Rohde & Schwarz electronics group offers innovative solutions in the following business fields: test and measurement, broadcast and media, secure communications, cybersecurity, monitoring and network testing. Founded more than 80 years ago, the independent company which is headquartered in Munich, Germany, has an extensive sales and service network with locations in more than 70 countries.

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

Certified Environmental Management
ISO 14001

Certified Quality Management
ISO 9001
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Thanks to its industry-leading technological expertise, Rohde & Schwarz is a reliable partner for shaping the future of communications, information and security.

Rohde & Schwarz develops, produces and markets a wide range of electronic capital goods for industry, infrastructure operators and government customers.

The independent group is among the technology and market leaders in all of its business fields, including wireless communications and RF test and measurement, broadcast and media, air traffic control and military radiocommunications, cybersecurity and network technology.

A worldwide service and support network safeguards customer investments.

Our business fields

<table>
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<th>Test and measurement</th>
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<tr>
<td>T&amp;M instruments and systems for wireless communications, aerospace and defense, automotive, research and industrial electronics applications.</td>
<td>Broadcast, post production and T&amp;M equipment for network operators, broadcasters, studios, the film industry and manufacturers of entertainment electronics.</td>
<td>Communications and signal monitoring technology for armed forces and air traffic control, security products for critical infrastructures as well as T&amp;M equipment for A&amp;D applications.</td>
<td>Network technology for professional users as well as IT security products to protect communications and information.</td>
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Test and measurement for aerospace and defense

As a leading manufacturer of high-end T&M equipment, Rohde & Schwarz fulfills the stringent requirements of the aerospace and defense sectors. Customers benefit from the company’s in-house expertise in military radiocommunications, air traffic control and signal intelligence. The extensive product range includes T&M equipment and systems for generating and analyzing signals up into the millimeterwave range. With their outstanding performance and measurement functions tailored to e.g. radar and satellite applications, these products meet the specific needs of the A&D sector. This includes protecting measurement data in secure areas as well as emulating obsolete instruments so that they can be replaced in legacy ATE systems by state-of-the-art components with the same functionality.

As a solution-oriented partner, Rohde & Schwarz supports R&D, manufacturing, quality assurance and service. Sustainable product strategies ensure that Rohde & Schwarz products keep up with advances in technology throughout the long lifecycles customary in these industries. Individual service agreements ensure maximum availability over the entire lifecycle. Tailored product and technology training enables customers to effectively use the solutions – a key element in working together.

Our portfolio

- Wide range of RF and microwave T&M instruments for lab and field measurements
- Catalog systems and customer-specific T&M systems
- Test and measurement solutions for radar, avionics, navigation, satellite communications and military radiocommunications
- Full range of EMC measuring equipment
- Millimeterwave and submillimeterwave components

Rohde & Schwarz offers an unsurpassed range of EMC test and measurement equipment. The R&S®ESW test receiver can perform measurements in line with all EMC-MIL standards.

The R&S®CMA180 not only makes it easy to test military radio equipment, it also generates the test signals needed to maintain navigation receivers.

VOR, ILS, MB, DME, TACAN, GBAS and satellite-based systems are important pillars of aviation navigation.

The R&S®ZVA network analyzer with the R&S®ZVAX-TRM extension unit can be used to characterize complex active DUTs such as SatCom converters and T/R modules.
Communications and reconnaissance equipment for armed forces

Secure radiocommunications systems
Today’s military missions are typically combined operations in a multinational environment. The key to success is achieving information superiority through network-centric operations. Rohde & Schwarz supplies interoperable radiocommunications systems for deployment on land, at sea and in the air. The company uses recognized standards to ensure that its IP-based system solutions are cost-effective, future-ready and adaptable.

These systems are designed for simultaneous data and voice transmission, consistently high voice quality and low latency. The company’s broad radio portfolio includes portable radios, radios for stationary applications and systems for use in vehicles, ships and airborne platforms. Thanks to efficient encryption processes, these products meet the most exacting domestic and international security requirements.

Our portfolio
- Integrated communications systems for military ATC as well as for the army, navy and air force
- Encryption technology for all classification levels

Reconnaissance
Reliable situational information is essential for making decisions in crisis situations and during military missions. Communications intelligence (COMINT) is a key factor. As a passive instrument, it can deploy its capabilities unobserved and far from the area of interest. This can actually help to de-escalate conflicts since objectives can be achieved without violating sovereignty.

Rohde & Schwarz has served this segment for decades. The company offers an extensive range of sensors (antennas, receivers, direction finders), signal processing and analysis systems and software for all frequency ranges from HF to SHF (SatCom) and for deployment on land, at sea and in the air. Our radar intelligence (ELINT) systems detect state-of-the-art LPI radars, effectively increasing the safety of deployed forces.

Our portfolio
- Communications intelligence systems
- Radar intelligence systems
- Satellite monitoring systems
- Signal analysis systems
- Receivers
- Direction finders
- Antennas
- Jammers
- Solutions for analyzing IP data streams
Cybersecurity solutions for business and government authorities
High-performance data networks and IT components are the backbone of business and society. The volume of dormant and transmitted data is growing exponentially, driven by the digitization of all business processes, the increasing outsourcing of IT services to the cloud and the emerging internet of things.

Highly interconnected networks attract unwanted attention. According to the estimates of reliable organizations, cyberattacks (especially theft of intellectual property) cost the global economy hundreds of billions of dollars each year. But intangible assets are not the only assets that need protection. The large quantities of sensitive public sector data as well as personal data generated by the financial sector, the health care system and online commerce also need to be protected. Manufacturers of network components and IT security technology have to provide secure, high-performance solutions for the transmission and storage of this data.

Rohde & Schwarz offers a wide range of infrastructure components for WAN, LAN and WLAN networking as well as cybersecurity products.

Our portfolio
- All components for secure WAN, LAN and WLAN networking
- Network security products, e.g. firewalls
- Products to protect web and cloud applications
- Products to protect desktop applications
- Secure products for mobile communications
- Tools for network traffic and use analysis

Service
Rohde & Schwarz operates a global service network in order to safeguard the investments of its customers.

The following services are offered locally worldwide:
- Calibration
- Maintenance and repair
- Product updates and upgrades
- Remote service over secure Internet channels

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, equipment and systems
- Software development
- Mechanical and electrical design
- Manufacturing to order
- Technical documentation
- Logistics concepts

Countries with unsecured borders in mountainous areas, forests or deserts can use aerial reconnaissance to protect their territory against illegal entry

Communications intelligence delivers essential information about the military situation

Along with long-lived, high-end products, we offer very dependable service with our extended warranty. You can decide which of our high-performance service packages is right for you.
Airborne radiocommunications
Chapter 1
Airborne radiocommunications

Rohde & Schwarz: market leader in safe airborne radiocommunications
Rohde & Schwarz is a close, long-standing partner of government authorities, armed forces and leading companies in the aerospace and defense industry.

The best airborne radio is a given
True independence is a choice
The SOVERON® AR from Rohde & Schwarz brings the latest generation of software defined airborne radios and network-capable waveforms to the skies. The SOVERON® AR offers wideband and secure voice and data communications for network centric operations. Thanks to the radio’s innovative technology, users can achieve information superiority during operations. Features include simultaneous voice and data transmission in wideband operation, superior frequency hopping procedures, highly secure encryption algorithms and radiocommunications networks that adapt to topological conditions, and the mobility required for operations (mobile ad hoc networking).

Rohde & Schwarz is the only provider to meet the civil aviation certification requirements of the European Aviation Safety Agency (EASA). Military aircraft can only be certified and operated without restrictions when they fulfill both military and civil requirements; this ensures combined civil and military operations.

Rohde & Schwarz has developed a family of network capable, wideband waveforms to handle diverse mission requirements. The SOVERON® WAVE series transmits up to two voice channels and data in parallel at high speed and with different priorities. Users can select the waveform that best matches their requirements regarding range, data rate and jamming immunity.

R&S®M3AR multiband VHF/UHF software defined radios are designed for line-of-sight communications in avionics. The compact and lightweight transceivers make them suitable for operation in all types of aircraft, including unmanned aerial vehicles (UAV).

- More than 8000 delivered units
- Successfully integrated in many aircraft platforms

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SOVERON® AR
Software Defined Airborne Radio

**Meets both civil and military avionic standards**
Since airspace worldwide is used largely for civil purposes, military aircraft must also meet civil standards in order to pass this airspace without restrictions. The SOVERON® AR can be used as a primary ATC radio. It is the only software defined airborne radio on the market that also meets civil safety avionic standards, providing full independence for unrestricted joint civil-military operations.

