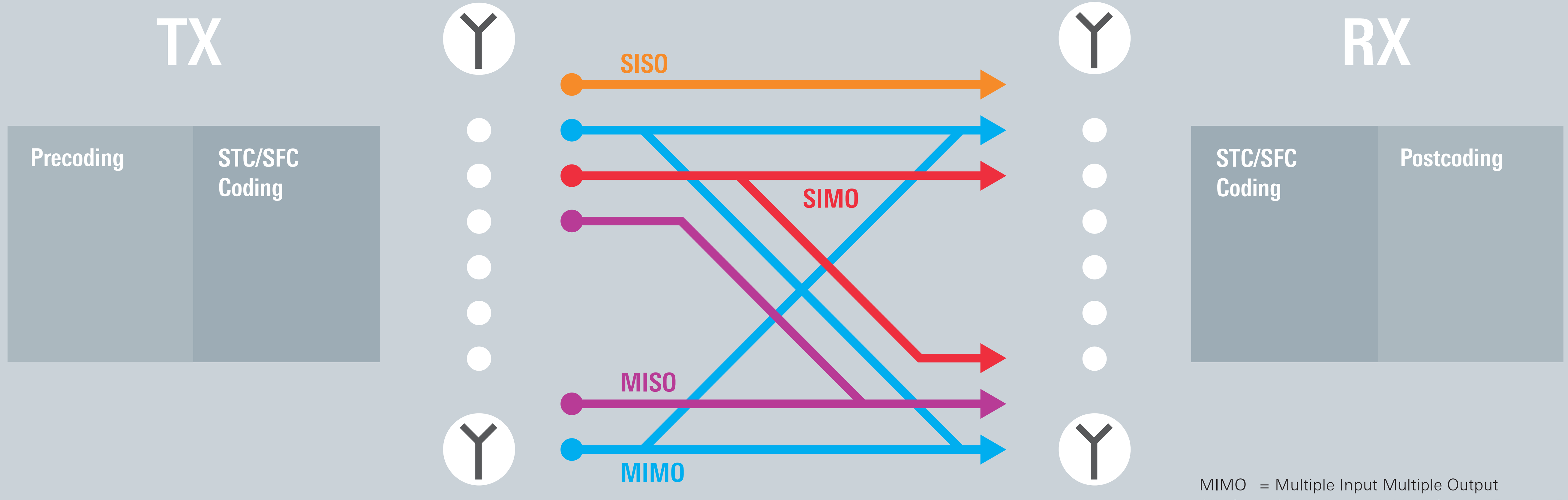
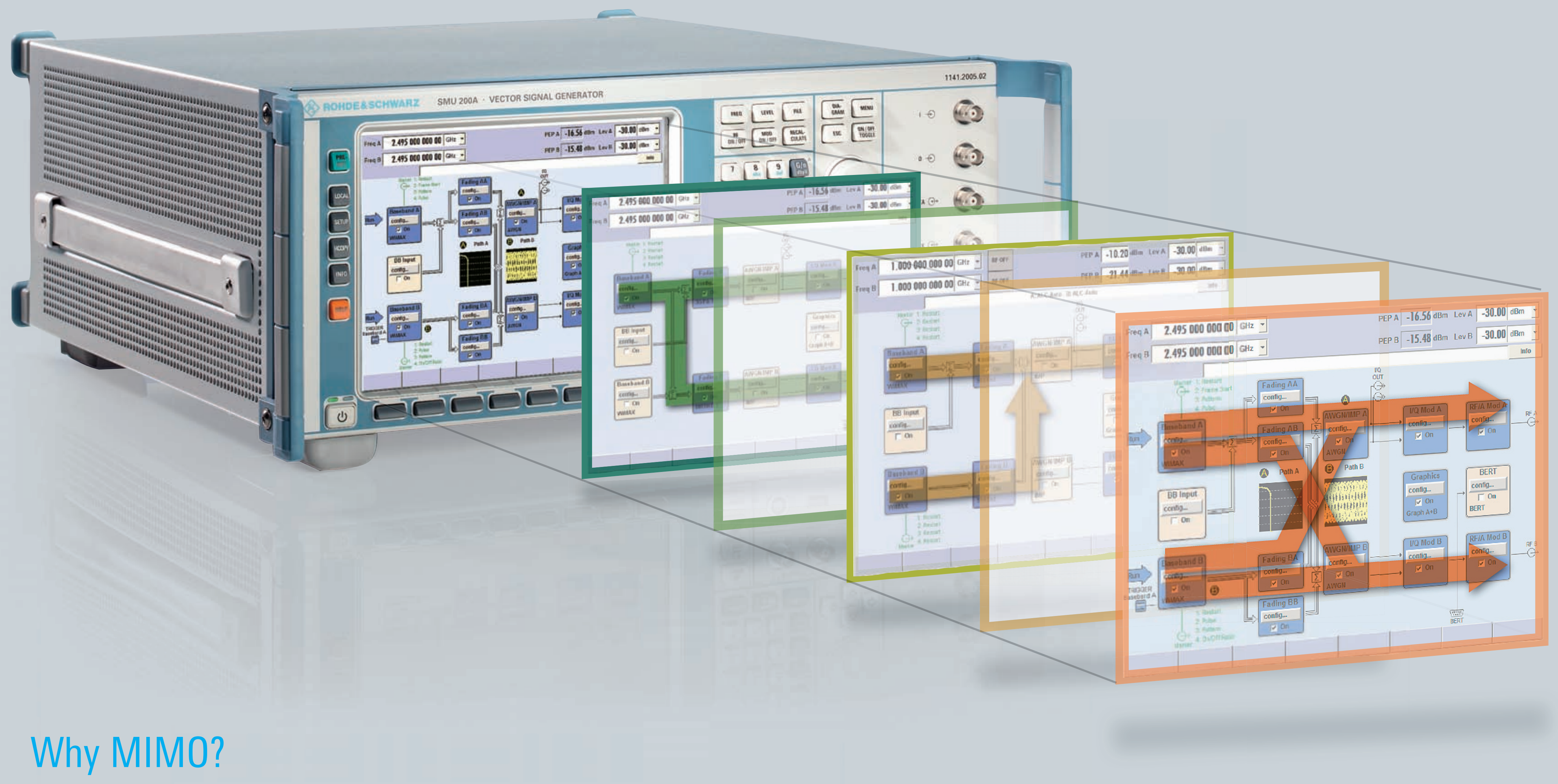
MIMO
Technical Overview



