



# **Qosmotec**

## **Software Solutions GmbH**

### **Technical Overview**

#### **“Qosmotec Propagation Effect Replicator QPER”**

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## **0 Document Control**

### **0.1 Imprint**

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### **0.2 Document Description**

This document gives an overview about the Qosmotec Handover Tester and Dynamic MIMO Tester QPER. It is intended to give potential customers a first technical insight into the architecture and the product's capabilities.

## **Qosmotec Propagation Effects Replicator QPER**

# **1 System Description**

## **1.1 General Concept**

The Qosmotec Propagation Effects Replicator QPER simulates mobile subscriber's mobility on the RF link in the test bed for all relevant wireless technologies. It is plugged into the RF link between a set of transceivers (base stations / (e)NodeBs) and test mobiles. The QPER hardware consists of a fully meshed broadband RF matrix with digitally controllable attenuators and delay lines on each RF path. This allows to simulate the most significant aspects of signal propagation, i.e.

- path loss
- phase shift

There are many application areas for the QPER system wherever mobility of network subscribers is necessary to be integrated into the test process, i.e.

- Signal degradation scenarios
- Handover / cell reselection enforcements
- Interfrequency handovers
- Multipath reception / Fast Fading scenarios
- Interoperability tests between mobiles and network components of various vendors
- Simulation of network predictions & optimization prior to physical installation
- Replay of drive tests in the lab
- Beamforming tests
- MIMO tests

## **1.2 Communication between Network Infrastructure and UEs**

The QPER system is available in various configurations from 2 (inputs) x 1(outputs) to 16x8. Figure 1 and 2 show an example for a 4x2 configuration, the external connections to the hardware and its internal connection scheme with attenuators and (optional) delay lines on each radio path.

The standard version of QPER hardware supports a frequency range of 500 MHz to 3000 MHz, covering the most relevant mobile network technologies from 2G to 4G. Specific versions for the lower frequencies (down to 10 MHz) and high frequencies (up to 6 GHz) are also available.

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Figure 1: QPER Hardware with 4 TRX inputs and 2 mobile group outputs

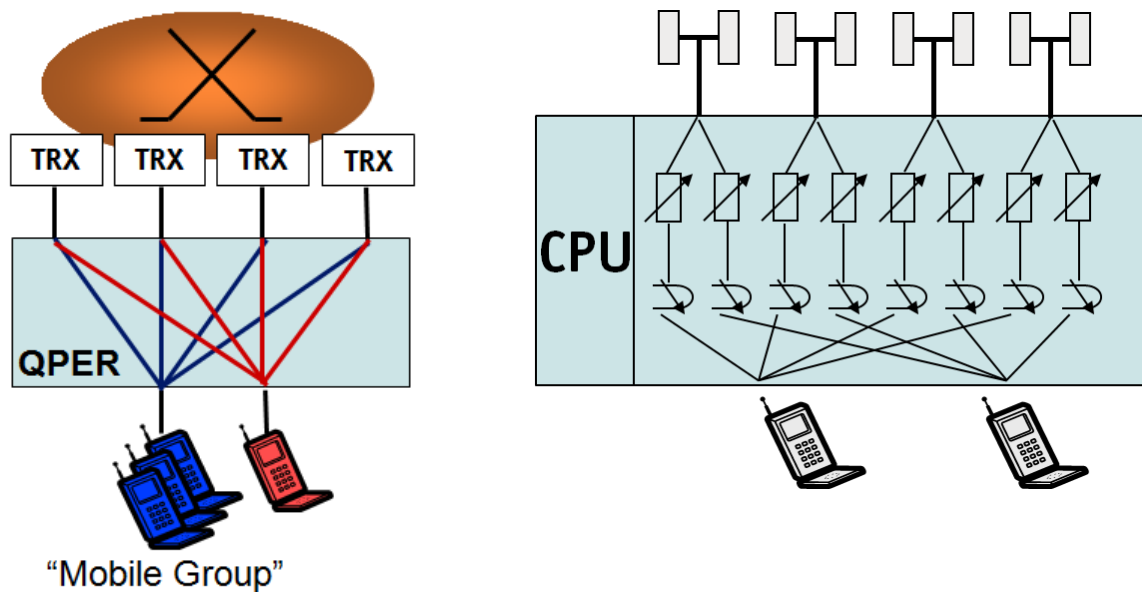


Figure 2: External and internal connection scheme for a 4x2 QPER system

One of the main characteristics is the fast and fully parallel control of all attenuators and delay lines. The hardware allows more than 4000 switching cycles per second. An internal real time operating system guarantees that all components are switched absolutely at the same time with äquidistant switching cycles. This allows to simulate even the effects of fast fading on the signal strength over the whole frequency range for a moving speed of up to 300 km/h.

The QPER system is controlled by a powerful simulation software, setting the internal attenuators and delay lines based on various signal propagation models, taking into account path loss, fading and phase shift models as well as antenna radiation patterns.

The user can very easily create complex radio propagation and handover scenarios without any knowledge about signal propagation using the simple Virtual Drive Test Mode. This allows to place representations of the connected equipment (TRX and mobile groups) into a virtual landscape, and simulate movements on configurable routes with changing speeds. The orientation is facilitated by loading background maps.