**Designed for ease of integration**
An essential part of the airborne radio development process is the continuous and intensive exchange of expertise with industrial partners to eliminate platform integration risks. Like no other radio, the SOVERON® AR was designed to ease the integration effort. It goes without saying that the radio has been qualified in line with MIL-STD-704F, MIL-STD-810F and MIL-STD-461F to minimize additional platform-specific qualification.

**Assured command and control (C2) superiority**
Rohde & Schwarz offers state-of-the-art wideband waveforms to achieve information superiority. Applications range from pure voice to high-speed tactical data covering all airborne platform scenarios. The waveforms permit reliable and secure communications in a fast-moving, harsh environment. Fast frequency hopping, advanced encryption technologies, simultaneous voice and data transmission and embedded mobile ad-hoc networking (MANET) capability are just a few examples of superior technology.

**Customized national data link solutions**
Based on the internationally accepted SCA standard, the strict separation between the radio platform and the waveform application allows customers to fully modify this part of the radio in line with national requirements. Developing an indigenous national waveform, including the crypto algorithm, gives customers true independence. During the initial phase, Rohde & Schwarz will train and support the customer, even in-country, until full autonomy is achieved.

**Key facts**
- Frequency range from 30 MHz to 512 MHz
- Control via MIL-STD-1553B data bus or RS-485 serial interface
- Standard ARINC 600 housing, 3 MCU
- Suitable for jet and propeller aircraft as well as helicopters and unmanned aerial vehicles (UAV)

**Waveforms**
- R&S®SECOS
- SOVERON® WAVE
- Fixed frequency STANAGs: 4204, 4205
- Fixed frequency civil: ED23C (civil ATC), ITU-R M.489-2 (maritime VHF)
- EPM STANAGs 4246, 4372 – on request
**Frequency range**
- 30 MHz to 88 MHz
- 108 MHz to 118 MHz (receive mode only)
- 118 MHz to 174 MHz
- 225 MHz to 512 MHz

**Receiver sensitivity**
- AM sensitivity: ≤ –103 dBm, 10 dB SINAD
- FM sensitivity: ≤ –108 dBm, 10 dB SINAD

**Guard receiver**
Supported guard frequencies: 40.5 MHz, 121.5 MHz, 158.8 MHz and 243 MHz plus one user-defined frequency (dedicated monitoring or scan mode)

**Transmit output power**
- AM: ≥ 20 W
- FM/MSK: ≥ 30 W
- QAM: ≥ 40 W PEP (with typ. crest factor of 3 dB to 4 dB)
- Power modes: high, medium, low

**GPS**
- Time of day (ToD) interface as per ICD-GPS-060A (HAVE QUICK interface)

**Environmental specification**
- Temperature range: –40°C to +71°C
- Storage temperature range: –54°C to +90°C
- Tests performed in line with MIL-STD-810F

**Electromagnetical specification**
- Tests performed in line with MIL-STD-461F

**Power input**
- 28 V DC nominal power supply
- In line with MIL-STD-704F, incl. floating power supply

**Applicable civil standards**
- Fixed frequency: ED-23C (classes 5 and H2), ICAO Annex 10
- Avionics development: DO-178C Level C, DO-254 DAL C

**SOVERON® WAVE**
- Data rates
  - SOVERON® WAVE AJ-NB: up to 110 kbps at 25 kHz
  - SOVERON® WAVE AJ-WB: up to 630 kbps at 250 kHz
  - SOVERON® WAVE WB: up to 2100 kbps at 500 kHz
- MANET capability for voice and data
- Data and up to two voice streams simultaneously
- Dynamic parameter adaption
- Different medium access schemes
  - Static and dynamic TDMA
  - CSMA/CA
- IPv4 transparent IP interface
- COMSEC
  - Embedded encryption using AES
- TRANSEC
  - Orthogonal fast frequency hopping
  - Hop rates independent of selected transmission mode
SOVERON® NETWORK MANAGEMENT

For SOVERON® software defined radios
Today’s armed forces need efficient, easy-to-use communications systems when on missions. Secure tactical radiocommunications requires thorough and comprehensive planning.

Configuring radio networks with many diverse parameters such as frequencies and users is a complex task. SOVERON® NETWORK MANAGEMENT simplifies network planning and ensures that configuration data is securely distributed to the SOVERON® software defined radios. Modern mission scenarios require dynamic communications systems.

Key facts
- Graphical radio and IP network planning with consistency checks
- Highly secure network management
- Ergonomic user interface
- Planning of interoperable networks for army, air force and navy
- Scalable and adaptable to user requirements

Configure radio and IP networks and securely manage crypto keys

Radio network planning for all mission scenarios
Mission planning requires comprehensive radio network planning that covers all possible mission scenarios. The Rohde & Schwarz system solution is ideal for dynamic missions at all tactical command levels.

Storage and distribution of data specific to the radio, radio network and IP network
When network planning has been completed, the data specific to the radio, radio network and IP network is transferred to the radios, either by LAN or by using a fill device that is connected to the radio.

Integration of resources from higher-level management systems
SOVERON® NETWORK MANAGEMENT is capable of integrating resource data from higher-level management systems for use in network planning.

State-of-the-art radio networks provide armed forces with an optimized communications structure
These networks automatically adapt to mission topologies and cover all tactical areas of operation. SOVERON® NETWORK MANAGEMENT combines high flexibility with high performance when planning radio networks.

Graphical user interface
Planning of interoperable networks for army, air force and navy
SOVERON® NETWORK MANAGEMENT offers one user interface for planning radio networks for the army, air force and navy. Each of these forces can separately plan their communications networks and, if required, connect to a higher-level, forces-wide radio network, without causing compatibility problems.

Seamless integration into user’s network infrastructure
Radio networks can be planned based on frequency ranges or network planning data located on external databases. SOVERON® NETWORK MANAGEMENT supports integration by providing a generic interface for exchanging XML formatted planning data with external management systems. The system can be used on military off-the-shelf (MOTS) PCs.

Modular, configurable applications
Network planning depends on the customer’s mission structure. Customers who have decentralized planning at various tactical levels may use several SOVERON® NETWORK MANAGEMENT radio network management systems. These modular systems can exchange their specific configuration data over the customer’s network.

Full support of SOVERON® software defined radios
The SOVERON® radio family comprises state-of-the-art software defined radios for the army, air force and navy. Based on a common platform, the radios ensure interoperability between the different forces.

Takes full advantage of SOVERON® WAVE
The state-of-the-art SOVERON® waveforms were developed for the advanced SOVERON® radio family. These IP-based waveforms provide robust, wideband communications even under difficult conditions. SOVERON® NETWORK MANAGEMENT enables users to configure and use these waveforms in their radio networks.

Standardized transmission protocols (TCP/IP)
IP-based radio network planning using SOVERON® NETWORK MANAGEMENT is the basis for flexible and efficient communications of the future. The SOVERON® radio family uses TCP/IP-based communications. IP addressing makes it possible to communicate beyond the transmitters’ range.

Backward compatible with R&S®M3xR radios
SOVERON® NETWORK MANAGEMENT also supports R&S®M3xR radios.
R&S®M3AR Software Defined Radios

The software defined, multiband-capable airborne transceivers of the R&S®M3AR family feature a modular design and state-of-the-art technology. This leads to high MTBF values and a long life. The compact, lightweight transceivers offer high performance, making them suitable for operation in all types of aircraft, including unmanned aerial vehicles. Different waveforms are available. These can be installed at any time to provide interoperability in a variety of operational scenarios.

The challenge
The R&S®M3AR family is the product of decades of experience, especially in the design and development of airborne radio equipment and software defined radio technology. The R&S®M3AR multiband, multimode, multirole radio is the solution of choice for reliable transmission of mission-critical information – for jet and propeller aircraft, helicopters and unmanned aerial vehicles.

Rohde & Schwarz satisfies the most demanding requirements of a multitude of airborne platforms. The R&S®M3AR transceivers are in operation around the world and feature high reliability even under extreme environmental conditions. The outstanding MTBF values ensure low maintenance effort and high availability.

A variety of optional EPM (ECCM) methods are available.

