Setting standards in spectrum monitoring
Radiocommunications have become an integral part of our modern civilization. In addition to the increasing number of human users of wireless technology, there is also major growth in devices and machines that exchange data via radio waves. Driven by technological advances and the growing popularity of new products, the demand for additional frequency spectrum is expanding. However, frequency spectrum represents a limited natural resource, making it critical to ensure intelligent planning of frequency usage along with rational allocation schemes and efficient monitoring techniques.

The Internet of Things (IoT) and machine-to-machine (M2M) communications no longer represent a future vision but have already become reality. For example, the intelligent home is increasingly networked while automation continues to advance in both industry and commerce. Sensors are used to transmit a wide variety of data to central computers. This provides the basis for lowering window blinds, optimizing truck routes and controlling logistics as well as manufacturing processes, to name a few examples. Large numbers of motor vehicles are now also using the radio spectrum for communications and safety. Thanks to ongoing research in car-to-car (C2C) communications, vehicles should soon be capable of exchanging data using wireless technology, of course. This can help to prevent accidents and better manage traffic flows.

Besides the exponential growth in radio services, new signal types are necessitating further advances in spectrum monitoring. The new signals provide higher data rates and consequently require more bandwidth. The number of digitally modulated signals is increasing in particular. This trend is especially challenging for regulatory authorities and other organizations that are responsible for spectrum management and monitoring. They need to keep pace with the ongoing changes while updating their spectrum monitoring systems on a sustainable basis so they can continue performing their diverse activities in an effective manner.
Rohde & Schwarz spectrum monitoring systems fully comply with ITU recommendations in terms of their overall design and their technical parameters. Furthermore, they use measurement procedures that are based on the international standard procedures specified by ITU. They even perform simultaneous measurements of multiple characteristic transmitter parameters. The operators can configure short- and long-term measurements either locally or remotely in remote monitoring stations. The R&S®ARGUS spectrum monitoring software supports operators with preset recommendations for different signals. If any measured values diverge from the target values, the system can automatically take predefined actions. For example, the system might identify the emission of interest, locate it, record it and trigger further measurements. In this manner, R&S®ARGUS makes a solid contribution to preventing potential disruptions due to transmitter overreach.

Other common measurements allow evaluation of the band and frequency occupancy. R&S®ARGUS determines statistical values as well as distributions of frequency usage versus time in order to discover free resources or congestion. Such measurements are also performed in line with ITU recommendations and are critical in the frequency allocation process, thereby leading ultimately to more efficient spectrum usage.

In addition, Rohde & Schwarz offers equipment and systems that can be used for on-site inspection of transmitter sites. ITU recommends creating a data set with the results of local measurements for every licensed transmitter site. Such measurements are typically performed during system commissioning. If problems are reported later in the vicinity of the transmitter site, the same measurements can be repeated to make it easier to identify and locate the source of interference.

**Measurements in line with ITU recommendations**

ITU is a specialized United Nations agency that coordinates the worldwide use of the frequency spectrum. ITU issues recommendations that national authorities apply within their areas of jurisdiction.

One of the many ITU recommendations: Make measurements with antennas having the same polarization as the signal.

Simultaneous replay of recorded audio and measurements.

Rohde & Schwarz and ITU

Rohde & Schwarz applies ITU recommendations in many aspects of its work. More than 50 years ago, the company joined ITU-R, which at that time was known as CCIR. Since then, Rohde & Schwarz has actively cooperated with experts from other organizations as part of various ITU study groups. The company is especially active in ITU-R study group 1, which is responsible for frequency usage and radiomonitoring. Experts in this study group work continuously to advance the spectrum monitoring guidelines.
Despite careful planning and management of the frequency spectrum, interference is still an everyday problem for many radiocommunications services. The effects of radio interference are as diverse as the causes. For example, interference to a TV picture is merely annoying. Dropped mobile phone calls can translate into lost revenue (or even lost customers) for network operators. However, interference to the radio links used by rescue workers and security services can cost lives in the worst case.