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A Drive Test Replay Mode allows to replay signal strength recordings taken during a drive test. Converters are available in order to extract the received signal level information from various drive test formats (e.g. ROMES and NEMO) and to import them into the QPER system. The same mode also allows to create own artificial signal strength scenarios very simply using Microsoft Excel.

QPER is a multi-user system, which can be accessed via LAN. The QPER software is running on windows operating system and can be installed on any laptop or workstation. It can be run with a local database for a non-shared usage of simulation scenarios as well as with a central database as common data repository shared by all system users.

A test automation interface is available, which replaces the usage of the graphical user interface for execution of simulation scenarios. The test automation interface can be used to integrate mobility simulation by QPER into any Windows or Linux based test automation platform. A full integration of mobility simulation with call generation is provided by the Qosmotec integrated test platform LTS.

The QPER attenuator / delay line matrix can be combined with an electronic RF switch. This is a cost efficient way to increase the number of QPER inputs for transceivers. The RF switch enables to connect all available transceivers in the test bed to the QPER system and use them on demand. This increases work efficiency, because it avoids the effort of changing cabling and reconfiguring the QPER system according to new connected hardware. The software control of the electronic RF switch is fully integrated into the QPER software together with the control of the attenuator / delay line matrix. Figure 3 shows, how a 4x4 QPER attenuator array is extended by a 16->4 RF switch. The four transceivers used in QPER can be selected freely from the set of available 16 connected transceivers in this configuration.

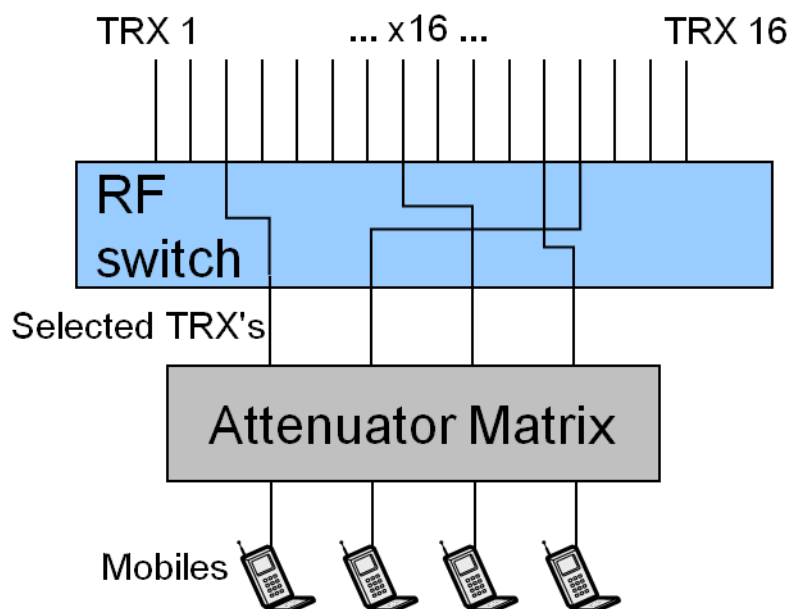


Figure 3: Extension of the QPER attenuator array with an electronic RF switch

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### 1.3 Communication in Ad-Hoc Networks

A mobile ad-hoc network (MANet) is characterized by the direct connection of mobile devices without a fixed network infrastructure. Thus, all devices need to communicate with each other, or can take over different roles, e.g. a router, wireless access point or a mobile receiver. Application areas for this are Wifi environments or car-to-car communication systems (vehicular ad-hoc networks), where each node participates in routing by forwarding data to other nodes. Figure 4 shows a typical use case in vehicular communication systems.

The specific testing demand in ad-hoc networks is the large variety of situations that can occur. The QPER virtual drive test approach facilitates this as it allows the user to emulate situations as they occur in real-life applications. With street maps in the background, the user can adjust the emulation as it would occur in practice and move the radio devices with variable speeds through the virtual landscape. The simulation is fully reproducible and can even replicate real driven routes by taking into account GPS recordings collected during a real drive test.