Key facts
- Frequency range from 30 MHz to 400 MHz
- Compact and lightweight with high transmit power (up to 20 W in AM mode and up to 30 W in FM mode)
- EPM (ECCM): HAVE QUICK I/II, SATURN, R&S®SECOS
- Approved for jet and propeller aircraft, helicopters and unmanned aerial vehicles
- Embedded NATO or R&S®SECOS encryption
- Suitable for communications with military and civil air traffic control (e.g. 8.33 kHz channel spacing or offset carrier receive operation)

Benefits and key features
Outstanding radio characteristics
- Excellent RF parameters
- Outstanding RF characteristics on a single platform with the R&S®MR6000A

### R&S®M3AR software defined radios

<table>
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<tr>
<th>R&amp;S®GB6500</th>
<th>R&amp;S®MR6000R</th>
<th>R&amp;S®MR6000A</th>
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The R&S®M3AR family consists of the R&S®MR6000A in an ARINC 600 housing and the R&S®MR6000R/R&S®MR6000L, both of which are form and fit compatible with ARC-164. The R&S®MR6000L is equipped with a local control panel while the R&S®MR6000R is remotely controlled. All R&S®M3AR radios can be remotely controlled via the MIL-STD-1553B data bus, as well as by the R&S®GB6500 control unit. The R&S®MR6000R or R&S®MR6000L can serve as a form, fit and function (F3) replacement for legacy AN/ARC-164 radios.
Flexible alternatives for operating the radios

<table>
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<th>e.g. R&amp;S®MR6000R</th>
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<td>e.g. R&amp;S®MR6000R</td>
<td>primary remote control unit</td>
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<td>Passive antenna</td>
<td>e.g. R&amp;S®MR6000R</td>
<td>bus controller</td>
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<td>intercom system</td>
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<tr>
<td>MIL-Bus B</td>
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<tr>
<td>28 V DC</td>
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</table>

Secure communications
- EPM (ECCM) methods for anti-jam communications
- Tap- and spoof-proof communications through integrated encryption
- Wideband interface for external encryption devices (e.g. ELCRODAT 4-2, KY58, KY100)

Flexible range of applications
- High power for secure communications even during very low level flights and higher altitude instrument flying
- Preset concept permits flexible participation in various networks through simple change of the preset
- Suitable for fixed-wing and rotary-wing aircraft operated by the air force, army and navy
- Flexible integration through different interfaces (MIL-STD-1553B data bus, RS-485) or front panel control
- Safety aspects in line with civil specifications (R&S®MR6000A)
- Very compact and lightweight (R&S®MR6000L/R)

Low maintenance effort
- Powerful built-in tests (BIT) for error detection and diagnostics
- High reliability due to robust design and high-quality components

R&S®M3AR family

R&S®MR6000A ARINC600 housing
The R&S®MR6000A, the most powerful radio in the R&S®M3AR family, features RF power of up to 20 W in AM mode or 30 W in FM mode. It is a radio with an integrated crypto module and embedded NATO encryption algorithms. The elimination of the external encryption device and cabling saves valuable space and weight in the aircraft.

R&S®MR6000R and R&S®MR6000L ARC-164 housing
These two radios, which come in ARC-164 housings, differ in that the R&S®MR6000R is designed for installation in the avionic bay and is remotely controlled, while the R&S®MR6000L is installed in the cockpit and is controlled via a local control panel. Despite weighing less than 4 kg, the R&S®MR6000R and R&S®MR6000L series offer outstanding reception and transmission performance.

R&S®MR6000E L-shaped radio
The Eurofighter Typhoon, the result of multinational cooperation at the European level, will take on future air force tasks. It goes without saying that in the area of secure radiocommunications, Rohde & Schwarz know-how will be deployed.

The R&S®MR6000E, developed especially for this aircraft, establishes the encrypted air-to-air voice radio link and is also used for voice communications with air traffic control. It supports the SATURN and HAVE QUICK II frequency hopping methods in line with STANAG 4372 and STANAG 4246. SATURN uses a 16 kbit/s voice encoder for high-quality voice communications. The R&S®MR6000E has a distinctive L form and, in addition to a MIL-STD-1553B data bus, also features an optical interface in line with STANAG 3910 for the Eurofighter Typhoon.
The convenient way to empower the capabilities of Rohde & Schwarz radios in networks

In today’s world, information exchange via voice and data is indispensable for military forces to fulfil their increasing mission requirements. Handling all these communications demands with their complex waveforms requires an extended network management system. Rohde & Schwarz provides such a radio network management system: the R&S®RNMS3000. The R&S®RNMS3000 enables military leaders to turn their Rohde & Schwarz combat radio equipment into a robustly networked communications system based on mission demands and complex hierarchical structures, especially in joint or combined missions. In the past, many parameters had to be adjusted on the radios and that required highly skilled users. In the future, the complex configuration will be done during the preparative management system configuration.

The R&S®RNMS3000 software supports centralized network management where one central organizational unit performs the complete mission planning as well as decentralized management where the various configuration steps are accomplished at different military hierarchical levels. The R&S®RNMS3000 software suite, consisting of the mission planner, the remote device loader and the remote distributor, offers the following functions:

- Management of security keys
- Frequency assignments
- Establishment of logical nets
- Distribution of mission files

The objective is to provide mission-tailored and secure radiocommunications networks.

Security key management

To establish a secure radiocommunications network, encryption key management and data ciphering are essential. The Rohde & Schwarz mission planner software enables the import and assignment of external, waveform-specific encryption keys in black form. These keys are generated by separate key generation tools. Rohde & Schwarz provides the equipment required for customer-specific key generation.
**Key facts**
- Support of all Rohde & Schwarz radios and all frequencies
- Support of voice and data services
- Network planning, mission file generation and distribution with one software suite
- Target-oriented software guidance with wizards

**Mission-tailored network planning**
- Frequency assignment
- Hop set generation and management
- Security key management
- Effective mission planning

**Comprehensive waveform support**
- NATO waveforms
- HF house waveforms
- R&S®SECOS waveform

**Mission-optimized radiocommunications plan transfer**
- Secure file transfer
- Effective hardware programming

**Extended mission data distribution**
- File distribution over existing IP networks
- Event log and status control

---

**Process sequence**

1. **Encryption key generation** → **Black file** → **R&S®RNMS3000** → **Remote device loader** → **Radio-communications plan transfer** → **Remote distributor** → **Mission data distribution** → **R&S®M3AR**

- Mission planner
- Frequency assignment
- Security key management
- Logical net establishment

- Radio-communications plan
- Fill device

- LAN RS-232

---

More information | www.rohde-schwarz.com
Chapter 2
Ground-based communications

Your partner from the microphone to the antenna
For air traffic control agencies, airport operators, service providers and the armed forces, absolute system availability is paramount in flight operations. To meet this need, Rohde & Schwarz offers customers an optimized portfolio of solutions and services.

Air traffic control (ATC) requires maximum operational safety. Rohde & Schwarz has been an established leading provider of ATC radio equipment for decades. More than 200 airports and control centers rely on our systems. We are the only manufacturer to offer complete IP-based solutions – from the controller working position (CWP) to the antenna – that perfectly support the VoIP ATC communications of the future in line with the EUROCAE ED-137 standard.

As airspace becomes more crowded, there is an increased demand for load-based reallocation of resources while ensuring efficient and sustainable air traffic control (ATC) in line with the highest safety standards. The first supra-regional and even cross border control center is operated by Ireland’s and Iceland’s air traffic control authorities and services the North Atlantic flight corridor using Rohde & Schwarz equipment.

In January 2017, the British Air Navigation Service Provider (ANSP) NATS awarded Rohde & Schwarz the order to supply a fully voice over IP (VoIP) solution for its second voice system to ensure secure radiocommunications in UK airspace. Within the framework of the Single European Sky (SES) initiative, NATS will modernize its entire air traffic management (ATM) infrastructure over the next few years. As part of this modernization, ATC communications will be converted from TDM-based systems to VoIP.

