Higher Order MIMO Testing with the R&S®SMW200A Vector Signal Generator

Application Note

Products:

- R&S®SMW200A
- R&S®SGS100A
- R&S®SGT100A

Due to its outstanding performance the R&S®SMW200A vector signal generator is ideal for testing MIMO receivers in a vast variety of applications offering maximum usability at minimum form factor. It can generate up to eight antenna signals simultaneously in its digital baseband – all standard-compliant and with antenna-specific coding. In addition, it can simulate the complete MIMO transmission channel with up to 32 fading channels, sufficient to emulate higher-order MIMO configurations such as 3x3, 4x4, and 8x4.

This application note explains how to use the SMW for testing higher order MIMO systems by presenting different key applications.

Application Note

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01.2016-1GP97_1E

ROHDE&SCHWARZ

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1 Introductory Note

The following abbreviations are used in this application note for Rohde & Schwarz products:

- The R&S®SMW200A vector signal generator is referred to as SMW
- The R&S®SGS100A SGMA RF source is referred to as SGS
- The R&S®SGT100A SGMA vector RF source is referred to as SGT
- Instrument options, e.g. R&S®SMW-K55 are referred to as SMW-K55

The abbreviation SGx denotes either a SGS or a SGT.

2 Overview

All modern wireless and mobile radio standards use the multiple input multiple output (MIMO) technology to increase data rates. For testing MIMO receivers with multiple receive antennas the SMW is the ideal test instrument. It can generate up to eight transmit antenna signals simultaneously in its digital baseband. The signals of all transmit antennas can be set up in one go from a single menu (coupled baseband sources) – all standard-compliant and with antenna-specific coding. In addition, the SMW is able to simulate the complete MIMO transmission channel and can thus generate realistic test signals for MIMO receivers. It supports up to 32 fading channels sufficient to emulate higher-order MIMO configurations such as 3x3, 4x4, and 8x4. The maximum fading bandwidth is 160 MHz. The SMW supports up to 8 fading channel at a fading bandwidth of 160 MHz, up to 16 fading channel at a fading bandwidth of 80 MHz and up to 32 fading channel at a fading bandwidth of 40 MHz[1]. The SMW comprises stimulus generation, MIMO channel emulation, and RF signal generation in a single box. Up to two RF outputs are available on the SMW; up to two additional RF outputs can be made available by connecting external instruments, such as the SGS signal generator. For ease of use the external instruments are controlled from the SMW such that the whole setup acts like a single unit.

[1] Please see the SMW data sheet [1] for details.

This application note presents some important MIMO applications which are supported by the SMW. At first, section 3 gives an overview of the various possible MIMO configurations. Section 4 explains how to connect external instruments to the SMW to increase the number of available RF outputs. Section 5 presents a general and detailed introduction on how to configure the SMW for MIMO testing based on the example of 2x2. The sections 6 to 10 present a specific MIMO application, respectively. The following table lists the different presented applications. This application note closes with a summary.

Supported MIMO applications presented in detail			
Application	**Section**	**MIMO configuration**	**Required instruments**
LTE Advanced carrier aggregation with 2x2 MIMO	6	2x 2x2	1 SMW, (2 SGx)[2]
Dual cell HSDPA with 2x2 MIMO	7	2x 2x2	1 SMW, (2 SGx)[2]
LTE multiuser MIMO	8	4x 1x2	1 SMW
WLAN 802.11ac with 3x3 MIMO	9	3x3	1 SMW, 1 SGx
LTE with 4x4 MIMO	10	4x4	1 SMW, 2 SGx

SGx denotes either a SGS or a SGT

Beyond these applications the following table lists some further example applications supported by the SMW (from firmware version 3.20.390.22 onwards).

Supported MIMO applications (not presented in detail)	
Application	**MIMO configuration**
LTE downlink with MIMO	8x4
LTE uplink with MIMO	4x8
Interference testing for LTE (wanted and interfering UE), each UE with MIMO	2x 2x4
Interference testing for WLAN (two devices/hotspots), each with MIMO	2x 2x4 2x 3x3 2x 4x2 2x 4x4
LTE carrier aggregation (2 component carriers) with MIMO for each carrier	2x 2x4 2x 4x2 2x 4x4
Dual cell LTE with MIMO for each cell	2x 2x4 2x 4x2 2x 4x4

[2] SGx is only needed if the component carrier spacing is so large that the component carriers do not fit into the internal ±80 MHz I/Q bandwidth of the digital baseband.

Please refer to reference [18] for details on these applications.

3 MIMO Configurations

The SMW is ideal for MIMO applications. It supports all important MIMO configurations such as 2x2, 3x3, 4x4, 8x2 and 8x4. Whenever more than two RF signals are required external instruments such as the SGS can be connected (see section 4 for details).

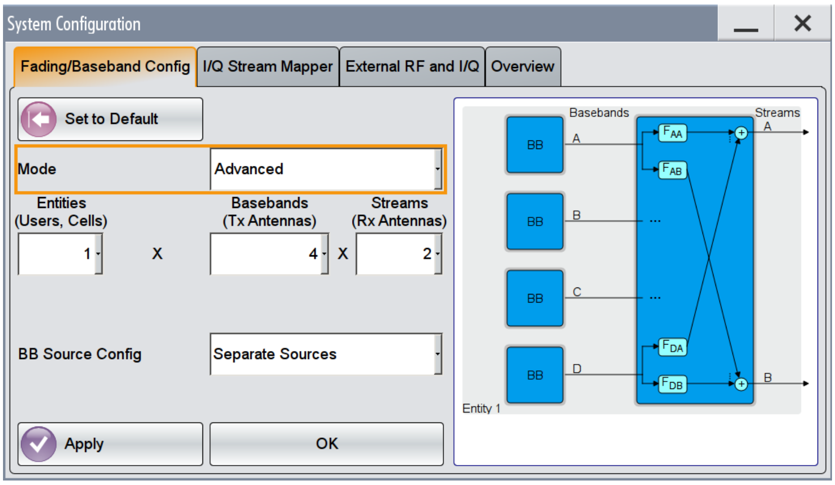
The SMW introduces the concept of “entities”. An entity can be e.g. a carrier, a cell or a user. The SMW can simulate MIMO fading for up to two entities in parallel which makes it possible to support also complex applications such as LTE Advanced carrier aggregation and dual cell HSDPA.

The following tables give an overview of the different MIMO configurations that can be implemented with the SMW. (See reference [1] and section 11 for required options).

Overview MIMO configurations		
One entity		
MIMO configuration	**Required instruments**	**Supported RF bandwidth**
1x2	1 SMW	160 MHz
1x3	1 SMW, 1 SGx	160 MHz
1x4	1 SMW, 2 SGx	160 MHz
1x8	1 SMW, 6 SGT	80 MHz
2x1	1 SMW	160 MHz
2x2 (See section 5)	1 SMW	160 MHz
2x3	1 SMW, 1 SGx	160 MHz
2x4	1 SMW, 2 SGx	160 MHz
2x8	1 SMW, 6 SGT	80 MHz
3x1	1 SMW	160 MHz
3x2	1 SMW	160 MHz
3x3 (See section 9)	1 SMW, 1 SGx	80 MHz
3x4	1 SMW, 2 SGx	80 MHz
4x1	1 SMW	160 MHz
4x2 (See section 8)	1 SMW	160 MHz
4x3	1 SMW, 1 SGx	80 MHz
4x4 (See section 10)	1 SMW, 2 SGx	80 MHz
4x8	1 SMW, 6 SGT	40 MHz
8x1	1 SMW	80 MHz
8x2	1 SMW	80 MHz
8x4	1 SMW, 2 SGx	40 MHz

Overview MIMO configurations		
Two entities		
MIMO configuration	**Required instruments**	**Supported RF bandwidth**
2x 1x2	1 SMW, (2 SGx)[3]	160 MHz
2x 1x3	1 SMW, 1 SGx, (3 SGT)[3]	80 MHz
2x 1x4	1 SMW, 2 SGx, (4 SGT)[3]	80 MHz
2x 2x1	1 SMW	160 MHz
2x 2x2 (See section 6)	1 SMW, (2 SGx)[3]	160 MHz
2x 2x3	1 SMW, 1 SGx, (3 SGT)[3]	80 MHz
2x 2x4	1 SMW, 2 SGx, (4 SGT)[3]	80 MHz
2x 3x1	1 SMW	80 MHz
2x 3x2	1 SMW, (2 SGx)[3]	80 MHz
2x 3x3	1 SMW, 1 SGx, (3 SGT)[3]	40 MHz
2x 3x4	1 SMW, 2 SGx, (4 SGT)[3]	40 MHz
2x 4x1	1 SMW	80 MHz
2x 4x2	1 SMW, (2 SGx)[3]	80 MHz
2x 4x3	1 SMW, 1 SGx, (3 SGT)[3]	40 MHz
2x 4x4	1 SMW, 2 SGx, (4 SGT)[3]	40 MHz

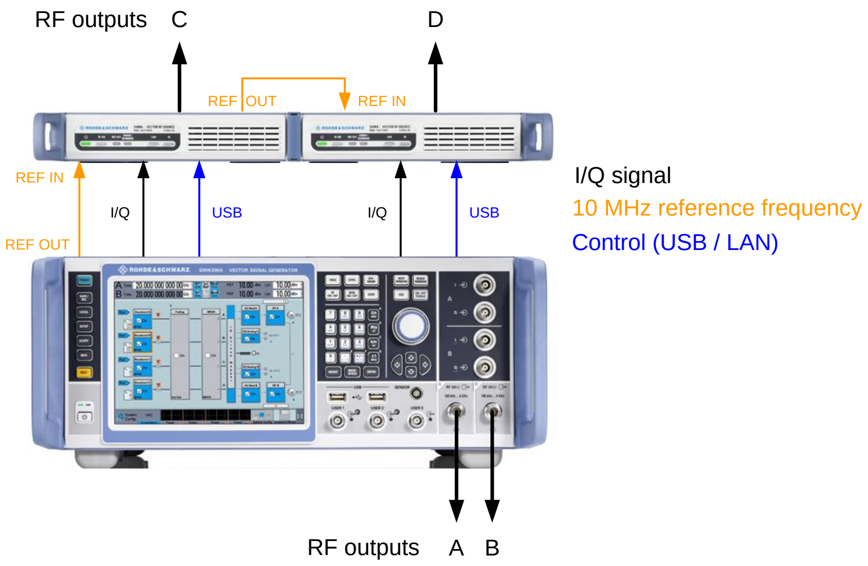
The different MIMO configurations can be set via the system configuration menu. The user has the choice to use the resulting internal signal routing with or without fading simulation (in both cases same options are required).



[3] It depends on the application if additional external RF outputs (SGS/SGT) are required.

4 External RF Outputs

The SMW offers up to two RF outputs. To increase the number of available RF outputs beyond two, external instruments such as the SGS or the SGT can be connected to the SMW. The SGx is ideal for this task as it is small, cost-efficient and offers outstanding signal quality. Although it is the perfect match for the SMW, other RF vector signal generators from Rohde & Schwarz can be used as well for upconverting the SMW's analog I/Q baseband signals to the RF. An example setup with two SGxs looks as follows:



Per SGx there are three connections needed:

- The I/Q output signals of the SMW are connected to the I/Q inputs of the SGx.
- The 10 MHz reference frequency of the SMW is connected to the SGx for frequency synchronization.
- A control line, either via USB or LAN, connects the SGx to the SMW for automatic remote control of the SGx

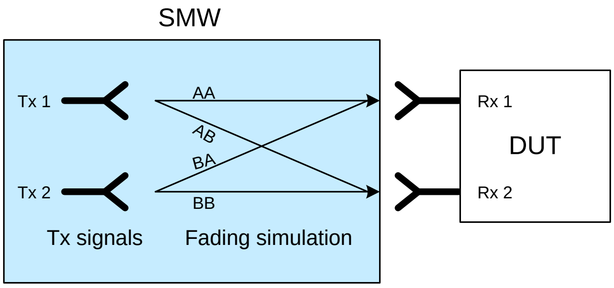
Use cables of the same type that are exactly equal in length to feed the analog I/Q signals to the SGS. This is important, since otherwise a delay between the I and the Q signal is introduced, which can degrade signal quality significantly. Also, use high quality adapters and do not accumulate adapters.
Use the R&S®SMU-Z6 digital cable (accessory) to feed the digital I/Q signal to the SGT.

The external SGx can be controlled directly from the SMW. This is a great benefit for the user since the whole setup consisting of one SMW and up to two SGSs or up to six SGTs behaves like a single unit. The settings for the SGxs are made on the SMW. They are automatically transferred to the connected SGx via the control line.

Please see reference [17] for how to connect and control the SGx. The procedure is straightforward and the handling of the external instruments is fast and easy.

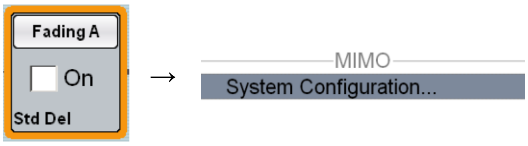
5 General 2x2 MIMO

A 2x2 MIMO test setup consists of two transmit signals and two receive antennas at the DUT. This MIMO configuration involves four fading channels (AA, AB, BA, and BB).

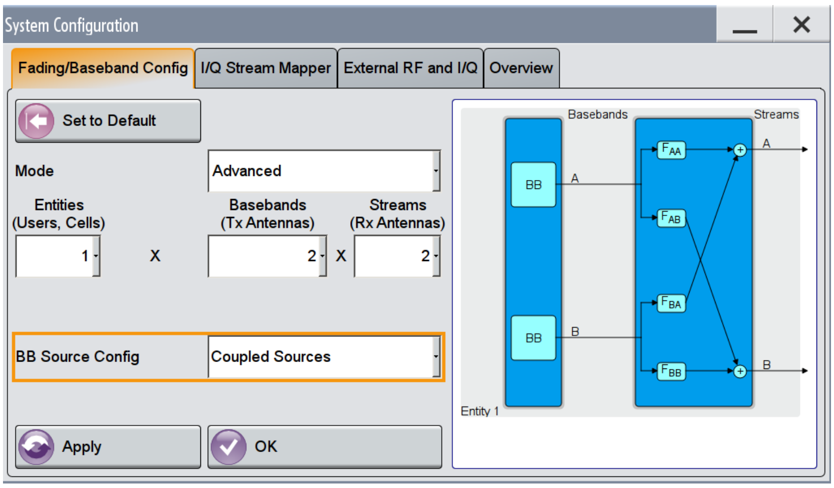


5.1 SMW System Configuration

To open the system configuration menu, press the “Fading A” button and select “System Configuration” from the list.