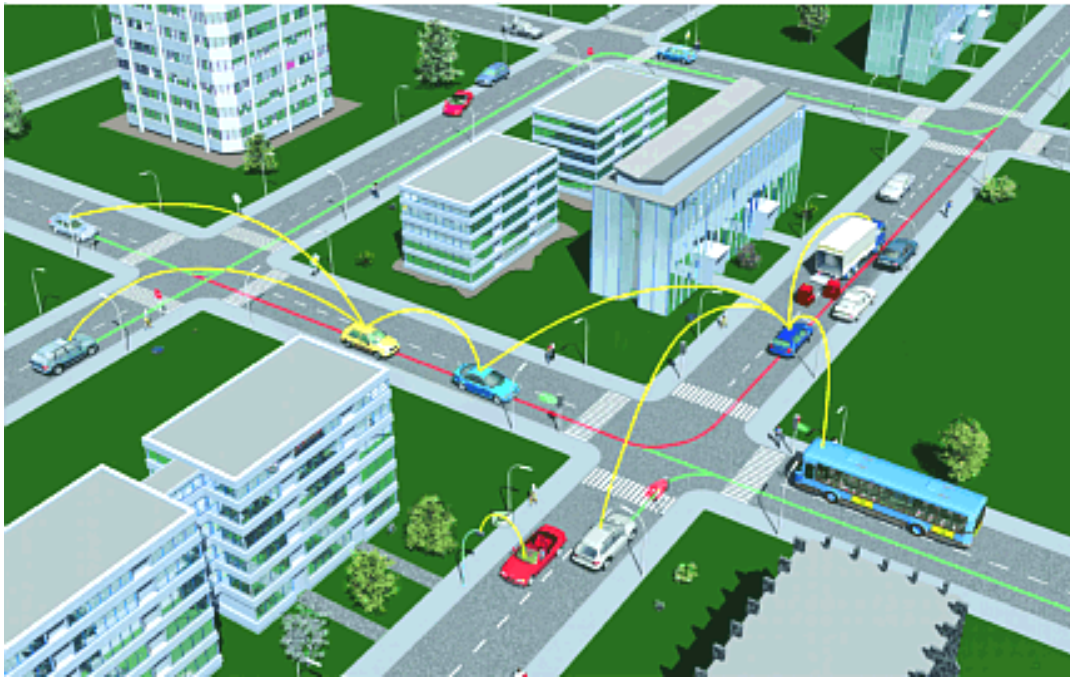


Figure 4: Vehicular ad-hoc network

For these kind of setups, a specific hardware setup is available that links all connected devices with controllable bi-directional attenuation paths. Each connected radio device can be configured by the user as a stationary network infrastructure element or as a mobile device. Hardware setups are available for up to 12 radio devices. Figure 5 shows a sample setup for 7 radio devices.

All other technical characteristics – especially the available frequency ranges - and capabilities of these systems are identical with those described in section 1.2. In particular, also MIMO devices can be connected to the system and the emulation links may be expanded by delay lines for simulating phase shifts between different radio paths in MIMO environments.

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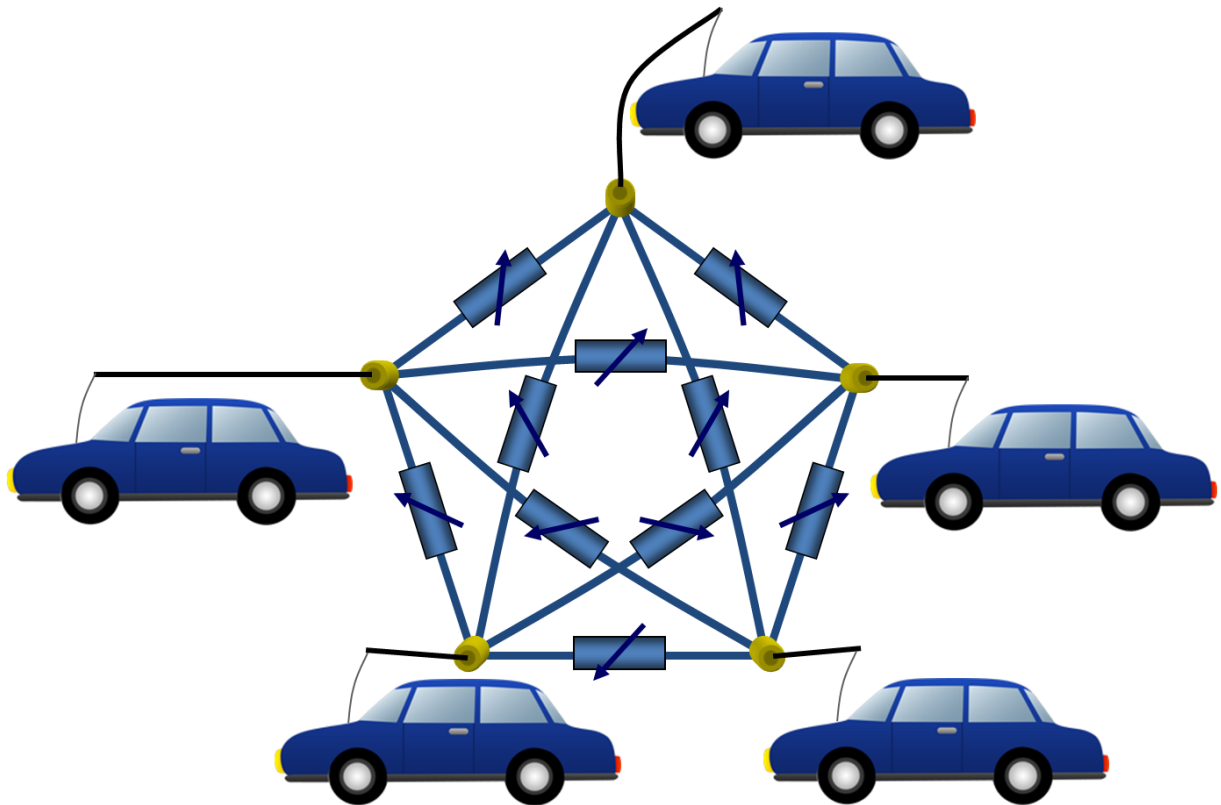


Figure 4: Connection scheme for an ad-hoc network simulation setup for up to 5 radio devices



## Qosmotec Propagation Effects Replicator QPER

## 2 QPER Usage

The QPER software features two independent control modes for setting the attenuators and delay lines on the QPER hardware.

