Receiver Diversity Channel Simulations for Broadcast Signaling

Application Note

Products:

- R&S®BTC
- R&S®SGT100A

Receiver diversity improves reception quality by using multiple antennas with a preferably low correlation factor between each receive path. The result is a much more robust reception, since a deep fade will not affect all received signals at the same time.

However, the complex geometry and positioning constraints for antennas of the receiving devices can introduce an unwanted correlation between channels. The popular diversity test setup consisting of several independent transmitters does not serve the needs of a realistic simulation, because radio channel correlation is not simulated.

This application note explains a compact and versatile MIMO test solution for any common broadcast standard with real time fading including the simulation of channel correlation for a 1x4 MIMO system.

The test setup allows very precisely specified individual multipath profiles.

Note:

Please find the most up-to-date document on our homepage http://www.rohde-schwarz.com/appnote/1GP114.

Application Note
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4.2017 – 1GP114_0e

ROHDE&SCHWARZ

Table of Contents

1 Readers Guide

Chapter 2 gives a short introduction to the concept of MIMO receiver diversity, broadcast technology, fading and relevant parameters needed for understanding and generating the 1x4 MIMO channel simulation.

Chapter 3 explains the test equipment setup and software configuration steps using Rohde & Schwarz signal generators.

Chapter 4 is the Appendix section, where the correlation matrix and its influence on the receiver diversity is discussed.

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

- The R&S®BTC Broadcast Test Center is referred to as BTC
- The R&S®SGT100A SGMA Vector RF Source is referred to as SGT
- Device Under Test is referred to as DUT

2 Overview

In order to make radio communications more robust, several different diversity modes are used. They include time diversity (different timeslots and channel coding), frequency diversity (different channels, spread spectrum, and OFDM), and also spatial diversity. Spatial diversity requires the use of multiple antennas at the transmitter and/or the receiver end. Multiple antenna systems are typically known as Multiple Input, Multiple Output systems (MIMO). Multiple antenna technology can also be used to increase the data rate (spatial multiplexing) instead of improving robustness. In case of spatial multiplexing different parts of data are transported on differently spaced parts of the link, hence trading robustness for parallel transfer.

In practice, both methods are used separately or in combination, depending on the channel condition. The next section introduces a short description of the technology that is relevant for this application note. A more detailed discussion on MIMO technology can be found in 1MA142 [1].

2.1 Receive Diversity

Receive (RX) diversity is the key focus of this application note. RX diversity uses more antennas on the receiver side than on the transmitter side. The simplest scenario consists of two RX and one TX antenna (SIMO, 1x2).

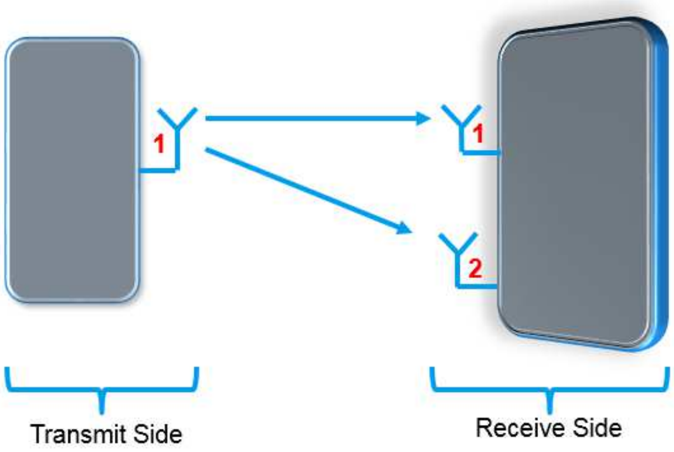


Fig. 2-1: SIMO antenna configuration [1]

Because special coding methods are not needed, this scenario is very easy to implement. Only two RF paths are needed for the receiver.

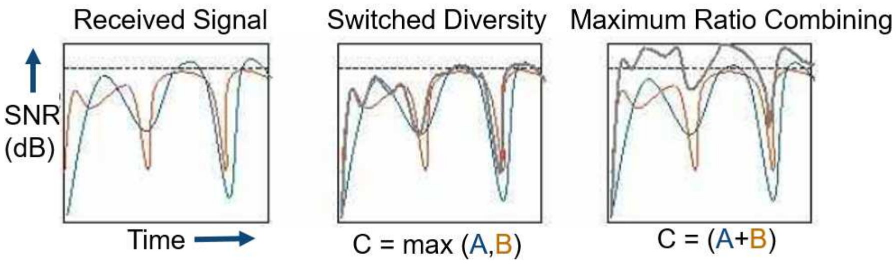


Fig. 2-2: RX diversity [1]

Because of the different transmission paths, the receiver sees two differently faded signals. By using the appropriate method in the receiver, the signal-to-noise ratio can now be increased. Switched diversity always uses the stronger signal, while maximum ratio combining uses the sum signal from the two signals (see Fig. 2-2).

2.2 Fading

A transmit signal from a transmit antenna arrives at the receive antenna not only by direct line of sight path but also via multiple propagation paths. The received field strength level may strongly vary due to atmospheric disturbances. This phenomenon is known as fading. The constant reflection of the electromagnetic waves, emitted by a transmitter, from walls of buildings, trees, mountain slopes and other reflecting natural or artificial obstacles is one of the major sources of the fading effect.

The reception of TV signals broadcast via satellite can be impaired by fading. A known phenomenon is flickering of the received picture, produced by planes flying past or a drop in receive field strength caused by an approaching thunderstorm. In many cases reception is stationary with a direct line of sight to the TV transmitter. However, terrestrial transmission not only provides for stationary operation but also for portable and mobile reception. This considerably accentuates the effects of fading.

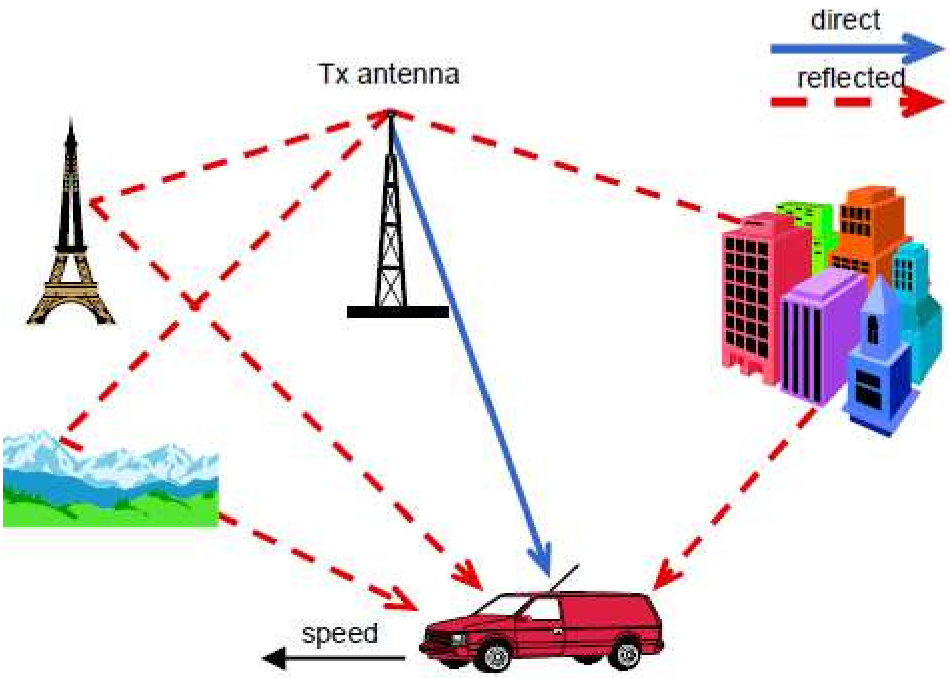


Fig. 2-3: Basic fading principle [2]

This means the transmitter signal travels along different reflection paths to the receiver (Fig. 2-3). The receiver detects all these signals, which typically have different time delays, levels, phases and even frequency shifts due to Doppler effects (caused by moving transmitters or receivers). In a MIMO system a complex fading channel exists between each transmit and receive antenna pair.

While the performance of a single input, single output (SISO) system with only one transmit and one receive antenna is degraded by the fading process, MIMO systems work best under multi-path conditions, i.e. in environments with strong differences to the number of radio paths received. Fading is an essential component in MIMO systems, since sufficiently different – i.e. in the best case, uncorrelated – fading channels are required to distinguish the data streams coming from the different transmit antennas.

