Mobile Network Testing
MNT Workshop

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Introducing Mobile Network Testing

- Core competencies
- Portfolio
- References
- Benefits
Rohde & Schwarz and SwissQual
The right partners in Mobile Network Testing

**Unique expertise**
- Setting industry standards from RF receiver design to HD voice and video quality

**Quality products**
- The strength of combined Rohde & Schwarz and SwissQual product portfolios
- Maximum level of RF/QoS/QoE data quality and conformity

**Customer focus**
- Innovative and targeted solutions defined with industry leading companies
Our areas of technology expertise

Engineering & Design
- Decades of experience in designing and engineering products for Mobile Network Testing

Testing true QoS & QoE
- End-user device-based testing concepts
- Stable test environments for fully reproducible, validated and accurate results
- The most complete range of test scenarios and KPIs

Internal applied research
- Defining new standards for ITU-T, ETSI and VQEG
Innovation from RF to application testing

- The first scanner measuring eMBMS and MIMO 4x4
- Our POLQA algorithm selected in 2010 as the new standard for perceptual voice
- Unique audio delay measurements for VoLTE testing
- The new standard (J343.1) for video MOS for YouTube
- The only solution measuring true RF performance
Introducing Mobile Network Testing

- Core competencies
- Portfolio
- References
- Benefits
## From data collection to insights

<table>
<thead>
<tr>
<th>Benchmarking</th>
<th>QualiPoc Freerider III</th>
<th>QualiPoc Freerider II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Quality Monitoring</td>
<td>QualiPoc Probe</td>
<td></td>
</tr>
<tr>
<td>Interference hunting</td>
<td>R&amp;S®PR100</td>
<td>R&amp;S®FSH</td>
</tr>
<tr>
<td>Handheld network analyzer</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Rohde & Schwarz**

*Mobile Network Testing*
## From data collection to insights

<table>
<thead>
<tr>
<th>RF scanners</th>
<th>Optimization</th>
<th>Data management, analysis &amp; reporting</th>
</tr>
</thead>
<tbody>
<tr>
<td>R&amp;S® TSME</td>
<td>QualiPoc Android</td>
<td>NQDI II</td>
</tr>
<tr>
<td>R&amp;S® TSMA</td>
<td>QualiPoc Probe</td>
<td>NQDI Classic</td>
</tr>
<tr>
<td>R&amp;S® TSMW</td>
<td>QualiPoc Freerider III</td>
<td>R&amp;S® ROMES4NPA</td>
</tr>
<tr>
<td>R&amp;S® TSMWL-CW</td>
<td>R&amp;S® ROMES</td>
<td>NQView</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SmartMonitor</td>
</tr>
</tbody>
</table>

**ROHDE & SCHWARZ**

Mobile Network Testing
Benchmarking products

Benchmarker II
Large scale and fully fledged drive test-based quality of experience benchmarking.

QualiPoc Freerider II
Walk test-based quality of experience benchmarking.

QualiPoc Freerider III
Extended walk and drive test-based quality of experience benchmarking and optimization.
Benchmarker II
The Reference Benchmarker

- Drive test
- Multi-channel (48)
- QoS/QoE testing
- RF trace
- Laptop controlled

Active ventilation
Multi-band, multi-technology RF scanner
Unique self healing feature to prevent redrives
Hot swappable modules to reduce downtimes
Optional TCM configuration to use unmodified devices

ROHDE & SCHWARZ
Mobile Network Testing
Benchmarker II
The Reference Benchmarker

Large scale and fully fledged drive test-based quality of experience benchmarking.