- The virtual drive test mode
- The drive test replay mode

The control of an additional RF switch to increase the number of inputs to the QPER hardware integrates seamlessly into the control software.

### 2.1 Virtual Drive Test Mode

Virtual drive testing is an intuitive visual approach to simulate RF conditions in a user specified landscape with varying radio propagation conditions. The advantage: It is that simple to use, that you need no knowledge about radio propagation conditions to create powerful radio simulation scenarios and handover situations.

The transceivers and mobiles connected to the hardware are displayed in a graphical user interface. By simple drag and drop actions, the user can create a graphical representation of the network. For better orientation it is possible to load a background map. Figure 4 shows an example for a drive test simulation.

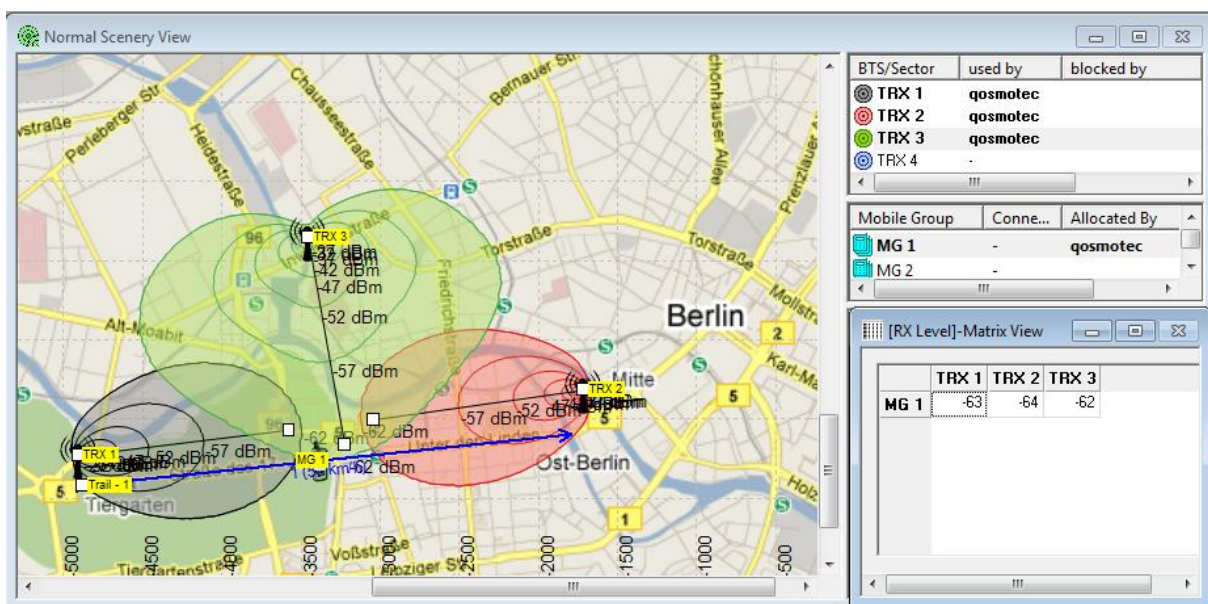


Figure 4: Virtual Drive Test with a map of Berlin as background image

### Path Loss

Mobiles can be moved along specified routes with a given speed or within random walk areas, where they move randomly with varying speed within given borders and ranges. The path loss between a transceiver and a mobile is calculated by QPER software distance dependent based on the selected path loss model and the 3D radiation pattern assigned to the transceiver. According to the calculated path losses, the attenuators on the affected radio links in the QPER hardware are set with every movement step of the mobile.

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All attenuation settings can be displayed to the user in terms of received signal strength (RxLevel), taking into account the system insertion loss and external cable loss. In Figure 4, the received signals during the virtual drive test are displayed in the RxLevel Matrix.

### Fading Effects

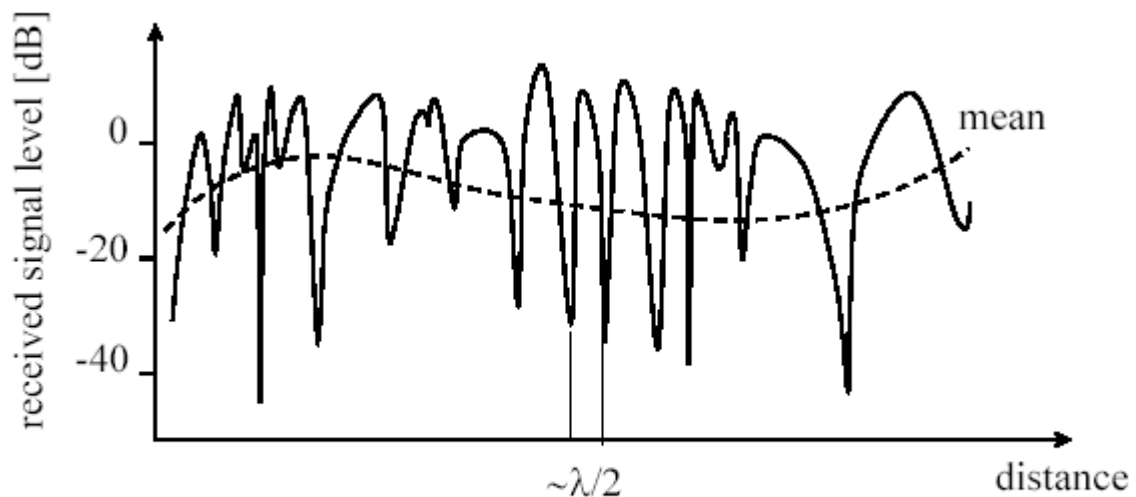
The QPER software accounts for effects of slow fading (shadowing) and fast fading (multipath) on the simulated signal strength.