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Full-range communications solutions for ATC/AD

Another ANSP
R&S®ATC-SBC
R&S®GT5400 NTP time server
R&S®VS5400 VoIP server
R&S®RS5400 radio server
R&S®DB5400 VCMS server
R&S®VCS-4G management terminal/R&S®RCMS II
R&S®SC5400 VoIP phone
R&S®GB5400 controller working position
Secured IP network
R&S®GW5420 telephony gateway
R&S®GW5450 VCS gateway
PBX
Analog phone
PSTN
R&S®VoIP radio
R&S®VoIP server
R&S®GW5410 radio gateway
Analog radio
3rd party IP PBX

Full-featured radiocommunications between air traffic controllers and pilots

The R&S®VCS-4G has been designed especially for civil ATC and air defense deployments. It enables full-featured radiocommunications between air traffic controllers and pilots, including specific radio remote control operations if required. For ground-to-ground communications, it also provides the full range of ATC/AD features with extensive interworking to conventional analog and digital VCSs and other related air traffic management (ATM) systems such as voice recorders. Additional voice services such as intercom, telephony and IP PABX are supported, too. One of the key advantages of this fully IP-based communications system is its very high scalability and availability. It allows system deployments ranging from a single controller working position (CWP) to full-scale area control centers (ACC) using the same technology and type of equipment. The system introduces new level of availability using its quad-redundancy topology. This includes distributed deployment over various sites for geographic redundancy of servers, but allows also center and radio radio site redundancy.

Compared to centralized traditional VCS solutions with single physical entity located in a specific place, the R&S®VCS-4G solution follows a modern distributed approach. Voice switching functionality is a built-in capability of each deployed R&S®VCS-4G component (CWPs, gateways, radio servers and VoIP telephony servers). Consequently, voice communications are spread out geographically without a central, single point of failure that would bring the entire system down.

Security of the LAN infrastructure is key for the service delivery. The R&S®VCS-4G can be perfectly combined with low latency R&S®SITLine encryptors providing strong network security.

The combination of R&S®VCS-4G components around a fully redundant secured IP LAN infrastructure flexibly fulfills all customer needs. The resulting system is a scalable, fault-tolerant solution for non-blocking voice switching based on modern IP network technology. Unlike conventional ATC operations, the R&S®VCS-4G is a future-ready
system that enhances overall performance and provides the latest functionality.

With its integrated portfolio of VoIP-based VCS systems and VoIP-based radios, Rohde & Schwarz has profound experience in providing reliable system solutions to replace increasingly aging conventional VCS installations.

As a professional system designed for voice communications in ATC/AD, the R&S®VCS-4G offers the following:

- Radiocommunications between air traffic controllers and airplane pilots via HF, VHF and UHF radios
- Telephone communications with external analog and digital telephone networks via a large variety of interfaces (FXO, FXS, LB, E&M, ISDN BRI, E1, ATS-R2, ATS-N5, ATS-QSIG, etc.)
- Intercom and telephone communications for internal users with direct, indirect and hotline/ instantaneous access
- Legal recording capabilities at the CWPs, telephony and radio interfaces (IP or analog/digital)
- Customization of graphical user interface and system infrastructure
- Interconnection/interworking with additional ATM systems or third-party services

In the past, ATC authorities interconnected their VCSs and radio sites via narrowband transmission lines. However, telecommunications service providers are increasingly phasing out their leased line services. As a result, the European Organization for Civil Aviation Equipment (EUROCAE) proposed the ED-137 standard for the use of IP in ATC voice communications. This standard was defined jointly by EUROCAE, ATC authorities and ATC equipment manufacturers. The R&S®VCS-4G already adheres to this EUROCAE standard. Moreover, the R&S®VCS-4G has been designed as a true IP solution that takes full advantage of IP technology to provide a cost-effective, future-ready VCS solution.

**Key facts**

- End-to-end IP technology from the CWP all the way to the radio while addressing increased safety requirements
- EUROCAE ED-137 compliant solution enabling interworking with other vendors’ equipment or neighboring ANSPs
- Large portfolio of gateways to support different migration scenarios from TDM to VoIP
- Distributed system architecture for high availability and cost-effective, pay-as-you-grow scalability
- Support for modern services beyond pure voice communications (e.g. video, text messaging, SCADA interworking)
- High flexibility and customizability to specifically meet different operational needs

- Intelligent leveraging of market-leading commercial off-the-shelf (COTS) products for reduced system costs
- Tight integration with Rohde & Schwarz radios (e.g. status monitoring, specific radio remote control operations)
- Single central monitoring system with integrated view of R&S®VCS-4G components and Rohde & Schwarz radios

**Benefits and key features**

**State-of-the-art, future-ready technology for investment protection**

- EUROCAE ED-137 based, field-proven technology
- High availability through distributed system architecture
- Non-blocking system capacity
- Future-ready technology

**Reduction of system costs**

- One partner from the microphone to the antenna
- Pay-as-you-grow scalability
- Integrated IP PABX functionality
- Intelligent leveraging of commercial off-the-shelf hardware and software
- Shared network infrastructure for voice and data services

**Smooth integration into existing ATM systems**

- Safeguarding capital investment in radio infrastructures
- Interworking with conventional voice communications systems and the PSTN
- Flexible support of any deployment scenario
- Compatible with all network topologies (enhanced star or ring)

**Comprehensive system management**

- Easy to deploy, manage, upgrade and extend
- Hot swappable interface cards
- Advanced fault management and system diagnostics
- Central monitoring of R&S®VCS-4G components and Rohde & Schwarz radios

**Custom system solutions**

- Flexible CWP concept and customizable touchscreen interface
- Sophisticated ATC role concept
- Monitoring and control of radio status information directly at the CWPs
- Various additional applications to improve situational awareness
- Interworking with existing telephony systems

**Next generation ATC features**

- Smooth migration to a fully IP-based ATC solution
- Sharing of resources
- Virtual center concepts
- Geographic redundancy
- Integrated use of third-party systems and equipment
R&S®Series4200 Software Defined Radios

The R&S®Series4200 represents the latest generation of stationary radios for both civil and military air traffic control. Possible applications range from small airport emergency systems requiring only a few radio channels to countrywide communications systems with several hundred radio channels.

**The R&S®Series4200 is available in six versions:**
*transceiver, transmitter and compact receiver*

The R&S®Series4200 radios for the VHF frequency range (112 MHz to 156 MHz) are suitable for civil applications. The R&S®Series4200 radios for the UHF frequency range (225 MHz to 400 MHz) are suitable for applications in military air traffic control (air force, navy, army aviation). The UHF transceiver allows an external encryption device to be connected.

**Wide application range and simplified radio planning, even in challenging environments**

The R&S®Series4200 offers an extremely wide range of possible configurations, allowing optimal adaptation to the desired application scenario

The radios were implemented on a software basis in order to provide users with the widest possible range of applications. New functions are implemented through software upgrades that Rohde & Schwarz makes available.

All R&S®Series4200 radios are multichannel radios, but they can also be software-configured for reliable operation as single-channel radios. Redundant operation of two radios in order to boost channel availability is possible without any external monitoring and switching equipment.

Standard functions include 8.33/25 kHz channel spacing for VHF and 8.33/12.5/25 kHz channel spacing for UHF, carrier offset 1 to 5 (VHF), ACARS and VDL mode 2 data mode (VHF), LAN remote control interface, serial interface for controlling automatic filters, and in-band signaling for push-to-talk (PTT) and squelch (SQ) with the ability to set different tones.

The R&S®Series4200 radios support digital voice transmission using the ITU-T G.703 PCM interface and VoIP in accordance with EUROCAE specifications.

Up to seven VoIP sessions can be established to the receiver or transmitter, allowing multiple VCS or remote audio units to access the radio simultaneously. The radio can be connected to a maximum of two VoIP voice recorders.

One of the highlights of the R&S®Series4200 is the receiver’s ability to detect simultaneous transmissions and alert air traffic controllers. Simultaneous transmissions most often occur on radio channels with high traffic volume and can present a safety risk.