Fully scalable architecture  Fully customizable user interface  From data to insights with NQDI II
Measurement solutions for true performance

- Independent of vehicle’s RF attenuation
- Closest solution to real-user experience
- Unique solution in the market

Smartphones with unmodified antennas for true performance

Smart Computer Module Rack

Active cooling phones housing
Benchmarker II Go
The All-in-One Benchmarker
Transportable solution for ad-hoc benchmarking drive test:
- Same power of Benchmarker II in smaller size
- 8 x phones pre-installed
  - (Up to 16)
- Scanner optional
  - R&S® TSME or TSMA supported
- Power from 12V Cigarette Lighter(s)
QualiPoc Freerider II
The Light Portable Benchmarker

- Walk test
- Multi-channel (6)
- QoS/QoE testing
- Customizable GUI

Lightweight and discreet backpack
Battery for up to 8 hours autonomy
Tablet controlled, smartphone based
QualiPoc Freerider III
The Ultimate Portable Benchmarker

- Walk & drive test
- Multi-channel (6)
- QoS/QoE testing
- RF trace
- Customizable GUI

- Active ventilation
- Multi-band, multi-technology RF scanner
- Custom-made, light-weight backpack
- Hot swappable batteries for high autonomy
- Tablet controlled, smartphone based
QualiPoc Freerider II & III

User-friendly, fully customizable GUI for highest operational efficiency

Campaign management
Map monitor
Benchmarking monitors
Service quality monitoring products

QualiPoc Probe
Unattended network wide non-stop service quality monitoring and optimization

SmartMonitor
Real-time fleet and test result monitoring
Service quality monitoring products

Unattended network-wide non-stop service quality monitoring

Unobtrusive remotely controllable network probe

24/7 real-time service quality monitoring in hotspots

Tailored backend for data management, alarming & reporting

ROHDE & SCHWARZ
Mobile Network Testing
QualiPoc
The Premier Handheld Troubleshooter

- Advanced RF optimization
- Service quality testing QoS/QoE
- Troubleshooting, testing, verification

Smartphone-based*, multi-function tool
Intuitive interface & customizable screen
OTA application updates
>250 KPI in real-time (incl. ETSI)
Full logging & decoding of multiple protocol layers on all technologies

Support of a wide range of the latest Android smartphones, including Samsung Galaxy, LG, Sony Xperia and Android tablets

ROHDE & SCHWARZ
Mobile Network Testing
QualiPoc
The Premier Handheld Troubleshooter

Handheld voice and data service quality troubleshooting and optimization

Quality MOS testing for voice and video
VoLTE optimization with unique audio delay testing
Enhanced Map Monitor to simply indoor measurements
QualiPoc Probe
The Autonomous Service Quality Probe

- Unattended, 24/7 real-time service quality monitoring
- KPI-based performance monitoring and alarming

Smartphone-based, ruggedized probe
Active ventilation
Mountable and lockable
Self healing feature
Integrated back-up battery system
SmartMonitor

- Web-based SmartMonitor application for Windows, Linux or OS X application server
- Dashboard providing the latest results and status of the probes in **real-time**
- Intuitive campaign configuration and fleet operation
- Fast and easy registering of new QualiPoc Probes
- Alarming interface
- Tailored user roles offer an efficient and secure system and fleet management
RF scanner products

**R&S® TSME**
Small, portable, separate PC

**R&S® TSMA**
For scanning with QualiPoc
System-in-a-box: PC and scanner with ROMES/Diversity

**R&S® TSMW**
Extended input frequency – 30 MHz to 6 GHz
IQ Streaming (TSMW-K1)
IQ Recording (TSMW-B1) with IQR
For Dual-Receiver Scanning (2x2 MIMO/Performance)
The Ultracompact Drive Test Scanner

- Multi-technology multi-band
- Drive & walk test
- Ready for MIMO 4x4
- LTE DL Alloc. Analysis, eMBMS

- Compact, lightweight design*
- Low power consumption
- 350MHz – 4.4 GHz
- Built-in GPS
- Automatic Channel Detection

*lightest available RF scanner in the market
TSMA
The Autonomous Mobile Network Scanner

- Multi-technology multi-band
- Drive & walk test
- LTE DL Alloc. Analysis, eMBMS
- Battery-operated

WiFi and Bluetooth
Scanner for QualiPoc and FRII
Runs PC based SW like R&S©ROMES
350MHz – 4.4 GHz; GPS receiver
Autonomous System-in-a-box
TSMW
The Universal Radio Network Analyzer