Slow fading effects are realized by overlaying the mobile's movement path with a shaded area, for which an additional shadowing value for each radio link is specified. This attenuation is added to the calculated path loss when the mobile moves within the area.

Fast fading effects are simulated similarly by overlaying the mobile's movement path with a fast fading area. For each radio link, the fast fading profile is specified, i.e.

- Rayleigh fading for simulation of NLOS conditions between transceiver and mobile
- Rician fading for simulation of LOS conditions. The K-factor parameter specifies the strength of the LOS path compared to the reflected paths

Figure 5 shows the heavy fluctuations on the received signal strength due to multipath reception.



Measured signal level as a function of the travelled distance

Figure 5: Effects of fast fading on the path loss

Inside a fast fading area, the fading profile for the signal strength is generated by a stochastic process and is added to the calculated path loss. Simulating fast fading require very quick signal strength changes in the magnitude of half of the signal wavelength. This is only possible because the QPER attenuators can be switched very quickly. More than 4000 switches per second are supported in parallel on all digitally controlled hardware components. A real-time handling guarantees, that äquidistant times are kept between the

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switches to simulate the fast fading effects most real-life like accounting for the exact moving speed.

Figure 6 and 7 visualize, how shaded areas and fast fading areas are applied in the QPER software. In the configuration panes on the right of the screenshot it is shown, that the fading effects can be set individually for each radio link (i.e. connection between mobile group and TRX).

