From SISO to MIMO – taking advantage of everything the air interface offers

In the heated race among mobile radio standards to improve transmission rates and reliability, spectral efficiency, network coverage, etc, the resource space as part of the air interface is increasingly becoming the focus of attention. Irrespective of the mobile radio standard, there is room for improvement in both transmission reliability and data throughput. This article describes how multiple antenna systems can fully utilize this resource and how such systems can be tested. Part 1 discusses SIMO and MISO systems; part 2, which will be published in News from Rohde & Schwarz 194, deals with MIMO systems.

Many paths, one destination: optimum reception quality

In classic TV broadcasting, multipath reception was undesired due to its impairing effect of producing ghost pictures, but in digital mobile radio it is used to improve transmission. Each additional transmission path used by a transmitter to reach a receiver increases reception performance and improves the signal-to-noise ratio (SNR). Multipath reception eases the effects of the strong receive level fluctuations a single transmission channel is subjected to in mobile operation. The probability that several channels are impassable at the same time is far smaller than if only one channel is used.

Another way to reduce strong receive level fluctuations and thus increase the transmission quality is the frequency hopping method specified in the GSM standard. In addition, suitable coding (e.g. interleaving) reduces the effects of short interruptions in transmission.

A yet unutilized means of improving the transmission quality is the use of additional antennas at the transmitter and / or receiver end. Various alternatives are available, depending on the antenna configuration (see box below).

From SISO to MIMO: diversities at a glance

SISO Single Input Single Output The classic and easiest way: one transmitting and one receiving antenna.

SIMO Single Input Multiple Output One transmitting and several receiving antennas. Is also often referred to as receive diversity. With reference to the downlink, this means one transmitting antenna at the base station and more than one receiving antenna at the mobile radiotelephone.

MISO Multiple Input Single Output Several transmitting antennas and one receiving antenna. Is also referred to as transmit diversity. With reference to the downlink, this means more than one transmitting antenna at the base station and one receiving antenna at the mobile radiotelephone.

MIMO Multiple Input Multiple Output Complete expansion: N transmitting antennas provide signals to M receiving antennas.

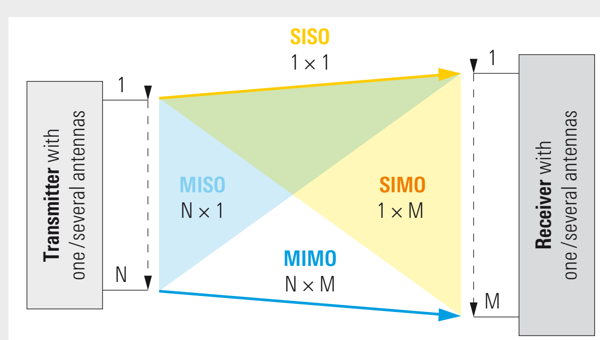

FIG 1 The different diversities at a glance.

SIMO – one transmitting antenna, multiple receiving antennas

The transmit signal of an antenna reaches a receiver with multiple antennas (FIG 2). There are various ways of evaluating these antenna signals (FIG 3). With switched diversity, the receiver always evaluates only the strongest receive signal and discards the weaker signals. Performance is best improved by maximum ratio combining (MRC): The sum of all signals is evaluated and nothing is lost.

MISO – multiple transmitting antennas, one receiving antenna

Several transmitting antennas provide signals for one antenna at the receiver. The following methods can be used, depending on what is emitted via the antennas:

Transmit diversity

With this method, the same signal is emitted via antennas that are situated close to each other. The geometric antenna arrangement ensures that a stronger signal arrives at the receiver. Multiple power amplifiers and antennas are therefore required at the transmitter end. Since the antennas are close to each other, the paths are largely correlated, considerably limiting the potential benefit.