- Multi-technology multi-band
- Drive Testing
- 2 Frontends
- LTE DL Alloc. Analysis, eMBMS

30 MHz to 6 GHz
IQ recording with R&S®IQR
IQ streaming via LAN
Built-in GPS
Pre-selection
Data management and analysis products

NQDI Classic
Scalable data analysis and reporting for optimization and benchmarking

R&S®ROMES4NPA
Automated network problem analyzer
NQDI Classic
Scalable data analysis and reporting

- Post processing system for network & service optimization and benchmarking, based on data from all radio technologies
- Automated data validation, detailed quality analysis and trouble-shooting, for voice & data services
- Offers generation of comprehensive reports and maps to benchmark networks and easily identify critical areas with underperformance
ROMES4NPA
Automated network problem analysis

- Providing a quick overview of multiple measurement files
- Saving time & money with little to no configuration & easy GUI
  - Automated analysis
  - KPI calculation
  - Map handling
  - Problem spotting
  - Coverage & interferences
  - Neighborhoods & Hos
  - MIMO, DLAA
  - Delta/comparison mode...
- Format compatibility
  - ROMES, QualiPoc
MNT activities at a glance

Regulator focus

- Ensuring **accurate** deployment
- Evaluating **channel occupancy**
- Searching & identifying **unlicensed transmitters**
- Checking **cell sites performances**
- Monitoring & troubleshooting (e.g. **interference hunting**)
- Ensuring **subscribers services** (**QoS & QoE**)
Who are our Customers?

- **Regulators**
  - NMHH (HU), OFCOM (UK), AGCOM (IT)

- **Network Operators**
  - Vodafone Group, AIS (TH), Bell (CA), Claro (CL)

- **Infrastructure Vendors**
  - Huawei

- **Service Companies**
  - Systemics (PL), Netcheck (DE), GWS (US)

- **“Special” (non traditional) customers**
  - CERN, NY Subway
Scanner, ROMES & NPA

New Features From Releases 4.88
ROMES Remote Control
- Allows remote control of ROMES scanner measurements including use of Automatic Channel Detection. The measurement configuration and result collection can be done on the same PC, or with remote commands through IP socket.
- The feature allows to deploy a distributed scanner measurement system and centrally collect results via an IP link on any platform (Windows, IOS, Linux etc.). This is particularly useful for monitoring applications.

Measurement file handling
- ROMES now offers the possibility to upload the measurement files (or part of it) to a FTP server automatically after measurement. Furthermore ROMES provides a small tool which allows the user to move all data from the measurement data folder as specified in the Preference Dialog to a specific folder on a USB Stick at one click.
- Seamless File-Splitting

RAN sharing
- RAN sharing is now supported to see all the coverage of all PLMNs. RAN sharing is getting more widespread in networks, and the scanner now gives a full view of the coverage, without the need to manually interpret SIB information.

Automatic Export
- It is possible to export the measurement file automatically after the measurement, so that no additional user interaction is necessary to get the required set of measurement data. This automation allows to build a fast and efficient workflow that is less error-prone.
**Scanner**

- **LTE MIMO 4x4 Scanner Measurements**
  - In combination with four TSMEs and ROMES4T1E driver, ROMES 4.89 provides MIMO 4x4 scanner measurements. The measurements of the MIMO matrix, the rank and condition number of the matrix provide an objective assessment of the RF channel to carry four spatial layers. This assessment is needed for optimization and troubleshooting of LTE MIMO 4x4 networks.

- **New CW Option for TSME/A/W**
  - CW Measurements are now available for R&S TSME / TSMA and TSMW. It is named R&S CW Scanner and the driver can be loaded from the “Receiver” section.

- **RF Powerscan on two TSMW**
  - Independent RF power measurements with two TSMWs on up to 4 frontends, e.g. for antenna comparison measurements.