The basic elements of fading are [3]:

1. Reflection: The first basic element of fading is reflection. Reflections or echoes occur at all obstacles in the propagation path of waves. Echoes are described by the reflected level and the phase shift caused by reflection. The level and phase shift depend on the reflecting material.
2. Doppler: The second basic element is the Doppler Effect, i.e. the frequency shift resulting from the movement of the receiver relative to the site of a transmitter.
3. Rice: Rice fading is caused by Doppler-shifted echoes with a Gaussian distribution, but in addition there is always a direct path from the Tx antenna to the Rx antenna.
4. Rayleigh: similar to Rice fading, is caused by Doppler-shifted echoes with a Gaussian distribution, but there exists no direct path from the Tx antenna to the Rx antenna.

A more detailed description on the types of fading can be found in [3].

Uncorrelated fading channels are, however, only a best-case scenario. Under real operating conditions, the different fading channels are not fully independent of each other, due to the geometric arrangement, especially proximity, of the antennas. For MIMO tests, it is therefore essential to simulate variable correlations between the different fading channels. Only by correlating the individual channels with each other a realistic simulation of the entire MIMO system can be achieved. This is important, since for MIMO systems the benefit depends on the degree of channel correlation, i.e. the higher the statistical independence of the different fading channels, the better the achievable data transfer rate [2].

3 Channel Simulation for 1x4 MIMO

In order to generate a 1x4 MIMO channel scenario simulation, the compact setup shown in Fig. 3-1 is a highly flexible test environment. The spatial diversity scenario is simulated using one baseband of the BTC acting as the transmitter sending out replicas of the signal simultaneously at the same frequency, to four receive antennas of the DUT receiver. The four paths, RF A, RF B, RF C and RF D can be configured to simulate four different radio channel simulations including all realistic propagation effects such as multipath propagation, signal delay, Doppler Effect due to motion etc. For this test setup, BTC and a pair of SGT is needed and signals up to 6 GHz can be generated.

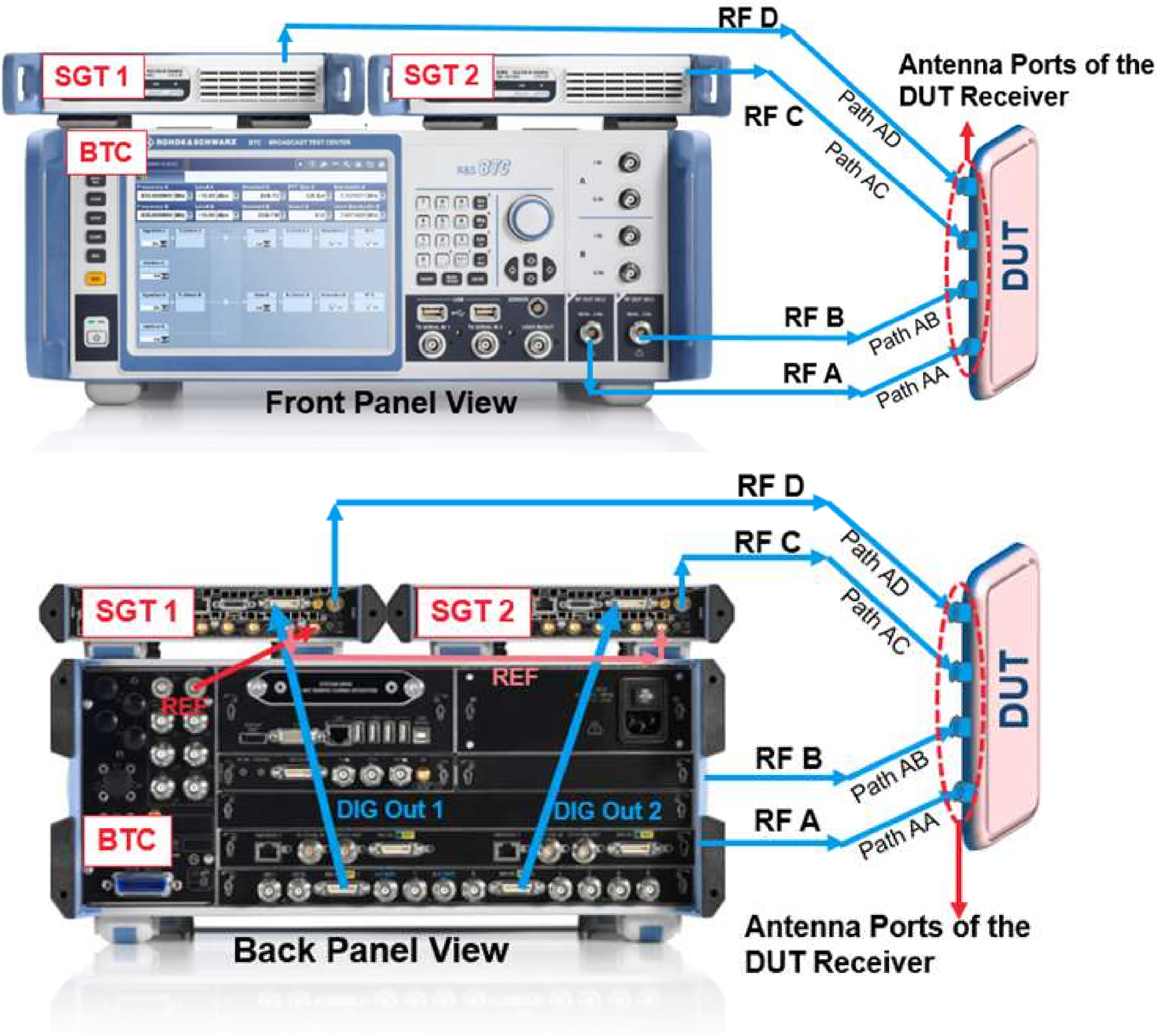


Fig. 3-1: Test setup for 1x4 MIMO receiver diversity channel simulation

The BTC and the two SGT instruments are cabled with each other in the following way (shown in Fig. 3-1):

- The Digital I/Q output 1 of the BTC is connected to the Digital I/Q input of SGT 1 and Digital I/Q output 2 of the BTC is connected to the Digital I/Q input of SGT 2
- The REF output of the BTC is connected to the 10 MHz Ref input of SGT1 and the Ref Out of SGT 1 is connected to the Ref In of SGT 2

Instrument control:
The BTC is controlling the SGT's over LAN. A LAN switch is used to connect BTC and the SGT to each other and the LAN Switch needs to be connected to a local network with DHCP server capabilities. BTC and SGT Network address mode need to be set to DHCP.

3.1 Hardware Requirements

The BTC and SGT base units need to be fitted with the following hardware in order to allow 1x4 MIMO channel simulation.

Required hardware options for BTC:

- Baseband generator, 1st & 2nd channel : R&S®BTC-B1, R&S®BTC-B2
- RF Path A and RF Path B: R&S®BTC-B3106, R&S®BTC-B3206
- Baseband Main Module, two I/Q paths to RF: R&S®BTC-B12
- Fading simulator (Path A & Path B): R&S®BTC-B1031, R&S®BTC-B1032
- Fading Simulator Extension (path A and path B): R&S®BTC-B1034

Required hardware options for SGT:

- RF frequency extension to 6GHz: R&S®SGT-KB106
- Cable for connecting R&S®Digital I/Q Interfaces: R&S®SMU-Z6

Further information is provided in Chapter 6 "Ordering Information".

3.2 Software Requirements

Depending on the specific testing requirement, the BTC and SGT units require valid software option licenses.

Required software options for BTC:

- Extended I/Q Interfaces: R&S®BTC-K2500
- MIMO Fading and Routing: R&S®BTC-K1034

At least one or multiple transmission standards, stream libraries and waveform libraries (based on testing requirements) need to be activated on the BTC using software options. The standards include DVB-T, DVB-T2, ATSC, ISDB-T, DTMB, T-DMB, etc. Further information is provided in Chapter 6 “Ordering Information”.