Space time block coding

The special feature of this method is not only that the same signal is emitted at two antennas that are located close to each other but also that different data blocks that are appropriately related to each other are sent: With space time block coding (STBC) in accordance with Alamouti, two different data blocks (d_1, d_2) are sent in a first step (FIG 4). In a second step, these two blocks are sent once more; but this time, block d_1 is sent in complex conjugation and block d_2 in complex conjugation with inverted sign. The data blocks are also sent with reversed antenna roles. This does not increase the transmission rate but significantly improves transmission reliability and coverage.

Currently defined test scenarios – that's how they are tested

GSM DARP phase 2

3GPP TS 45.005, release 7, annex N, defines test scenarios for a SIMO system with two receiving antennas. It is referred to as a Single Input Dual Output (SIDO) system (FIG 5).

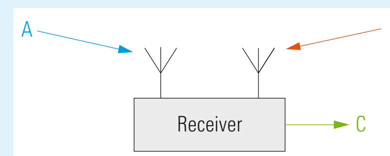

FIG 2 The transmit signal of an antenna reaches a receiver with multiple antennas.

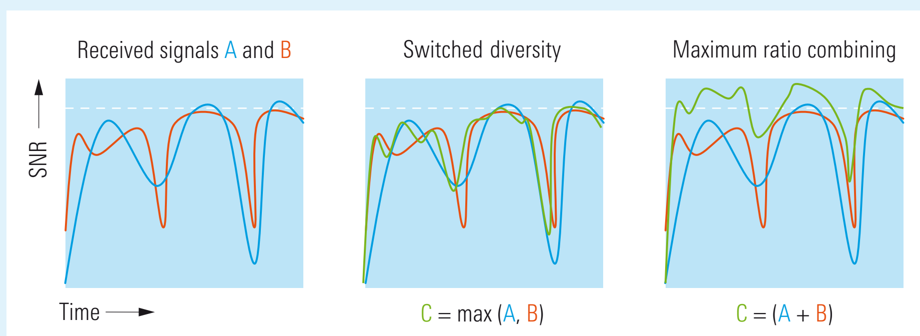

FIG 3 Comparison between switched diversity and maximum ratio combining at a receiver with two antennas.

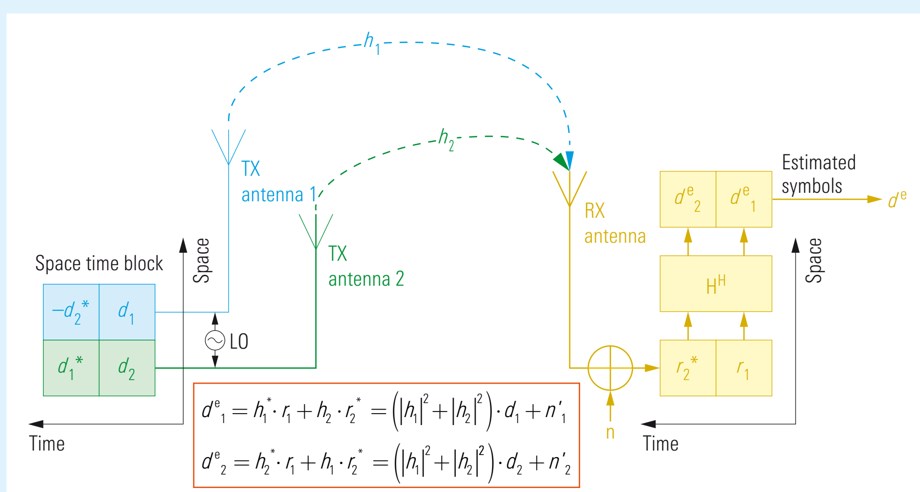

FIG 4 Dual Input Single Output (DISO) with space time block coding in accordance with Alamouti. Here, the mobile radiotelephone "sees" two different data streams (e.g. STBC) at an antenna which are generated by the signaling unit. From the base station emulator's point of view, two downlink signals with different data and correlated fading conditions are generated. The two signals are added after the fading process.

The base station emulator generates two downlink signals (referred to as "TX wanted" in FIG 5) with identical data content and correlated fading profiles. Thus, no additional demands are placed on this emulator.