- **eMBMS Support**

- **The WiMAX Scanner supports the ACD functionality**
Automatic Channel Detection

- **Challenge:** in many cases the channels to be scanned are not known
- **Solution:** Automatic Detection of active channels (xARFCN) in a set of selected bands

**Two modes**
- **Stationary Detection (Simple Mode):**
  - scanner tests every channel in the band and then stops the detection
  - Slower, but useful for a one-time detection before starting a drive
- **Smart Detection (requires TSMW-K27 RF Power Scan):**
  - scanner continuously analyses spectrum in the band, to speed up channel detection, and to detect new channels during a drive
  - Continuous dynamic detection during a drive, captures new channels and re-allocations of spectrum (e.g. caused by LTE – GSM refarming)

- Detected channels are automatically added to the workspace
- ROMES can automatically create a template where the detected channels are saved and can be loaded in a workspace for future use
Regulator solutions
Automatic Channel Detection (ACD)

- Automatic, fast detection (all active channels, all technologies)
- Only technology and bands/frequency range needed as input
- Stationary, smart detection modes
- Position estimation option
- Scanner based
ACD Status View

- Each band with spectrum view
- Decoded carrier bandwidth and network information (mouseover enlarges)
- Provider logo from ROMES network provider database
- GSM channels from GSM scanner (no ACD)
- Horizontal line: RSSI

Detection activity:
- Green: currently checking
- Yellow: will be checked next

Found in View → Basic View → ACD Status View
Analyze cross-country interference
ACD View improvement
MCC & MNC always displayed – RAN sharing support

- Easier check against expected numeric values of both elements
  (instead of reading the provider name)
BTS Position Estimation

- **Automatic, fast** localization estimation of active transmitters
- **Information gathered on adjacent, known/unknown networks**
  - All technologies
  - All operators
- **Generation, maintenance**
  - Base station lists including
  - ARFCN, (E-)UARFCN
  - Estimated Position
  - MCC, MNC, LAC, Cell ID…
- **Scanner** based
Regulator solutions
Coverage & interference analysis

- Automatic, fast detection (all issues types in all technologies)
- Statistical & reporting capabilities
- Problem spot analysis
  - Coverage & interference
  - Network, neighbor list
  - HO...
- Map handling
- Scanner based
- Mobile based
Regulator solutions
QoS & QoE analysis

- Ensuring subscriber services (voice as well as data)
- Statistical & reporting capabilities
- Problem categorization
  - Coverage & interference
  - Blocked/dropped calls
  - HO...
- Mobile based
Regulator solutions
Emitters localization

- **Automatic, fast, accurate** localization of active emitters
- Powerful direction finder, R&S®DDF007
  - Receivers/spectrum analyzers can be considered as well
- **No DF experience** needed
- Remotely controlled
- Quick vehicle integration
LTE Scanner Subband View Enhancement

- LTE signals can be interfered from narrowband or wideband interferer
- Subband view shows interferer on RB level
- RS-SINR and RSRQ (new) can be used for interference analysis
RF Powerscan View and Export Enhancement

- For spectrum analysis measurements of power peaks are needed
- New automatic assignment of fixed markers to the 4 highest peaks in the spectrum
- Fixed marker measurements can be viewed and exported to ASCII
eMBMS : Support of early / new features

„First solution supporting scanning in eMBMS enabled networks“

- In **eMBMS subframes** no PCI-specific Reference Signals are available, but MBSFN-Reference Signals
- Scanner needs to know (from SIBs) where eMBMS is present and where not, to measure correctly in eMBMS enabled networks

3 MHz – 15 RB

1 frame = 10 subframes = 10 ms

Source: http://www.pewscorner.host-ed.me/LTE/te_resource_grid.html

New with K32: RSRP/RS SINR per MBSFN area ID
Smartphones

- **Samsung Exynos support**
  The Samsung Chipset is now supported to be used in “Smartphone Mode” by ROMES. The new chipset driver ROMES4SAM is required. In addition, the “Classic Mode” is supported since 4.88

- **Smartphone WLAN Support**
  - WLAN Scanning and WLAN Offloading for mobiles connected as “Smartphone” to ROMES is now available.

- **New DQA Job: Youtube**
  - The DQA job “Youtube Streaming” is now available in the DQA job list for mobiles connected as “Smartphone” to ROMES.

