 2 RF units, 1 SMU with 1 BB units and 1 RF units or 3 SMBV	--
8	Non-contiguous 1x15 + 1x15 MHz CCs	Band 1 (2.1 GHz) Band 3 (1.8 GHz)	FDD	1 SMU with 2 BB units and 2 RF units or 2 SMBV	--
9	UL/DL: Non-contiguous 10 MHz CC@UHF + 10 MHz CC@Band 8	800 MHz band Band 8 (900 MHz)	FDD	1 SMU with 2 BB units and 2 RF units or 2 SMBV	--
10	Non-contiguous 2x20 + 10 + 2x20 MHz CCs	Band 39 (1.8 GHz) Band 34 (2.1 GHz) Band 40 (2.3 GHz)	TDD	1 SMU with 2 BB units and 2 RF units and 1 SMU with 1 BB unit and 1 RF path or 3 SMBV	--
11	UL: 1x20 MHz CCs DL: 2x20 MHz CCs	Band 7 (2.6 GHz)	FDD	UL: 1 SMU with 1 BB unit and 1 RF unit or 1 SMBV DL: 1 SMU with 2 BB units and 2 RF units or 2 SMBV	1 SMBV or 1 single channel SMU
12	UL/DL: 20 MHz CCs @ Band 7 DL : Non- contiguous 20 + 20 MHz CCs @ 3.5 GHz band	Band 7 (2.6 GHz) 3.5 GHz band	FDD	UL: 1 SMU with 1 BB unit and 1 RF unit or 1 SMBV DL: 1 SMU with 2 BB units and 2 RF units and 1 SMU with 1 BB unit and 1 RF path or 3 SMBV	--

4 Signal Analysis with FSQ, FSG or FSV

The universal LTE analysis capabilities of FSQ, FSG and FSV are applicable also for LTE release 8 compatible component carriers of LTE-Advanced signals. In the following it is described how to configure the FSx accordingly.

4.1 Modulation Analysis of the Different Component Carriers

With the EUTRA/LTE Analysis Software the different component carriers (each up to 20 MHz bandwidth) are analyzed separately by setting the center frequency to the center of the LTE-Advanced component carrier to be analyzed. Thus all the measurement functions of the EUTRA/LTE Analysis software are applicable. In the following some measurement examples are shown.
In the measurement example of Figure 39 the constellation diagram of the component carrier centered at 3.54 GHz is seen in the (upper) screen A of an FSV. Screen B shows the signal level over time (capture buffer) and indicates also the Frame Start Offset (duration of external trigger to frame start). This indication can be used to test or to adjust the synchronous frame start of different component carriers.