To test real-world scenarios at the receiver, different combinations of modulated interferers (co-channel and adjacent-channel interferers) and additive white Gaussian noise (AWGN) are applied to the two inputs of the mobile radiotelephone. These combinations are distributed among the two antennas (FIG 5). The co-channel interferer superimposes the downlink signal on the same frequency, while the adjacent-channel interferer is available one channel (200 kHz) next to this. As far as time is concerned, both interferers match the downlink signal.

You can thus implement a model for multi-interferer scenarios very easily using Rohde & Schwarz equipment (FIG 6). The signaling unit (the R&S®CRTU-G protocol tester or the R&S®CMU 200 radiocommunication tester) generates the downlink signal TX 1 (wanted signal), which is distributed by the R&S®AMU 200 A fading simulator (see box below) among the two receive paths using two correlated fading profiles. The correlation factor between the two fading profiles can be set. The interferer can be generated in various ways; see the following example:

R&S®SMU 200 A with two RF outputs (up to 3 GHz)

A baseband unit of the R&S®SMU 200 A vector signal generator generates a modulated interferer (in the baseband). The two fading modules provided in the generator then perform correlated fading for the two outputs. Two RF interferers with correlated fading are thus obtained by means of the two RF frontends (FIG 7).

WCDMA

Receive diversity

3GPP TS 34.121, release 6, defines tests for a Single Input Dual Output (SIDO) system. As with GSM, the objective is to improve transmission in the downlink by means of an additional receiving antenna. In contrast to GSM, the fading profiles are not correlated and, apart from one AWGN interferer per antenna, no other scenarios with interferers are planned. Thus, the GSM test configurations also apply to WCDMA, with only minor simplifications required.

R&S®AMU 200 A baseband signal generator and fading simulator

The new R&S®AMU 200 A combines the functionalities of a realtime I/Q source, an arbitrary waveform generator, and a channel simulator in a single box. Even complex signal scenarios can be easily generated due to the optional two-path capability. The impact of interfering signals, noise, multipath propagation, and antenna diversity on the function of a DUT can very easily and reproducibly be simulated using a single instrument.

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The most important features:

- Two-channel fading simulator; supports predefined fading scenarios
- Arbitrary waveform generator with 16 / 64 / 128 Msamples
- Scalable platform
- One or two signal paths
- Supports many digital standards such as GSM/EDGE, 3GPP FDD, CDMA2000®, LTE/EUTRA, TD-SCDMA, WLAN, WiMAX, DVB-H, GPS, etc
- Wide range of signal inputs and outputs
- Three-year calibration cycle

The R&S®AMU 200 A baseband signal generator and fading simulator will be described in further detail in the next issue of News from Rohde & Schwarz.

Transmit diversity

Transmit diversity is already used with WCDMA, and test solutions are available, e.g. the R&S®TS 8950 W WCDMA test system including a built-in R&S®CRTU-W.

WiMAX (IEEE 802.16e)

The tests defined in Wave 1 are all based on SISO; the validation of these tests began at the end of 2006. With Wave 2, real MIMO with multiple transmitting and multiple receiving antennas including beamforming (due to the directionality of the antenna array of the base station, the transmission lobe follows the movement of the mobile radiotelephone) will be possible in the course of this year. The discussion about the implementation is in full swing.

Unfortunately, complete specifications and scenarios for testing MIMO systems are currently (i.e. March 2007) not yet available. Part two of this article will be published in News from Rohde & Schwarz 194 and deal with MIMO's remarkable capabilities and, above all, with testing such systems.