- **WiFi use for DQA jobs**
  - More flexible testing capabilities by selecting, whether the Mobile Network, Wifi, or Mobile network/WiFi (combined) is used for data transfers
17.0 Release planned for April 2017
- Scanners
- ROMES
- NPA
- Misc.
ROMES 17.0
5G scanner prototype @ 28GHz (engineering demonstrator)

What can be measured with the prototype setup?

- Sync signal detection and measurement (primary PSS, secondary SSS, extended sync signal ESS detection) of a pre-5G (5GTF) waveform at 28 GHz

- Beamforming reference signal measurement to compare beam coverage (multiple beams)

- Sync signals and Beamforming reference signals are located in a spectrum of approx. 20 MHz

- RF power scan for pre-5G carrier (100 MHz for each carrier)

- CIR (Channel Impulse Response) measurement for multiple beams
ROMES 17.0

Block diagram of prototype / demonstrator measurement setup

- R&S 28 GHz Omnidirectional antenna (R&S®AC004R/L2)
- Downconverter and Local oscillator (LO)
- R&S®TSME (ultra compact drive / walktest scanner)
- ROMES 17.0 (beta) with pre-5G scanner extension
ROMES 17.0

General information about the 5G scanner prototype @ 28 GHz

- This is not a commercial product (yet)!

- Requirements collection / product definition / improvements for commercial product is ongoing

  ➔ Any feedback is appreciated!!

- It is possible to use this setup for exhibitions and demos for key customers (in coordination with PM!!)

- For any questions and comments please contact scanner PM (M. Mielke)
ROMES4 17.0

LTE Uplink Allocation Analyzer (ULAA)

- New TSMX-K33 option

- Analyzes allocations in uplink

- Analysis on cell and UE level
  - RB usage
  - Throughput
  - MCS

- Ideal for Optimization & Benchmarking

- ULAA and DLAA can be run simultaneously
CW Scanner
NB-IoT Channel Filter

- New Channel Filter for NB-IoT carrier

- Allows NB-IoT CW and power scan measurements (e.g. NB-IoT in-band operation)

- Filter Name: NB-IoT LTE 1 PRB

- Filter Type: rectangular, 180kHz bandwidth, one PRB

- Supported ROMES measurements: CW, RF Power Scan with TSMW/E/A
TETRA Scanner
Display of TEDS / TETRA2 Signals

- Supported Views:
  - TETRA Scanner Spectrum View
  - TETRA Scanner Top N view

Many parameters remain empty for TEDS

- Available Signals:
  Carrier, Ptotal, MCC, MNC, Color rate, Coderate, Modulation type, Burst Mod ER, Pilot Mod ER, Header Mod ER, Data MER, SICH Error rate, AACH Error rate, Data Error rate; Signal Frequency (calculated from Carrier and its frequency offset)

TETRA Scanner Spectrum View: TEDS carrier are marked red
- Scanners
- ROMES
- NPA
- Misc.
New devices support
Samsung S8/S8+, Sony XZ Premium

- Samsung S8/S8+, Sony XZ Premium supported in Classic Mode

- Critical early device testing for latest Samsung and Sony flagships
  - Making sure end users get full benefit from latest network & mobile features
Other supported device
Netgear Aircard 810

- LTE Cat 11, up to 600 Mbit/s with 3CA + 256 QAM
- Qualcomm Snapdragon X12
- Supported bands:
  - 4G LTE FDD 800/900/1800/2100/2600 MHz
  - 4G LTE TDD 2300/2600/2600 MHz
  - 3G 850/900/1900/2100 MHz
VoWiFi calls support

New feature

- Support for both QP mode & Classic Mode
  - Feature to be supported by the mobile phone, SIM card & network operator
  - Refer to the ONF document for other prerequisites

- Easily compare with VoLTE to make sure end customers get similar quality
  - MOS, call setup, drop rate…

- Check if the WLAN type might affect the results with a WLAN network scan
  - E.g. different setup times?
  - Only available in Classic Mode
TCM support
Optimal conditions for reliable results