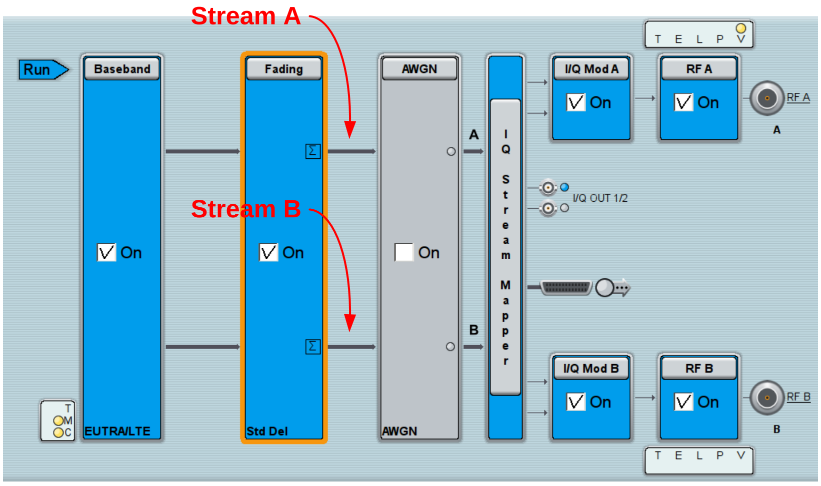


In the “Fading/Baseband Config” tab make the following settings:



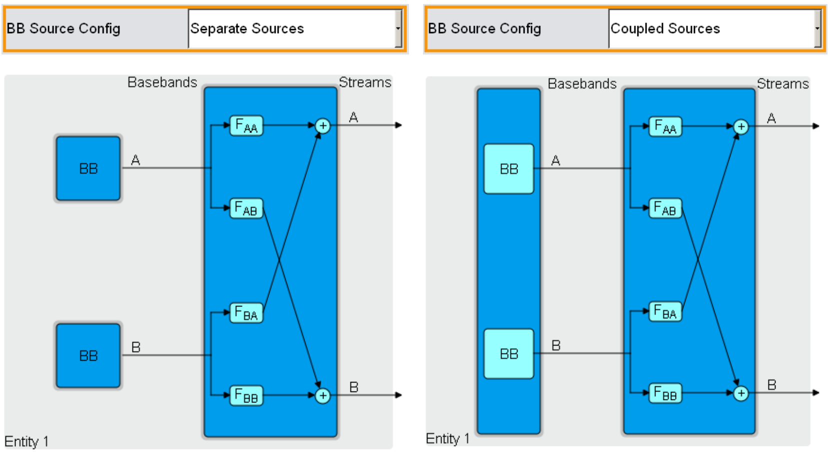
Press the “Apply” button to actually apply the settings. The resulting signal routing is shown in the block diagram.

Baseband A generates the first, baseband B the second transmit (Tx) signal. The internal real-time fading simulators simulate the four fading channels. The resulting streams A and B correspond to the signals at the following points in the block diagram:



5.1.1 Baseband Source Configuration

The SMW offers two modes for the configuration of the baseband section. The user can chose between separate and coupled baseband sources:



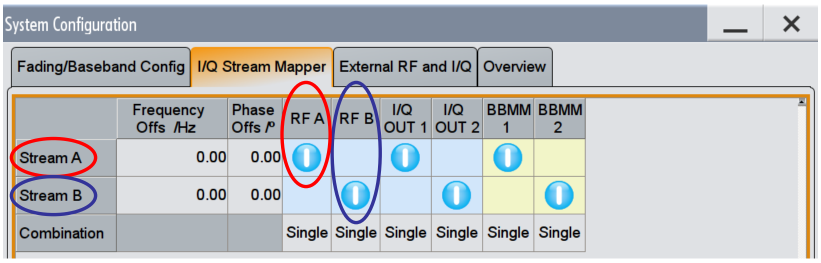
Especially for MIMO scenarios, coupled sources make the configuration quick and easy. The user just needs to configure the wanted settings once. The configuration of the second baseband is eliminated.

The SMW offers the baseband coupling feature for the MIMO supporting digital standards LTE and WLAN.

5.1.2 Stream Mapping

The following menu is used to map the I/Q streams of the digital baseband section to the various outputs (RF, analog, digital) of the SMW.

To route the streams A and B to the RF outputs A and B respectively, make the following settings in the “I/Q Stream Mapper” tab:



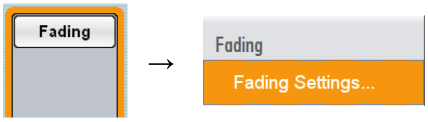
5.2 Fading Simulation Settings

Terminology:

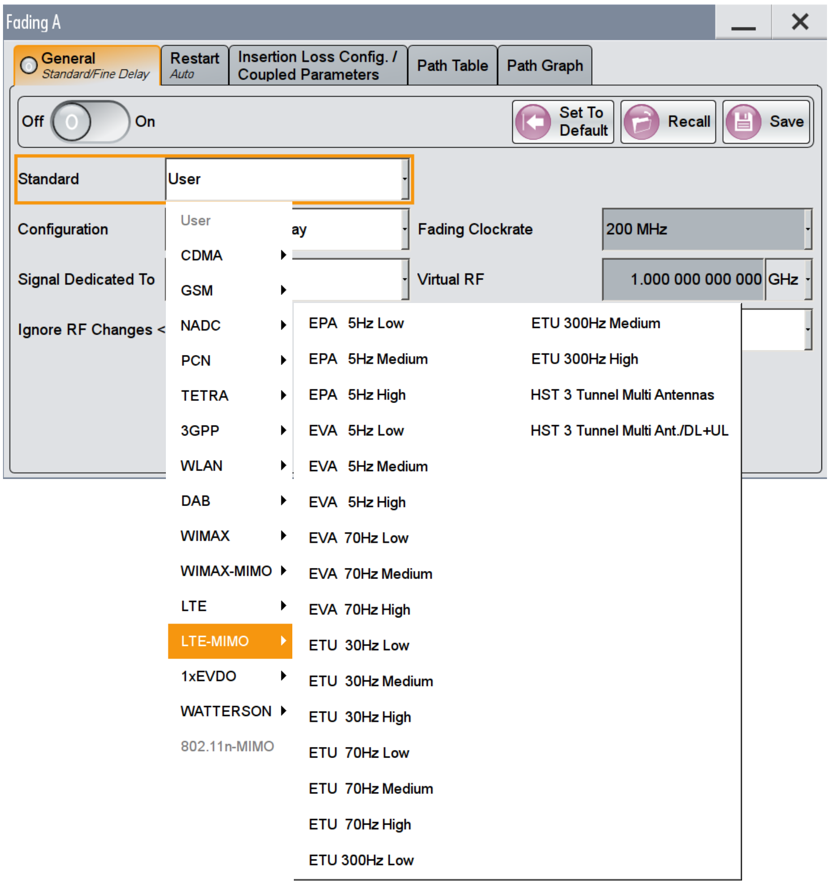
- Fading channel:
  2x2 MIMO has four fading channels (AA, AB, BA, BB) between the transmit and receive antennas.

- Fading path:
  Each fading channel can consist of several fading paths (i.e. fading taps). The number of fading paths within one fading channel can be configured.

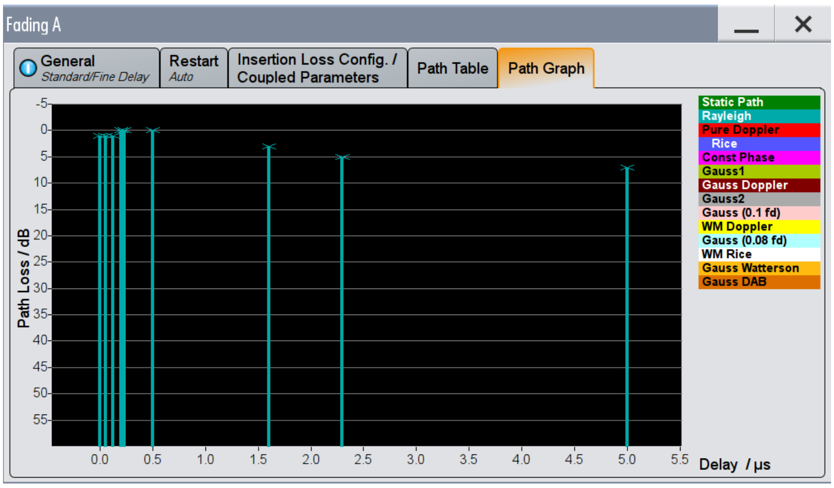
To open the fading menu, press the “Fading” button and select “Fading Settings” from the list.



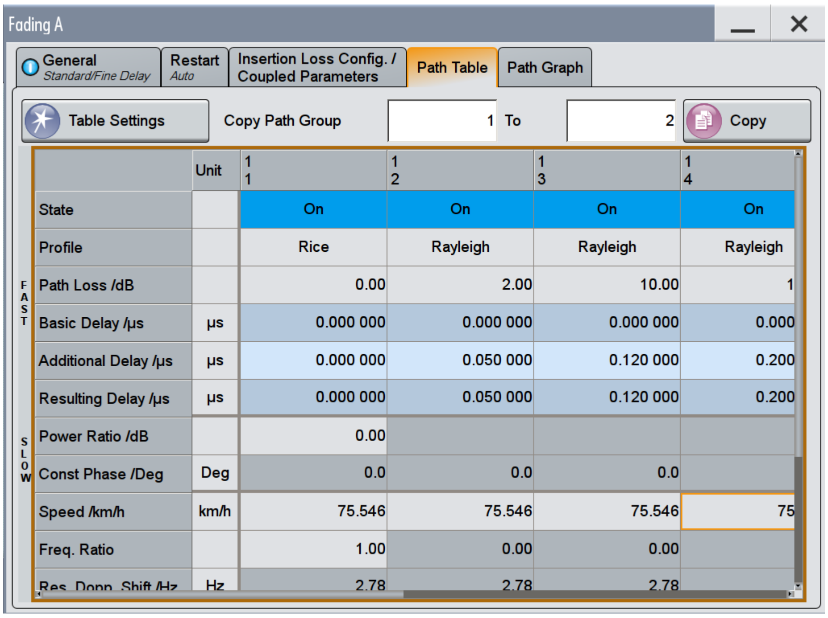
In the “General” tab the user can chose various predefined settings that are in accordance with test scenarios stipulated in modern mobile radio standards. For example, fading scenarios for LTE are supported, including the specified correlation (high, medium, low) between the fading channels. All fading settings are automatically configured in accordance with the selected fading scenario.



The selected fading scenario is shown graphically as power delay profile in the “Path Graph” tab.

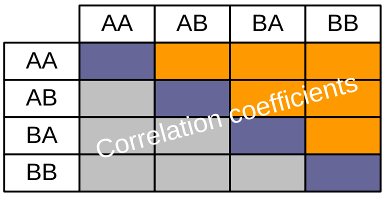


Instead of selecting a predefined fading scenario, the user can also configure a custom scenario. In the “Path Table” tab, the user can specify the number of active fading paths, their delay and attenuation, the fading profile to be used (e.g. Rayleigh), as well as all path related settings.



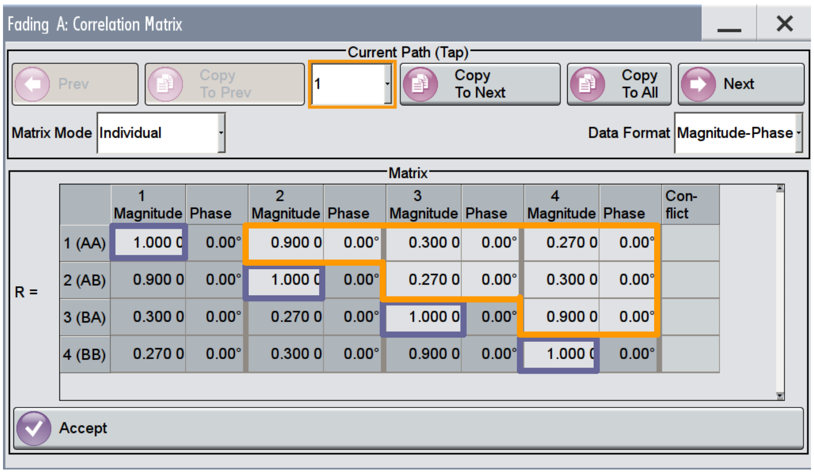
5.2.1 MIMO Correlation Matrix

To test MIMO receivers under real-world conditions, a certain degree of correlation between the fading channels has to be simulated. The correlation is quantified in terms of a matrix. For 2x2 MIMO this correlation matrix is a 4x4 matrix representing the correlation of the four fading channels (AA, AB, BA, BB).



The correlation between two fading channels is defined by a correlation coefficient that is a measure for the similarity of the two signals. The correlation coefficient is a complex quantity expressed as a pair of numbers in either Cartesian form (real-imaginary) or polar form (magnitude-phase). The polar form is more descriptive, since it directly gives the magnitude and phase relationship of the two signals.

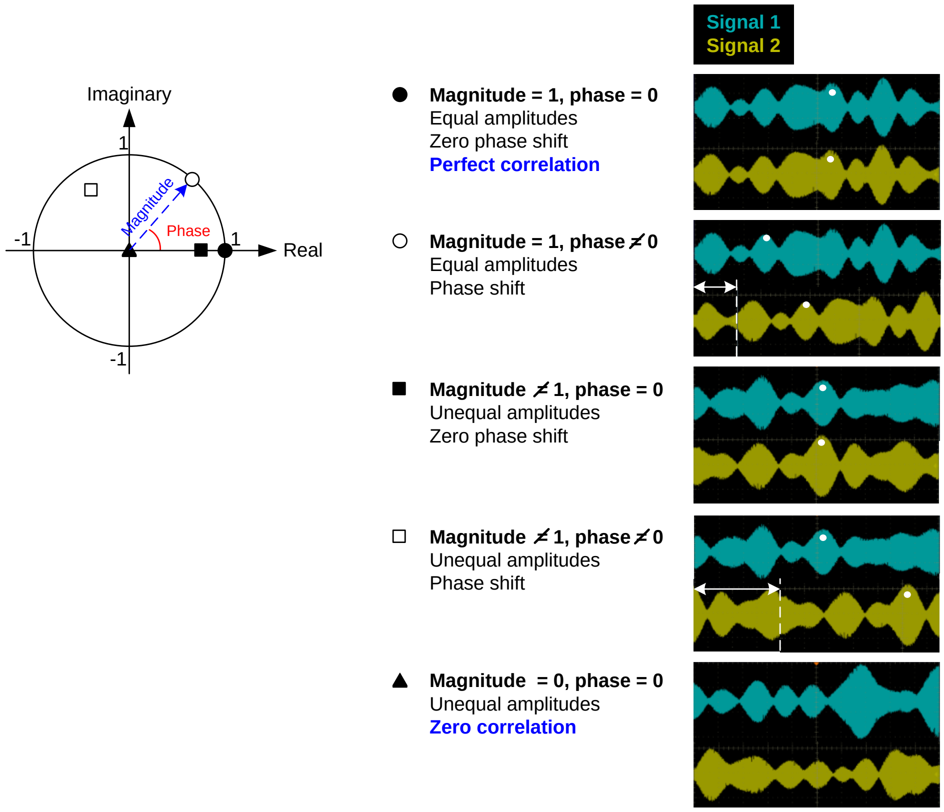
In the path table, press on “Matrix” to open the correlation matrix menu. Note that a correlation matrix applies to the selected fading path only. Each path has its own correlation matrix that can be defined individually. The matrix of one fading path can also be copied to other fading paths.



Perfect correlation is achieved when magnitude = 1 and phase = 0, whereas magnitude = 0.00 (and phase = 0)[4] gives absolutely no correlation. To simulate ideal conditions for MIMO, i.e. no correlation between the fading channels, set all correlation coefficients to zero (default setting) except for the diagonal matrix elements. They represent the correlation of one fading channel with itself and are therefore usually set to magnitude = 1 (see reference [16] for more information on the diagonal elements and their special use). To create real-world conditions, set the off-diagonal elements to nonzero values to simulate a certain degree of correlation between the fading channels.

The following figure illustrates graphically the effect of nonzero magnitude and phase values. Five example correlation coefficients and the corresponding correlations between two test signals are shown. In simple terms, the more the values differ from magnitude = 0, the higher the correlation is and hence the less efficient the MIMO system is.

[4] If magnitude = 0, it is common practice to define phase = 0, although the phase is not a definite value in this case. It could be any arbitrary real value.