### The different R&S®Series4200 radio versions

- **VHF (112 MHz to 156 MHz)**
  - **R&S®SU4200**
    - VHF transmitter
  - **R&S®EU4200C**
    - compact VHF receiver
  - **R&S®XU4200**
    - VHF transceiver
Ground-based communications

**Key facts**
- VHF frequency range from 112 MHz to 156 MHz
- UHF frequency range from 225 MHz to 400 MHz
- Output power of 50 W for VHF and UHF
- Automatic main/standby operation
- USB service port for configuration and software downloads
- Remote control and remote monitoring via Ethernet interface
- Best signal selection in the receiver
- Data transmission in line with VDL mode 2 standard
- VoIP in line with EUROCAE ED-137
- Detection of simultaneous transmissions in the receiver

**Benefits and key features**

**Easy to use even in challenging environments**
- Demanding system requirements of civil air traffic control are met or exceeded
- Excellent RF characteristics
- Adjacent channel power better than required by ETSI standard
- Very low transmitter noise
- High intermodulation rejection
- High output power at high modulation depth
- Very low receiver noise
- Receiver with excellent immunity to interference
- Crossmodulation rejection better than required by ETSI standard
- Two squelch criteria available
- Low noise/low distortion receiver mode

**Maintenance-free operation**
- Extensive self-test routines
- Simple remote monitoring and remote control
- Automatic adaptation to ambient conditions
- Easy remote switching when using redundant radios
- Electronic inventory and recalibration
- No recalibration for 15 years with optional OCXO

**Straightforward operation and configuration**
- PC-based tools with graphical user interface
- Reliable protection against operating errors
- Warning messages in case of unauthorized local operation
- Easy remote control and monitoring via IP connection

**Flexibility for system integration**
- Adaptation of in-band signaling for PTT and squelch to existing voice communications systems
- Flexibility in management system selection
- Seamless transition from analog to digital voice transmission in the ground segment
- Support for voice over IP

**Small footprint due to compact, modular design**
- Very compact design
- Three basic modules: transmitter, receiver, power supply unit

---

**UHF (225 MHz to 400 MHz)**

- **R&S®XD4200**
  - UHF transceiver
- **R&S®SD4200**
  - UHF transmitter
- **R&S®ED4200C**
  - compact UHF receiver
Ground-based communications

R&S® M3SR Series4100 Software Defined Radios

HF radio family for stationary communications
Rohde & Schwarz has developed a state-of-the-art generation of communications systems designed to take HF radio to the next level. Shortwave communications are a resource that can be set up easily, offer extreme reliability and are highly valued by security authorities and organizations as well as military users all over the world.

The R&S®M3SR Series4100 HF radios are innovative, versatile software defined radios (SDR) that belong to the popular R&S®M3SR radio family. Possible applications include typical applications in civil air traffic control and embassy radio systems and air defense applications.

Software defined radios lower logistics effort and reduce operating costs. In particular, the costs of warehousing spare parts and of maintenance are reduced tremendously. Having fewer internal hardware components also helps to significantly boost reliability compared to conventional radios.

The R&S®M3SR Series4100 is a powerful radio platform that can be extended at any time. This helps to provide a safe, future-ready investment.

In addition to the existing HF house waveforms, the R&S®M3SR Series4100 radios also support frequency hopping waveforms. Different models for ATC and air defense applications are available. The radios include HF wideband functionality to establish long-range data links on a 24 kHz channel. The probability of achieving permanently high data rates can be increased thanks to a well-tuned embedded radio HF wideband concept for 48 kHz channels.

Key facts
- Frequency range: 1.5 MHz to 30 MHz (transmission), 10 kHz to 30 MHz (reception)
- Power classes of 150 W, 500 W, 1000 W and standalone receiver
- LINK 11, LINK 22, LINK Y support
- Embedded secure voice and data capability
- IP over air capability
- SIP-based remote voice operation

Benefits and key features
IP for easy integration
- R&S®IPoA protocol functionality
- R&S®IPoA embedded services
  - Alarm messages
  - Short data messages
  - GPS reporting
- IPoA with STANAG 4538
- Voice over IP, SIP and phone patch
- Audio and remote control via IP
- Phone patch
- Domain connect

Interoperable waveforms for multinational cooperation
- ALE-2G
- ALE-3G, STANAG 4538
- HF modem
Secure and reliable communications

- Secure digital voice (SDV)
- Last ditch voice
- R&S®SECOM-H EPM (ECCM)
- Management of black keys for additional security

Unrivaled radio parameters

- Collocation capability due to excellent receiver specifications
- Selective level control for optimum transmit power (software option)
- Digitally tuned RF selection (hardware option)
- Digital IF and audio signal processing

Suitable for a wide range of situations

- Three power classes and suitable line of accessories
- HF broadband system

Easy operation

- Clear status display
- Preconfigured menus
- Radio configuration only by authorized personnel

Low maintenance effort

- Rugged design, suitable even for difficult environmental conditions
- Powerful built-in test (BIT)
- Excellent reliability
- Easy module exchange

Logistical structure

The logistical structure of the R&S®M3SR Series4100 is based on radio models that are available for the R&S®EK4100 receiver, the R&S®GX4100 receiver/exciter and the R&S®XK4115 150 W transceiver.

Each radio model consists of:

- Hardware base unit
- Radio software
- Software and hardware options

The base units are all ruggedized with a splashproof IP32 front panel. The radio software for these base units can be ordered in the form of “A” software (with no export restrictions) or “D” software (requires an export license).

Depending on customer requirements, individual hardware and software options can be added to the system.

The final type designation and the order number for a custom-configured R&S®EK4100A/R&S®EK4100D or R&S®XK4115A/R&S®XK4115D are order-specific. This unique order number makes it possible to clearly identify any customized unit with all of its options.

R&S®M3SR Series4100 power classes

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<th>Power Class</th>
<th>Description</th>
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<td>R&amp;S®EK4100A/D receiver</td>
<td>1000 W HF power amplifier</td>
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<tr>
<td>R&amp;S®XK4115A/D 150 W transceiver</td>
<td>500 W transceiver systems</td>
</tr>
<tr>
<td>R&amp;S®GX4100A/D HF receiver/exciter</td>
<td>1000 W transceiver systems</td>
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<tr>
<td>R&amp;S®IN4000A power supply</td>
<td>R&amp;S®IN44150 power supply</td>
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<tr>
<td>R&amp;S®IN4150 power supply</td>
<td>R&amp;S®IN4190 power supply</td>
</tr>
<tr>
<td>R&amp;S®VK4150 500 W HF power amplifier</td>
<td>R&amp;S®VK4190 1000 W HF power amplifier</td>
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</table>
Ground-based communications

R&S®M3SR Series4400 Software Defined Radios

VHF/UHF radio family for stationary communications
To ensure secure radiocommunications and successful accomplishment of missions, today's stationary radio-communications solutions for civil and military applications must meet extremely demanding RF requirements and also provide high operating reliability. The R&S®M3SR Series4400 software defined radio family is designed for stationary civil and military secure voice and data communications. It features high modularity and outstanding specifications. The R&S®M3SR Series4400 radios provide continuous AM and FM transmission coverage from 100 MHz to 512 MHz. The radios were developed in line with international civil air traffic control guidelines and standards (ICAO Annex 10, EN 300676). The radios also fulfill UHF communications requirements in line with EN 302617.

The R&S®M3SR Series4400 offers military customers a wide range of interfaces and associated proprietary frequency hopping waveforms, as well as radiocommunications in line with NATO standards. Military data transmission methods such as LINK 11 and LINK 22 are supported. To ensure that existing R&S®M3SR Series4400 systems remain up-to-date, their functionality can be enhanced through subsequent software downloads and, if necessary, by using new hardware modules.

Key facts
- Extended frequency range from 100 MHz to 512 MHz for coverage of various civil and military communications modes
- Output power up to 100 W for deployment with EPM (ECCM) waveforms for increased performance
- TCP/IP-based interfaces for remote control, voice over IP (VoIP) and service/maintenance activities
- Simple network management protocol (SNMP) for radiomonitoring and remote control applications with automated TRAP reporting
- Continuous transmission at temperatures up to +55°C
- Interfaces for external cipher units and modems

Benefits and key features

Secure communications
- NATO and proprietary EPM (ECCM) waveforms
- 70 MHz up/downconverter for external modems (optional)
- Methods for secure data transmission over TDMA-based radio networks (optional)
- Interface for external encryption devices
- Remote key loading
- Support for various LINK methods

Ease of operation
- Intuitive graphical user interface (GUI)
- Password-protected access
- Plain-text status and warning messages
- Automatic remote control access management

Flexible range of applications
- Software defined radio concept
- VoIP interface (optional)
- Highly modular design for scalable radios
- Flexibility when selecting the voltage source (multirange AC power supply, direct DC input)

Unrivaled radio parameters
- Excellent RF characteristics
- Robust design for unfavorable RF conditions
- Integratable UHF circulator with VHF bypass function for improved intermodulation rejection (optional)
- Frequency agile pre/postselector for best interference-free operation (optional)
- 70 MHz wideband interface for modem applications (optional)

Flexible and safe investment for the future
- Hardware and software upgrades
- Integrated in the NATO logistics structure
- Low lifecycle costs

Low maintenance
- IP-based maintenance tool supporting radio cloning
- Powerful built-in test (BIT)
- No tuning of the RF modules required
- High reliability
**Voice over Internet protocol (VoIP)**

The R&S®M3SR Series4400 radios offer a voice over IP (VoIP) interface in addition to the analog ports. VoIP operates on a standard IP infrastructure and eliminates the need for conventional analog infrastructures. The R&S®M3SR VoIP solution is based on the EUROCAE ED-137 VoIP standard.