- Allows to use testmobiles in TCM (TCMQP variant)
  - Robust, thermo-insulated casing
  - Easy access to test device through hinged top with single latch
  - VRB/TCM monitoring & device control

- Results independent from seasonal temperature variations through temperature control
- Profit from native UE antenna performance
VoWiFi
New Technology

- ROMES4NPA now aggregates VoWiFi results as well as VoLTE
- Reporting done on setup types, RATs, IMS KPIs

Automated/easy analysis and comparisons of voice
ROMES4 17.1

NB-IoT scanner

Possible operation modes

- **Stand-alone operation** utilizing spectrum currently being used by GSM systems as a replacement of one or more GSM carriers
- **Guard operation** utilizing the unused resource blocks within a LTE carrier’s guard-band
  - No affection the capacity of LTE Carrier
- **In-band operation** utilizing resource block within a normal LTE carrier
  - Flexible Assignments of resources between LTE and NB-IoT. (No fixed predefined PRB location NB-IoT)
ROMES4 17.1

NB-IoT Applications

- Detect NB-IoT cell (given EARFCN and offset for NB-IoT anchor subcarrier)

- Measure coverage & quality of the NB-IoT signal
  - Validate deep indoor penetration
  - Validate co-existence with existing networks (LTE, GSM)
  - Validate coverage prediction/network planning tools
  - Troubleshoot & optimize NB-IoT networks

- Functionality is planned in two phases
ROMES4 17.1
LTE NB IoT Scanner Phase 1

- Detection of LTE NB IoT cells
  - Use primary/secondary synchronization signals
  - Search done in a general way so that all modes are supported
    - Standalone, guard & inband operation

- Coverage Measurements using synchronization signals
  - RSSI of Primary/Secondary signals
  - Primary/Secondary signal power (correlated)
  - Carrier power to Interference and Noise Ratio – CINR
  - Channel Impulse Response – CIR
ROMES4 17.1
Netgear Nighthawk M1

- Max 1 Gbps download speeds & 150 Mbps upload speeds
- LTE CAT 16, LTE Advanced 4-band CA, 4x4 MIMO
- Up to 4X Carrier Aggregation
- LTE/4G 700/900/1800/2100/2600 MHz
- 3G 850/900/1900/2100 MHz
Coexistence of LTE and WiFi in unlicensed 6GHz band
- Interference from LTE eNodeBs (own, other operators)
- Interference from WiFi
- Interference from any other radio technology (e.g. radar)

Scanner can provide
- LTE coverage and quality measurements RSRP, RSRQ, RS-SINR, RSSI
- WiFi Packet measurements, type (802.11a, n, or ac) detection under investigation
- Channel usage: %LTE, %WiFi, %other
- Collision detection: LTE/WiFi or LTE with other technologies

New SW option on TSMW
ROMES4 17.2

Improved campaign management

- Faster & easier campaign handling for higher efficiency
- Campaign configuration possible without HW being connected
- Enhanced device (scanner, smartphones) & job selections

Better campaign configuration
- Scanner
- QoS tests
- Loading & saving
Reference Signal (RS) measurements for NB IoT

- Reference Signal CINR - RS-CINR
- Reference Signal Received Power (RSRP)
- Reference Signal Received Quality (RSRQ)
Test Device Containment Module (TCM)

- Testing Solution standards
- TCM Introduction
- Tests and Field results
- Conclusions
Current (and future) Mobile Devices

- Phone (built-in) internal antennas:
  - **MIMO** uses multiple antennas
  - Electronically tuned with no 50 Ohm *ground reference*
  - Flexible (FPCB) antennas for the newest devices
    - The Challenge: where to attach the RF external antenna connector?
    - Overheating issues and CPU performance

*Source: Flickr.com techstage, 2015*
ETSI Technical Report 102 581

Old standard:
- Drive Test Solution should use
  - External RF Antenna connected to mobile devices
  - Attenuators (usually between 6 and 8 dB) considering
    - Antenna gain
    - Vehicle and human body attenuation