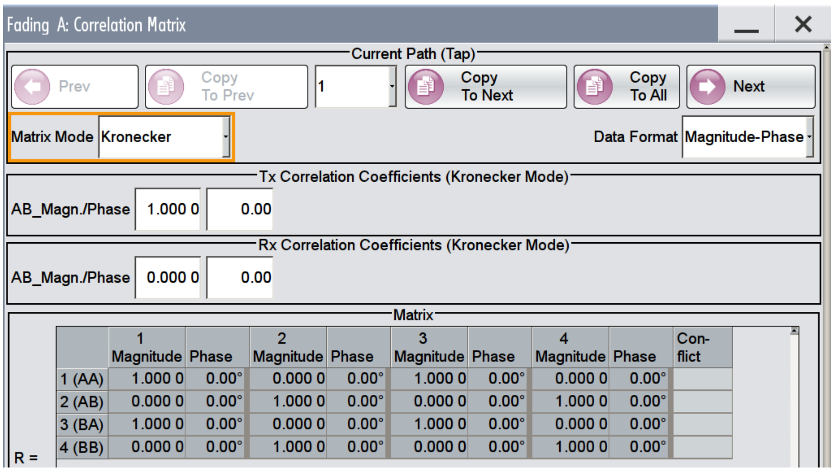
The user can choose between three ways to configure the correlation matrix: “Individual” mode, “Kronecker” mode, and “AoA / AoD” mode (angle of arrival / angle of departure).

- Individual mode:

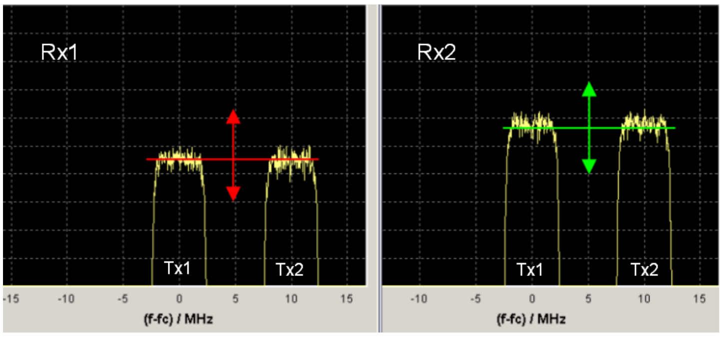
In this mode, the user can set the correlation coefficients directly. Only the matrix elements marked in orange in above screenshot need to be set, as they already fully describe the correlations among the four fading channels. The remaining off-diagonal matrix elements are determined automatically by exploiting the complex conjugate symmetry across the diagonal. For example, matrix element [BB,AB] describes the correlation between channels AB and BB. This correlation is also described by matrix element [AB,BB]. Thus, the values entered into matrix element [BB,AB] define the values of matrix element [AB,BB] and vice versa.

- Kronecker mode:

This mode is based on the Kronecker assumption of separable transmit and receive correlations, i.e. the correlation between the Rx antennas is assumed to be independent from the correlation between the Tx antennas. The Kronecker mode simplifies the configuration of the matrix. The user can specify transmitter (Tx) and receiver (Rx) correlation coefficients. Based on these all matrix elements are automatically calculated and displayed. The Tx correlation coefficient correlates path AA with BA and path AB with BB, i.e. the two transmitter signals Tx1 and Tx2 are faded in a correlated way. Accordingly, the Rx correlation coefficient correlates path AA with AB and path BA with BB, i.e. the two receiver signals Rx1 and Rx2 are faded in a correlated way.

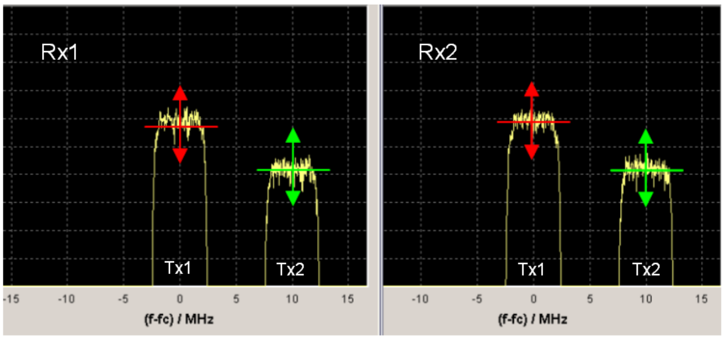


For example, a Tx correlation coefficient of 1 (magnitude) means perfect correlation of the two transmitter signals. This case is shown in the following figure. The left side of the figure shows the signal at the first receive antenna (Rx1), while the right side of the figure shows the signal at the second receive antenna (Rx2). The shown spectra are snapshots of the Rx signals, both measured at the same point in time. In order to distinguish the two transmit signals Tx1 and Tx2 in the spectrum, a frequency offset of 10 MHz has been applied to Tx2.[5] The figure shows that the two transmit signals are faded in a perfectly correlated way, while the two receive signals differ (because the Rx correlation coefficient is set to 0).



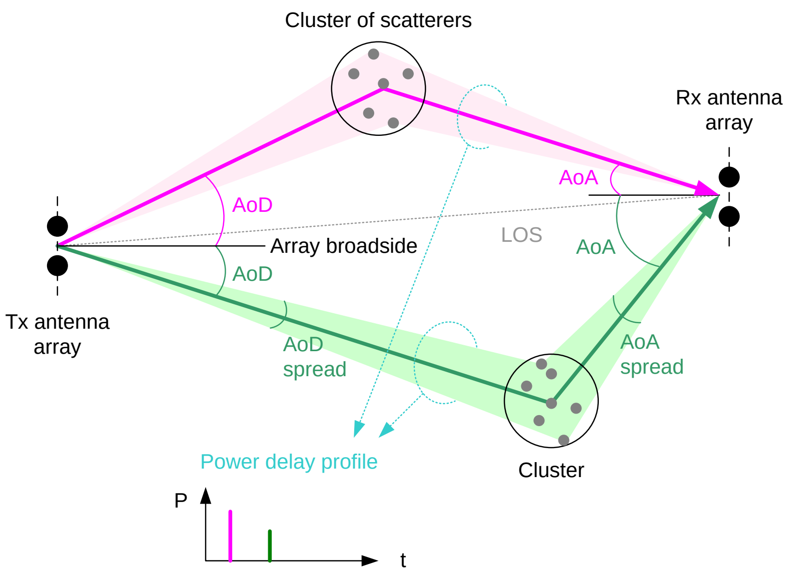
For example, to simulate perfect Rx signal correlation and no Tx signal correlation, set the Rx correlation coefficient to 1 (magnitude) and the Tx correlation coefficient to 0 (magnitude). This case is shown in the following figure. Now, Tx1 and Tx2 are faded independently, while the Rx signals are perfectly correlated.

[5] In MIMO applications the two Tx signals are always transmitted at the same center frequency. The frequency offset is merely applied for demonstration purposes.

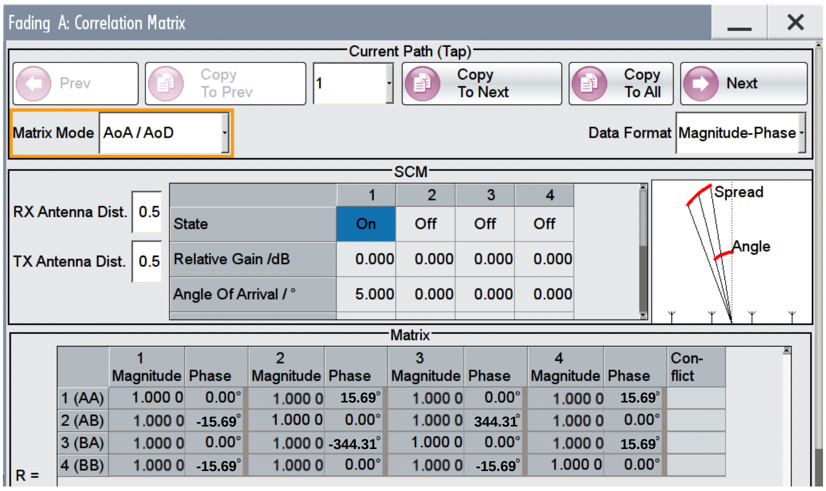


- AoA /AoD mode:

This mode is based on the spatial channel model (SCM). In contrast to analytical channel models like the Kronecker model which derive the MIMO matrix without any consideration of propagation parameters, the SCM is a stochastic physical model which uses physical propagation parameters (e.g. AoD, AoA, number of propagation paths, path delay, path power) and their statistical behavior to derive the MIMO matrix [14]. Also in the SCM, the number of propagation paths, path delay, and path power can be reproduced by a power delay profile. Each propagation path is characterized by a AoD, AoA and respective angular spread. These parameters remain fixed for the respective path, i.e. are not time-variant. The number and configuration of the antennas at the transmitter and the receiver is also considered in the model. See reference [3] for details on SCM.

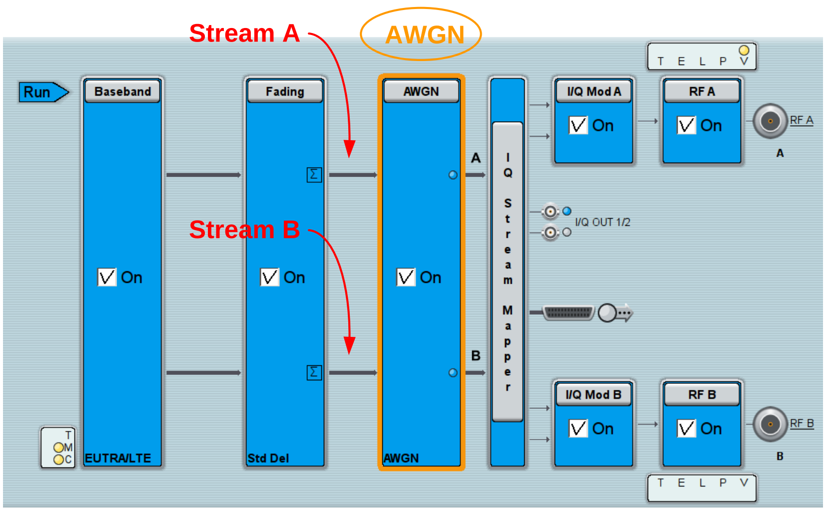


In the SMW, the user can specify the AoD, AoA and the corresponding angular spreads for each fading path of the power delay profile. The angular spectrum can be set to follow a uniform, Gaussian, or Laplacian distribution. It is sufficient to configure one “ray” per fading path (although the GUI allows configuring up to four “rays” per fading path). In addition, the antenna distance at transmitter and receiver side can be set. Based on these setting the MIMO correlation matrix is calculated, i.e. all matrix elements are automatically calculated and displayed.

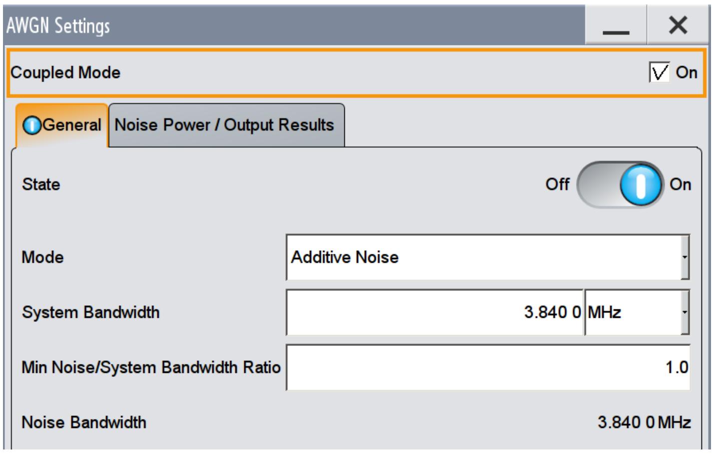


5.3 AWGN

The SMW can superimpose noise on the baseband I/Q streams. An additive white Gaussian noise (AWGN) signal with selectable system bandwidth can be added to the streams after fading simulation. For example, the AWGN signal can be used for simulating a certain signal-to-noise ratio at the receiver to test the receiver sensitivity.



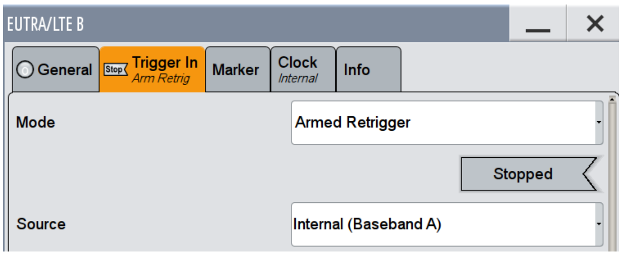
It is possible to specify the AWGN independently for each stream. If the “Coupled Mode” parameter is enabled, the same AWGN settings are used for each stream. In any case, the AWGN is statistically independent for each stream.



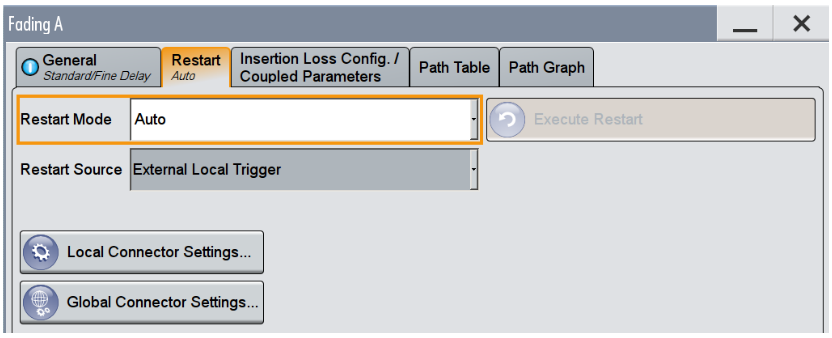
5.4 Synchronization

For MIMO it is essential that baseband A and B start simultaneously. This is assured in the SMW for the 2x2 system configuration as well as for any other MIMO system configuration ("Advanced" mode). Either an internal or an external trigger signal can be used to start the basebands.

When using coupled baseband sources synchronization is assured automatically. When using separate baseband sources the trigger settings of baseband B are automatically adjusted to achieve synchronization: baseband B is triggered by baseband A.

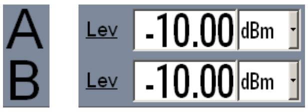


The fading simulators run by default in "Auto" mode. If this mode is used, a (re)start of the basebands cause an automatic (re)start of the fading statistics. At a restart, the simulated fading processes start from the beginning with the same statistics as previously, thus reproducing the exact same fading conditions for testing under repeatable conditions.



5.5 Leveling

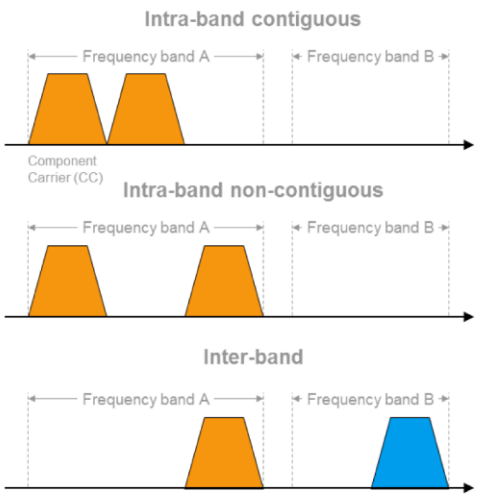
Since Tx signal generation, fading simulation, and signal upconversion is completely done within a single instrument, leveling of the RF output power is straightforward. Simply, set the level of RF output A and B to the wanted value.