Required software options for SGT:

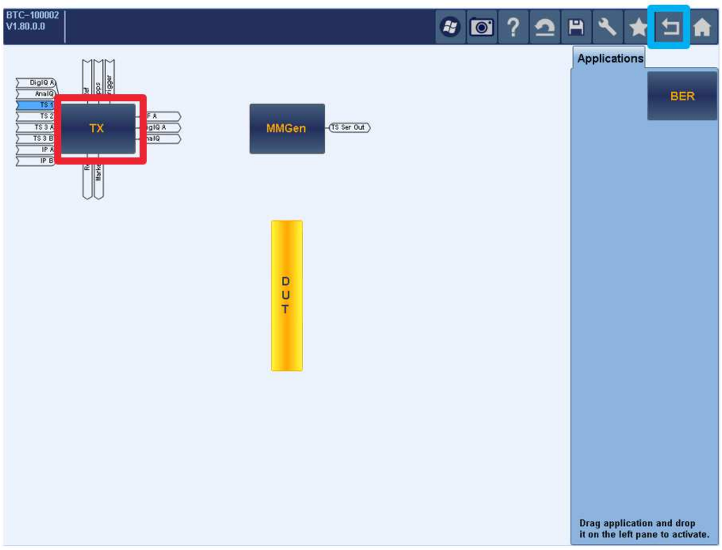
- Digital Baseband Connectivity: R&S®SGT-K18

Further information is provided in Chapter 6 “Ordering Information”.

3.3 Configuring BTC for 1x4 Radio Channel Simulation

This section explains how to configure the BTC and SGT.

- Connect the BTC with the two SGT as shown in Fig. 3-1.

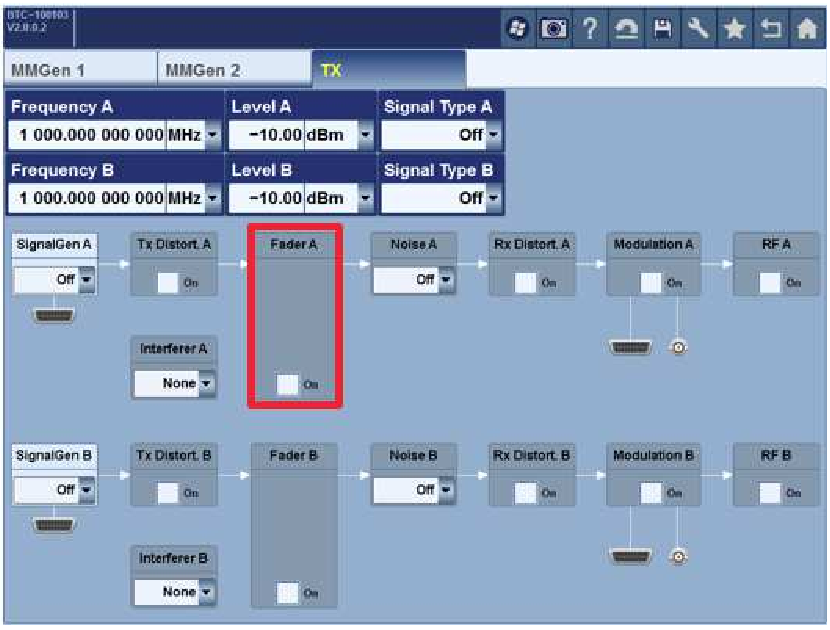


Drag application and drop it on the left pane to activate.

Fig. 3-2: Application selection on BTC

- *Preset* the BTC
- Click on the TX settings box (as shown in Fig. 3-2)

NOTE: The back button (marked in Blue) on the top right corner is used to go back to home screen (as shown in Fig. 3-2)



BTC-100103
V2.0.0.2

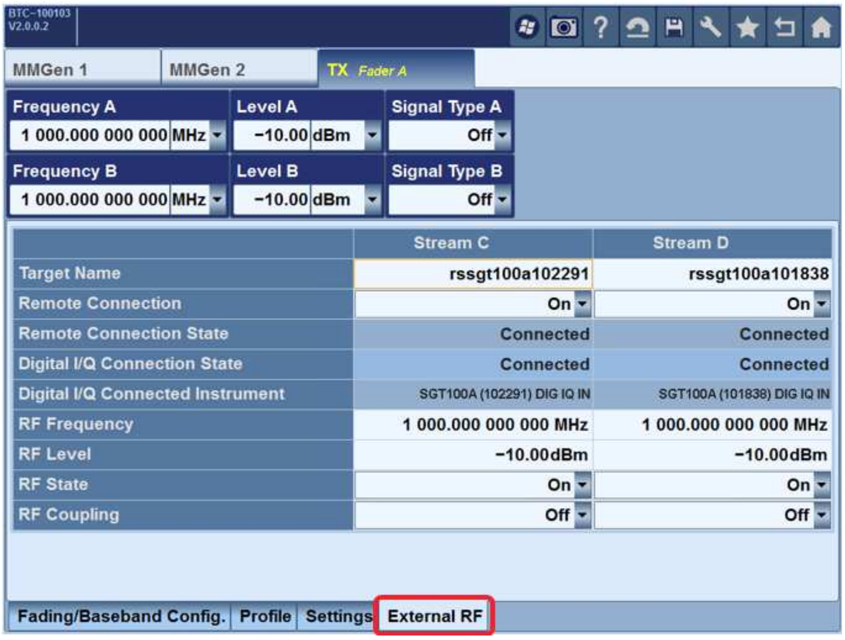
MMGen 1 | MMGen 2 | TX

Frequency A	Level A	Signal Type A
1 000.000 000 000 MHz	−10.00 dBm	Off

Frequency B	Level B	Signal Type B
1 000.000 000 000 MHz	−10.00 dBm	Off

Fig. 3-3: Main Menu of the TX application of the BTC

- Go in to *Fader A*



BTC-100103
V2.0.0.2

MMGen 1 | MMGen 2 | TX *Fader A*

Frequency A	Level A	Signal Type A
1 000.000 000 000 MHz	−10.00 dBm	Off

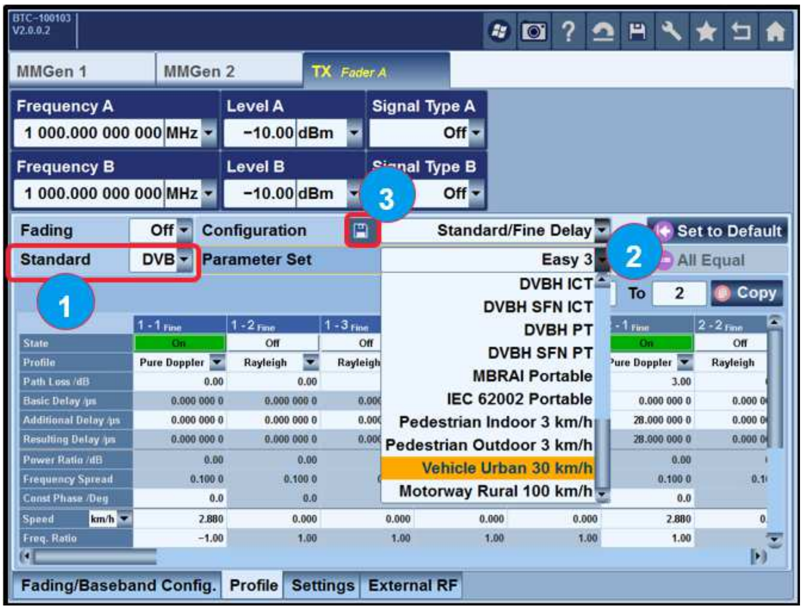
Frequency B	Level B	Signal Type B
1 000.000 000 000 MHz	−10.00 dBm	Off

	Stream C	Stream D
Target Name	rssgt100a102291	rssgt100a101838
Remote Connection	On	On
Remote Connection State	Connected	Connected
Digital I/Q Connection State	Connected	Connected
Digital I/Q Connected Instrument	SGT100A (102291) DIG IQ IN	SGT100A (101838) DIG IQ IN
RF Frequency	1 000.000 000 000 MHz	1 000.000 000 000 MHz
RF Level	−10.00dBm	−10.00dBm
RF State	On	On
RF Coupling	Off	Off

Fig. 3-4: Configuring the SGT pair from the BTC

- In the *TX Fader A*, select *External RF* and configure as shown in Fig. 3-4
  - Enter Target name to connect BTC to an external SGT. The format of *Target Name* is rssgt100a<serial_number_of_SGT>(see Fig.3-4)
  - Switch Remote Connection to ON.
  - If an external SGT is connected, the BTC automatically sets the following parameters on SGT over the control line:

    - Preset
    - RF frequency = 1GHz
    - RF Level = -10dBm
    - Ext. Ref = ON
    - RF output state =OFF
    - I/Q modulator state =ON
    - Digital I/Q input state =ON
    - Sample Rate Source = USER DEFINED
    - Digital I/Q input sample rate = 200MHz
  - Set RF Frequency and level setting as per user requirement, but make sure the frequency of all RF paths must be the same. In case that RF coupling is activated, RF frequency and level setting on SGT follows the RF frequency-/level setting on BTC.