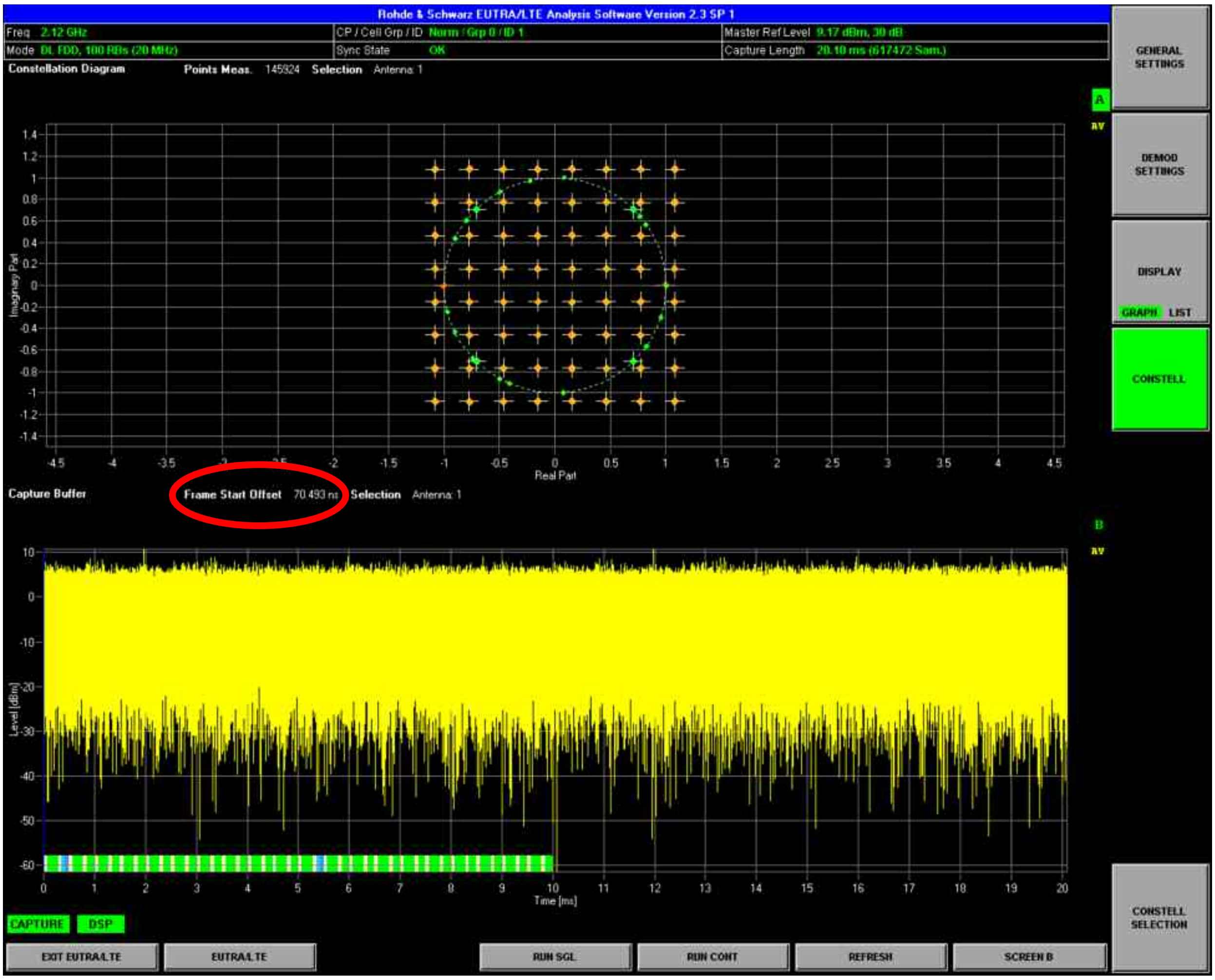


Figure 39: The Frame Start Offset indication in screen B is useable to check or to adjust synchronous timing of the different component carriers (via Marker delay of SMU).

The Result Summary table is displayed for I/Q measurements when the display mode is set to LIST. This table shows the overall measurement results and optionally provides limit checking for EVM values in accordance with the selected standard, see Figure 40.

Item	Min	Mean	Mean Limit	Max	Max Limit	Unit
EVM PDSCH QPSK			17.50			%
EVM PDSCH 16QAM			12.50			%
EVM PDSCH 64QAM		0.49	8.00			%
EVM Phys. Channel	0.47	0.49		0.52		%
EVM Phys. Signal	0.46	0.48		0.51		%
EVM All	0.48	0.49		0.52		%
Frequency Error	-122.82	-122.04		-121.48		Hz
Sampling Error	-0.07	-0.06		-0.05		ppm
Time Alignment Error Δ2,1						ns
Time Alignment Error Δ3,1						ns
Time Alignment Error Δ4,1						ns
IQ Offset	-53.45	-53.31		-53.21		dB
IQ Gain Imbalance	0.00	0.00		0.00		dB
IQ Quadrature Error	0.00	0.00		0.01		°
OSTP	-1.75	-1.64		-1.53		dBm
Power	-1.71	-1.67		-1.64		dBm
Crest Factor		11.97				dB

Figure 40: The Result Summary Table shows overall IQ measurement results and optionally provides EVM limit checking in accordance with the selected standard.

The EVM vs. Carrier display shows the EVM of each carrier, averaged over all available OFDM symbols (Screen A of Figure 41).
The EVM vs. Symbol display shows the EVM of each symbol, averaged over all OFDM data carriers. The results are displayed on a per-symbol basis. (Screen B of Figure 41).