Rohde & Schwarz has a large portfolio of products for interference hunting to enable users to verify, identify and locate any radio interference they might encounter. Stationary and mobile monitoring stations work with R&S®ARGUS software to provide different ways to verify and locate radio interference. Spectral displays visualize unwanted emissions on affected frequencies. In the hands of skilled spectrum monitoring officials, demodulated audio can also provide useful clues as to the source of radio interference. Rotator-controlled directional antennas are useful for separating interference from wanted signals. For interference caused by intermodulation, R&S®ARGUS has an interactive measurement mode that computes all of the relevant frequencies for intermodulation products.

The R&S®MobileLocator mode provided by R&S®ARGUS is a proven efficient tool for intuitive interference searching. It is used in moving DF vehicles. In densely built-up areas, the multipath propagation of signals makes it difficult to locate them. R&S®MobileLocator performs a statistical evaluation of the bearings to generate usable results. The system shows a color-coded probability cloud on a digital map. As the vehicle moves away from the blue toward the yellow, the colors become increasingly intense. Finally, a red circle appears on the map, representing the location of the emission.

Additional tools available from Rohde & Schwarz include the R&S®PR100 portable receiver and the R&S®HE300 handheld active directional antenna. Together, they form a small but effective system for simple measurements and manual direction finding. As the operator turns the antenna in the direction of the emission, the level increases. An audio tone can be enabled to help trace the final meters of the path to the interference source.
Wide-ranging coverage measurements

Coverage is an economic factor. The existence of mobile phone network operators and broadcast stations depends on the coverage they provide. In addition, regulatory authorities have to control their and other services’ coverage.

Digitization in the broadcasting and mobile radio sectors has led to increasing challenges for coverage measurements. Systems from Rohde & Schwarz have kept pace with the requirements and provide comprehensive measurements for all common standards. For example, a TV analyzer such as the R&S®ETL can be used with the R&S®BCDRIVE broadcast drive test software to measure field strength and many other signal quality parameters. When integrated in a vehicle, the drive test system can generate conclusive data on the actual broadcast reception in a region of interest.

Coverage measurements in the mobile radio sector are similarly complex. Rohde & Schwarz offers powerful, flexible tools for assessing the quality of service (QoS) in a specific coverage area. This includes automatic detection of the active channels for all mobile radio standards as well as detection, analysis and location of interference in order to accelerate radiolocation, e.g. with R&S®MobileLocator. The quality of service (QoS) and quality of experience (QoE) are also assessed. Due to increasing usage of mobile broadband communications devices, the current focus is on data transmission speed.

SwissQual, a wholly-owned Rohde & Schwarz subsidiary, specializes in benchmarking, optimization and service quality monitoring for mobile radio networks. The company also builds and implements software for managing and evaluating measurement data. This helps Rohde & Schwarz to supply comprehensive solutions for wide-ranging coverage measurements.
EMC measurements

Electromagnetic compatibility (EMC) measurements can prevent interference and negative influences on the environment and on electronic devices. EMC measurements determine the radiation emitted by a device and verify compliance with permissible values.

Rohde & Schwarz offers a complete portfolio of instruments, components and test systems for a wide spectrum of EMC and regulatory measurements. Due to increasing global trade involving electronic devices, more and more regulatory authorities and other government agencies perform compliance testing. Rohde & Schwarz systems enable dependable measurement of electromagnetic emissions from such devices that can impact other equipment as well as broadcasting and other radio services.

Electromagnetic compatibility (EMC) is the capability of an electrical device or system to operate in its electromagnetic environment without disturbing it or being disturbed by it. EMC is an important criterion of product quality. To ensure EMC of a product in the most economical way, appropriate measures should be taken early in the design phase.

In line with the definition, EMC is subdivided into electromagnetic interference (EMI) and electromagnetic susceptibility (EMS). Legislation prescribes compliance with maximum values for EMI and minimum values for EMS. The applicable limits, the measurement methods and instruments to be employed are specified in the relevant standards.

This helps to prevent interference to electronic equipment while promoting problem-free usage of the frequency spectrum. Rohde & Schwarz also offers test systems that can be used to verify compliance with personal safety limits.