Signals such as PTT and squelch are also transmitted via VoIP protocol, making such systems much easier and less expensive to connect. Redundancy can be economically and effectively built into the infrastructure. The radio’s analog interfaces remain active and can be used as usual.

**Fully integrated into Rohde & Schwarz IP-based VCS**

The R&S®M3SR Series4400 radios can be used together with the R&S®VCS-4G voice communications system (VCS) as shown in the figure below. The R&S®VCS-4G takes full advantage of IP technology to provide a scalable, cost-effective solution. It supports VCS services such as air-to-ground communications, intercom and telephony services. The IP-based distributed architecture provides additional benefits, such as the integration of new services and pay-as-you-grow scalability.
R&S®RNMS3000 Radio Network Management System

The convenient way to empower the capabilities of Rohde & Schwarz radios in networks

Increased significance of a radio network management system

In today’s world, information exchange via voice and data is indispensable for military forces to fulfil their increasing mission requirements. Handling all these communications demands with their complex waveforms requires an extended network management system. Rohde & Schwarz provides such a radio network management system: the R&S®RNMS3000.

The R&S®RNMS3000 enables military leaders to turn their Rohde & Schwarz combat radio equipment into a robustly networked communications system based on mission demand and on complex hierarchical structures, especially in joint or combined missions. In the past, many parameters had to be adjusted on the radios and that required highly skilled users.

In future, the complex configuration will be done during the preparative management system configuration. The R&S®RNMS3000 software supports centralized network management where one central organizational unit performs the complete mission planning as well as decentralized management where the various configuration steps are accomplished at different military hierarchical levels. The R&S®RNMS3000 software suite, consisting of the mission planner, the remote device loader and the remote distributor, offers the following functions:

- Management of security keys
- Frequency assignments
- Establishment of logical nets
- Distribution of mission files

The objective is to provide mission-tailored and secure radiocommunications networks.
Security key management
To establish a secure radiocommunications network, encryption key management and data ciphering are essential. The Rohde & Schwarz mission planner software enables the import and assignment of external, waveform-specific encryption keys in black form. These keys are generated by separate key generation tools. Rohde & Schwarz provides the equipment required for customer-specific key generation.

Key facts
- Support of all Rohde & Schwarz radios and all frequencies
- Support of voice and data services
- Network planning, mission file generation and distribution with one software suite
- Target-oriented software guidance with wizards

Benefits and key features
Mission-tailored network planning
- Frequency assignment
- Hop set generation and management
- Security key management
- Effective mission planning

Comprehensive waveform support
- NATO waveforms
- HF house waveforms
- R&S SECOS waveform

Mission-optimized radiocommunications plan transfer
- Secure file transfer
- Effective hardware programming

Extended mission data distribution
- File distribution over existing IP networks
- Event log and status control

Process sequence

![Process sequence diagram](image-url)
For ATC and air defense applications

R&S®RCMS II is a software solution for monitoring the complete communications chain from the controller working position to the radio and for remote control of Rohde & Schwarz radios.

R&S®RCMS II enables operators of air traffic control (ATC) systems and air defense (AD) systems to monitor Rohde & Schwarz radios, R&S®VCS-4G devices and other SNMP-capable components from one or more locations. Remote control of Rohde & Schwarz radios is also supported. This allows a cost-effective quick response to error conditions and provides the ability to set operational parameters for various ATC/AD scenarios.

R&S®RCMS II is designed for monitoring scenarios ranging from individual airports to countrywide radiocommunications systems. The monitored and controlled devices are shown in both a tree view and a map view. The map view shows the location and basic configuration of each device. Individual devices can be selected and managed quickly and easily. The system data is recorded for customer-specific statistical analysis using third-party applications.

The R&S®RCMS II software can easily be configured for customer-specific ATC/AD systems. By using off-the-shelf computer hardware and existing network infrastructure, the required capital expenditures and operational costs can be kept to a minimum. With R&S®RCMS II, it is quick and easy to integrate completely new sites or add to-be-monitored devices to expand an existing site.

Key facts
- Monitoring of the complete communications chain from the controller working position to the radio
- No additional hardware required for monitoring and controlling radios at the individual sites
- Support for Rohde & Schwarz radios with EPM (ECCM) capabilities for military applications
- Redundant system for continuous monitoring and control
- Overall status report sent to higher-level monitoring system via SNMP
- Complete situational overview of the radio sites through monitoring of SNMP-capable devices

Various applications using the R&S®RCMS II architecture

![Diagram of various applications using the R&S®RCMS II architecture]
Benefits and key features

Optimum operational efficiency
- Remote monitoring of radios and R&S®VCS-4G devices
- Remote control of radios

Wide range of analysis features
- Recording and analysis of system events
- Data stored for customer-specific statistical analysis

Customized system solutions
- High level of scalability
- Expandability of existing R&S®RCMS II systems

State-of-the-art technology with off-the-shelf hardware
- Windows® platform
- IP technology
- Time synchronization via network time protocol (NTP)

Secure and reliable operation
- Flexible user management
- High availability

Interoperation with other components in the ATC/AD system
- Integration of SNMP-capable devices
- Status information for higher-level monitoring center

Application scenarios

Failure of a radio at an airport
One of the radios at an airport with separate transmitter and receiver locations has exhibited a fault. The corresponding standby radio was activated automatically and is now in operation. R&S®RCMS II registers the event and displays it on the R&S®RCMS II workstation in the management center. By selecting the radio with the fault, more detailed information about the fault is shown, such as temperature, voltage and VSWR. Upon command, R&S®RCMS II instructs the radios to carry out a built-in test, which will then provide additional information about the fault condition. This information is forwarded to the maintenance center where the appropriate repair measures are initiated.

Countrywide ATC system with multilevel monitoring
R&S®VCS-4G devices and radios at various locations around the country are monitored by regional ATC centers throughout the day. At night, when traffic volumes are low, communications activities are monitored from a central location. R&S®RCMS II also monitors all the R&S®VCS-4G devices and radios at night from this central location.

Changing radio parameters for an air defense application
A military operation requires changing the frequencies and modes of operations used for each mission. For a new mission, a predefined mission parameter set is selected. Upon command, R&S®RCMS II in the control center activates the mission parameter set (preset page) in the ground radios at the remote sites.
# Accessories for ground-based communications

## Control units, multi-link controller, system rack, switching unit

<table>
<thead>
<tr>
<th><strong>R&amp;S®GB4000C Control Unit</strong></th>
<th><strong>R&amp;S®GB4000V Remote Audio Unit</strong></th>
<th><strong>R&amp;S®KG4200 ATC System Rack</strong></th>
<th><strong>R&amp;S®ASMS02 Automatic Switching Main Standby Unit</strong></th>
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<tbody>
<tr>
<td><strong>Controlling, configuring and monitoring R&amp;S®M3SR radios via Ethernet</strong> The R&amp;S®GB4000C control unit is used to control, configure and monitor R&amp;S®M3SR radios via Ethernet. All required settings on the radio can be made using the control unit. It can also be used to operate several R&amp;S®M3SR radio systems (only one at a time) in an IP network. The R&amp;S®GB4000C is available as a standalone remote control unit and as an embedded local control panel. The control panel comes as a ruggedized model for demanding environmental conditions.</td>
<td><strong>Provides audio, PTT and squelch to and from radios in a remote location</strong> The R&amp;S®GB4000V is a remote audio unit, designed for use in both civil and military applications. It is ideally suited to small communications systems where a dedicated voice switch is not present.</td>
<td><strong>Standard rack for R&amp;S®Series4200 radios</strong> The R&amp;S®KG4200 system rack is the basis for a fully equipped radio system consisting of R&amp;S®Series4200 radios. Even systems with a large number of radio channels can be implemented in a minimum of space. Thanks to the standardized setup, various types of commercial-of-the-shelf (COTS) equipment can be integrated alongside the radios. The radio equipment and options can easily be installed, retrofitted and removed.</td>
<td><strong>For R&amp;S®M3SR Series4100 radios</strong> The R&amp;S®ASMS02 provides redundancy for reliable, high availability radiocommunications solutions without having to duplicate the entire system. It uses one antenna system (antenna and ATU) and two R&amp;S®M3SR Series4100 radios (main and standby radio).</td>
</tr>
</tbody>
</table>
### Multicouplers, circulator frame, circulator module

**R&S® ATCMC ATC Multicoupler**

Active 8-port and 16-port VHF/UHF signal distribution

- The space-saving R&S® ATCMC optimally supports typical ATC system installations with eight receivers operated in parallel on one antenna. The R&S® ATCMC16 features simultaneous signal distribution to up to 16 receivers. The multicoupler's integrated, steep-sided filters reliably suppress interference from high-power VHF, TV and TETRA/BOS signals.