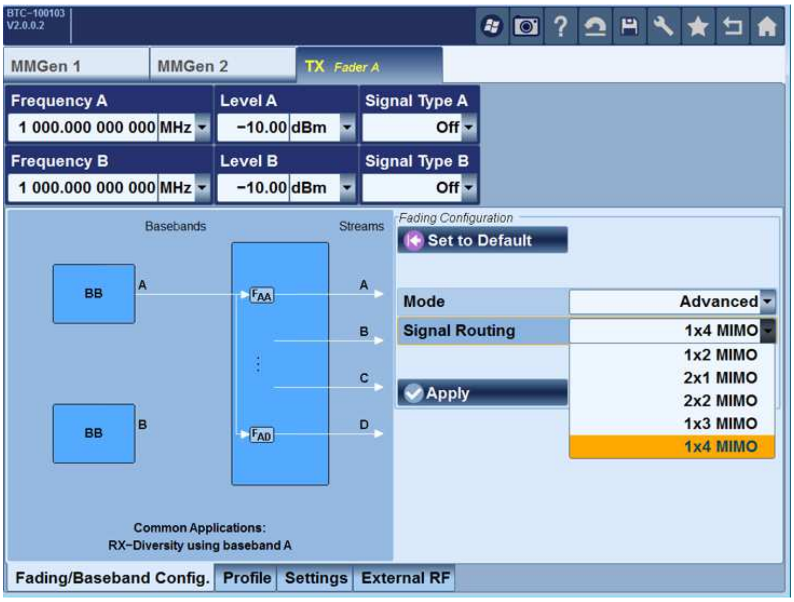


Frequency A 1 000.000 000 000 MHz
Level A −10.00 dBm
Signal Type A Off
Frequency B 1 000.000 000 000 MHz
Level B −10.00 dBm
Signal Type B Off
Fading Off
Configuration Standard/Fine Delay
Standard DVB
Parameter Set Easy 3

Fig. 3-5: Selecting and saving pre-defined Fading profile

- Follow the sequence as shown in Fig. 3-5
  - 1: Select the relevant *Standard from DVB, DAB, ATTC*
  - 2: Select the desired fading profile from the drop down menu
  - 3: Click the save icon to *Save Fading Profile*

In order to set user defined arbitrary fading profile, skip steps explained for* Fig. 3-5 *and* Fig. 3-7*.



Frequency A: 1 000.000 000 000 MHz
Level A: −10.00 dBm
Signal Type A: Off
Frequency B: 1 000.000 000 000 MHz
Level B: −10.00 dBm
Signal Type B: Off
Mode: Advanced
Signal Routing: 1x4 MIMO

Fig. 3-6: Baseband Configuration on BTC

- Go in to Fading/Baseband Config. (shown in Fig. 3-6)
  - Set *Mode: Advanced*
  - Set *Signal Routing : 1x4 MIMO*
  - Select *Apply*

Fading: On
Configuration: Standard/Fine Delay
Standard: User

Fig. 3-7: Coping pre-defined fading profile in MIMO configuration

- Switch *Fading: ON and Standard :User (shown in* Fig. 3-7*)*
- Click on the Save icon and Recall the file from Step 3 of Fig. 3-5

At this point, re-apply the baseband settings as mentioned in Fig. 3-6.

Frequency A: 1 000.000 000 000 MHz
Level A: −10.00 dBm
Signal Type A: Off
Frequency B: 1 000.000 000 000 MHz
Level B: −10.00 dBm
Signal Type B: Off
Fading: Off
Configuration: Standard/Fine Delay
Standard: User
Copy Path Group 1 To 2

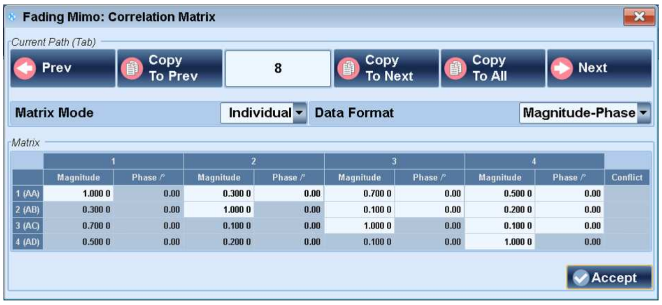
	1 - 1 Fine	1 - 2 Fine	1 - 3 Fine	1 - 4 Standard	1 - 5 Standard	2 - 1 Fine	2 - 2 Fine
Power Ratio /dB	10.00	0.00	0.00	0.00	0.00	10.00	
Frequency Spread	0.100 0	0.100 0	0.100 0	0.100 0	0.100 0	0.100 0	0.1
Const Phase /Deg	0.0	0.0	0.0	0.0	0.0	0.0	
Speed km/h	2.988	2.988	2.988	2.988	2.988	2.988	2
Freq. Ratio	0.50	1.00	1.00	1.00	1.00	0.50	
Freq. Shift /Hz	0.000 0	0.000 0	0.000 0	0.000 0	0.000 0	0.000 0	0.0
Res. Doppler Shift /Hz	2.77	2.77	2.77	2.77	2.77	2.77	
Coefficient	Matrix...	Matrix...	Matrix...	Matrix...	Matrix...	Matrix...	Matrix...
Lognormal State	Off	Off	Off	Off	Off	Off	Off
Local Constant /m	200.0	200.0	200.0	200.0	200.0	200.0	2
Standard Dev. /dB	0	0	0	0	0	0	

Fig. 3-8: Fading profile and antenna correlation matrix configuration

- Follow the sequence as shown in Fig. 3-8

NOTE: *In case of arbitrarily setting fading profile, set relevant fading profile, signal delay, speed etc. for all multipath signals (i.e. 1-1, 1-2,… ,2-1, 2-2…. and so on).*

- 1: Scroll down to coefficient parameter
- 2: Click on correlation matrix box



Current Path (Tab): 8

Matrix Mode: Individual

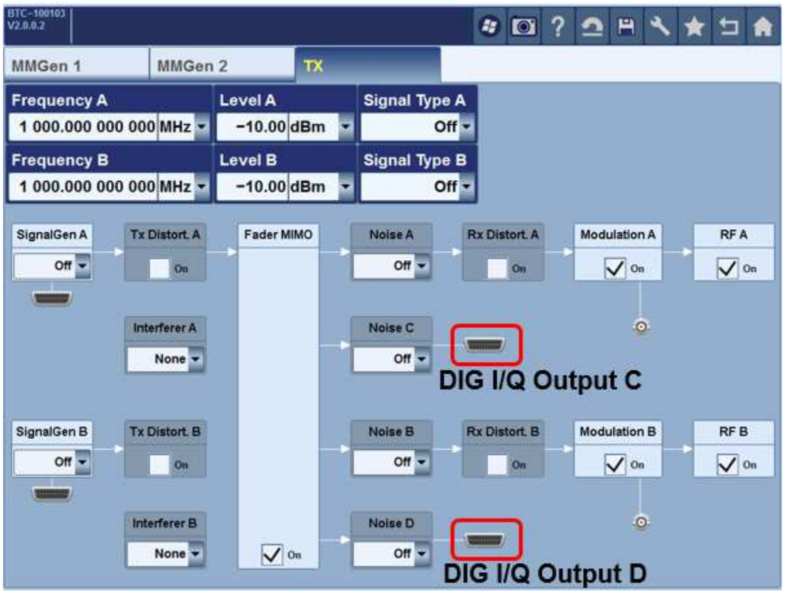
Data Format: Magnitude-Phase

	1		2		3		4		
	Magnitude	Phase /°	Magnitude	Phase /°	Magnitude	Phase /°	Magnitude	Phase /°	Conflict
1 (AA)	1.000 0	0.00	0.300 0	0.00	0.700 0	0.00	0.500 0	0.00	
2 (AB)	0.300 0	0.00	1.000 0	0.00	0.100 0	0.00	0.200 0	0.00	
3 (AC)	0.700 0	0.00	0.100 0	0.00	1.000 0	0.00	0.100 0	0.00	
4 (AD)	0.500 0	0.00	0.200 0	0.00	0.100 0	0.00	1.000 0	0.00	