High-precision EMC measurements with the R&S®ESRP EMI test receiver and the R&S®HL562E ULTRALOG antenna.
Fixed monitoring stations

Fixed monitoring stations are the backbone most regulatory authorities rely on. Their officers remain in their regular working environment and have a range of equipment at their disposal. However, due to the networking capabilities that have developed in recent decades, unattended, remotely controlled stations are also common today.

The R&S®UMS product line is a family of compact, unattended, standalone monitoring and radiolocation systems. Their infrastructure requirements are minimal, and the systems can be mounted directly on a mast. This avoids long antenna cables, reducing signal loss and increasing system sensitivity. The latest member of this family is the R&S®UMS300 compact monitoring system. It combines angle of arrival (AOA) and time difference of arrival (TDOA) location and fulfills all ITU recommendations for spectrum monitoring systems.

Rohde & Schwarz provides equipment for stationary spectrum monitoring stations that are operated on a standalone basis or in a network with other stations. Typically, the individual stations can access data in the spectrum management system. They allow operators to perform highly efficient measurements from the comfort of their control rooms. Antennas for stationary spectrum monitoring stations are usually mounted on a high mast for optimal coverage. Unattended monitoring stations are also increasingly common. They are controlled by operators at another station or from a regional or national control center.

Fixed monitoring stations

Fixed monitoring stations are the backbone most regulatory authorities rely on. Their officers remain in their regular working environment and have a range of equipment at their disposal. However, due to the networking capabilities that have developed in recent decades, unattended, remotely controlled stations are also common today.

Rohde & Schwarz provides equipment for stationary spectrum monitoring stations that are operated on a standalone basis or in a network with other stations. Typically, the individual stations can access data in the spectrum management system. They allow operators to perform highly efficient measurements from the comfort of their control rooms. Antennas for stationary spectrum monitoring stations are usually mounted on a high mast for optimal coverage. Unattended monitoring stations are also increasingly common. They are controlled by operators at another station or from a regional or national control center.

Example block diagram of a fixed monitoring station

The Rohde & Schwarz direction finders

The correlative interferometer principle, in combination with a 9-element circular antenna array, delivers optimum performance in terms of accuracy, sensitivity and immunity to multipath propagation. This is especially important in urban areas where not only the direct wave but also reflections arrive at the DF antenna.

The R&S®UMS product line is a family of compact, unattended, standalone monitoring and radiolocation systems. Their infrastructure requirements are minimal, and the systems can be mounted directly on a mast. This avoids long antenna cables, reducing signal loss and increasing system sensitivity. The latest member of this family is the R&S®UMS300 compact monitoring system. It combines angle of arrival (AOA) and time difference of arrival (TDOA) location and fulfills all ITU recommendations for spectrum monitoring systems.

The Rohde & Schwarz direction finders

The correlative interferometer principle, in combination with a 9-element circular antenna array, delivers optimum performance in terms of accuracy, sensitivity and immunity to multipath propagation. This is especially important in urban areas where not only the direct wave but also reflections arrive at the DF antenna.
Mobile monitoring stations

Mobile monitoring stations can be specialized for certain tasks such as interference investigation or coverage measurements. Alternatively, mobile stations can be configured for universal use – for general measurements, to home in on signals and for other tasks.

Standard mobile monitoring stations are typically equipped with omnidirectional and directional antennas as well as separate DF antennas. They are also outfitted with a tiltable telescopic mast to make it easy to install and change antennas. Alternatively, the DF antenna can be mounted on the roof of the vehicle to allow DF measurements while the vehicle is moving. In this manner, the mobile monitoring station can home in on signals, which is important for pursuing interferences. Rohde & Schwarz offers suitable vehicle concepts and system integration for any requirement.

Mobile monitoring stations are indispensable in interference hunting. They are typically used in situations where stationary systems are too far away from the location of interest. However, a mobile monitoring station is more than just a monitoring system installed in a vehicle. During system integration, Rohde & Schwarz pays close attention to the special requirements to be met by the overall system. Important issues here include personnel safety, ergonomics and efficiency. The Rohde & Schwarz engineers work to optimize the system for the available space while minimizing the weight. The power supply is also tailored to the type of work that will be done.