Note that, if fading simulation is applied, the instantaneous power of the RF output signal fluctuates in time. The set RF level denotes the average power of the faded signal without AWGN. If AWGN is applied, the noise level adds to the set RF level. This means, the actual RF output power is the sum of the set RF level and the specified noise level.

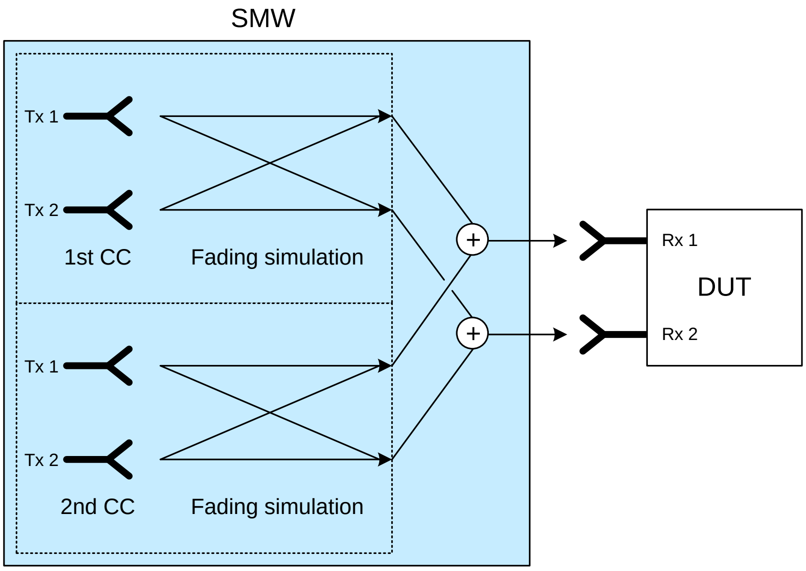
6 LTE Advanced Carrier Aggregation with 2x2 MIMO

In LTE Advanced (LTE-A), multiple carriers can be aggregated to increase transmission bandwidth and thus peak data rates. Although up to five component carriers (CC) can be aggregated, initial LTE Advanced (3GPP Release 10) deployments will use a maximum of two component carriers. In the frequency domain, the carriers can be placed in the same frequency band (intra-band) as well as in different frequency bands (inter-band). For intra-band carrier aggregation, contiguous and non-contiguous placement is possible.



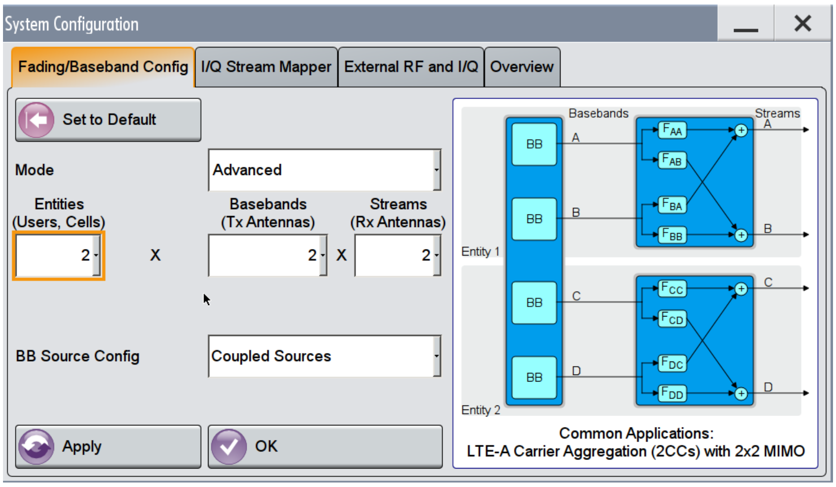
Please see reference [4] for comprehensive information on LTE-A.

LTE-A carrier aggregation with two CCs and 2x2 MIMO involves two transmit antenna signals, each consisting of two CCs. Each CC shall be faded independently.
In the SMW, each CC is generated by an individual baseband source to achieve independent fading for each CC. This means, the four fading channels of 2x2 MIMO double: in total, eight independent fading channels need to be simulated – a challenge, but feasible with a single SMW.



6.1 SMW System Configuration

Open the system configuration menu. In the “Fading/Baseband Config” tab make the following settings:



Press the “Apply” button to actually apply the settings. The resulting signal routing is shown in the block diagram.

Entity 1 generates the first, entity 2 the second component carrier. Each CC is subject to real-time 2x2 MIMO fading.

6.1.1 Stream Mapping

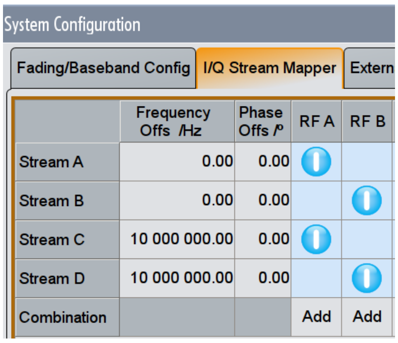
The resulting streams A and B correspond to the first CC. Streams C and D correspond to the second CC. To form the wanted LTE-A signal the component carriers need to be combined. The two CCs can be combined in two ways:

- Internal addition for intra-band carrier aggregation:
  The SMW adds the streams internally. Outputs RF A and RF B are used to feed the signals to the two receive antennas of the DUT.
  This method can be applied, if the two CCs fit into the ±80 MHz I/Q signal bandwidth of the digital baseband section.

- External addition for inter-band carrier aggregation:
  The streams are separately upconverted to the RF. This is achieved with two additional external RF outputs (e.g. from two SGxs). The RF signals are then added with external RF combiners. The combined signals are fed to the two receive antennas of the DUT.

Internal Addition in the Baseband

To add streams A and C, map both streams to RF output A. To add streams B and D, map both streams to RF output B. Make the following settings in the "I/Q Stream Mapper" tab:



System Configuration

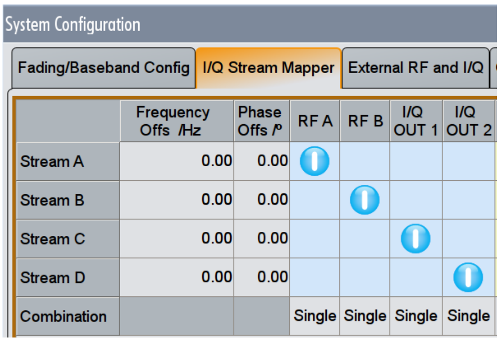
Fading/Baseband Config | I/Q Stream Mapper | Extern

	Frequency Offs /Hz	Phase Offs /°	RF A	RF B
Stream A	0.00	0.00	●	
Stream B	0.00	0.00		●
Stream C	10 000 000.00	0.00	●	
Stream D	10 000 000.00	0.00		●
Combination			Add	Add

Apply a frequency offset for streams C and D. This frequency offset has to be identical for streams C and D and determines the spacing of the two component carriers.
To achieve a large CC spacing, use in addition a negative frequency offset for streams A and B.

External Addition in the RF

To upconvert streams A, B, C, and D separately to the RF, map streams A and B to the RF outputs A and B and streams C and D to the analog I/Q outputs 1 and 2. Make the following settings in the "I/Q Stream Mapper" tab:

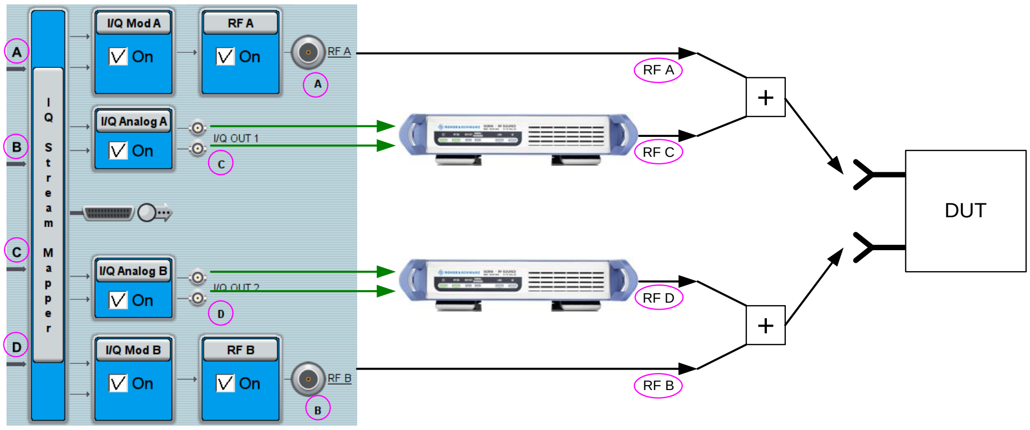


	Frequency Offs /Hz	Phase Offs /°	RF A	RF B	I/Q OUT 1	I/Q OUT 2
Stream A	0.00	0.00				
Stream B	0.00	0.00				
Stream C	0.00	0.00				
Stream D	0.00	0.00				
Combination			Single	Single	Single	Single

6.1.2 External RF Outputs

Note that this section applies only for external signal addition. Skip this section if you use internal signal addition.

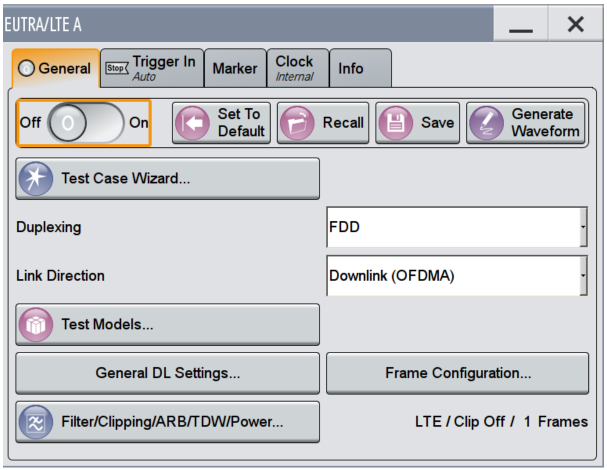
Two SGxs are used as I/Q upconverters to increase the number of available RF outputs from two to four. Connect the I/Q output signals of the SMW to the two SGxs. Add RF signals A and C by means of an external RF combiner. Add RF signals B and D by means of a second external RF combiner.



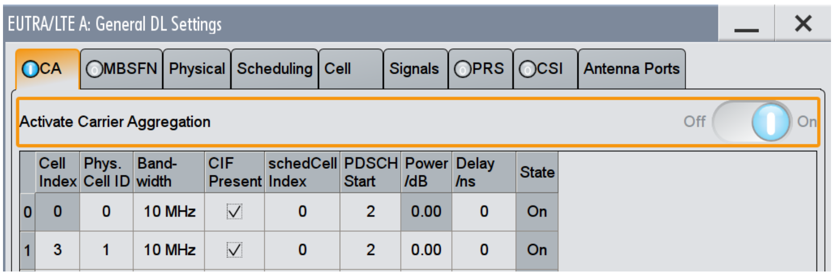
The SGxs are controlled directly from the SMW. The settings for the SGx are made in the “External RF and I/Q” tab and are automatically transferred to the connected SGx via the control line. See section 4 for details. Set the RF frequency of the SGx such that there is a frequency offset for signals RF C and D with respect to signals RF A and B. This frequency offset has to be identical for both SGxs and determines the spacing of the two component carriers.

6.2 LTE Advanced Signal Configuration

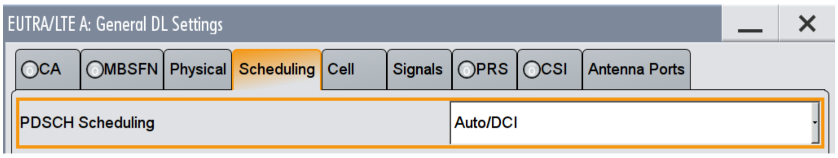
Since coupled baseband sources are used for this application, the basebands are configured all at once from a common menu.



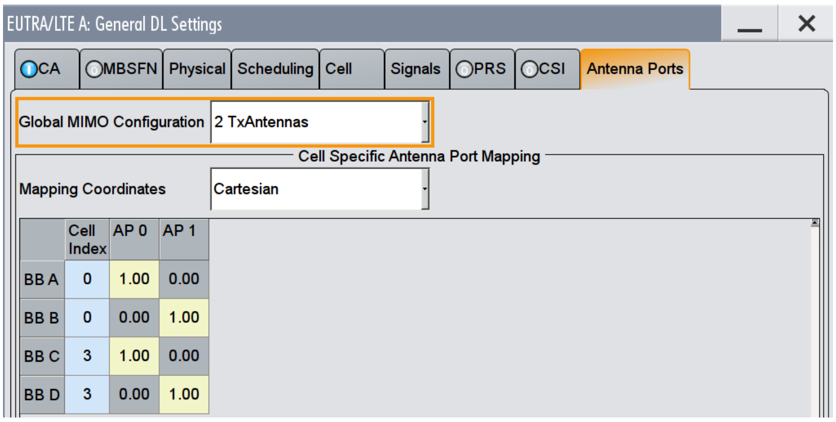
Touch the “General DL Settings” button. In the “CA” tab of the “General DL Settings” menu, carrier aggregation is already activated per default with two CCs. In this example, the first CC has the “Cell Index” 0 and the second CC has the “Cell Index” 3 (selected arbitrarily). To achieve cross-carrier scheduling, the “schedCell Index” parameter is set to “0” for both CCs, i.e. both CCs are scheduled by the CC that has “Cell Index” 0.



Change to the “Scheduling” tab and set the “PDSCH Scheduling” parameter to “Auto/DCI”. In this mode, the PDSCH allocations are configured automatically and standard-conform according to the selected PDCCH DCIs (see further down).

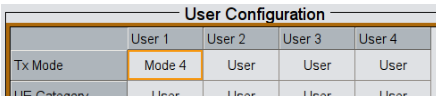


Change to the “Antenna Ports” tab. The “Global MIMO Configuration” parameter is preset to “2 TxAntennas” corresponding to 2x2 spatial multiplexing. The table illustrates the applied mapping of the four basebands (BB A to BB D) to the antenna ports (AP 0 and AP 1).

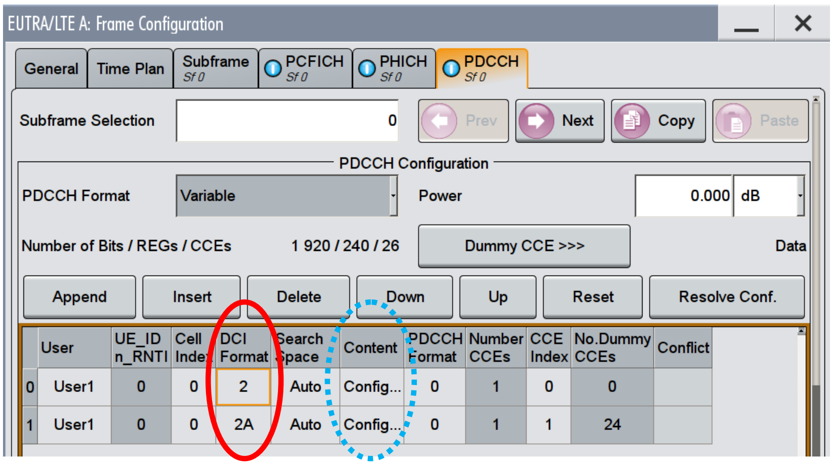


Basebands A and B generate the first CC (with "Cell Index" 0). Basebands C and D generate the second CC (with "Cell Index" 3).
Basebands A and C are mapped to antenna port 0, basebands B and D to antenna port 1, i.e. baseband A and C generate the first antenna signal, baseband B the second antenna signal. Each antenna signal includes automatically the appropriate downlink reference signal as well as all other antenna-specific properties.