MIMO = Multiple Input Multiple Output
SIMO = Single Input Multiple Output (Receive Diversity)
MISO = Multiple Input Single Output (Transmit Diversity)
SISO = Single Input Single Output



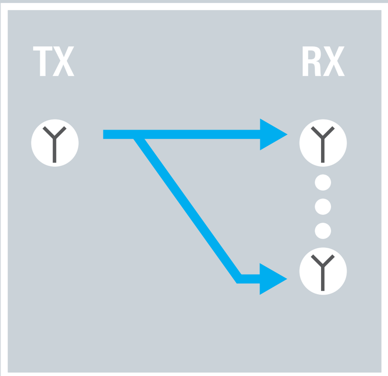


Figure 1:
Schematic of a receive diversity or SIMO (Single Input Multiple Output) system

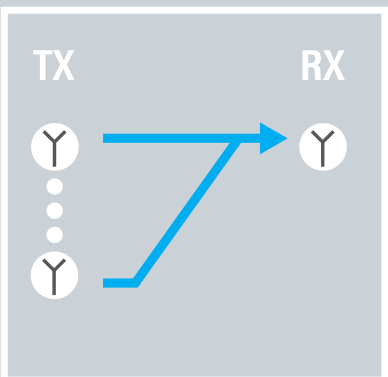


Figure 2:
Schematic of a transmit diversity or MISO (Multiple Input Single Output) system

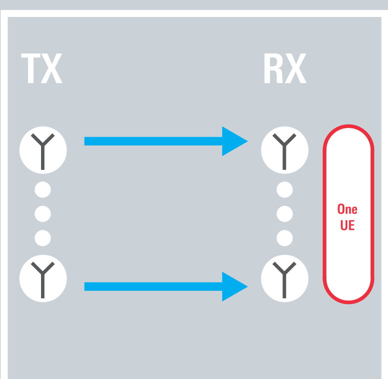


Figure 3:
Schematic of an SDM MIMO (Multiple Input Multiple Output) system

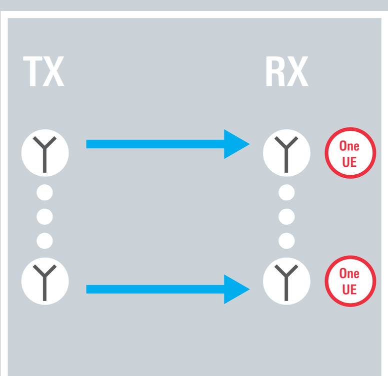


Figure 4:
Schematic of an SDMA MIMO system

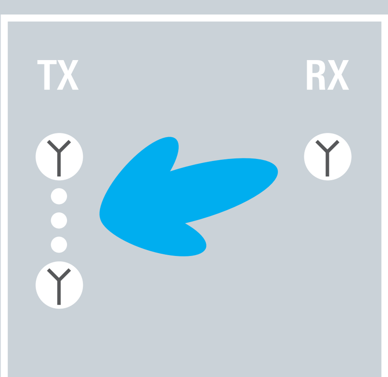


Figure 5:
Schematic of a beamforming system

Why MIMO?