Fig. 3-9: Correlation Matrix Configuration

- Set Correlation matrix as required
    - Select *Copy to All* and Accept
    -

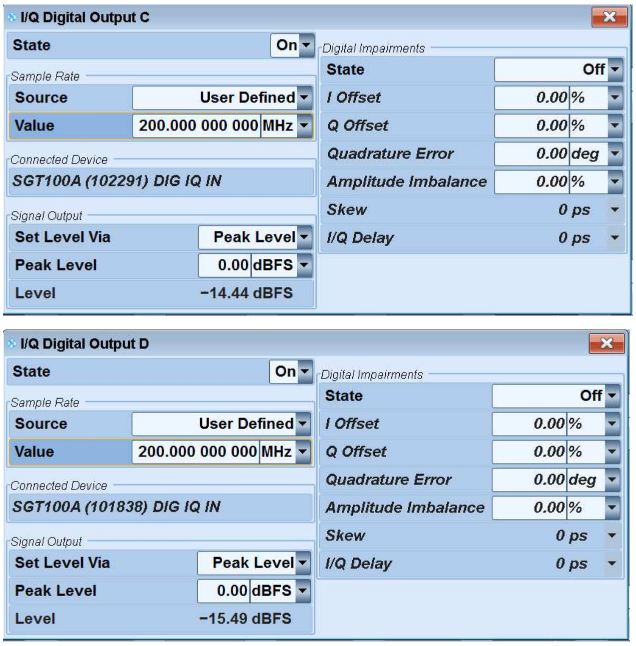
NOTE: *Fig. 3-9 shows a realistic setting of the correlation matrix, a detailed discussion on the topic can be found at the end of this application note in the* Appendix *section.*



Frequency A: 1 000.000 000 000 MHz
Level A: -10.00 dBm
Signal Type A: Off
Frequency B: 1 000.000 000 000 MHz
Level B: -10.00 dBm
Signal Type B: Off
SignalGen A: Off
Tx Distort. A: ☐ On
Noise A: Off
Rx Distort. A: ☐ On
Modulation A: ☑ On
RF A: ☑ On
Interferer A: None
Noise C: Off
SignalGen B: Off
Tx Distort. B: ☐ On
Noise B: Off
Rx Distort. B: ☐ On
Modulation B: ☑ On
RF B: ☑ On
Interferer B: None
Fader MIMO: ☑ On
Noise D: Off

Fig. 3-10: Main menu of TX Application on BTC

- Switch on Modulation A , RF A, Modulation B and RF B
- Next Click on Dig I/Q Output C and Dig I/Q Output D (Fig. 3-10)
    - Set I/Q Digital Output C and I/Q Digital Output D as shown in Fig. 3-11



I/Q Digital Output C

State: On

Sample Rate

Source: User Defined

Value: 200.000 000 000 MHz

Connected Device

SGT100A (102291) DIG IQ IN

Signal Output

Set Level Via: Peak Level

Peak Level: 0.00 dBFS

Level: −14.44 dBFS

Digital Impairments

State: Off

I Offset: 0.00 %

Q Offset: 0.00 %

Quadrature Error: 0.00 deg

Amplitude Imbalance: 0.00 %

Skew: 0 ps

I/Q Delay: 0 ps

I/Q Digital Output D

State: On

Sample Rate

Source: User Defined

Value: 200.000 000 000 MHz

Connected Device

SGT100A (101838) DIG IQ IN

Signal Output

Set Level Via: Peak Level

Peak Level: 0.00 dBFS

Level: −15.49 dBFS

Digital Impairments

State: Off

I Offset: 0.00 %

Q Offset: 0.00 %

Quadrature Error: 0.00 deg

Amplitude Imbalance: 0.00 %

Skew: 0 ps

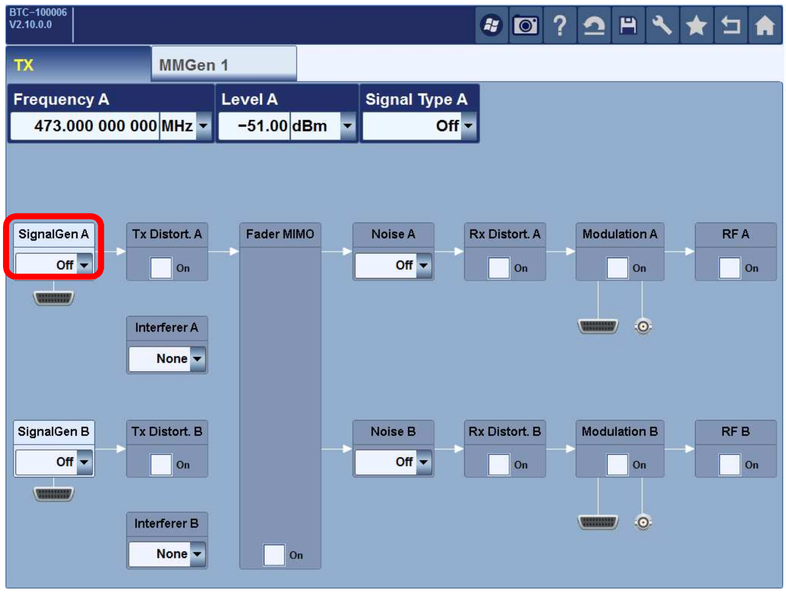
I/Q Delay: 0 ps

Fig. 3-11: I/Q Digital Output

- Configure both I/Q Digital Output C and D as shown in Fig. 3-11,
  - Switch State: On
  - Source: User Defined
  - Sample Rate Value: 200 MHz

The 1x4 spatial diversity MIMO channel simulation using BTC and SGT pair is now successfully implemented. Next, set the desired broadcast transmission standard and start receiver diversity measurements.

3.4 Generation of Signals with Different Transmission Standards



Frequency A: 473.000 000 000 MHz

Level A: −51.00 dBm

Signal Type A: Off

SignalGen A: Off

Interferer A: None

Noise A: Off

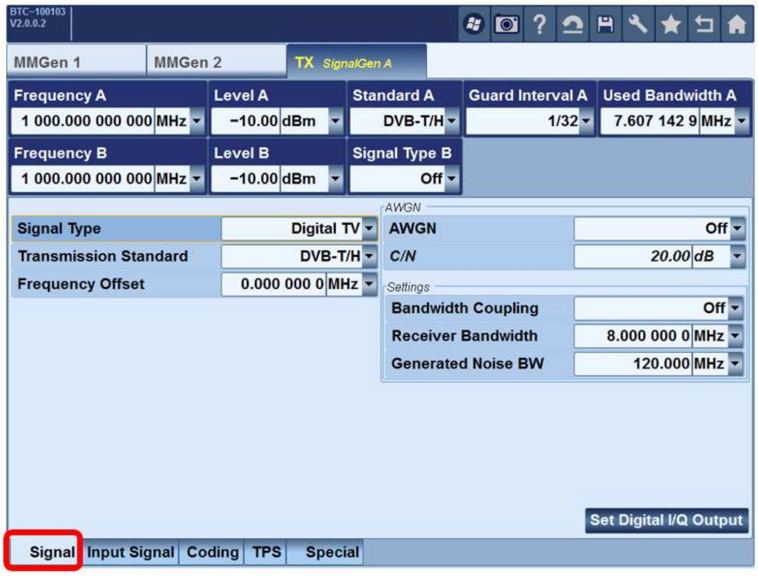
SignalGen B: Off

Interferer B: None

Noise B: Off

Fig. 3-12: Main Menu of the TX application of the BTC

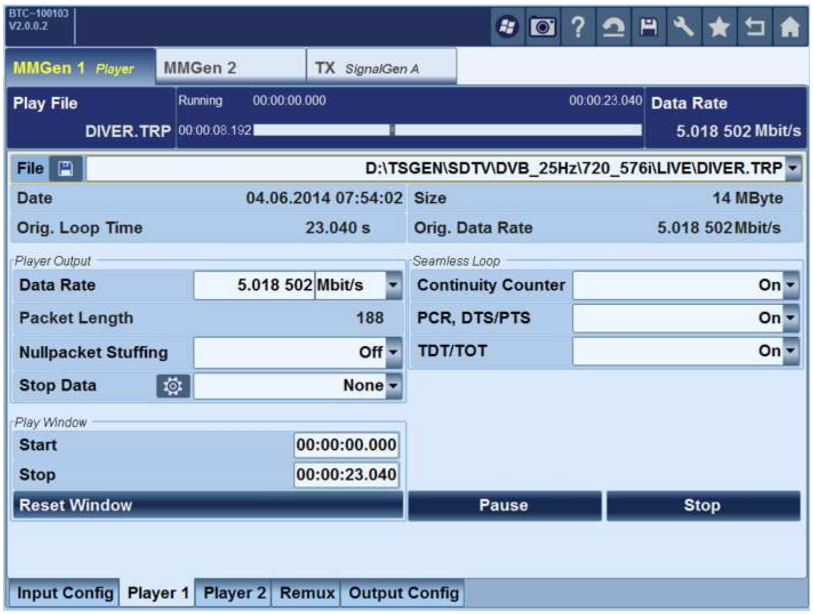
- Go in to *SignalGen A (shown in* Fig. 3-12*)*