-suppresses distortion signals from high-power transmitters in the stop band
- Band-selective in the VHF or UHF ATC frequency range
- 1-to-8 or 1-to-16 distribution
- Automatic emergency power switchover
- Overvoltage protection
- Floating alarm contact

**R&S® ADMC8 Multicoupler**

Active UHF multicoupler for 8-port ATC signal distribution

- The space-saving R&S® ADMC8 optimally supports typical ATC system installations with eight receivers operated in parallel on one antenna. The multicoupler's integrated, steep-sided filters reliably suppress interference from high-power VHF FM and TV signals. The intelligent switching concept maximizes the operational reliability of the ATC receiving system by preventing a single point of failure in the amplifiers.

- Suppresses adjacent signals from high-power transmitters
- Band-selective in the UHF ATC frequency range
- 1-to-8 distribution
- Automatic emergency power switchover
- Overvoltage protection
- Floating alarm contact
- Specifications in line with environmental data of the R&S® M3SR Series 4400

**R&S® KR420 Circulator Frame and R&S® KR420-Z1 Circulator Module**

VHF/UHF circulator for the R&S® Series 4200 radios

- The R&S® KR420 circulator frame and the R&S® KR420-Z1 circulator module were developed to reduce unwanted interference.

- The R&S® KR420-Z1 circulator module was designed for the R&S® Series 4200 radios. It consists of a VHF or UHF circulator module with single or double circulator, termination and an optional VSWR meter.

- Attenuates reflected signals from the antenna to the transmitter by up to 50 dB
- VSWR meter monitors the voltage standing wave ratio between antenna and circulator
- VSWR meter allows the radio to recognize any degradation in the antenna matching or an antenna failure even though the circulator is interconnected
- Circulator frame can accommodate up to 10 circulator modules
- Circulator frame can be installed in an R&S® KG4200 ATC system rack together with the R&S® Series 4200 radios

### Communications antennas for the VHF and UHF frequency band

**R&S® HK001E UHF Coaxial Dipole**

225 MHz to 450 MHz – UHF omnidirectional antenna for vertical polarization

- The R&S® HK001E UHF coaxial dipole is a vertically polarized, omnidirectional antenna for fixed and mobile applications, particularly for use on board ships. It is suitable for both transmission and reception. A mast stub mounted on the dipole's base plate provides a convenient antenna interface for customer applications.

- The entire antenna system is splash water resistant. The antenna can also be fitted upside down, if required.

- Ideal for military aeronautical radio
- For use on ships
- RCS optimized
- Rugged design
- Minimal wind load
- High protection against lightning strikes in the vicinity

More information | www.rohde-schwarz.com
**Communications antennas for the VHF and UHF frequency band**

**R&S®HK012E VHF Coaxial Dipole**

100 MHz to 174 MHz – VHF omnidirectional antenna for vertical polarization

The R&S®HK012E VHF coaxial dipole is a vertically polarized, omnidirectional antenna for fixed and mobile applications, particularly for use on board ships. It is suitable for both transmission and reception. A mast stub mounted on the dipole’s base plate provides a convenient antenna interface for customer applications.

The entire antenna system is splash water resistant. The antenna can also be fitted upside down, if required.

- Ideal for civil aeronautical radio
- For use on ships
- RCS optimized
- Rugged design
- Minimal wind load
- High protection against lightning strikes in the vicinity

**R&S®HK014E VHF/UHF Coaxial Dipole**

100 MHz to 2 GHz – VHF/UHF omnidirectional antenna for vertical polarization

The R&S®HK014E VHF/UHF coaxial dipole is a vertically polarized, omnidirectional antenna for fixed and mobile applications, particularly for use on board ships. It is suitable for both transmission and reception. A mast stub mounted on the dipole’s base plate provides a convenient antenna interface for customer applications.

The entire antenna system is splash water resistant. The antenna can also be fitted upside down, if required.

- Extremely wide frequency range
- High suppression of skin currents
- Filled-in vertical radiation pattern
- High protection against lightning strikes in the vicinity
- Sturdy design
- RCS optimized
- Minimal wind load
- Particularly for use on ships

**Communications antennas for the HF frequency band**

**R&S®HX002H1 150 W HF Dipole**

1.5 MHz to 30 MHz – with integrated antenna tuning unit for stationary applications

The R&S®HX002H1 150 W HF dipole is suitable for setting up radio links over any distance. In particular, the optimized omnidirectional coverage ensures high transmission reliability over short and medium distances.

Special attention was paid to lightning protection. The integrated antenna tuning unit is protected against lightning strikes and was tested with 10 kV/10 kA discharges.

- Omnidirectional coverage with high-angle radiation (NVIS)
- No skip zone
- Integrated antenna tuning unit for support of fast frequency hopping in line with R&S®SECOM-H
- Silent tuning
- Compatible with R&S®M3SR Series4100 HF transceivers
- Setup close to neighboring antennas possible

**R&S®HL451 Log-Periodic HF Antenna**

2 MHz to 30 MHz – transmission and reception of horizontally polarized waves over medium and long distances

The compact, rotatable R&S®HL451 log-periodic HF antenna can be used for transmission and reception of horizontally polarized waves.

The antenna’s transmission frequency range from 5 MHz to 30 MHz makes it particularly suitable for communications over medium and long distances. Reception is possible from 2 MHz so that all distances can be covered.

The antenna has been optimized for small size, low weight and minimum maintenance.

- Reception from 2 MHz
- Transmission from 5 MHz
- Unshortened half-wave elements for high gain despite extremely small size
- Easy and quick assembly
- Low maintenance
- Suitable for roof mounting
Antenna filters, antenna tuning units (ATU)

R&S®FU214A VHF Filters, R&S®FD213A UHF Filters, R&S®FD213A2 UHF Filter (dual type), R&S®FT213A VHF/UHF Filter

VHF/UHF automatic filters for R&S®M3SR software defined radios

The R&S®FU214A and R&S®FD213A filters are single-cavity high-precision automatic filters. The filters are an essential part of any radio site where the reciprocal influence of neighboring radio systems must be restricted. The filters allow simultaneous operation of multiple radio systems in very tight spaces. As a result, sustainable, higher quality radio links can be achieved.

- Excellent mechanical precision
- Short tuning time
- Compact 19” 3 HU design
- Embedded distress channel bypass
- Very low insertion loss

R&S®FD221/FU221 Double Cavity Filter Units

Double-cavity filters

The R&S®FD221 and R&S®FU221 filters are an essential part of radio equipment. They are used at radio sites where the reciprocal influence of neighboring radio systems must be selectively restricted. Selective restriction is the only way multiple radio systems can be simultaneously operated in very tight spaces.

These units make it possible to achieve sustainable, higher quality radio links that are more reliable.

Up to four filters can be combined using a VHF or UHF two- or four-way combining array to create a multicoupler solution. Only a single antenna is needed to couple multiple transmitters or receivers.

R&S®HS9043 VHF/UHF Cavity Antenna Filter

For multiport filters or multicouplers

The R&S®HS9043 cavity antenna filters are proven “workhorses” that have been used successfully for decades. They are used in single-channel systems where medium power handling capacity and medium selectivity are sufficient. The filters make it possible to set up radio-communications systems where radios can be simultaneously operated in very tight spaces.

- Manually tuned
- Excellent mechanical precision
- Versatility for use in multiport filters or multicouplers
- Reasonable size
- Good price/performance ratio

R&S®FK41xx Antenna Tuning Units

The R&S®M3SR Series4100 HF system provides different antenna tuning units (ATU)

All Rohde & Schwarz antenna tuning units operate in the frequency range from 1.5 MHz to 30 MHz, where an antenna impedance transformation into 50 Ω in both receive and transmit directions is performed.

The ATUs allow a silent tuning over the entire frequency range from 1.5 MHz to 30 MHz. This results in a low probability of intercept (LPI). Rohde & Schwarz ATU frequency setting is performed very quickly and without any emission of RF power.