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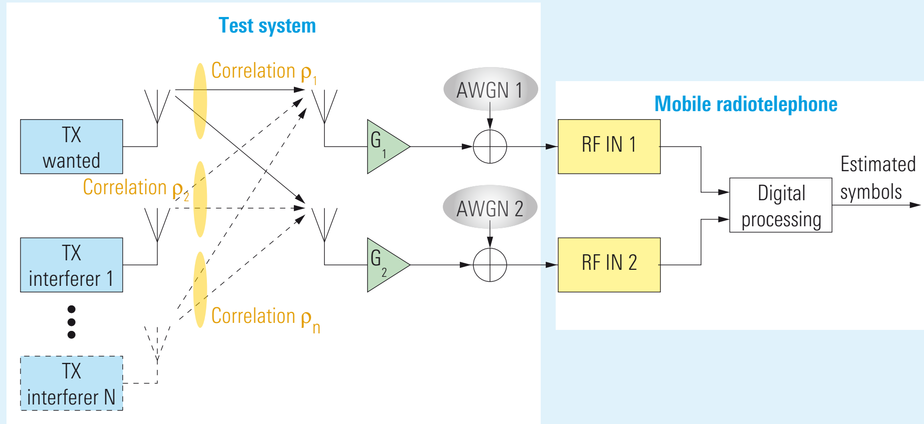

FIG 5 Channel model of tests in line with GSM DARP Phase 2. "TX wanted" refers to the downlink signal transmitted to the two receiving antennas via correlated multipath propagation (correlation factor ρ). G_1 and G_2 symbolize the different gain of the two mobile radiotelephone antennas. AWGN 1 / 2 are the two noise sources, which – like the modulated TX interferers – belong to the real-world scenario. The modulated interferers are subjected to correlated fading. RF IN 1 / 2 are the two inputs of the mobile radiotelephone.

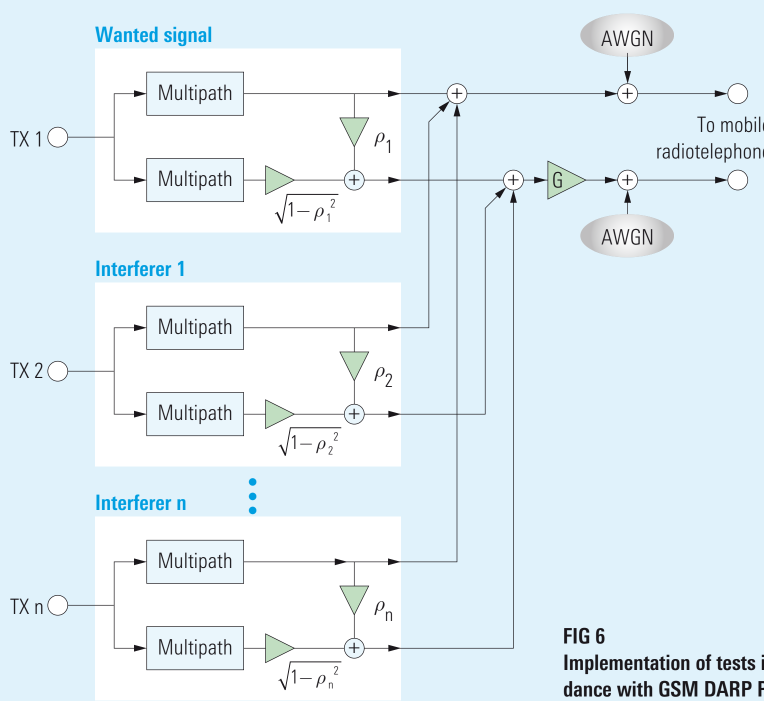

FIG 6 Implementation of tests in accordance with GSM DARP Phase 2

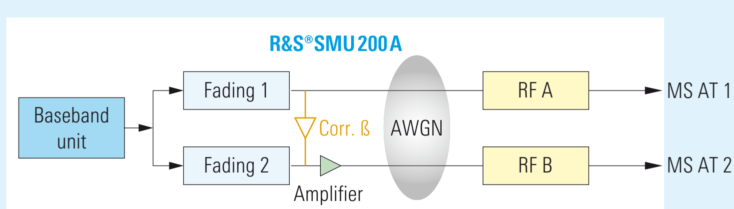

FIG 7 An R&S®SMU 200 A with one baseband unit generates a modulated interferer, which is subjected to correlated fading at the two RF outputs.