Frequency A: 1 000.000 000 000 MHz
Level A: −10.00 dBm
Standard A: DVB-T/H
Guard Interval A: 1/32
Used Bandwidth A: 7.607 142 9 MHz
Frequency B: 1 000.000 000 000 MHz
Level B: −10.00 dBm
Signal Type B: Off
Signal Type: Digital TV
Transmission Standard: DVB-T/H
Frequency Offset: 0.000 000 0 MHz
AWGN: Off
C/N: 20.00 dB
Bandwidth Coupling: Off
Receiver Bandwidth: 8.000 000 0 MHz
Generated Noise BW: 120.000 MHz

Fig. 3-13: Transmission standard selection on BTC

- Click on *Signal* menu (Fig. 3-13)
  - Signal type : Digital TV
  - Transmission Standard: Select the required terrestrial standard (such as DVB-T, DVB-T2, ATSC, ISDB-T, DTMB, T-DMB)
  - Set Receiver Bandwidth as required
  - Next go in to *Input Signal* menu and set *Source* as *MM Generator*
- From Fig. 3-2, click on *MMGen 1* and then click on *Player*



Play File: DIVER.TRP
Running 00:00:00.000 00:00:23.040
00:00:08.192
Data Rate: 5.018 502 Mbit/s
File: D:\TSGEN\SDTV\DVB_25Hz\720_576i\LIVE\DIVER.TRP
Date: 04.06.2014 07:54:02
Size: 14 MByte
Orig. Loop Time: 23.040 s
Orig. Data Rate: 5.018 502 Mbit/s
Data Rate: 5.018 502 Mbit/s
Packet Length: 188
Nullpacket Stuffing: Off
Stop Data: None
Continuity Counter: On
PCR, DTS/PTS: On
TDT/TOT: On
Start: 00:00:00.000
Stop: 00:00:23.040

Fig. 3-14: MM Generator player setting

- Configure the MMGen 1 player as shown in Fig. 3-14
    - Select DIVER.TRP file from *D:\TSGEN\SDTV\DVB_25Hz\720_576i\LIVE\DIVER.TRP*

At this point, the instruments are properly configured and ready for testing the DUT receive diversity performance.

4 Appendix

Correlation Matrix Configuration

In order to test MIMO receivers under real-world conditions, a certain degree of correlation between the emulated radio channels has to be simulated. Channel correlation defines the coupling relationship between the signals transmitted over the individually faded channels. This coupling is quantified in terms of a correlation matrix.

The correlation between two fading paths is defined by a complex correlation coefficient that is a measure for the similarity of the two signals. The complex correlation coefficient is expressed as a pair of numbers in either Cartesian form (Real-Imag) or polar form (Magnitude-Phase). The polar form is perhaps more descriptive, since it directly gives the amplitude and phase relationship of the two signals. Perfect correlation means Magnitude = 1.00 and Phase = 0.00, whereas Magnitude = 0.00 and Phase = 0.00 means absolutely no correlation

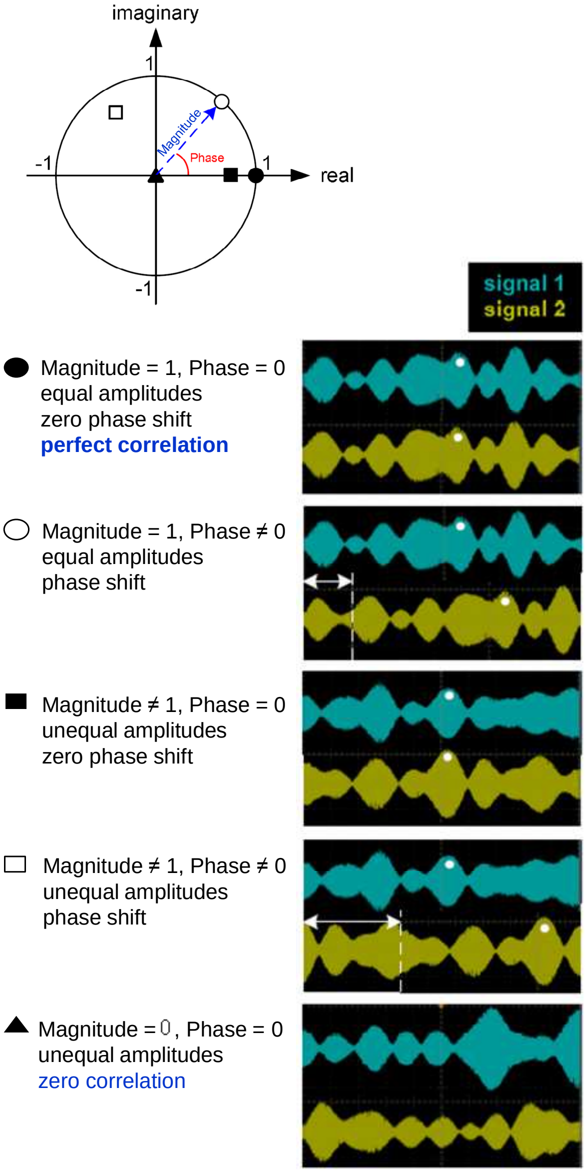


Fig. 4-1: Illustration of the complex correlation coefficient in polar form (Magnitude and Phase). Five example correlation coefficients are depicted. The corresponding correlations between two test signals are shown. [2]

In order to show the influence of the correlation for best case scenario, a 10 MHz frequency offset is set for all of the four RF paths. **Note: This is not a realistic scenario. The frequency offset is just needed here for demonstration purposes.**

In real MIMO applications the four TX signals are transmitted at the same center frequency.

RF A: 1000 MHZ, **RF B**: 990 MHz, **RF C**: 980 MHz, **RF D**: 970 MHz

Current Path (Tab): 1

Matrix Mode: Individual

Data Format: Magnitude-Phase

Matrix

	A		B		C		D		
	Magnitude	Phase /°	Magnitude	Phase /°	Magnitude	Phase /°	Magnitude	Phase /°	Conflict
1 (AA)	● 1.000 0	0.00	● 0.000 0	0.00	● 0.000 0	0.00	0.000 0	0.00	
2 (AB)	0.000 0	0.00	● 1.000 0	0.00	● 0.000 0	0.00	0.000 0	0.00	
3 (AC)	0.000 0	0.00	0.000 0	0.00	● 1.000 0	0.00	0.000 0	0.00	
4 (AD)	0.000 0	0.00	0.000 0	0.00	0.000 0	0.00	1.000 0	0.00	

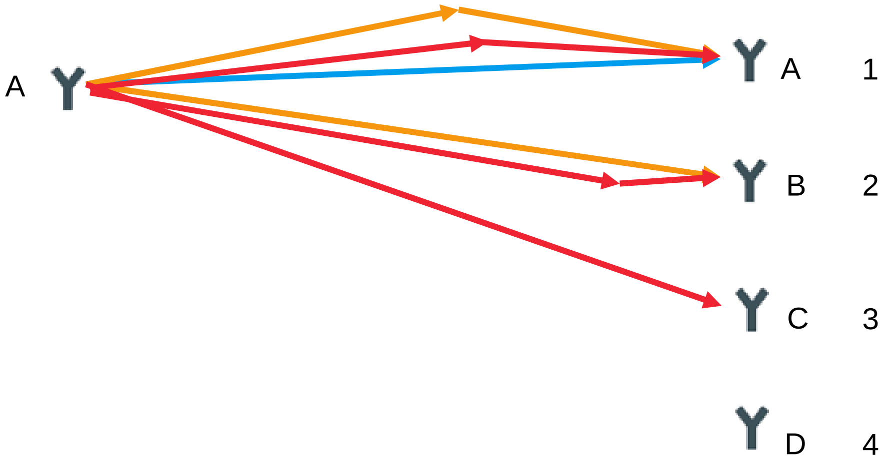


Fig. 4-2: Best case scenario for antenna correlation

Fig. 4-2 shows the best case scenario, Transmit TX (A) to Receive RX (A) has a correlation of 1.00. The second transmission AB direct line of sight connection has 1.00 correlation, the coupling because of AB transmission has no correlation. The transmission channels are colored in orange. The AC LOS connection has 1.00 correlation, the two other AA and AB has no correlation. The channel for AC case is marked in red. The forth channel for AD is not shown for clarity. This is best case scenario because all direct line of sight connection are statistically independent.