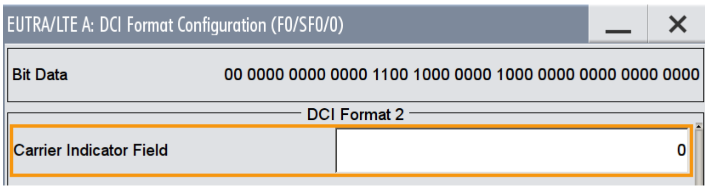
In the LTE main menu, touch the "Frame Configuration" button. In the "General" tab of the "Frame Configuration" menu, the user can set the number of subframes that he wants to configure via the "No of Configurable Subframes" parameter. If wanted, the user can select a specific transmission mode for the "User 1" to "User 4". This step can principally be omitted, but it may help users who want to have certainty that their made settings are according to a specific transmission mode.



Change to the "PDCCH" tab and add a second row to the DCI table by touching the "Append" button. In this example, the "Cell Index" parameter is set to "0" in both rows, because this is the cell index of the scheduling CC (see "CA" tab of the "General DL Settings" menu). In both rows, set the "DCI Format" to "2" or "2A" for the selected "User" (e.g. "User1"). DCI formats 2 and 2A are used for closed loop and open loop spatial multiplexing, respectively.



In the first row, touch “Config…” to open the “DCI Format Configuration” menu. Set the “Carrier Indicator Field” to “0”, because this is the cell index of the first CC. All settings made in the “DCI Format Configuration” menu correspond now to this CC. Optionally, configure the content by editing e.g. the “Resource Block Assignment”, “Modulation and Coding Scheme”, and “Precoding Information” parameters as wanted.



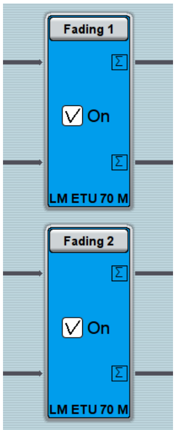
Go back to the “PDCCH” tab and touch “Config…” in the second row of the DCI table. In the “DCI Format Configuration” menu, set the “Carrier Indicator Field” to “3”, because this is the cell index of the second CC in this example. All settings made in the menu correspond to the second CC. Optionally, configure the content for this CC.

The PDCCH Configuration applies to the selected subframe only (“Subframe Selection” parameter). Therefore, configure the DCI format and the content for every configurable subframe.

Please see reference [15] or the SMW online help for comprehensive information on the LTE setting parameters mentioned in this section.

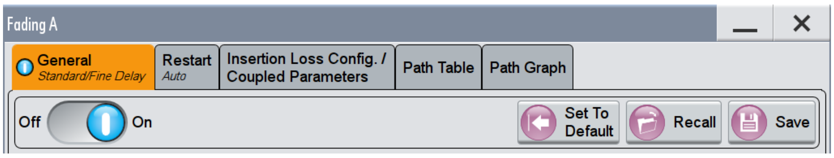
6.3 Fading Simulation Settings

Since two independent fading entities are used for this application, both fading entities need to be configured individually. This is however straightforward when using a predefined fading scenario.



In the “General” tab of the fading menu the user can chose from various predefined MIMO settings for LTE. The standard-compliant fading scenarios include also the specified correlation (high, medium, low) between the fading channels. All fading settings are automatically configured in accordance with the selected MIMO scenario. Set the same fading scenario in both fading entities.

Besides selecting a predefined fading scenario, the user can also configure a custom scenario if needed (see section 5.2 for details). To set the same fading scenario in both fading entities, save the settings of the first entity and recall them in the second entity.



Note that although the same fading scenario is used in both fading entities, the fading process is statistically independent for each entity.

6.4 Synchronization

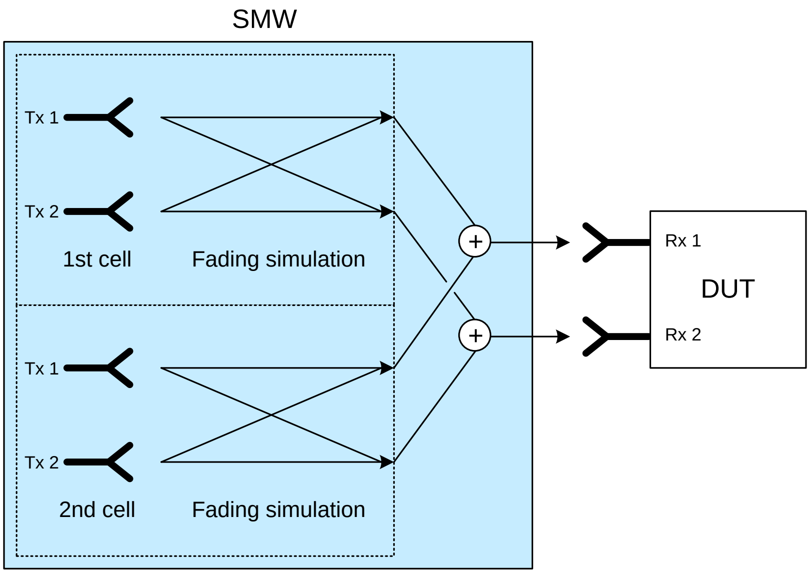
The coupling of the baseband sources guarantees their synchronization.

The fading simulators can be run in “Auto” mode. In this mode, a (re)start of the baseband cause an automatic (re)start of the fading statistics. The two fading simulators are thus indirectly synchronized via the baseband. Turn on fading simulation before turning on the baseband.

7 Dual Cell HSDPA with 2x2 MIMO

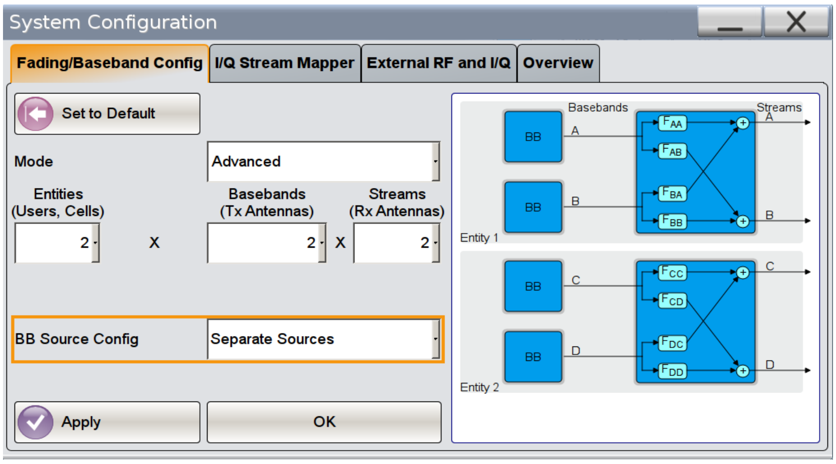
Dual Cell (DC) HSDPA is an evolution of HSPA defined to increase transmission bandwidth and thus peak data rates by means of carrier aggregation in the downlink. DC-HSPA is defined in the 3GPP specification Release 8. From Release 9 onwards it is possible to combine DC-HSPA with MIMO. Release 9 also introduces dual band operation for DC-HSPA, i.e. the two carriers need no longer to be adjacent in the frequency domain but can be in two different frequency bands. Please see reference [5] for comprehensive information on HSPA.

Dual Cell HSDPA involves two different cells. Each cell shall use 2x2 MIMO transmissions. This gives four signals that shall be faded independently.
In the SMW, each of the four signals is generated by an individual baseband source. Since MIMO is used on both cells, eight independent fading channels need to be simulated, which can be done with a single SMW.



7.1 SMW System Configuration

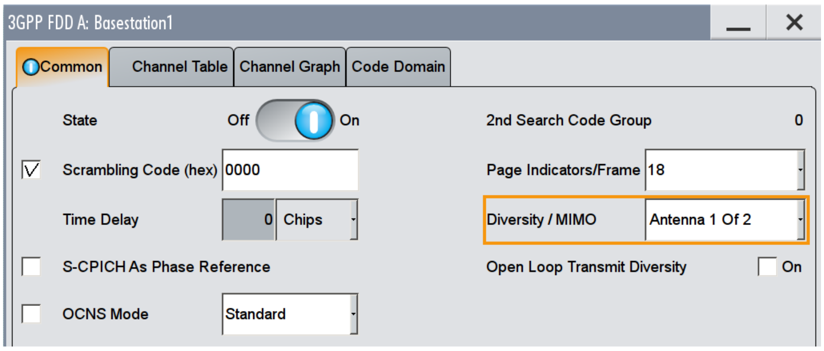
The system configuration is basically identical to the application described in section 6. Please refer to this section for details. The only exception is that for dual cell HSDPA separate baseband sources are used.



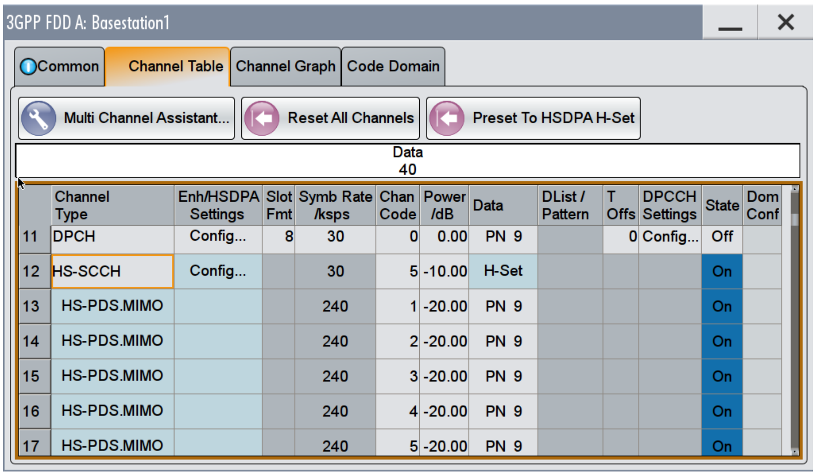
7.2 HSDPA Signal Configuration

Since separate baseband sources are used for this application, each baseband needs to be configured individually.

Start with configuring the first cell, i.e. basebands A and B. Set up baseband A to generate the transmit signal of the first antenna: set the “Diversity/MIMO” parameter to “Antenna 1 Of 2” in the “Common” tab of the selected base station, e.g. BS1. Disable the parameter “Open Loop Transmit Diversity”.



To set up channels with channel coding and MIMO pre-coding proceed as follows. In the “Channel Table” tab, select the “Channel Type” “HS-SCCH” and touch “Config…” to open the “Enhanced HSDPA Mode” menu. Set the “HSDPA-Mode” parameter to “H-Set”. The user can choose from predefined H-Sets, e.g. choose the H-Set “9 (16QAM/QPSK)”. Make sure that the “HS-SCCH Type” parameter is set to “Type 3 (MIMO)”. In addition to a HSDPA H-Set, enable the following channels: P-CPICH, P-CCPCH, P-SCH, S-SCH, PICH.



Configure the signal of baseband A as wanted. Afterwards continue with setting up baseband B to generate the transmit signal of the second antenna. Baseband B uses basically the same settings as baseband A. Therefore, save the settings of baseband A and recall them for baseband B. The only setting that needs to be adjusted in baseband B is the “Diversity/MIMO” parameter. Set it to “Antenna 2 Of 2” in the “Common” tab of the selected base station.

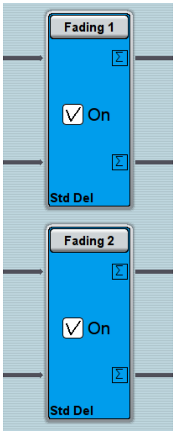
Please see also reference [6] for additional information on HSDPA MIMO operation.

Continue now with configuring the second cell, i.e. basebands C and D. Start with the settings required for MIMO operation: Set up baseband C and D to generate the transmit signals of the first and second antenna, respectively. For this, recall the settings of baseband A in both basebands. In baseband D, adjusted the “Diversity/MIMO” parameter to “Antenna 2 Of 2”. The next step is to make the settings required for dual cell operation: Disable the channels P-CCPCH, P-SCH, S-SCH, and PICH in both basebands, because they are transmitted only by the first cell (serving cell).

Please see references [6], [7], and [8] for additional information on dual cell HSDPA operation.

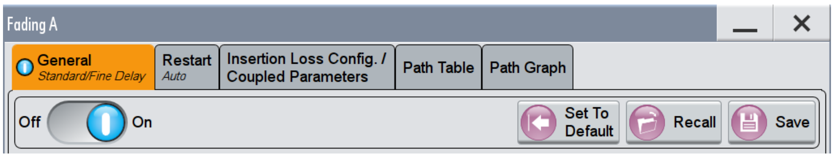
7.3 Fading Simulation Settings

Since two independent fading entities are used for this application, both fading entities need to be configured individually. This is however straightforward when using a predefined fading scenario.



In the “General” tab of the fading menu the user can chose from various predefined settings for 3GPP. All fading settings are automatically configured in accordance with the selected fading scenario. Set the same fading scenario in both fading entities.

The user can specify a correlation between the fading channels by configuring the MIMO correlation matrix (see section 5.2 for details). The user has also the possibility to configure a custom scenario if desired. To set the same fading scenario in both fading entities, save the settings of the first entity and recall them in the second entity.



Note that although the same fading scenario is used in both fading entities, the fading process is statistically independent for each entity.

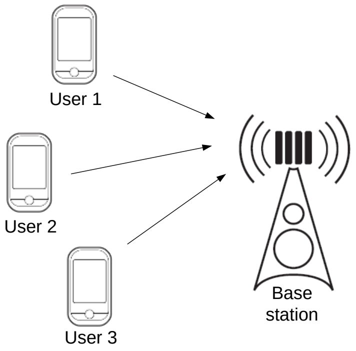
7.4 Synchronization

It is assured that all four basebands start simultaneously. Baseband A triggers the other three basebands B, C, and D. The required trigger settings in basebands B, C, and D are automatically set.

The fading simulators can be run in “Auto” mode. In this mode, a (re)start of the basebands cause an automatic (re)start of the fading statistics. The two fading simulators are thus indirectly synchronized via the basebands. Turn on fading simulation before triggering the basebands.

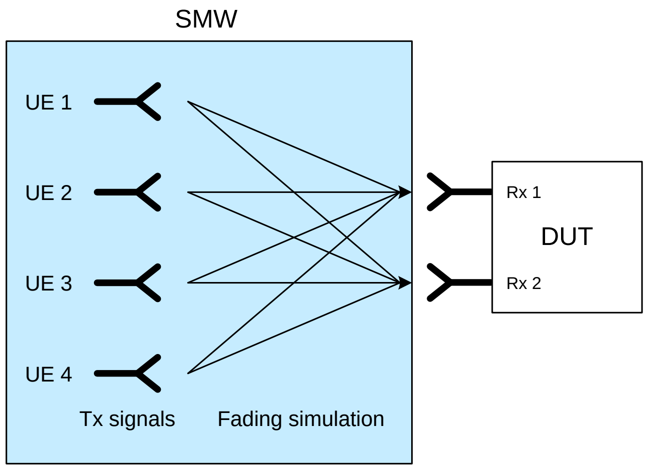
8 LTE Multiuser MIMO

The concept of multiuser MIMO (MU-MIMO) is that a base station communicates simultaneously with multiple users which share the same radio channel. MU-MIMO increases the overall network capacity by deploying multi-antenna base stations and multiple single-antenna mobile users. For initial commercial LTE deployment two antennas at the base station and one antenna at the UE is the standard case.