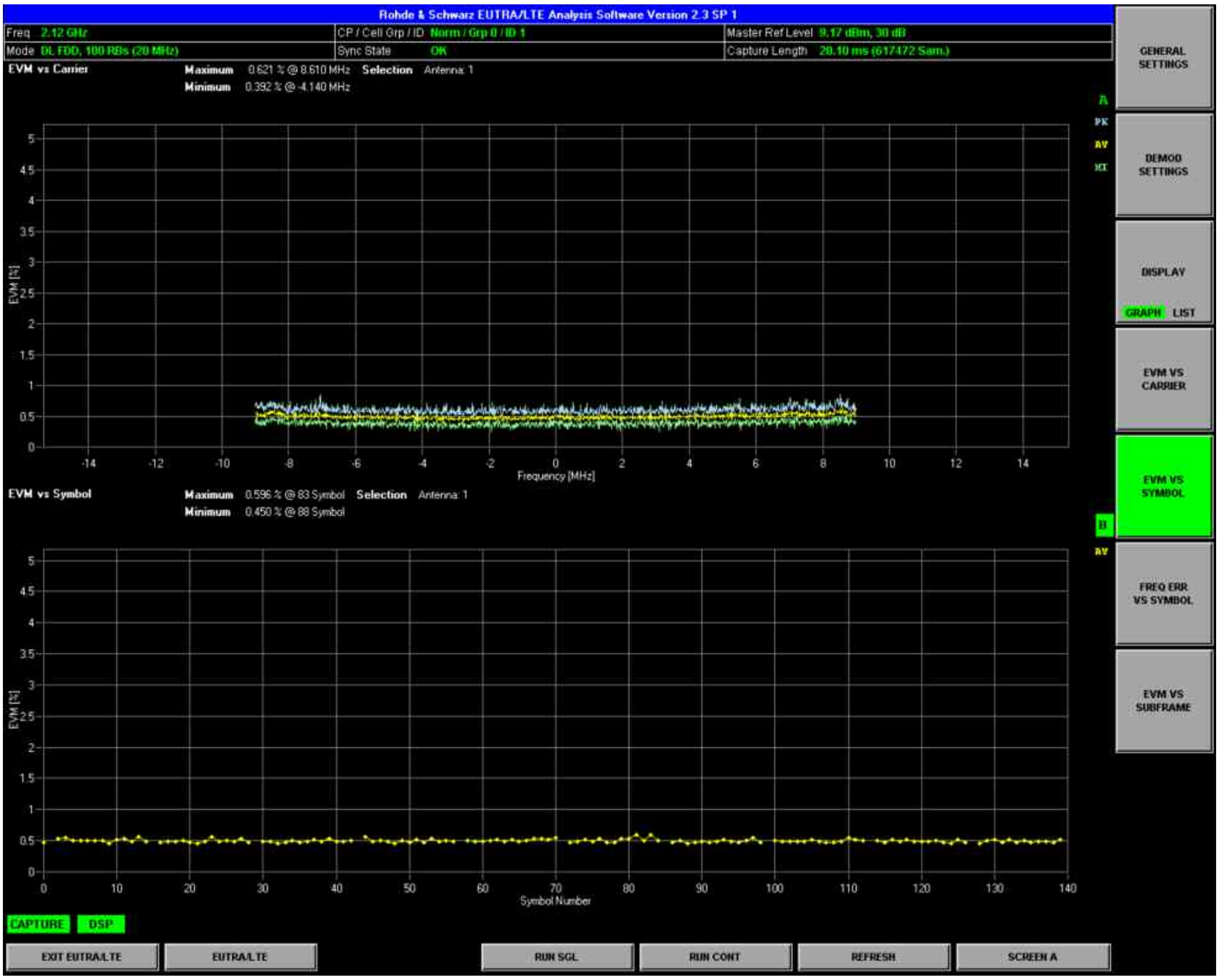


Figure 41: In screen A (upper) EVM vs Carrier, in screen B (lower) EVM vs. symbols is shown.

Screen A of Figure 42 shows the Symbol Allocation Summary, screen B shows the channel flatness.

Figure 42: In screen A (upper) the allocation table, in screen B (lower) the channel flatness is shown.