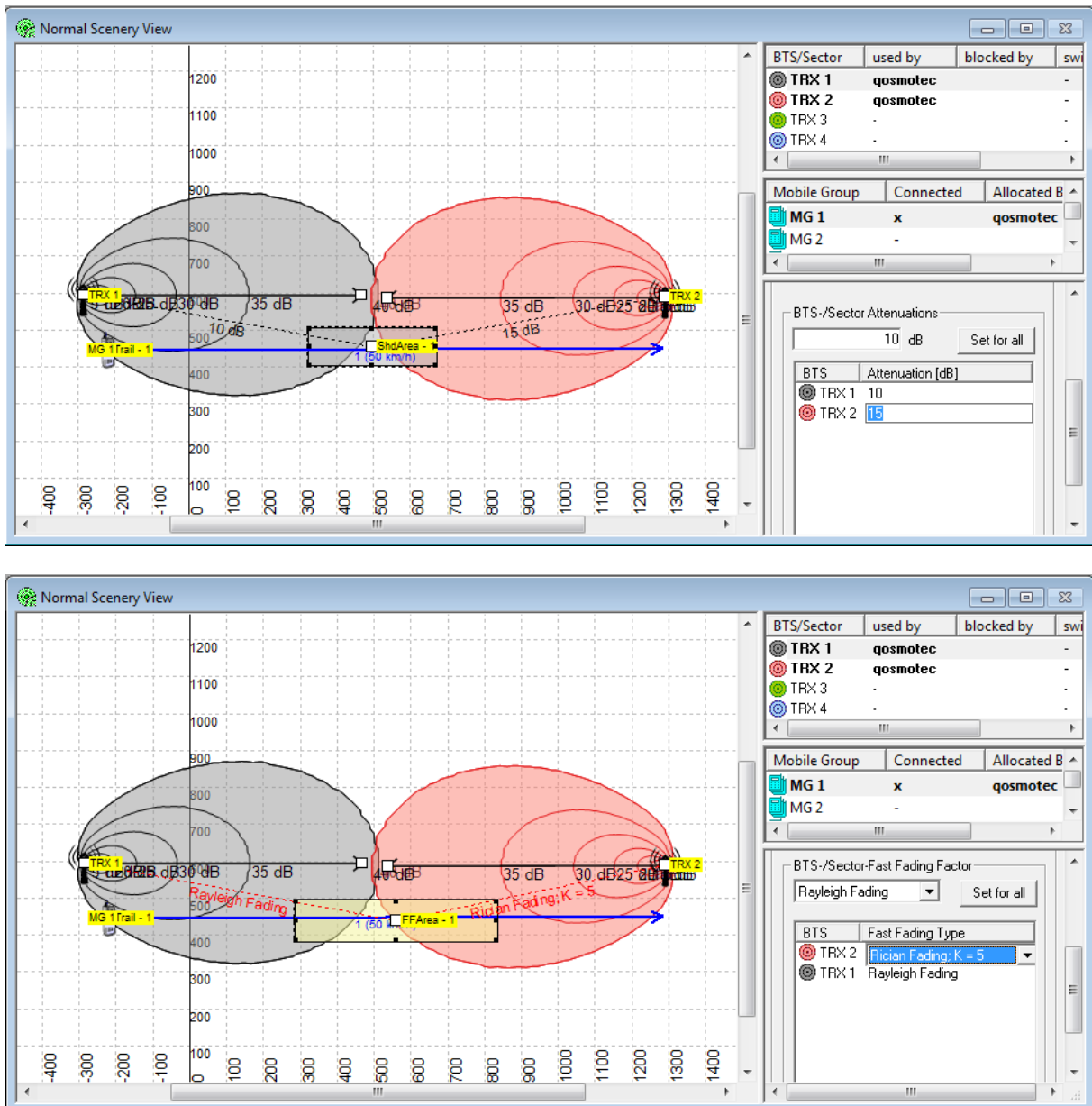


Figure 6 & 7: Applying slow fading and fast fading to a virtual drive test simulation

## MIMO and Beamforming

In MIMO and beamforming environments, transceiver and / or mobile consist of multiple antenna elements, resulting in more than one radio transmission path. These transmission paths are phase different.

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The phase differences on radio transmission paths are taken into account by delay lines inserted into each radio path in the QPER hardware. By connecting each antenna element to its own QPER port, the radio link between transceiver and mobile is simulated by several RF paths in the matrix. These paths are set with equal attenuations, but different delays. This results in different phase shifts on the multiple radio paths.

The phase shifts are calculated according to the positions of transceivers and mobiles within the virtual landscape accounting for the antenna orientations. The simulated phase shifts for each connection are displayed in degrees as well as channel coefficients, that form the channel matrix in a MIMO constellation. This is shown in Figure 8 for a 8x8 MIMO situation with the phase shift view on the right side.

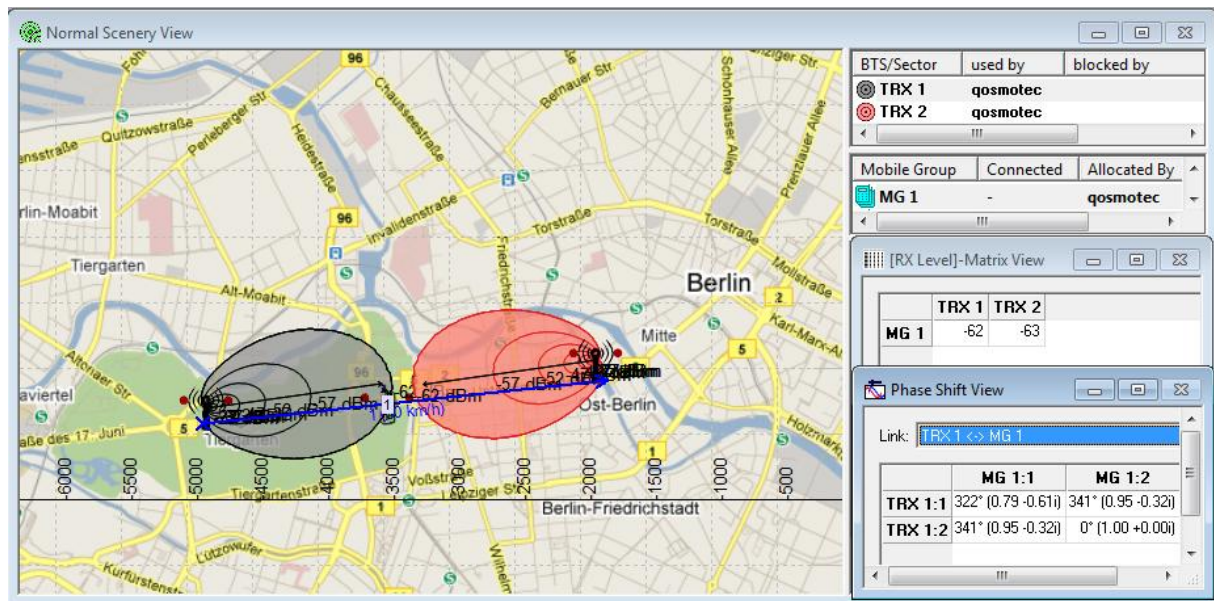


Figure 8: Simulation of phase shifts in a 2x2 MIMO environment

## 2.2 Drive Test Replay Mode

QPER can be used to replay recorded drive tests. For this, the signal strength information for selected cells have to be extracted from the drive test file and mapped to transceivers connected to the QPER hardware. The QPER software supports that with a conversion tool that reads the signal strength information from various drive test file formats and translates them into QPER compatible signal strength tables, that can be applied on the QPER hardware. In Figure 9 such an extraction of 4 cells from a drive test file is displayed. If a selected cell is temporarily invisible, it is automatically set to the lowest simulated value. This is the case for the cell marked by the blue line in the displayed example.