LTE uses MU-MIMO in the uplink. For example the LTE performance test case 8.3.3 “ACK missed detection for multi-user PUCCH format 1a” defined in the 3GPP technical specification 36.141 (Release 8) shall verify the base station receiver’s ability to detect ACK on the wanted signal in the presence of interfering signals under multipath fading propagation conditions. This test involves four different users – a wanted and three interfering UEs – transmitting their signals to a base station (DUT). Each UE has one transmit antenna. The base station receives the four signal streams via two receive antennas.

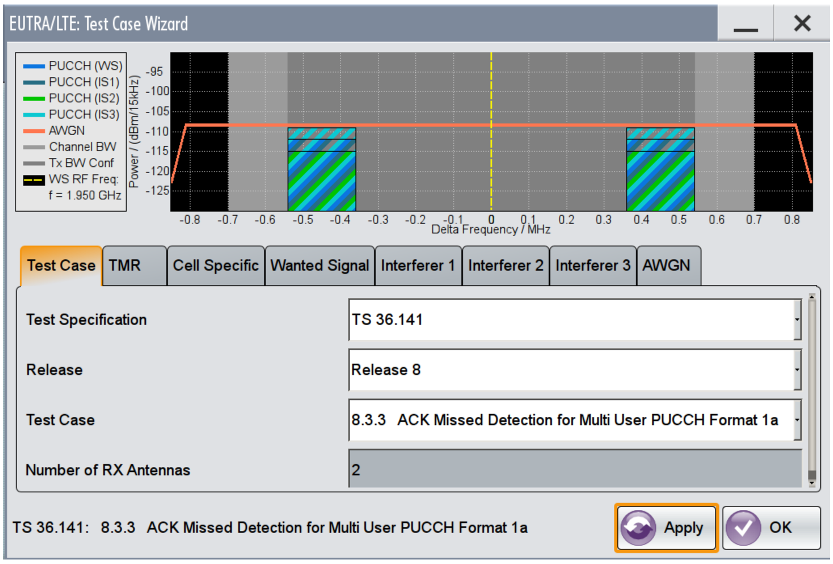
In the SMW, this scenario can be implemented using a 4x2 MIMO configuration. The whole test setup consists of only a single SMW. It is able to generate all four UE signals and to simulate the required eight fading channels.



8.1 LTE Test Case Wizard

To set up the LTE performance test case 8.3.3, the user can use the LTE test case wizard.

The wizard configures the SMW in line with test cases in the 3GPP technical specification 36.141 (Release 8). The user can simply select the desired test case and the wizard sets the system configuration, baseband signals, fading simulation and AWGN signals – automatically and standard-compliant. The test case wizard is part of the SMW-K55 LTE option and makes the configuration of the SMW fast and simple.

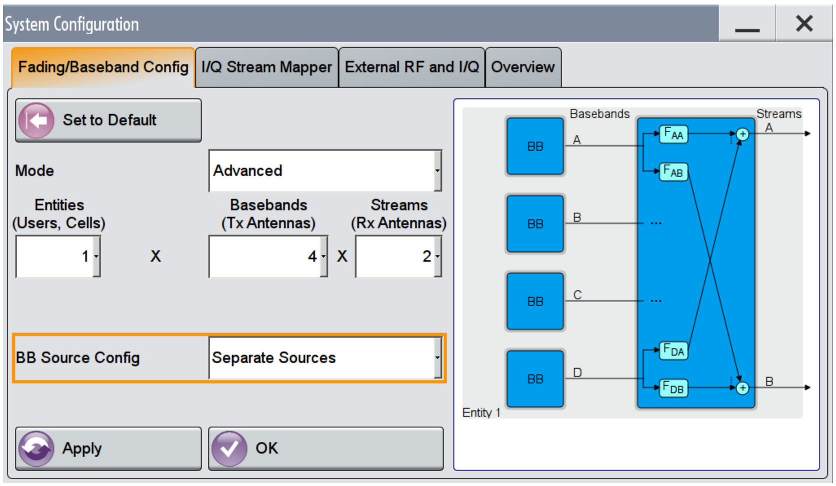


Please see also reference [2] for additional information on the LTE test case wizard.

For a deeper understanding, the following sections describe how the test case wizard sets up the SMW for the LTE test case 8.3.3 “ACK missed detection for multi-user PUCCH format 1a”.

8.2 SMW System Configuration

In the “Fading/Baseband Config” tab of the system configuration menu, the wizard makes the following settings:

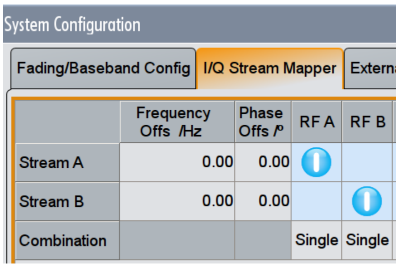


The resulting signal routing is shown in the block diagram.

For MU-MIMO, separate baseband sources are used. Baseband A generates the first, baseband B the second, baseband C the third and baseband D the fourth UE signal. The internal real-time faders simulate the eight fading channels AA, AB, BA, BB, CA, CB, DA, and DB.

8.2.1 Stream Mapping

To route the resulting streams A and B to the RF outputs A and B respectively, the wizard makes the following settings in the “I/Q Stream Mapper” tab:



8.3 LTE UE Signal Configuration

Since separate baseband sources are used for this application, each baseband is configured individually by the wizard.

The signals of the wanted UE and the three interfering UEs are set up in line with the technical specification:

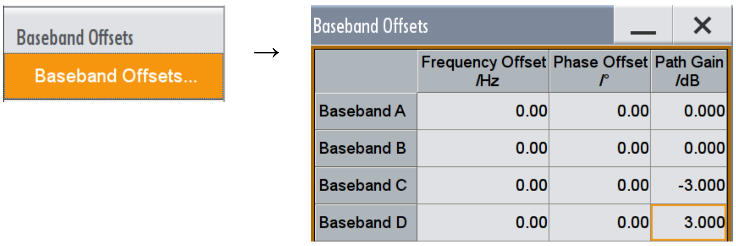
- PUCCH channel with format 1a
- Normal cyclic prefix
- Cell ID is 150
- Parameter “Delta shift” is 2
- Parameter “N(1)_cs” is 0
- ACK/NACK pattern is 1

- Parameter “n_PUCCH” is 2 (wanted UE), 1 (interferer 1), 7 (interferer 2), 14 (interferer 3)
- Interferer power levels relative to wanted UE are 0 dB (interferer 1), -3 dB (interferer 2), 3 dB (interferer 3)

To reproduce the interferer power levels as stipulated in the test case, the baseband signals need to be leveled relative to each other. The wizard uses the baseband offsets to achieve this. See section 8.3.1.

8.3.1 Setting relative UE Power Levels

To obtain different UE power levels, the baseband signals can be leveled relative to each other using the baseband offsets. Click on any “Baseband” block and select “Baseband Offsets” from the list. In the “Baseband Offsets” menu, the user can set the parameter “Path Gain” for each baseband signal. For example, if -3 dB is set for baseband C and +3 dB is set for baseband D, the level of baseband D is 6 dB lower than that of baseband C.



The baseband offsets can therefore be used to set different UE power levels. The set power offsets (i.e. path gains) apply even if an advanced MIMO routing is in use.[6]

8.4 Fading Simulation Settings

The SMW supports various predefined settings for LTE. All fading settings are automatically configured in accordance with the selected scenario.

The performance test case 8.3.3 specifies the use of the “ETU70” propagation conditions for all four UE signals. The LTE test case wizard simply sets the “ETU 70Hz” predefined scenario.

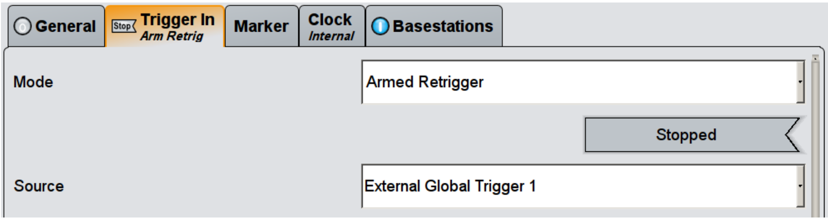
8.5 Synchronization

In general, when using an advanced MIMO routing it is assured that all four basebands start simultaneously. Baseband A triggers the other three basebands B, C, and D. The required trigger settings in basebands B, C, and D are automatically set.

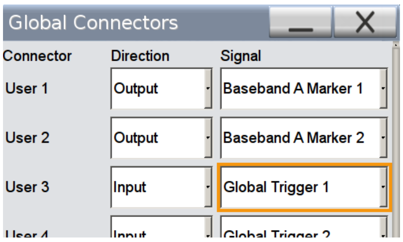
[6] This is different to the predecessor instrument R&S®SMU200A and improves usability.

For the performance test case 8.3.3, the basebands are triggered by an external trigger signal that is provided by the base station. The wizard adjusts the trigger settings of baseband A automatically as follows:

Baseband A:



Per default, the "Global Trigger 1" logical signal is linked to the physical connector "User 3" on the SMW front panel. Apply the physical trigger signal to this connector.



The user can also link the "Global Trigger 1" logical signal to another "User" connector if wanted. See reference [2] for details on the configuration of the global connectors.

The fading simulator runs in "Auto" mode. In this mode, a (re)start of the basebands causes an automatic (re)start of the fading statistics.

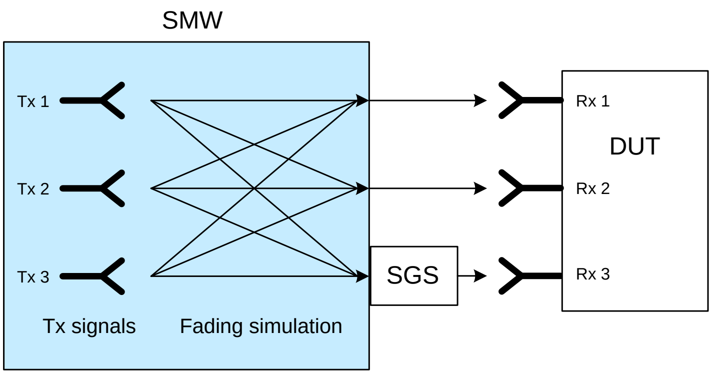
9 WLAN 802.11ac with 3x3 MIMO

The 802.11ac standard was developed with the goal of significantly improving the data throughput of existing WLAN. It builds on its predecessor standard 802.11n. The 802.11ac standard uses frequencies in the 5 GHz and provides new (partly optional) features that are necessary to meet 802.11ac goals such as high channel bandwidths (e.g. 80+80 MHz and 160 MHz), up to eight spatial streams, and MU-MIMO.

MIMO is used for WLAN since the introduction of 802.11n with 2x2, 2x4, 4x2, and 3x3 configurations. For 802.11ac the same configurations are used. Challenging for fading simulators is the required high bandwidth and in parallel the high number of fading taps.

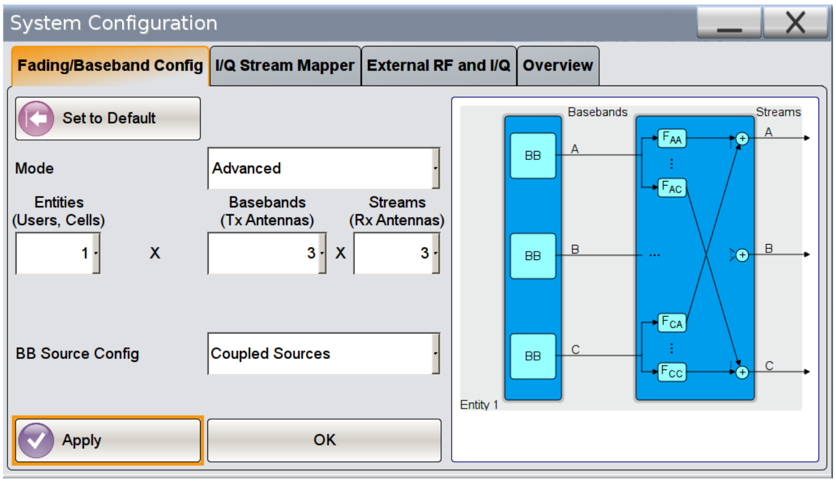
Please see also reference [9] for additional information on the WLAN 802.11ac technology.

WLAN 802.11ac with 3x3 MIMO involves three 802.11ac transmit signals and three receive antennas at the DUT. The signals shall have a channel bandwidth of 80 MHz each.
In the SMW, the 3x3 MIMO configuration (nine fading channels) can be simulated in real-time. Additionally, the SMW supports a baseband and fading bandwidth of 80 MHz in this configuration with up to 20 fading paths (taps) per fading channel.



9.1 SMW System Configuration

Open the system configuration menu. In the “Fading/Baseband Config” tab make the following settings:



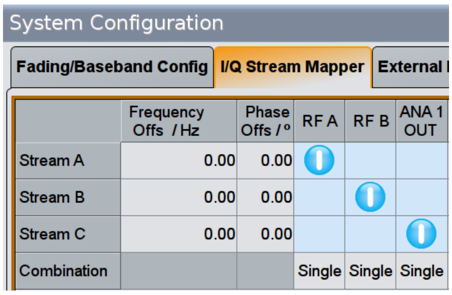
Press the “Apply” button to actually apply the settings. The resulting signal routing is shown in the block diagram.

Baseband A generates the first, baseband B the second, and baseband C the third 80 MHz 802.11ac transmit signal. The internal real-time faders simulate the nine fading channels AA, AB, AC, BA, BB, BC, CA, CB and CC. After fading simulation, there are three resulting streams: A, B, and C.

9.1.1 Stream Mapping

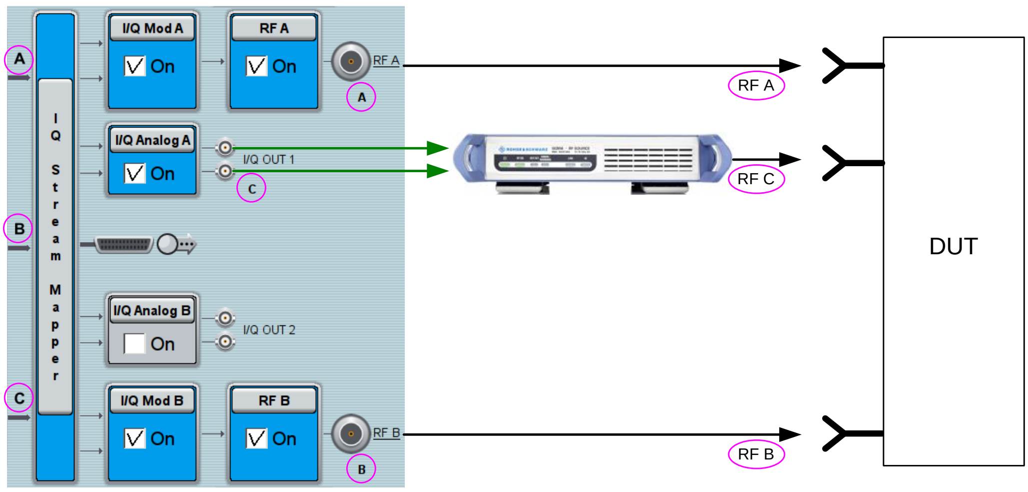
Two of the three streams can be directly output from the SMW as RF signals. The third stream can be externally upconverted to the RF using an additional SGx. The resulting three RF signals are fed to the receive antennas of the DUT.