4.2 ACLR-Test with Configurable Multi-carrier ACLR Measurement Function

The LTE - ACLR measurement function of FSx is easily configurable also for contiguously or non-contiguously placed LTE-Advanced signals. Within the Channel Power/ACLR function switch on the EUTRA/LTE Square standard. Change the Number of TX Channels and Channel Settings accordingly (Number of TX Channels: 4, Channel Bandwidth: TX1: 18.015 MHz, ADJ: 18.015 MHz, Channel Spacing: 20 MHz) for a configuration as described in chapter 3.3.1. See measurement examples of FSQ (Figure 43) and FSV (Figure 44).

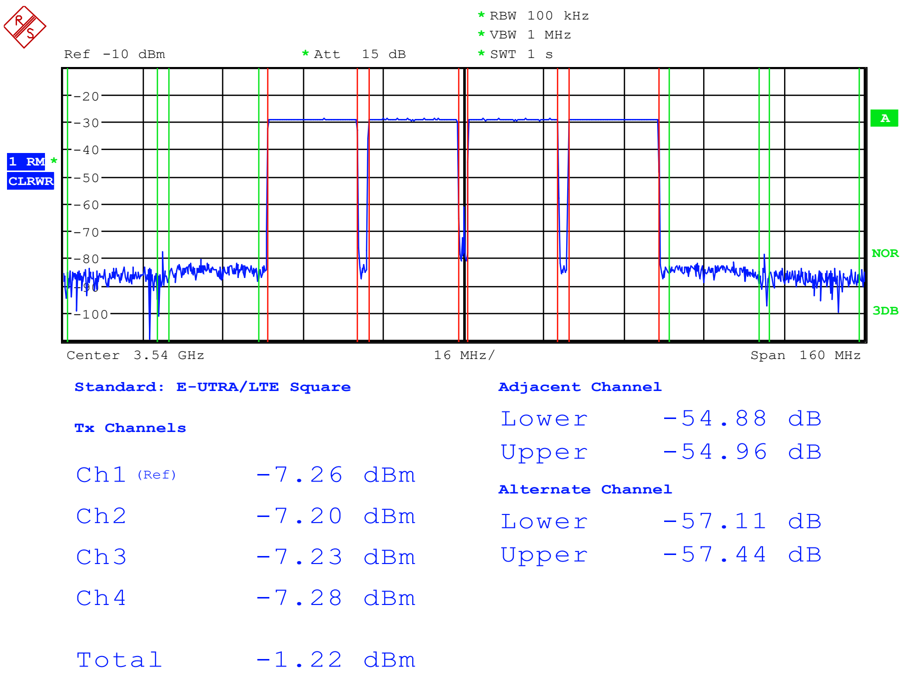
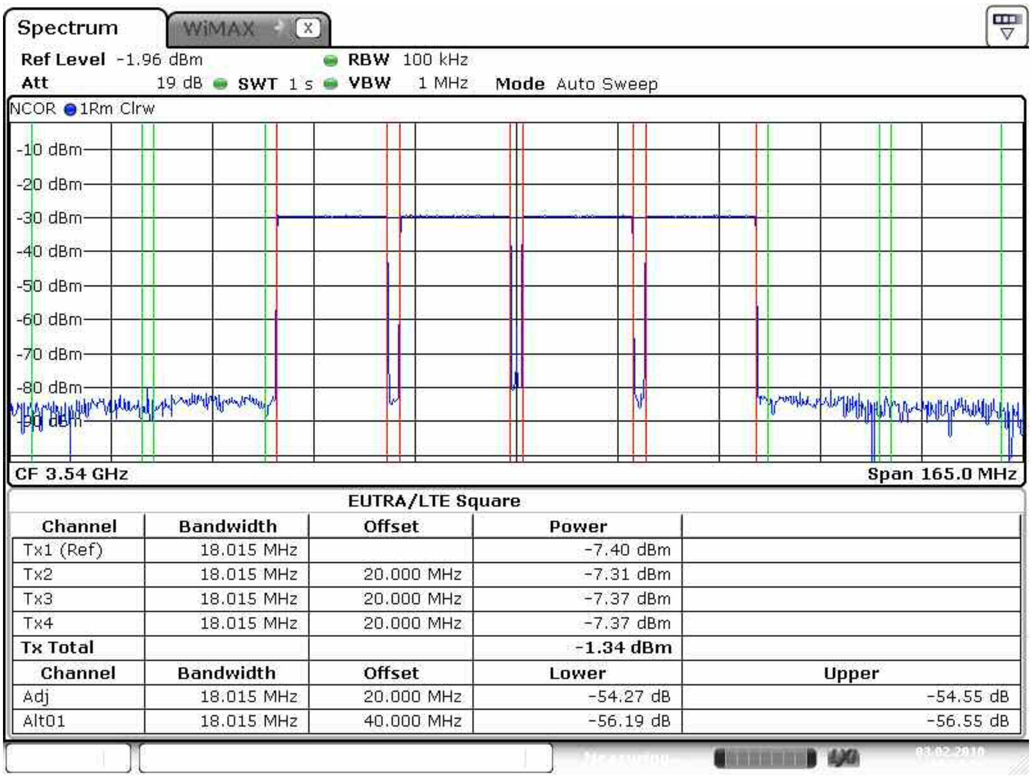