These signal strength tables can also be generated or modified by users manually using a table calculation program like Excel. With a time resolution of 1 ms, attenuation or RxLevel settings can be specified for dedicated RF links in the QPER hardware. Doing this, the user can specify any arbitrary dynamic signal profile that he cannot graphically create using the virtual drive test mode, e.g. for reconstruction of RF situations experienced in the field.

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The drive test replay mode offers various execution possibilities, like

- forward, backward and automatically repeated execution of files
- accelerated and decelerated execution
- concatenated execution of files

These execution methods enable a flexible usage of the created files without necessity for editing them when applying minor changes like execution speed etc.

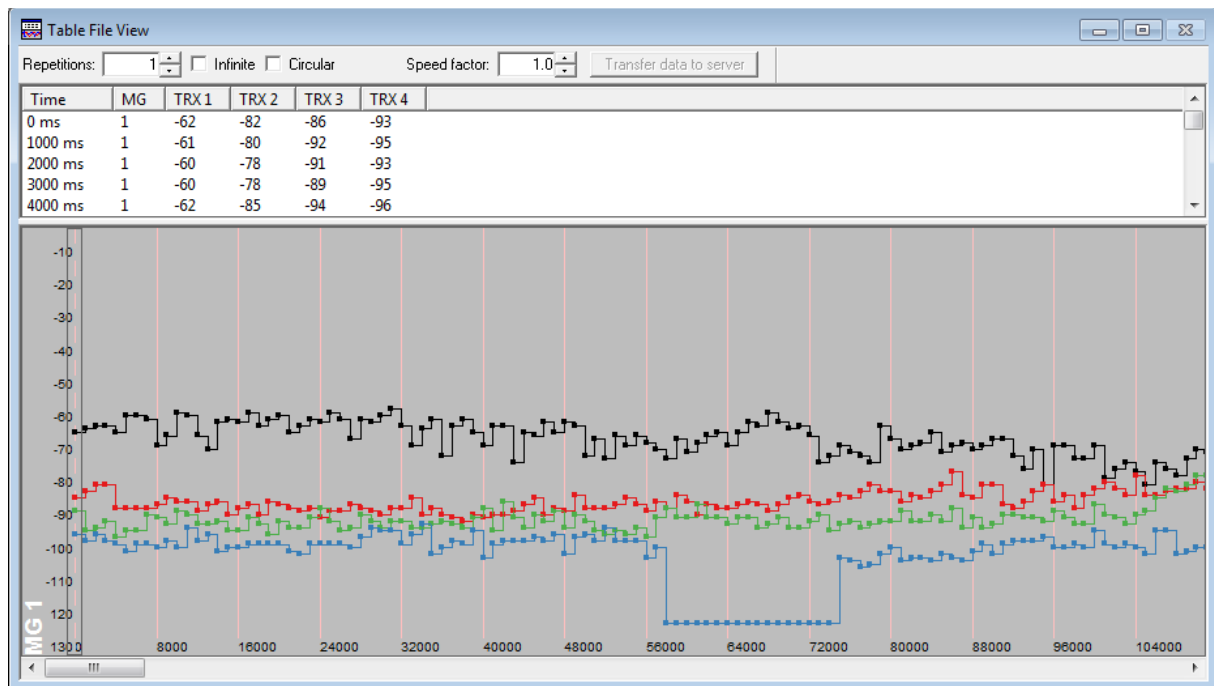


Figure 9: Replaying the received signal strength from 4 selected cells of a recorded drive test

## 2.3 Integrated RF Switch

An electronic RF switch extends the number of transceivers connected to the QPER system at the same time. From the set of available transceivers, a subset can be selected that shall be mapped to the QPER attenuator matrix inputs.

The electronic RF switch integrates seamlessly into the QPER software. Now simply more transmitters become available in QPER: instead of the number of input ports on the attenuator and delay line hardware, you can now use the number of input ports on the RF switch. As soon as a transmitter is used in QPER, the respective RF switch input is automatically mapped to any free output and thus becomes available for the simulation. If all RF switch outputs in use, the QPER software does not allow to use any other than the currently switched transceivers for a simulation. As soon as at least one RF switch output becomes free again, QPER offers again the full choice of transmitters for creating an RF scenario.



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Figure 10 displays this integration for an RF switch with 16 inputs and 4 outputs into the QPER software. 16 transceivers are displayed, but only 4 of them can be used for a simulation in virtual scenery mode, the others are greyed out.