Mobile monitoring stations are used in addition to fixed stations to provide maximum flexibility. When integrated into a suitable platform, a radiomonitoring system can operate wherever the vehicle carrying the platform has access. This is why many customers opt for vehicles with off-road capabilities.
Transportable and portable monitoring stations

Transportable and portable radiomonitoring stations offer the highest flexibility. These compact units complement fixed and mobile stations in day-to-day operations.

Transportable measurement stations from Rohde & Schwarz can be temporarily deployed at locations where continuous measurements are not required. They can be remotely controlled and/or operated in automatic measurement mode. The antennas are typically mounted on a tripod, allowing operations close to the “scene of action”. Temporary measurements of this type are commonly used to locate sporadic interference or to perform preventive spectrum monitoring such as in the context of major events.

The portable systems from Rohde & Schwarz can be operated while “on the go”. They are a very flexible solution that is typically used close to emitters and in buildings. Rohde & Schwarz offers powerful receivers and direction finders that provide this flexibility.

Transportable and portable radiomonitoring stations offer the highest flexibility. These compact units complement fixed and mobile stations in day-to-day operations.

Transportable measurement stations from Rohde & Schwarz can be temporarily deployed at locations where continuous measurements are not required. They can be remotely controlled and/or operated in automatic measurement mode. The antennas are typically mounted on a tripod, allowing operations close to the “scene of action”. Temporary measurements of this type are commonly used to locate sporadic interference or to perform preventive spectrum monitoring such as in the context of major events.

The portable systems from Rohde & Schwarz can be operated while “on the go”. They are a very flexible solution that is typically used close to emitters and in buildings. Rohde & Schwarz offers powerful receivers and direction finders that provide this flexibility.

Covering HF to SHF with only one portable monitoring set: R&S®PR100 and R&S®HE300 with exchangeable antenna elements.

Frequency from 9 kHz to 20 MHz
Frequency from 20 MHz to 200 MHz
Frequency from 200 MHz to 500 MHz
Frequency from 500 MHz to 7.5 GHz
Frequency from 7.5 GHz to 18 GHz
Since all Rohde & Schwarz spectrum monitoring stations can be networked with other stations, they can be used to build nationwide radiomonitoring networks. Such networks can be expanded on a flexible and heterogeneous basis since differently equipped monitoring stations (i.e., stationary, mobile and transportable) can be interconnected. R&S®ARGUS supports almost any desired configuration.

A nationwide spectrum monitoring system from Rohde & Schwarz can be controlled by a small team from a central control center or multiple regional control centers. The spectrum monitoring stations are controlled via the network. To provide continuous updates on the operating status of unattended monitoring stations, the R&S®ARGUS-SIS station information system runs at all times and generates an alarm if a disruption occurs.

All Rohde & Schwarz spectrum monitoring systems have open interfaces to existing spectrum management systems. R&S®ARGUS also supports integration of existing third-party equipment. As a result, customers can make a step-by-step conversion to R&S®ARGUS in order to obtain the ultimate in investment protection.

Hybrid TDOA – AOA geolocation

Classic geolocation makes use of the angle of arrival (AOA) principle. Direction finders determine the direction to a transmitter by measuring the angle of arrival of the incoming wavefront. Combining the results of two or more direction finders reveals the location of the transmitter. Time difference of arrival (TDOA) has meanwhile proven to be an excellent complement to AOA. TDOA utilizes the effect that a signal reaches receivers at different distances from the transmitter at different times. These time differences of arrival are used to calculate the location of the transmitter.

Rohde & Schwarz has developed a way to combine the advantages of both principles. These hybrid monitoring systems are extremely flexible and have outstanding geolocation capabilities.
Rohde & Schwarz offers a comprehensive portfolio of equipment, software and additional components for spectrum monitoring applications. By combining these modules in diverse ways, individual systems can be configured. The systems can be expanded step by step, networked and replaced if necessary with newer generations of equipment. ITU recommendations are always taken into account.