Figure 43: Multi-carrier ACLR measurement of FSx on an LTE-Advanced signal (4 component carriers each with 20 MHz bandwidth created in Multi-carrier Arbitrary Waveform mode with an SMU)

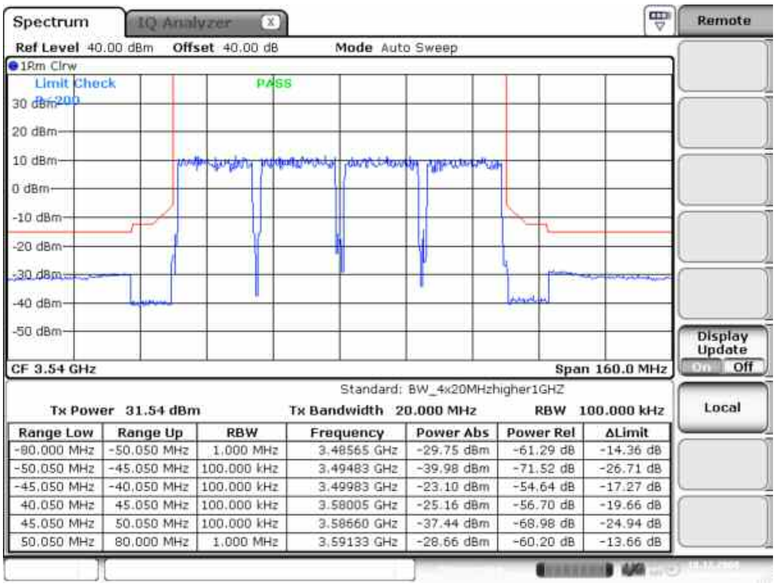


Channel	Bandwidth	Offset	Power	
Tx1 (Ref)	18.015 MHz		-7.40 dBm	
Tx2	18.015 MHz	20.000 MHz	-7.31 dBm	
Tx3	18.015 MHz	20.000 MHz	-7.37 dBm	
Tx4	18.015 MHz	20.000 MHz	-7.37 dBm	
Tx Total			**-1.34 dBm**	
Channel	**Bandwidth**	**Offset**	**Lower**	**Upper**
Adj	18.015 MHz	20.000 MHz	-54.27 dB	-54.55 dB
Alt01	18.015 MHz	40.000 MHz	-56.19 dB	-56.55 dB

Figure 44: Measurement like in Figure 43 but with an FSV

4.3 Test of Operating Band Unwanted Emissions (Spectrum Emission Mask)

The measurement of unwanted emissions in the operating band (spectrum emission mask) is also configurable for LTE-Advanced signals. Figure 45 shows the test of Operating Band Unwanted Emissions (Spectrum Emission Mask) on an LTE-Advanced signal containing 4 x 20 MHz component carriers with an FSV. The example emission mask (BW_4x20MHzhigher1GHZ.XML) included in this application note was generated by modifying the file BW_20_0_MHz_CFhigher1GHz.xml (Category B).
In order to use it copy the file to the directory C:\R_S\INSTR\sem_std\LTE\DL\CategoryB on the instrument and activate it by pressing the *Load Standard* softkey.