The spectrum for this scenario is shown in Fig. 4-3. All the 4 channels are statistically independent of each other.

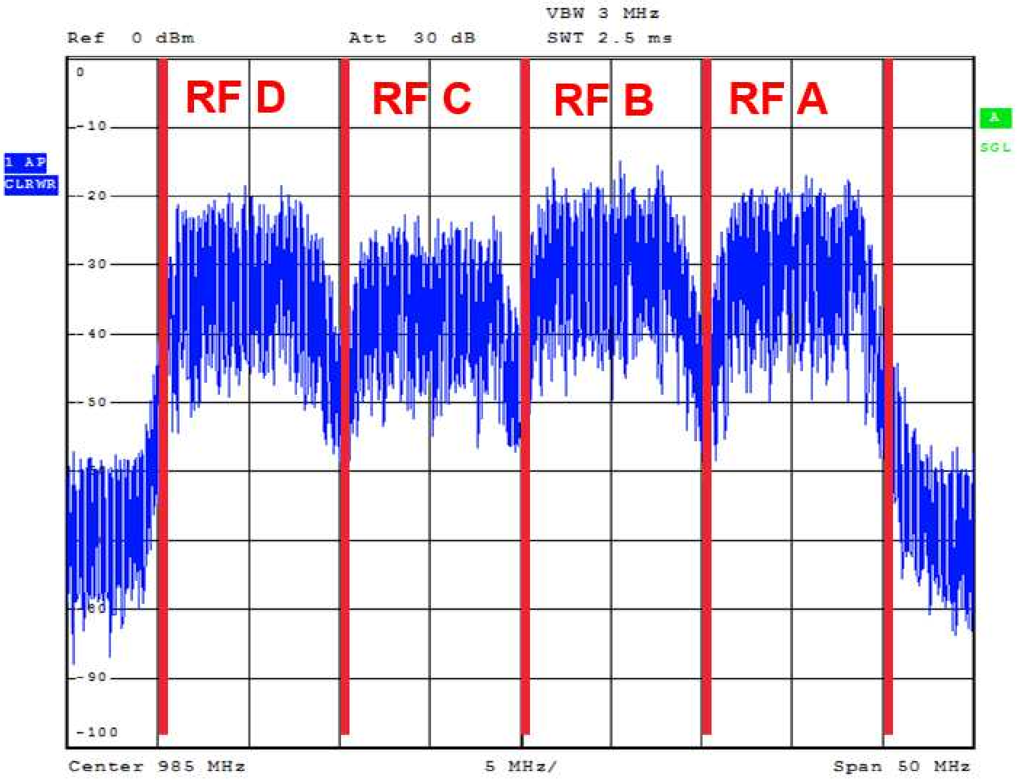
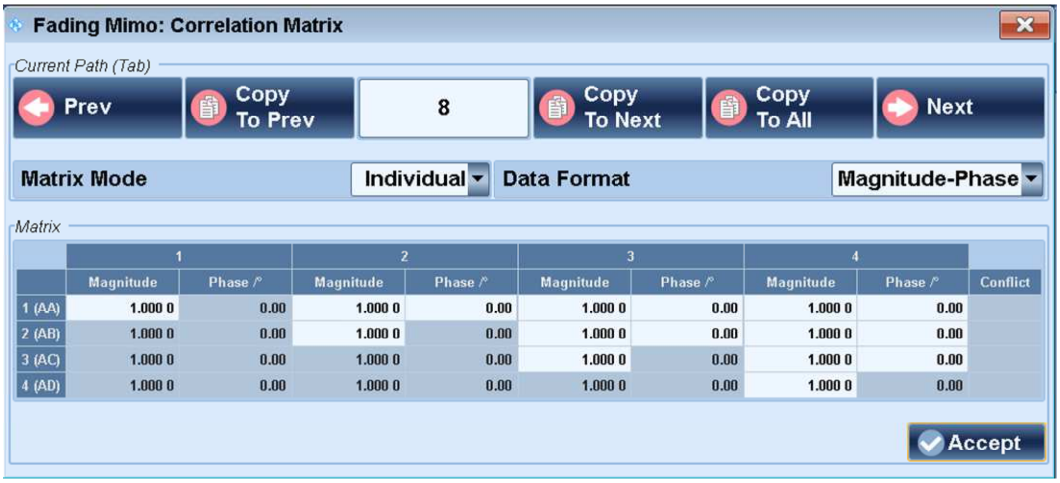


Fig. 4-3: Spectrum demonstrating all statistically independent channels

In order to show the influence of the correlation for worst case scenario, a 10 MHz frequency offset is set for all of the four RF paths. **Note: This is not a realistic scenario. The frequency offset is just needed here for demonstration purposes.**

In real MIMO applications the four TX signals are transmitted at the same center frequency.

RF A: 1000 MHZ, **RF B**: 990 MHz, **RF C**: 980 MHz, **RF D**: 970 MHz



Fading Mimo: Correlation Matrix

Current Path (Tab): 8

Matrix Mode: Individual

Data Format: Magnitude-Phase

Matrix

	1		2		3		4		
	Magnitude	Phase /°	Magnitude	Phase /°	Magnitude	Phase /°	Magnitude	Phase /°	Conflict
1 (AA)	1.000 0	0.00	1.000 0	0.00	1.000 0	0.00	1.000 0	0.00	
2 (AB)	1.000 0	0.00	1.000 0	0.00	1.000 0	0.00	1.000 0	0.00	
3 (AC)	1.000 0	0.00	1.000 0	0.00	1.000 0	0.00	1.000 0	0.00	
4 (AD)	1.000 0	0.00	1.000 0	0.00	1.000 0	0.00	1.000 0	0.00	