To map streams A and B to RF outputs A and B and stream C to the analog I/Q outputs 1, make the following settings in the “I/Q Stream Mapper” tab:



9.1.2 External RF Outputs

The SGx is used as I/Q upconverter to increase the number of available RF outputs from two to three. Connect the I/Q output signal of the SMW to the SGx.

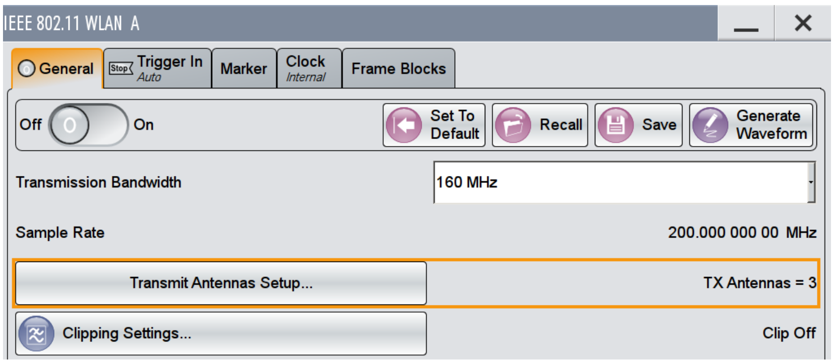


The SGx is controlled directly from the SMW. The settings for the SGx are made in the "External RF and I/Q" tab and are automatically transferred to the connected instrument via the control line. See section 4 for details.

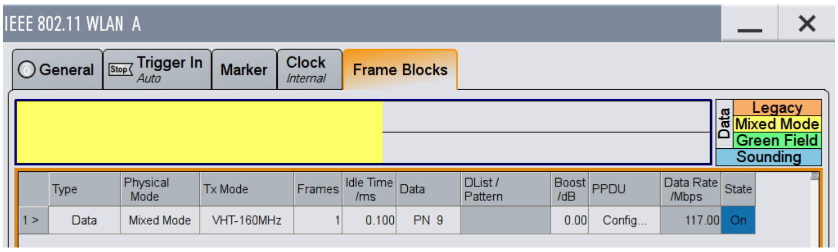
9.2 WLAN 11ac Signal Configuration

Since coupled baseband sources are used for this application, the basebands are configured all at once from a common menu.

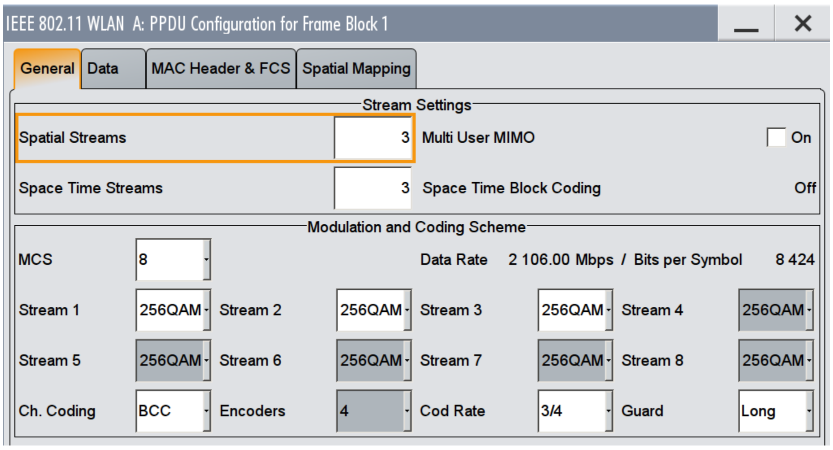
In the "General" tab of the 802.11 WLAN menu, set the parameter "Transmission Bandwidth" to 80 MHz. The number of transmit antennas is already preset according to the selected 3x3 MIMO system configuration (see section 9.1). The "TX Antenna Setup" menu is fully preset and does not need to be edited by the user.



In the "Frame Blocks" tab, the user can set the number of frames to be generated and the idle time for the very high throughput (VHT) 80 MHz channel.



Touch "Config…" to open the PPDU configuration menu. In this menu, the user can specify the spatial and space-time streams, the modulation and coding scheme (MCS), the data and header settings, the spatial mapping and more. Please see reference [10] for a detailed description.



9.3 Fading Simulation Settings

In the "General" tab of the fading menu the user can chose from predefined MIMO settings for WLAN 11ac. The fading scenarios include also the correlation between the fading channels specified for WLAN 11ac. All fading settings are automatically configured according to the selected MIMO scenario.

The SMW supports up to 20 fading paths (taps) per fading channel.

Besides selecting a predefined fading scenario, the user can also configure a custom scenario if needed (see section 5.2 for details).

9.4 Synchronization

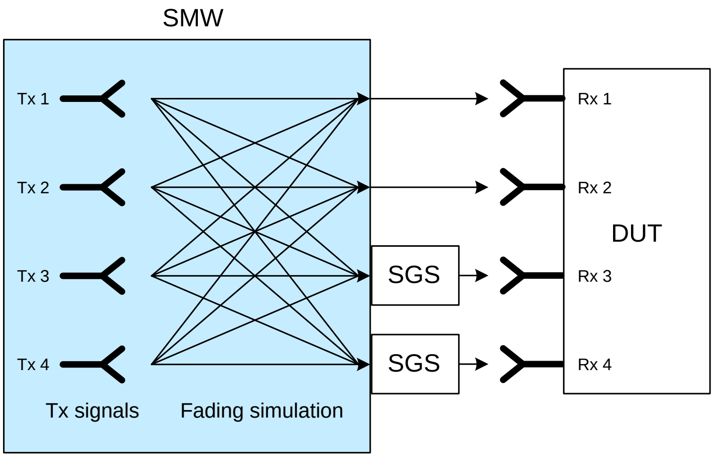
The coupling of the baseband sources guarantees their synchronization.

The fading simulator can be run in "Auto" mode. In this mode, a (re)start of the baseband cause an automatic (re)start of the fading statistics. Turn on fading simulation before turning on the baseband.

10 LTE with 4x4 MIMO

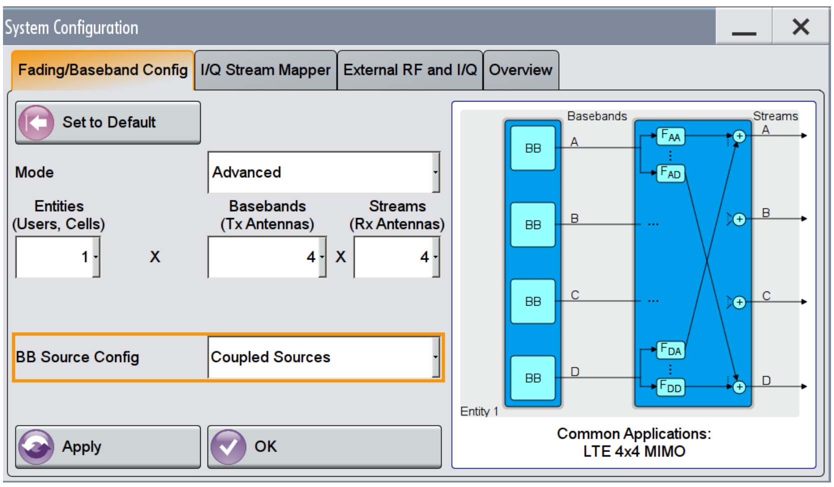
4x4 MIMO transmission in the downlink is part of the 3GPP technical specification Release 8. Release 10 (LTE-A) introduces higher order MIMO schemes, i.e. 8x8 in the downlink and 4x4 in the uplink. Please see references [11], [12], and [4] for comprehensive information on LTE and LTE-A. Reference [13] provides information on the MIMO transmission modes defined for LTE.

LTE with 4x4 MIMO involves four LTE transmit signals and four receive antennas at the DUT. The 4x4 MIMO configuration has sixteen fading channels that can be simulated in real-time with a single SMW.



10.1 SMW System Configuration

Open the system configuration menu. In the “Fading/Baseband Config” tab make the following settings:



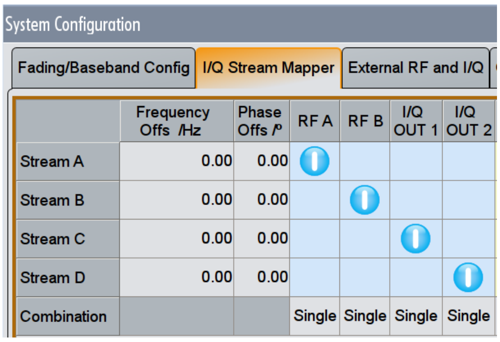
Press the “Apply” button to actually apply the settings. The resulting signal routing is shown in the block diagram.

Baseband A generates the first, baseband B the second, baseband C the third and baseband D the fourth LTE Tx signal. The internal real-time faders simulate the sixteen fading channels AA, AB, AC, AD, …, DA, DB, DC, and DD. After fading simulation, there are four resulting streams: A, B, C and D.

10.1.1 Stream Mapping

Two of the four streams can be directly output from the SMW as RF signals. The other two streams can be externally upconverted to the RF using two additional SGxs. The resulting four RF signals are fed to the receive antennas of the DUT.

To map streams A and B to RF outputs A and B and streams C and D to the analog I/Q outputs 1 and 2, make the following settings in the “I/Q Stream Mapper” tab:

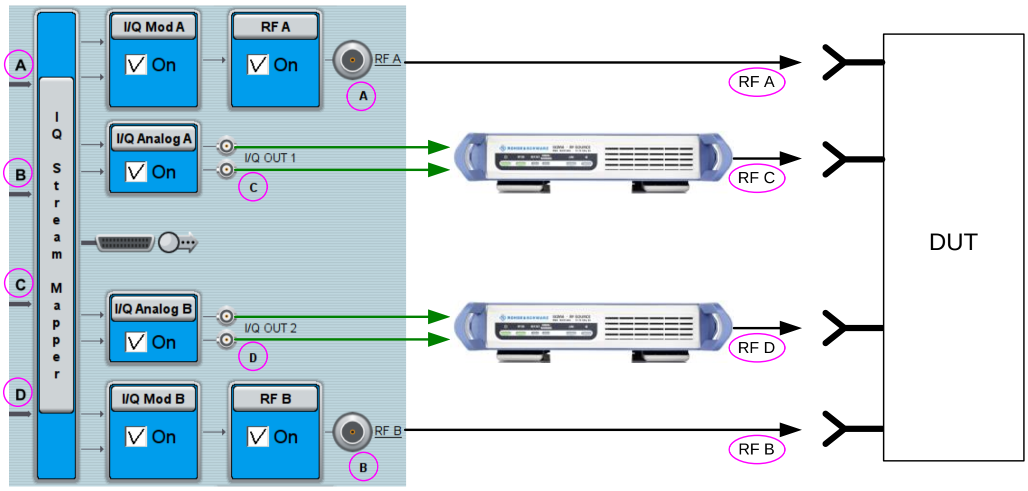

System Configuration

Fading/Baseband Config | I/Q Stream Mapper | External RF and I/Q

	Frequency Offs /Hz	Phase Offs /°	RF A	RF B	I/Q OUT 1	I/Q OUT 2
Stream A	0.00	0.00				
Stream B	0.00	0.00				
Stream C	0.00	0.00				
Stream D	0.00	0.00				
Combination			Single	Single	Single	Single

10.1.2 External RF Outputs

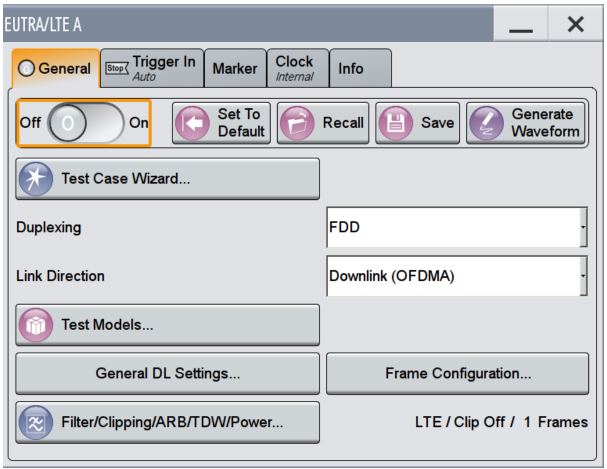
Two SGxs are used as I/Q upconverters to increase the number of available RF outputs from two to four. Connect the analog I/Q output signals of the SMW to the two SGxs.



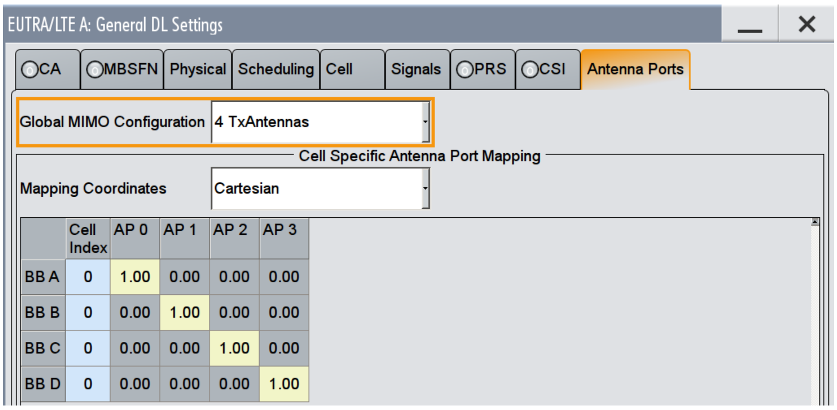
The SGxs are controlled directly from the SMW. The settings for the SGx are made in the “External RF and I/Q” tab and are automatically transferred to the connected SGx via the control line. See section 4 for details.

10.2 LTE Signal Configuration

Since coupled baseband sources are used for this application, the basebands are configured all at once from a common menu.

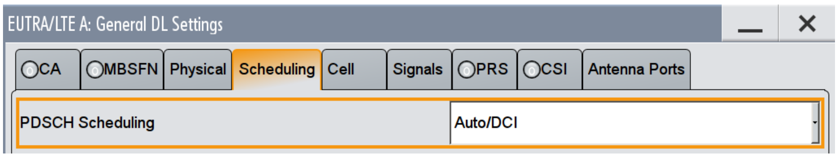


Touch the “General DL Settings” button. In the “Antenna Ports” tab of the “General DL Settings” menu, the “Global MIMO Configuration” parameter is preset to “4 TxAntennas”. The table illustrates the applied mapping of the four basebands (BB A to BB D) to the antenna ports (AP 0 to AP 3).

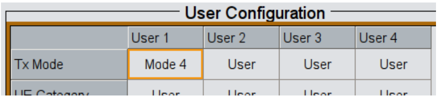


Baseband A is mapped to antenna port 0, baseband B to antenna port 1, and so on, i.e. baseband A generates the first antenna signal, baseband B the second antenna signal, and so on. Each antenna signal includes automatically the appropriate downlink reference signal as well as all other antenna-specific properties.

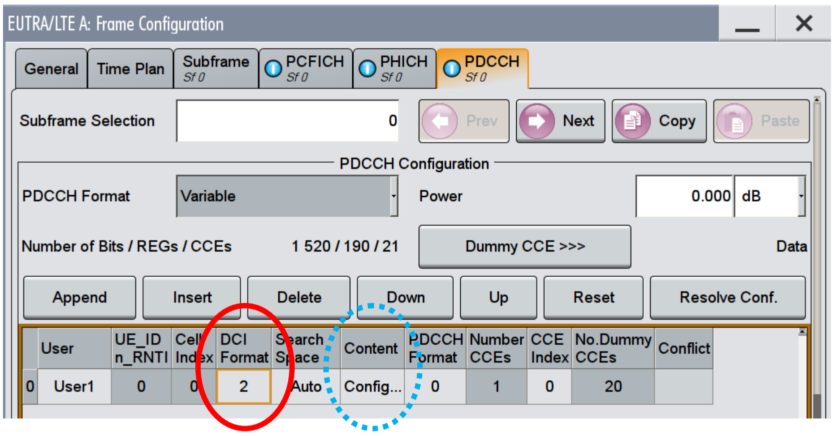
Change to the “Scheduling” tab and set the “PDSCH Scheduling” parameter to “Auto/DCI”. In this mode, the PDSCH allocations are configured automatically and standard-conform according to the selected PDCCH DCIs (see further down).