Range Low	Range Up	RBW	Frequency	Power Abs	Power Rel	ΔLimit
-80.000 MHz	-50.050 MHz	1.000 MHz	3.48565 GHz	-29.75 dBm	-61.29 dB	-14.36 dB
-50.050 MHz	-45.050 MHz	100.000 kHz	3.49483 GHz	-39.98 dBm	-71.52 dB	-26.71 dB
-45.050 MHz	-40.050 MHz	100.000 kHz	3.49983 GHz	-23.10 dBm	-54.64 dB	-17.27 dB
40.050 MHz	45.050 MHz	100.000 kHz	3.58005 GHz	-25.16 dBm	-56.70 dB	-19.66 dB
45.050 MHz	50.050 MHz	100.000 kHz	3.58660 GHz	-37.44 dBm	-68.98 dB	-24.94 dB
50.050 MHz	80.000 MHz	1.000 MHz	3.59133 GHz	-28.66 dBm	-60.20 dB	-13.66 dB

Figure 45: Spectrum emission mask measurement with an FSV on a contiguously placed LTE-Advanced signal (4 x 20 MHz component carriers) generated by an SMU

5 Literature

1. **3GPP TR 36.815 V0.3.0** (2009-10) 3rd Generation Partnership Project-Technical Specification Group Radio Access Network-Further Advancements for E-UTRA LTE-Advanced feasibility studies in RAN WG4 (Release 9)
2. **3GPP TR 36.913 V 8.0.1**, Technical Specification Group Radio Access Network; Requirements for further advancements for Evolved Universal Terrestrial Radio Access (E-UTRA) LTE-Advanced, Release 8;
3. Rohde & Schwarz: 1MA169 "LTE-Advanced Technology Introduction" Application Note
4. Rohde & Schwarz: Operating Manual: Vector Signal Generator R&S®SMU200A
5. Rohde & Schwarz: Operating Manual: Vector Signal Generator R&S®SMBV100A
6. Rohde & Schwarz: Operating Manual Baseband Signal Generator R&S®AMU200A
7. Rohde & Schwarz: Operating Manual: Vector Signal Analyzer R&S®FSQ
8. Rohde & Schwarz: Operating Manual: R&S®FSQ/FSV-K100/-K102/-K104 EUTRA/LTE DL PC Software
9. Rohde & Schwarz: Operating Manual: Vector Signal Analyzer R&S®FSV
10. Rohde & Schwarz: R&S FSQ/FSV-K101/-K105 EUTRA/LTE UL User Manual

6 Additional Information

This Application Note is subject to improvements and extensions. Please visit our website in order to download new versions. Please send any comments or suggestions about this Application Note to TM-Applications@rohde-schwarz.com.

7 Ordering Information

Ordering Information		
Vector Signal Generator		
SMU200A		**1141.2005.02**
SMU-B10	Baseband Generator	1141.7007.02
SMU-B13	Baseband Main Module	1141.8003.04
SMU-B14	Fading Simulator	1160.1800.02
SMU-B10**x**	1st RF path	
SMU-B20**x**	2nd RF path	
SMU-B17	Baseband Input	1142.2880.02
SMU-K55	Digital Standard LTE/EUTRA	1408.7310.02
SMBV100A		**1407.6004.02**
SMBV-B106	RF 9 kHz – 6 GHz	1407.9703.02
SMBV-B10	Baseband Generator with Digital Modulation (real-time) and ARB (32 Msample), 120 MHz RF BW	407.8907.02
SMBV-K18	Digital Baseband Connectivity	1415.8002.02
Baseband Signal Generator		
AMU200A		**1402.4090.02**
AMU-B10	Baseband Generator with ARB	1402.5300.02
AMU-B13	Baseband Main Module	1402.5500.02
AMU-B18	Digital IQ output	1402.6006.02
AMU-K252	Digital Standard EUTRA/LTE	1402.9457.02
Signal Analyzers		
FSQ	**Up to 3, 8, 26, 31 or 40 GHz**	**1155.5001.xx**
FSG	**Up to 8 or 13 GHz**	**1309.0002.xx**
FSV	**Up to 3, 7, 13, 30, 40 GHz**	**1307.9002.xx**
FS**x**-K100	EUTRA/LTE Downlink	1308.9006.02
FS**x**-K104	EUTRA/LTE Downlink, TDD	1309.9422.02

xx stands for the different frequency ranges (e.g. 1155.5001.26 up to 26 GHz)

Note: Available options are not listed in detail. Please contact your local Rohde & Schwarz sales office for further assistance.

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