In Nov-2015 ETSI has released an updated version of technical report 102 581 where it is stated: "The test’s result showed that the effort of simulating the behavior of internal mobile phone antennas which use dual polarized MIMO and automatic band switching techniques or other smart functions increased extremely and can no longer be achieved by usage of external antennas and a specific attenuation only. The measurement model based on the external antennas reliably reflects the user experience only in the environments which do not require MIMO technology."
Test Device Containment Module (TCM)

- Testing Solution standards
- TCM Introduction
- Tests and Field results
- Conclusions
Introducing the Device Containment Module

Solution coping with all these challenges

- **Internal** (built-in) mobile device antennas
- **Unmodified** mobile devices
  - Real MIMO performance
- **Stable and uniform conditions** for testing devices
- **Measurement reliability** through advanced self-healing
- **Controllable attenuation** to simulate real use case and different clutters
Test Device Containment Module (TCM)
TCM for Benchmarker II

- Use of the device (built-in) **internal antennas**
- Installed in a **vehicle roof box** (up to 16 in one roof box)
  - Alternative to the existing **DMR** (Device Module Rack) and **ASM** (Audio Slide-in Module)
Test Device Containment Module (TCM)

Details

- Hinged case for easy access
  - Easily replaceable device for future upgrades
- Unique self-healing functions
  - Automatic reboot to recover the test device
- Active thermal conditioning for a superior temperature control
  - Thermal insulating foam inside and airtight container
  - No air exchange between the container and the outside
  - Internal active airflow for heating/cooling
- Stable and optimal temperature inside the module
  - 25°C (± 2°C)
  - ..for external temperature ranges from +45°C to -40°C
- Patent pending
Influence of temperature in performance
Testing throughput on Galaxy S5 – Lab Tests

Configuration:
- **SM-G901F** (Android 4.4.4, Snapdragon 805)
- Different Temperatures applied (5°C / 15°C / 35°C)
- Simulated Network (using **R&S® CMW500**)
  - 2 Aggregated Carriers (Band 7, Band 3)
  - Max throughput = 2x127.552 Mbps

Results: Average Net Application Throughput (measured on the device)
- 5°C Celsius → 218 Mbps
- 15°C Celsius → 190 Mbps
- 35°C Celsius → 121 Mbps

Conclusions
- **Stable temperature conditions** needed for **maximum results comparability**
Attenuation and Mounting

- Attenuation
  - Easily removable absorber foam “hood” layer
  - Used to emulate a controlled (omni-directional) attenuation

- Installation in the Vehicle Roof Box
  - No exposure to electro-magnetic radiation for the vehicle’s crew
TCM in the Vehicle Roof Box (VRB) installation

- Internal hosting and power distribution / air conditioning for all devices
- Optional **inside light** and alarm for burglary protection
- **IP65 rated** cable duct for cable entry into vehicle
  - Applied at vehicle roof or rear side window replacement
TCM in the Vehicle Roof Box (VRB) installation

- Up to 16 TCMs inside a VRB
- VRB accessible from both sides
- Glossy white coating for high sunlight / thermal reflection
- Identical temperature - conducted airflow through internal fans
- Identical RF conditions for all modules inside the roof-box
Facing All The Facts

- NO WAY back to External antennas for Smartphones
- NOT the Customer Experience anymore

Motivation
- Frequency depending antenna gain and electrical attenuation creates unbalance between 800 and 2600 MHz
- Highly unknown antenna diagrams in dense configurations
- Reduced MIMO 2x2 performance
- No 50 Ohm reference points for all antennas
- Not possible to disassemble phones
- Not future proof
- 4x4 MIMO, WiFi and 5G Massive MIMO requirements

R&S is the only vendor that provides a specification of performance of the offered solution.
DACH Press Measurements

- **CHIP** is a computer and communications magazine published in several countries of Europe and Asia.

- **CHIP Online** is the independent web portal of the CHIP brand. It is one of the most-visited media portals in the German language area, providing hardware and software tests and price comparisons. As of December 2014, it is a top 20 site in Germany.

- As part of their test results they publish periodically the results of a Benchmarking campaign amongst all the Operators in Germany using R&S equipment.
DACH Press Measurements
Thank you!