In the LTE main menu, touch the "Frame Configuration" button. In the "General" tab of the "Frame Configuration" menu, the user can set the number of subframes that he wants to configure via the "No of Configurable Subframes" parameter. If wanted, the user can select a specific transmission mode for the "User 1" to "User 4". This step can principally be omitted, but it may help users who want to have certainty that their made settings are according to a specific transmission mode.



Change to the "PDCCH" tab and set the "DCI Format" to "2" or "2A" for the selected "User" (e.g. "User1"). DCI formats 2 and 2A are used for closed loop and open loop spatial multiplexing, respectively.



Optionally, touch "Config…" to configure the content. In the "DCI Format Configuration" menu, the user can edit e.g. the "Resource Block Assignment", "Modulation and Coding Scheme", and "Precoding Information" parameters as wanted.

The PDCCH Configuration applies to the selected subframe only ("Subframe Selection" parameter). Therefore, configure the DCI format and the content for every configurable subframe.

Please see reference [15] or the SMW online help for informative and comprehensive information on the LTE setting parameters mentioned in this section.

10.3 Fading Simulation Settings

In the “General” tab of the fading menu the user can chose from various predefined MIMO settings for LTE. The standard-compliant fading scenarios include also the specified correlation (high, medium, low) between the fading channels. All fading settings are automatically configured in accordance with the selected MIMO scenario. Especially the preconfigured correlations, i.e. the preconfigured correlation matrix is of great help for the user, since for 4x4 MIMO a 16x16 matrix needs to be configured, which would require quite an effort.

MIMO correlation matrices for high correlation

1x2 case	$R_{high} = \begin{pmatrix} 1 & 0.9 \\ 0.9 & 1 \end{pmatrix}$
2x2 case	$R_{high} = \begin{pmatrix} 1 & 0.9 & 0.9 & 0.81 \\ 0.9 & 1 & 0.81 & 0.9 \\ 0.9 & 0.81 & 1 & 0.9 \\ 0.81 & 0.9 & 0.9 & 1 \end{pmatrix}$
2x4 case	$R_{high} = \begin{bmatrix} 1.0000 & 0.9883 & 0.9542 & 0.8999 & 0.8999 & 0.8894 & 0.8587 & 0.8099 \\ 0.9883 & 1.0000 & 0.9883 & 0.9542 & 0.8894 & 0.8999 & 0.8894 & 0.8587 \\ 0.9542 & 0.9883 & 1.0000 & 0.9883 & 0.8587 & 0.8894 & 0.8999 & 0.8894 \\ 0.8999 & 0.9542 & 0.9883 & 1.0000 & 0.8099 & 0.8587 & 0.8894 & 0.8999 \\ 0.8999 & 0.8894 & 0.8587 & 0.8099 & 1.0000 & 0.9883 & 0.9542 & 0.8999 \\ 0.8894 & 0.8999 & 0.8894 & 0.8587 & 0.9883 & 1.0000 & 0.9883 & 0.9542 \\ 0.8587 & 0.8894 & 0.8999 & 0.8894 & 0.9542 & 0.9883 & 1.0000 & 0.9883 \\ 0.8099 & 0.8587 & 0.8894 & 0.8999 & 0.8999 & 0.9542 & 0.9883 & 1.0000 \end{bmatrix}$
4x4 case	$R_{high} = \begin{bmatrix} 1.0000 & 0.9882 & 0.9541 & 0.8999 & 0.9882 & 0.9767 & 0.9430 & 0.8894 & 0.9541 & 0.9430 & 0.9105 & 0.8587 & 0.8999 & 0.8894 & 0.8587 & 0.8099 \\ 0.9882 & 1.0000 & 0.9882 & 0.9541 & 0.9767 & 0.9882 & 0.9767 & 0.9430 & 0.9430 & 0.9541 & 0.9430 & 0.9105 & 0.8894 & 0.8999 & 0.8894 & 0.8587 \\ 0.9541 & 0.9882 & 1.0000 & 0.9882 & 0.9430 & 0.9767 & 0.9882 & 0.9767 & 0.9105 & 0.9430 & 0.9541 & 0.9430 & 0.8587 & 0.8894 & 0.8999 & 0.8894 \\ 0.8999 & 0.9541 & 0.9882 & 1.0000 & 0.8894 & 0.9430 & 0.9767 & 0.9882 & 0.8587 & 0.9105 & 0.9430 & 0.9541 & 0.8099 & 0.8587 & 0.8894 & 0.8999 \\ 0.9882 & 0.9767 & 0.9430 & 0.8894 & 1.0000 & 0.9882 & 0.9541 & 0.8999 & 0.9882 & 0.9767 & 0.9430 & 0.8894 & 0.9541 & 0.9430 & 0.9105 & 0.8587 \\ 0.9767 & 0.9882 & 0.9767 & 0.9430 & 0.9882 & 1.0000 & 0.9882 & 0.9541 & 0.9767 & 0.9882 & 0.9767 & 0.9430 & 0.9430 & 0.9541 & 0.9430 & 0.9105 \\ 0.9430 & 0.9767 & 0.9882 & 0.9767 & 0.9541 & 0.9882 & 1.0000 & 0.9882 & 0.9430 & 0.9767 & 0.9882 & 0.9767 & 0.9105 & 0.9430 & 0.9541 & 0.9430 \\ 0.8894 & 0.9430 & 0.9767 & 0.9882 & 0.8999 & 0.9541 & 0.9882 & 1.0000 & 0.8894 & 0.9430 & 0.9767 & 0.9882 & 0.8587 & 0.9105 & 0.9430 & 0.9541 \\ 0.9541 & 0.9430 & 0.9105 & 0.8587 & 0.9882 & 0.9767 & 0.9430 & 0.8894 & 1.0000 & 0.9882 & 0.9541 & 0.8999 & 0.9882 & 0.9767 & 0.9430 & 0.8894 \\ 0.9430 & 0.9541 & 0.9430 & 0.9105 & 0.9767 & 0.9882 & 0.9767 & 0.9430 & 0.9882 & 1.0000 & 0.9882 & 0.9541 & 0.9767 & 0.9882 & 0.9767 & 0.9430 \\ 0.9105 & 0.9430 & 0.9541 & 0.9430 & 0.9430 & 0.9767 & 0.9882 & 0.9767 & 0.9541 & 0.9882 & 1.0000 & 0.9882 & 0.9430 & 0.9767 & 0.9882 & 0.9767 \\ 0.8587 & 0.9105 & 0.9430 & 0.9541 & 0.8894 & 0.9430 & 0.9767 & 0.9882 & 0.8999 & 0.9541 & 0.9882 & 1.0000 & 0.8894 & 0.9430 & 0.9767 & 0.9882 \\ 0.8999 & 0.8894 & 0.8587 & 0.8099 & 0.9541 & 0.9430 & 0.9105 & 0.8587 & 0.9882 & 0.9767 & 0.9430 & 0.8894 & 1.0000 & 0.9882 & 0.9541 & 0.8999 \\ 0.8894 & 0.8999 & 0.8894 & 0.8587 & 0.9430 & 0.9541 & 0.9430 & 0.9105 & 0.9767 & 0.9882 & 0.9767 & 0.9430 & 0.9882 & 1.0000 & 0.9882 & 0.9541 \\ 0.8587 & 0.8894 & 0.8999 & 0.8894 & 0.9105 & 0.9430 & 0.9541 & 0.9430 & 0.9430 & 0.9767 & 0.9882 & 0.9767 & 0.9541 & 0.9882 & 1.0000 & 0.9882 \\ 0.8099 & 0.8587 & 0.8894 & 0.8999 & 0.8587 & 0.9105 & 0.9430 & 0.9541 & 0.8894 & 0.9430 & 0.9767 & 0.9882 & 0.8999 & 0.9541 & 0.9882 & 1.0000 \end{bmatrix}$

This matrix data is taken from the 3GPP test specification 36.141.

Nevertheless, besides selecting a predefined fading scenario, the user can also configure a custom scenario if needed (see section 5.2 for details).

10.4 Synchronization

The coupling of the baseband sources guarantees their synchronization.

The fading simulator can be run in “Auto” mode. In this mode, a (re)start of the baseband cause an automatic (re)start of the fading statistics. Turn on fading simulation before turning on the baseband.

11 Summary

This application note showed why the SMW is the ideal instrument for testing MIMO receivers and explained how to use the SMW in different key applications.

The SMW is outstanding because it can generate up to eight antenna signals simultaneously in its digital baseband – all standard-compliant and with antenna-specific coding. It can simulate the complete MIMO transmission channel with up to 32 fading channels sufficient to emulate higher-order MIMO configurations such as 3x3, 4x4, and 8x4. The SMW offers up to two RF outputs and the possibility to increase that number up to eight in total by connecting external instruments, such as the SGS or the SGT signal generator. For ease of use the external instruments are controlled from the SMW such that the whole setup acts like a single unit.

Due to its outstanding capabilities the SMW is the ideal test equipment for a vast variety of MIMO applications offering maximum usability at minimum form factor. This application note presented some key applications which are listed in the following table together with the required instrument options.

Presented MIMO applications				
Options overview				
Application	**MIMO configuration**	**Required instruments**	**Required options[7] for SMW**	
LTE Advanced carrier aggregation with 2x2 MIMO	2x 2x2	1 SMW, (2 SGx)[8]	1 SMW-B103 1 SMW-B203 1 SMW-B13T 2 SMW-B10 4 SMW-B14	1 SMW-K74 2 SMW-K55 2 SMW-K85 (2 SMW-K84) (2 SMW-K522) (2 SMW-K62)
Dual cell HSDPA with 2x2 MIMO	2x 2x2	1 SMW, (2 SGx)[8]	1 SMW-B103 1 SMW-B203 1 SMW-B13T 2 SMW-B10 4 SMW-B14	1 SMW-K74 2 SMW-K42 2 SMW-K83 (2 SMW-K522) (2 SMW-K62)
LTE multiuser MIMO	4x 1x2	1 SMW	1 SMW-B103 1 SMW-B203 1 SMW-B13T 2 SMW-B10 4 SMW-B14	1 SMW-K74 2 SMW-K55 (2 SMW-K84) (2 SMW-K85) 2 SMW-K62

[7] Please cross-check the required options with your local Rohde & Schwarz sales division.

The full option designation can be looked up on the product website at www.rohde-schwarz.com.

[8] SGx only needed if the carrier spacing is so large that the CC/cell signals do not fit into the internal ±80 MHz I/Q bandwidth of the digital baseband.

Presented MIMO applications			
Options overview			
Application	**MIMO configuration**	**Required instruments**	**Required options[7] for SMW**
WLAN 802.11ac with 3x3 MIMO	3x3	1 SMW, 1 SGx	1 SMW-B106 1 SMW-B206 1 SMW-B13T 2 SMW-B10 4 SMW-B14 1 SMW-K74 2 SMW-K54 2 SMW-K86 2 SMW-K522 (2 SMW-K62)
LTE with 4x4 MIMO	4x4	1 SMW, 2 SGx	1 SMW-B103 1 SMW-B203 1 SMW-B13T 2 SMW-B10 4 SMW-B14 1 SMW-K74 2 SMW-K55 (2 SMW-K84) (2 SMW-K85) (2 SMW-K62)

To perform tests in the LTE frequency bands that go beyond 3 GHz the options SMW-B106 and SMW-B206 are required instead of the options SMW-B103 and SMW-B203.

12 Abbreviations

ACK	Acknowledgement
AoA	Angle of arrival
AoD	Angle of departure
AWGN	Additive white Gaussian noise
BB	Baseband
CC	Component carrier
DC	Dual carrier
DHCP	Dynamic host configuration protocol
DUT	Device under test
GUI	Graphical user interface
HSDPA	High speed downlink packet access
I/Q	In-phase/quadrature
IP	Internet protocol
LTE	Long term evolution
LTE-A	LTE Advanced
MIMO	Multiple input multiple output
MU	Multi user
PUCCH	Physical uplink control channel
RF	Radio frequency
Rx	Receive
SCM	Special channel model
Tx	Transmit
UE	User equipment
WLAN	Wireless local area network

13 References

[1] Rohde & Schwarz, R&S®SMW200A Specifications (data sheet)
[2] Rohde & Schwarz, R&S®SMW200A Operating Manual
[3] 3GPP Technical Report TR 25.996 (V10.0.0), “Spatial channel model for MIMO simulations”
[4] Rohde & Schwarz White Paper, “LTE-Advanced Technology Introduction” (1MA169)
[5] Rohde & Schwarz White Paper, “HSPA+ Technology Introduction” (1MA205)
[6] Rohde & Schwarz Application Note, “Testing HSPA+” (1MA121)
[7] Rohde & Schwarz Application Sheet, “Generating an Uplink Dual Cell HSDPA Test Signal” (1ZKD-26)
[8] Rohde & Schwarz Application Sheet, “Generating a Downlink Dual Cell HSDPA Test Signal” (1ZKD-27)
[9] Rohde & Schwarz White Paper, “802.11ac Technology Introduction” (1MA192)
[10] Rohde & Schwarz Application Note, “Generating Signals for WLAN 802.11ac” (1GP94)
[11] Rohde & Schwarz White Paper, “UMTS Long Term Evolution (LTE) Technology Introduction” (1MA111)

[12] Rohde & Schwarz White Paper, “LTE Release 9 Technology Introduction” (1MA191)

[13] Rohde & Schwarz Application Note, “LTE Transmission Modes and Beamforming” (1MA186)

[14] Faisal Darbari, Robert W. Stewart and Ian A. Glover (2010). MIMO Channel Modelling, Signal Processing, Sebastian Miron (Ed.), ISBN: 978-953-7619-91-6, InTech, Available from: http://www.intechopen.com/books/signal-processing/mimo-channel-modelling

[15] Rohde & Schwarz, EUTRA/LTE Digital Standard for R&S®Signal Generators Operating Manual

[16] Rohde & Schwarz Application Note, “Guidelines for MIMO Test Setups – Part 2” (1GP51)

[17] Rohde & Schwarz Application Note, “Connecting and Interfacing with SGMA Instruments” (1GP103)

[18] Rohde & Schwarz Application Note, “Multi-Channel Signal Generation Applications with R&S®SMW200A – Overview” (1GP106)

14 Ordering Information

Please visit the Rohde & Schwarz product websites at www.rohde-schwarz.com for comprehensive ordering information on the following Rohde & Schwarz instruments:

- R&S®SMW200A vector signal generator
- R&S®SGT100A SGMA vector RF source
- R&S®SGS100A SGMA RF source

About Rohde & Schwarz
Rohde & Schwarz is an independent group of companies specializing in electronics. It is a leading supplier of solutions in the fields of test and measurement, broadcasting, radiomonitoring and radiolocation, as well as secure communications. Established more than 75 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. Company headquarters are in Munich, Germany.

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- Continuous improvement in environmental sustainability
- ISO 14001-certified environmental management system

Certified Quality System
ISO 9001

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