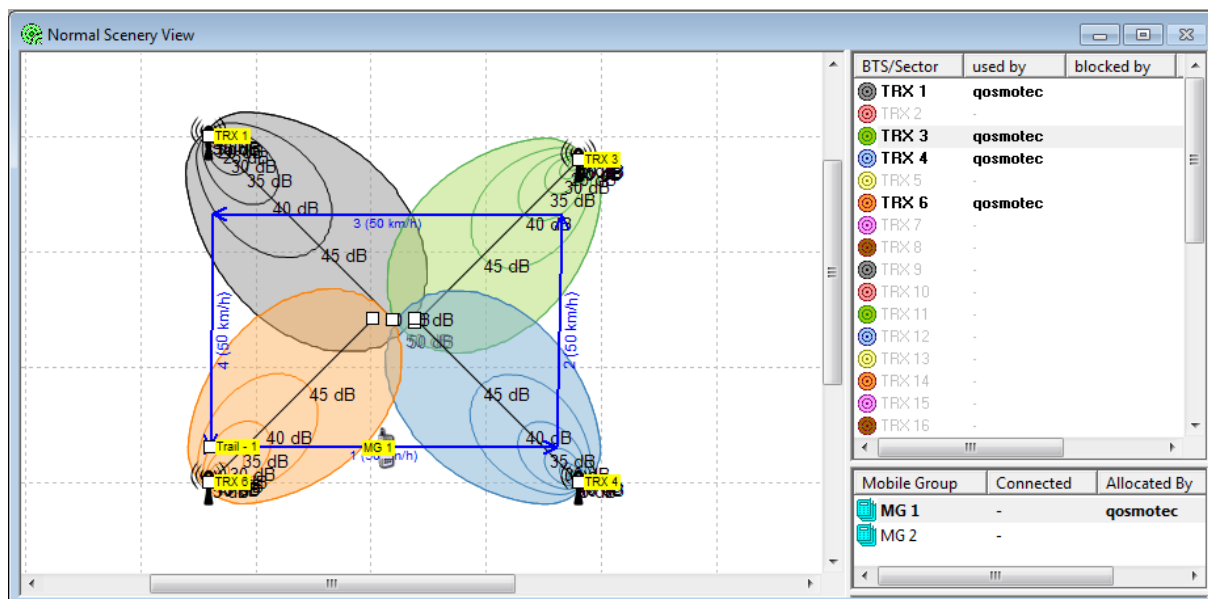


Figure 10: Integration of an RF switch into the QPER software allows the parallel usage of 4 out of 16 connected base stations to the QPER system

## Qosmotec Propagation Effects Replicator QPER

### 3 Technical Data

Frequency range: 500 – 3000 MHz (standard version)  
 300 – 6000 MHz (extended version)  
 lower frequency ranges on special request

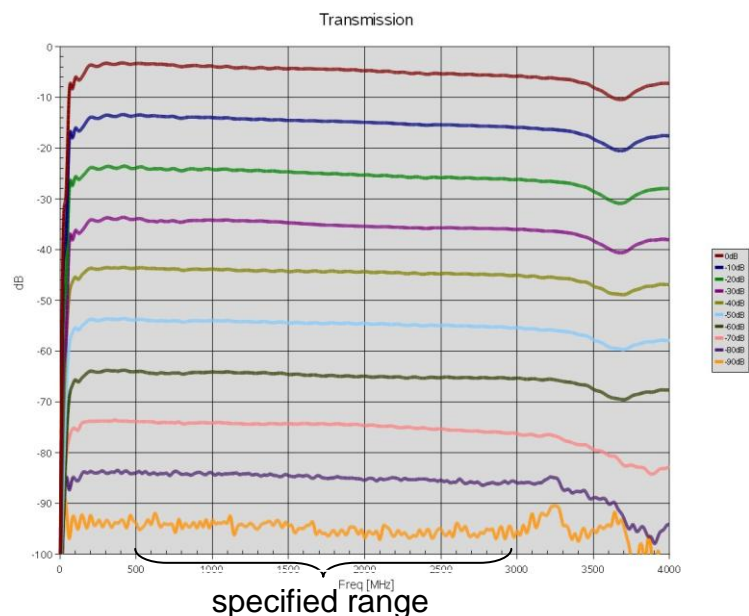
Impedance: 50  $\Omega$

Dynamic attenuation range: 0 – 95.5 dB

Attenuation steps: 0.5 dB

Attenuation accuracy:  $\pm 0.8$  dB or 2.5 % ref. to insertion loss

Linearity diagram



Dynamic electrical delay range: 0 - 705.56 ps ( $\triangleq$  0 – 254° @ 1GHz phase shift)

Electrical delay steps: 5.56 ps ( $\triangleq$  2° @ 1 GHz)

Phase shift accuracy:  $\pm 2^\circ$  @ 1 GHz

Number of switches: > 4000 / sec, real time, up to 128 parallel settings  
 (i.e. up to 512.000 HW settings per second)

Max. input power: + 23 dBm

Insertion loss @ 0dB: size dependant,  
 max. 5 dB for attenuators  
 max. 11 dB for delay lines

RF-connectors: N(f) or SMA(f), front- and/or rear side mounted

Path loss propagation models: Free space path loss  
 Okumura-Hata models  
 Walfisch-Ikegami models

**Qosmotec Propagation Effects Replicator QPER**

Fading effects on signal strength:	Rayleigh Fading (NLOS model) Rician Fading (LOS models)
Drive test file formats:	Rohde & Schwarz ROMES Drive Tester ASCII format Rohde & Schwarz TSMU Scanner XML format Anite NEMO open file format MEDAS general file format
Operating system:	Windows XP, Vista or 7 for client application Windows XP, Vista 7 or Linux System for API
Data storage:	Locally in file system for non-shared usage Centrally in database for multi-user application
Number of users:	unlimited parallel user access to the system