The Rohde & Schwarz product line encompasses a wide range of highly sensitive active and passive antennas for mobile and stationary use, providing complete coverage for the frequency range from 100 Hz to 40 GHz. Their broadband capabilities minimize the number of antennas needed for covering wide frequency ranges. The radiomonitoring antennas can be easily arranged on a single mast using both directional and/or omnidirectional elements to provide optimum reception for signals of any polarization.

**Product families**

**Antennas**

The entire Rohde & Schwarz product portfolio is developed in-house and manufactured in the company’s own production facilities. A constant focus on customer feedback helps the company to enhance its products in accordance with market and customer requirements.

**Receivers**

A comprehensive range of monitoring receivers is available for finding interference sources and performing precise measurements from 8 kHz to 26.5 GHz and even up to 100 GHz using frequency converters.

**Direction finders**

The Rohde & Schwarz family of direction finders ranges from portable instruments to high-speed scanning direction finders and covers all DF and radiolocation applications. Innovative active/passive switchover capabilities included in the antennas help to adapt the direction finders to any signal environment.

**Signal and spectrum analyzers**

Signal and spectrum analyzers are extremely useful for performing EMC measurements as well as for demodulating and analyzing highly complex, diverse signals. The company’s extensive product portfolio ranges from the portable R&S®FSH to the high-end R&S®FSW.

**System devices**

Do you need to switch signal paths, generate a frequency standard or rotate directional antennas? Rohde & Schwarz has system devices for every application.

**Measurement antennas**

Measurement antennas from Rohde & Schwarz feature small parameter spread in production. As a result, they are to a high degree compliant with relevant EMC standards and offer outstanding accuracy. They are calibrated on our accredited open area test site.

**Omnidirectional monitoring antennas**

Omnidirectional antennas from Rohde & Schwarz offer high sensitivity and are designed to deliver a 360° continuous radiation pattern. They are universal antennas and can be used in a wide range of monitoring applications.

**Directional monitoring antennas**

When it comes to measuring signals arriving from specific angles of incidence, directional antennas are the right choice. They provide high gain in the desired direction. This increases the system’s sensitivity and does away with undesired emissions.

**Compact outdoor monitoring systems**

The R&S®UMS family of universal monitoring systems comprises compact, standalone radiomonitoring stations that perform automatic measurements under remote control around the clock. An alarm system alerts operators when specific events occur.

**Digital broadcast and mobile radio signal analyzers**

Specialized signal analyzers for broadcast and mobile radio measurements can be used to perform coverage measurements and detect interference directly at the transmitter. Possible choices include instruments like the R&S®ETL, combinations such as the R&S®TSMA and R&S®ROMES, and solutions from SwissQual.

**System devices**

Do you need to switch signal paths, generate a frequency standard or rotate directional antennas? Rohde & Schwarz has system devices for every application.
The R&S®ARGUS software is designed for efficient spectrum monitoring. Despite the software’s huge range of measurement and evaluation functions, it is still easy to use. The intuitive user interface and signal-specific configurations help to guide users through the relevant measurements. This simplifies work and prevents errors. R&S®ARGUS is based strictly on ITU recommendations.

R&S®ARGUS allows manual, interactive and automatic measurements. In automatic measurement mode, the system launches measurements at user-defined time points. If any deviation from the specified nominal values is detected, the system can automatically trigger appropriate actions. For example, this might involve recording the signal, locating the emission and alerting a system user.

For many types of measurements, R&S®ARGUS prepares the device setups on a signal-dependent basis. The software has relevant data saved in particular for the latest digital signals encountered in broadcast and mobile radio applications. A wizard guides the operator through the measurement to minimize the manual settings. This reduces the operator’s workload and helps to avoid errors.

Specialized receivers and analyzers are needed to make conclusive measurements on broadcasting or mobile radio signals as well as on WLAN and other digitally modulated signals. For example, the R&S®ETL TV analyzer provides detailed information about a wide range of technical parameters as well as the quality of broadcast signals. The analyzer can be fully integrated into the R&S®ARGUS system landscape like other system components such as antenna switches, rotator controllers and filter units.