Earlier generations of mobile communications systems concentrated on manipulating both frequency and the time dimension to maximize data throughput.
The variations caused by multiple signal paths were regarded as a disadvantage to be minimized. With the benefits of today's higher computing power, multiple-input, multiple-output (MIMO) antenna technology deliberately uses multiple signal paths to transmit more data and to increase data throughput. With MIMO, a matrix of channels is created using multiple antennas at multiple locations to provide additional multiple signal paths.

Orthogonal frequency division multiplexing (OFDM) transmission technology is essential to MIMO. It transmits multiple signals simultaneously over a large number of carriers that are spaced at precise frequencies. For MIMO, the critical benefit of OFDM is its high robustness against fast multipath fading. Additional OFDM benefits include higher spectral efficiency and resilience to RF interference.

MIMO: Improving Service in All Directions

MIMO technology supports several techniques to improve performance:

Receive and Transmit Diversity
By adding transmission or reception antennas – thus resulting in more signal paths – the signal-to-noise ratio is increased. As the signal quality is improved, the data rate also increases. Any system that has 2x2 (or more) antennas requires the use of space-time or space-frequency codes to transmit multiple copies of a data stream. This ensures that enough copies of the stream reach the receiver in a condition that is sufficient for reliable decoding (Fig. 1+2).

Space Division Multiplexing (SDM)
In a 2x2 system, the ideal approach is to double the data rate as compared to SISO by transmitting independent and separately encoded data signals known as streams from each transmit antenna. The space dimension is reused, i.e. multiplexed. SDM is also referred to as single-user MIMO or spatial multiplexing (Fig. 3).

Space Division Multiple Access (SDMA)
Cell capacity can be increased by using feedback about the signal-to-noise ratio from each stream for each user in order to select the stream most effective for the user. SDMA is also referred to as multi-user MIMO or virtual/collaborative MIMO. The radiation pattern of the base station – both in transmission and reception – is adapted to each user to obtain the highest possible gain for the user.

The performance of all modes mentioned above can be improved by spacing the multiple antennas as far apart as possible to minimize correlation between fading channels (Fig. 4).

Beamforming
In earlier cellular network systems, the base station radiated the signal equally in all directions because it had poor information about the position of the mobile units. This resulted in wasted transmission to points with no users as well as interference in adjacent cells. MIMO antennas use spatial information to improve performance in selected directions (Fig. 5).

Beamforming creates beams in a signal from a base station in order to increase signal power and to improve the signal-to-noise ratio in a specific direction.
The increase that is obtained when compared with omnidirectional transmission is known as the transmission gain. Beamforming controls the phase and relative amplitude of the signal at each transmitter in order to create a pattern of constructive and destructive interference in the wavefront. Beamforming is most effective when the antennas are spaced at half the wavelength.

Why is Fading a Must for Testing MIMO Systems?

To distinguish between the signals from each transmission antenna, MIMO makes use of the different fading characteristics of the individual channels as well as coding. In an ideal world, each MIMO antenna would transmit signals that are not influenced at all by signals transmitted by other antennas in the system. But in the real world, the spatial separation between antennas is too small to avoid crosstalk between antennas. Therefore, the fading characteristics of channels are correlated in amplitude, delay, and phase.

As a result, realistic receiver tests in a MIMO system require not only the generation of a standard-conforming signal for each transmission antenna but a fading simulator as well. The only way to achieve truly useful conformance and performance test results is to simulate multiple faded channels, including the simulation of complex correlation factors between the channels.

Rohde & Schwarz Supports MIMO Testing

Performance tests on MIMO receivers require not only a multiple vector signal generator but a multichannel fading simulator as well. The R&S®SMU200A vector signal generator can do all this in one box. For tests on a 2x2 MIMO receiver, two standard-conforming signals may be generated and four fading channels simulated.
The same functionality is available for the R&S®AMU200A baseband generator and fading simulator.

For a complete test scenario, the analysis of MIMO signals is also necessary. The R&S®FSQ from Rohde & Schwarz offers MIMO functionality for LTE, Mobile WiMAX 16e, and WLAN 11n. The MIMO functionalities in the R&S®TS89xx conformance test systems are flexible and standard-conforming.

MIMO implementation in standards

MIMO Parameters in	Mobile WiMAX™	HSPA+	LTE	IEEE 802.11n	1xEV-DO Rev C
Tx Diversity	Yes	Yes	Yes	Yes	Yes
DL Spatial Multiplexing	Yes	Yes	Yes	Yes	Yes
DL Beamforming	Yes	Yes	Yes	Yes	Yes
DL Precoding	Yes	Yes	Yes	Yes	Yes
DL Space Time Coding (STC) / DL Space Frequency Coding (SFC)	STC		SFC	STC	STC
UL Multi User MIMO / Collaborative MIMO	Yes		Yes	Yes	
max Number of BS Antennas	2 (8 partly for Beamforming)	2 (4)	4	4	4
max Number of MS Antennas	2 (8 partly for Beamforming)	2	2 (4)	4	4
Implementation	mandatory	optional	mandatory	mandatory	

Mobile WiMAX is a trademark of the WiMAX Forum.

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