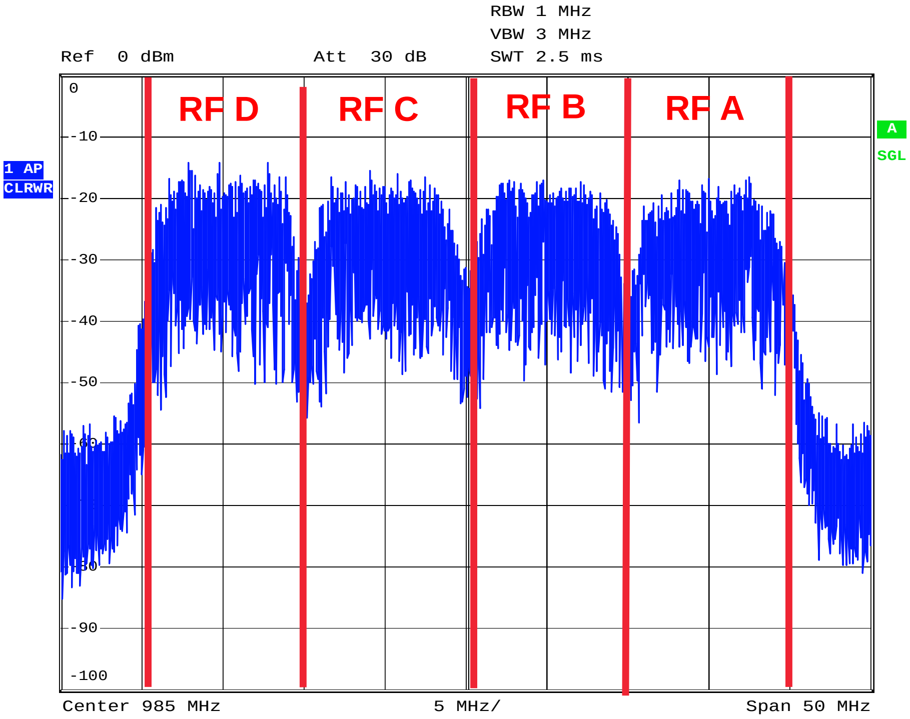


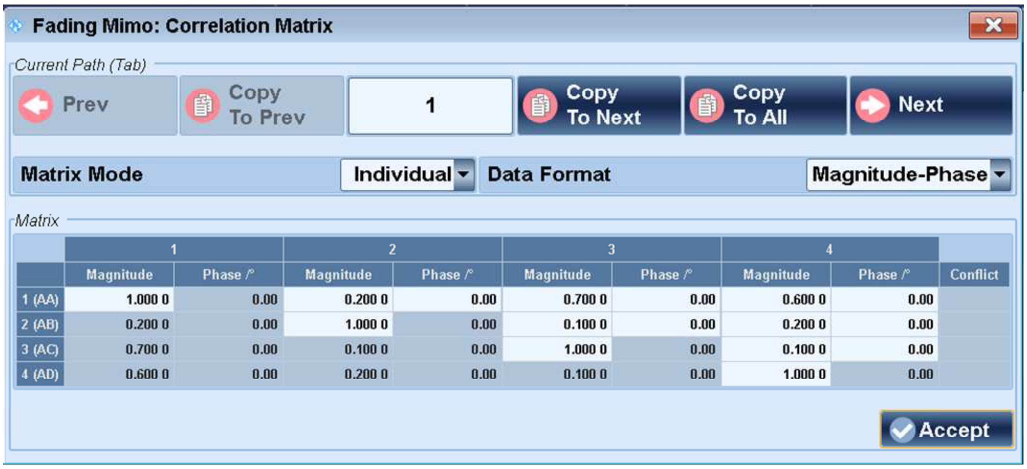
Fig. 4-4: Spectrum demonstrating all statistically dependent channels (Worst case scenario)

Fig. 4-4 shows the worst case scenario. All streams are statistically dependent. This means that all the transmission channels undergo the same fading effects. In case of a deep fade, all channels would be effected the same way and the receive data throughput would drop significantly. Therefore, MIMO diversity benefit is not experienced here at all.

In order to show the influence of the correlation for a real world scenario, a 10 MHz frequency offset is set for all of the four RF paths. **Note: This is not a realistic scenario. The frequency offset is just needed here for demonstration purposes.**

In real MIMO applications the four TX signals are transmitted at the same center frequency.

RF A: 1000 MHZ, **RF B**: 990 MHz, **RF C**: 980 MHz, **RF D**: 970 MHz



Current Path (Tab): 1

Matrix Mode: Individual

Data Format: Magnitude-Phase

Matrix

	1		2		3		4		
	Magnitude	Phase /°	Magnitude	Phase /°	Magnitude	Phase /°	Magnitude	Phase /°	Conflict
1 (AA)	1.000 0	0.00	0.200 0	0.00	0.700 0	0.00	0.600 0	0.00	
2 (AB)	0.200 0	0.00	1.000 0	0.00	0.100 0	0.00	0.200 0	0.00	
3 (AC)	0.700 0	0.00	0.100 0	0.00	1.000 0	0.00	0.100 0	0.00	
4 (AD)	0.600 0	0.00	0.200 0	0.00	0.100 0	0.00	1.000 0	0.00	

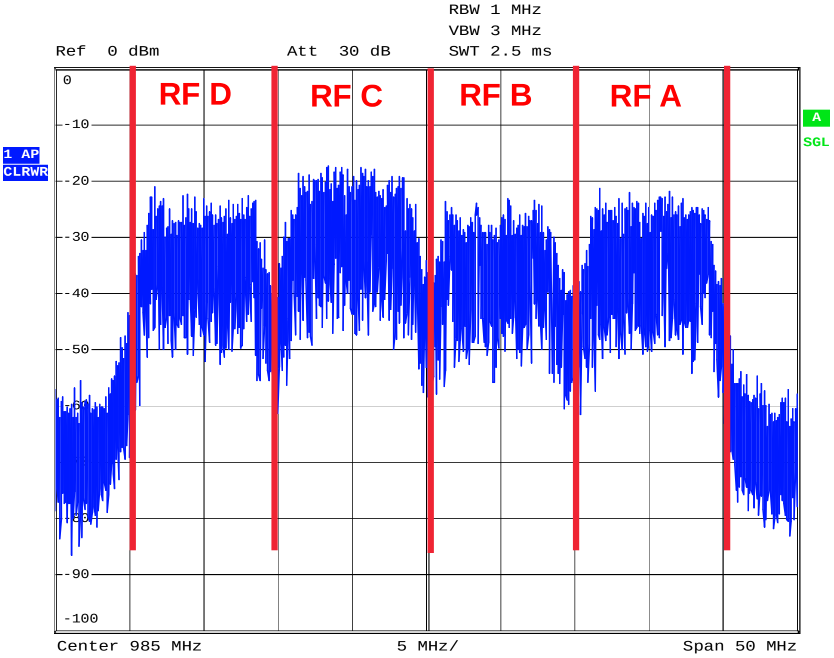


Fig. 4-5: Spectrum demonstrating all statistically dependent channels (Real World scenario)

Fig. 4-5 shows the spectrum derived from the correlation matrix of a real world scenario where each channel has a bit of coupling with all other antennas in the MIMO system. Of course, in addition to the amplitude variation, there would also be phase offsets. However, if the antennas are positioned far apart from each other and have a high degree of isolation, the coupling ratio could also be zero. The correlation matrix would have to be adjusted as per testing requirement.

5 Literature

1. 1MA142: Introduction to MIMO, Schindler, Schulz, Application Note, Rohde & Schwarz
2. 1GP51: Guidelines for MIMO Test Setups, C. Tröster, Application Note, Rohde & Schwarz
3. 7BM05: Fading Channel Simulation in DVB, Application Note, Rohde & Schwarz

6 Ordering Information

Designation	Type	Order No.
Broadcast Test Center*		
R&S®BTC	Broadcast Test Center	2114.3000.02
R&S®BTC-B3106	Frequency range 100 kHz up to 6 GHz, RF Path A	2114.3200.02
R&S®BTC-B3206	100 kHz to 6 GHz, RF path B	2114.3400.02
R&S®BTC-B1	Baseband Generator 1st channel	2114.3500.02
R&S®BTC-B2	Baseband Generator 1st channel	2114.3600.02
R&S®BTC-K2500	Extended I/Q Interfaces Analog and digital IQ-Inputs and Outputs Enables installed hardware interfaces	2114.7293.02
R&S®BTC-B11	Baseband Main Module, one I/Q path to RF	2114.6500.02
R&S®BTC-B12	Baseband Main Module, two I/Q paths to RF	2114.6600.02
R&S®BTC-B3100	Low Phase Noise	2114.6000.02
R&S®BTC-B1031	Path A Fading Simulator	2114.3700.02
R&S®BTC-B1032	Path B Fading Simulator	2114.3800.02
R&S®BTC-B1034	Fading Simulator (path A and path B)	2114.3900.02
R&S®BTC-K1034	MIMO Fading and Routing 20 Path, Bandwidth 160 MHz	2114.7064.02
R&S®BTC-K1031	Dynamic Fading Additional fading profiles Birth Death, Moving propagation and more	2114.7158.02
R&S®BTC-K1040	AWGN Generator Package up to 160 MHz bandwidth, additive white Gaussian noise, option package (2 paths)	2114.7770.02
R&S®BTC-K20	Multimedia Generation Suite	Included with base unit
R&S®BTC-K501	DVB-T DVB-H, realtime coder, 2 k-, 4k- and 8k mode	2114.6980.02
R&S®BTC-K502	J.83/A/B/C Coder (DVB-C, US-Cable, ISDB-C) realtime coder, 16, 32, 64, 128, 256QAM up to 8 Msymb/s 64, 256, 1024QAM, up to 5.36Msymb/s	2114.6997.02
R&S®BTC-K516	DVB-T2 Coder	2114.7035.02

R&S®BTC-K518	ATSC M/H, 8VSB Coder	2114.7135.02
R&S®LIB-K56	ATSC and ATSC Mobile DTV streams	2116.9412.02
R&S®LIB-K57	DVB-T2 MI Streams	2116.9429.02
SGMA Vector RF Source*		
R&S®SGT100A	SGMA Vector RF Source	1419.4501.02
R&S®SGT-KB106 (optional)	Frequency extension to 6 GHz	1419.5708.02
R&S®SGT-K18	Digital Baseband Connectivity	1419.6240.02
R&S®SMU-Z6	Cable for connecting R&S®Digital I/Q Interfaces	1415.0201.02

*Other signal generator are available as well. More Options are available. The instrument's minimum configuration for this application is shown in the table. Please ask your local representative for a suitable configuration according to your needs.

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Sustainable product design

- Environmental compatibility and eco-footprint
- Energy efficiency and low emissions
- Longevity and optimized total cost of ownership

Certified Quality Management
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