With its open interfaces, R&S®ARGUS allows triggering of measurements from the spectrum management system; the measurement results are then returned to the system by R&S®ARGUS. Similarly, data can be read into the software from the spectrum management system’s database. This makes it easy to create a list of licensed transmitters and then find unlicensed emitters with on-site measurements.

Users enjoy the ergonomically optimized user interface (currently available in six languages). All information, including measurement results, statistics, transmitter data, license details and scheduled measurements, is stored in a database and can be displayed in tabular or graphical form.

Especially with large nationwide spectrum monitoring systems, it is important to have precise information at all times about the status, availability and utilization of the individual instruments and stations. The R&S®ARGUS-SIS station information system delivers all such information in real time to regional or nationwide control centers, including a clear presentation on an electronic map.

Following measurement and evaluation, the typical workflow ends with the creation of informative reports. R&S®ARGUS stands out with its support for a wide range of report templates. Depending on the intended recipient, the desired information is automatically arranged in the correct sequence and format.
For 80 years, Rohde & Schwarz has stood for quality, precision and innovation in all fields of wireless communications.

The privately owned company group has a global presence. It develops, produces and markets a wide range of electronic capital goods for industry, infrastructure operators and government agencies.

Rohde & Schwarz is among the market leaders in all of its business fields, including wireless communications and RF test and measurement, terrestrial TV broadcasting and technologies related to the interception and analysis of radio signals.

Numerous subsidiaries and representatives not only ensure competent and customer-oriented on-site support anywhere in the world, they also safeguard customer investments with comprehensive service and support offerings.

More information: www.rohde-schwarz.com

Our business fields

<table>
<thead>
<tr>
<th>Test and measurement</th>
<th>Secure communications</th>
</tr>
</thead>
<tbody>
<tr>
<td>T&amp;M instruments and systems for wireless communications, general-purpose electronics and aerospace and defense applications</td>
<td>(Radio) systems providing encrypted communications and IT security solutions for armed forces, government agencies and industry</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Radiomonitoring and radiolocation</th>
<th>Broadcasting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectrum monitoring systems and radiomonitoring equipment for regulatory authorities as well as for homeland and external security</td>
<td>Broadcasting, measuring and studio equipment for network operators, broadcasters, studios, the film industry and manufacturers of entertainment electronics</td>
</tr>
</tbody>
</table>
Rohde & Schwarz operates a global service network in order to safeguard the investments of its customers. The following on-site services are offered worldwide:

- Calibration
- Maintenance and repair
- Product updates and upgrades

Rohde & Schwarz regional service centers, plants and specialized subsidiaries provide a wide range of additional services:

- System integration
- System support
- Installation and commissioning
- Application support
- Development of customized modules, instruments and systems
- Software development
- Mechanical and electrical design
- Manufacturing to order
- Technical documentation
- Logistics concepts

From pre-sale to service. At your doorstep.
Sustainable product design

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

About Rohde & Schwarz
The Rohde & Schwarz electronics group offers innovative solutions in the following business fields: test and measurement, broadcast and media, secure communications, cybersecurity, radiomonitoring and radiolocation. Founded more than 80 years ago, this independent company has an extensive sales and service network and is present in more than 70 countries. The electronics group is among the world market leaders in its established business fields. The company is headquartered in Munich, Germany. It also has regional headquarters in Singapore and Columbia, Maryland, USA, to manage its operations in these regions.

Regional contact
- Europe, Africa, Middle East | +49 89 4129 12345
customersupport@rohde-schwarz.com
- North America | 1 888 TEST RSA (1 888 837 87 72)
customer.support@rsa.rohde-schwarz.com
- Latin America | +1 410 910 79 88
customersupport.la@rohde-schwarz.com
- Asia Pacific | +65 65 13 04 88
customersupport.asia@rohde-schwarz.com
- China | +86 800 810 82 28 | +86 400 650 58 96
customersupport.china@rohde-schwarz.com

Rohde & Schwarz GmbH & Co. KG
www.rohde-schwarz.com

Rohde & Schwarz Training
www.training.rohde-schwarz.com