ATU selection guide

<table>
<thead>
<tr>
<th>Output power</th>
<th>R&amp;S®FK4115M</th>
<th>R&amp;S®FK4115U</th>
<th>R&amp;S®FK4190M</th>
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<tr>
<td>150 W</td>
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Antenna length

2 m 3 m 4 m 5 m 6 m 7 m 8 m 9 m 10 m 11 m 12 m 15 m 30 m 50 m

More information | www.rohde-schwarz.com 33
Chapter 3
Waveforms for line-of-sight communications

Flying platforms in army, airforce and navy
Armed forces are vulnerable to intentional or unintentional eavesdropping and jamming in today’s communications scenarios. Electronic protective measures (EPM) protect radio links from electronic countermeasures (ECM) such as jamming. These methods ensure a jam-free radio link. To protect radio links from tapping and spoofing; the information being transmitted can be encrypted via embedded encryption or additional external encryption devices.

Secure voice communications
Secure, effective radiocommunications are essential for mission success in military organizations and state agencies. There is a rapidly growing demand for network-capable and reliable waveforms that are suitable for a wide range of simultaneous voice and data transmissions. In addition to using commercial IP data interfaces, it is crucially important to flexibly network various organizational units. SOVERON® WAVE take the possible hierarchical structures of communications users into consideration and reflect them in the radio network.

In addition to multiple simultaneous voice transmissions, SOVERON® WAVE also offer a strong encryption concept for exchanging voice and data messages. The waveforms are adapted to environmental conditions at all times and help ensure continuously stable communications. The waveforms provide high data rate transmissions within self-administered ad hoc networks.

Datalinks
High-performance waveforms designed to fulfill communications needs well into the future. The waveforms of the SOVERON® WAVE for the SOVERON® software defined radio family are based on state-of-the-art technology and form a viable, future-ready foundation for Rohde & Schwarz radiocommunications systems. Rohde & Schwarz drew on its many years of experience in secure radiocommunications in the VHF/UHF band to develop the SOVERON® WAVE.

These waveforms enable reliable communications in an anti-access and area-denial environment. Powerful frequency hopping and highly advanced encryption technologies are used to compensate for the influence of follower jammers and interception. The waveform suite provides the best options for transmitting secure high data rates without satellites in a jammed environment in various ground, air and combined ground-air-ground scenarios. Simultaneous voice and data capability significantly reduces the need for additional radios. The waveforms provide an increased situation awareness through adaptive high bandwidth IP networking. An embedded mobile ad hoc networking concept enables continuously stable communications within agile networks.

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<td>LOS waveforms</td>
<td>SOVERON® WAVE</td>
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<td>HAVE QUICK II</td>
<td>Anti-jam UHF radio system</td>
<td>38</td>
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<td></td>
<td>SATURN</td>
<td>Second generation anti-jam tactical UHF radio for NATO</td>
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<tr>
<td></td>
<td>R&amp;S® SECOS</td>
<td>Secure communications system</td>
<td>39</td>
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Type Designation Description Page
LOS waveforms
SOVERON® WAVE High data rate waveform suite High-performance waveforms designed to fulfill communications needs well into the future 36
HAVE QUICK II Anti-jam UHF radio system NATO standard for jam resistant voice communications 38
SATURN Second generation anti-jam tactical UHF radio for NATO New generation, fast frequency hopping algorithm 38
R&S® SECOS Secure communications system Waveform for use in fast airborne platforms as well as shipborne and vehicular applications 39
SOVERON® WAVE

High-performance waveforms designed to fulfill communications needs well into the future

The waveforms for the SOVERON® radio family are based on state-of-the-art technology and form a viable, future-ready foundation for Rohde & Schwarz radiocommunications systems. Rohde & Schwarz drew on its many years of experience in secure radiocommunications in the VHF/UHF band to develop SOVERON® WAVE.

These waveforms enable reliable communications in an anti-access and area-denial environment. Powerful frequency hopping and highly advanced encryption technologies are used to compensate for the influence of follower jammers and interception. SOVERON® WAVE provides the best options for transmitting secure high data rates without satellites in a jammed environment in various ground, air and combined ground-air-ground scenarios. Simultaneous voice and data capability significantly reduces the need for additional radios. The waveforms provide an increased situation awareness through adaptive high bandwidth IP networking. An embedded mobile ad hoc networking concept enables continuously stable communications within agile networks.

SOVERON® WAVE ensures interoperability across platforms such as land, sea and air, supporting up to four thousand nodes. The waveforms are based on a unique, upgradeable concept that meets today’s and tomorrow’s communications demands. The figure on page 2 shows the interacting networking waveforms in different scenarios.

Network-capable waveforms with advanced encryption concept for international missions

Secure, effective radiocommunications are essential for mission success in military organizations and state agencies. There is a rapidly growing demand for network-capable and reliable waveforms that are suitable for a wide range of simultaneous voice and data transmissions. In addition to using commercial IP data interfaces, it is crucially important to flexibly network various organizational units. SOVERON® WAVE takes the possible hierarchical structures of communications users into consideration and reflect them in the radio network.

In addition to multiple simultaneous voice transmissions, SOVERON® WAVE also offers a strong encryption concept for exchanging voice and data messages. The waveforms are adapted to environmental conditions at all times and help ensure continuously stable communications. The waveforms provide high data rate transmissions within self-administered ad hoc networks.
Four waveforms

SOVERON® WAVE includes four waveforms:

- **SOVERON® WAVE WB** (high data rate wideband)
- **SOVERON® WAVE AJ-WB** (high data rate anti-jam wideband)
- **SOVERON® WAVE AJ-NB** (high data rate anti-jam narrowband)
- **SOVERON® WAVE AJ-NB-S** (anti-jam narrowband soldier)

These network-capable waveforms permit users to transmit voice and data simultaneously. The waveforms are fully IP-based, providing user-transparent IP communications. Such an interface substantially simplifies the use of external applications. The waveforms include mobile ad hoc networking functionality and adaptive data rate adjustment. This ensures that the best network-based communications performance is achieved, independent of the environment.

The SOVERON® WAVE AJ-NB waveform provides a VHF/UHF frequency hopping functionality for mobile units and high-speed airborne platforms. The waveform covers wide transmission ranges and is highly robust against follower jammers and deception. The waveform uses a TDMA-based transmission concept. The soldier waveform (SOVERON® WAVE AJ-NB-S) is optimized for use on handheld radios.

The SOVERON® WAVE AJ-WB waveform provides a UHF frequency hopping functionality used primarily by mobile forces that require high data volumes. The waveform covers wide transmission ranges and is highly robust against follower jammers and deception. The TDMA waveform allows users to transmit large amounts of data without sacrificing anti-jam performance.

The SOVERON® WAVE WB waveform is a UHF fixed frequency waveform featuring a CSMA/CA channel access method. This waveform is designed for networks with high data volumes and wide ranges. The waveform supports a versatile range of applications such as videoconferencing.

The waveforms of SOVERON® WAVE are compatible with SCA 2.2.2.

Key facts

- Ad hoc networking to automatically update radio network topologies
- Simultaneous voice and data transmissions for effective communications with less equipment
- High network capability with up to 4000 addressable radios
- TCP/IP traffic optimizer to effectively transmit TCP/IP via radio links
- IP-based waveforms to provide a standard interface to reduce application and infrastructure integration efforts
- Orthogonal frequency hopping capability to avoid interferences of radiocommunications nets used in parallel

Waveform services

- Voice service
- Data services
- Quality of service
- UDP feedback mechanism
- TCP/IP traffic optimizer

Wireless communications

- Automatic data rate adaption
- Receive quality indication (RQI)
- Dynamic channel access method with collision avoidance
- Automatic repeat request (ARQ)

Advanced networking capabilities

- Ad hoc networking
- Multihop capability
- Transparent relay data operation
- Multicast and unicast

Powerful security concept

- Communications security (COMSEC)
- Red/black separation

Electronic protection mechanisms and time management

- Transmission security (TRANSEC)
- Time management

Management tools

- SOVERON® RNMS network management system
- SOVERON® CRYPTO security management system

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<th>Encrypted voice and data</th>
<th>Networking</th>
<th>Data rate</th>
<th>Range</th>
<th>Frequency hopping</th>
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<td>standard</td>
<td>high</td>
<td>●</td>
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</table>
HAVE QUICK II overview

HAVE QUICK II is a tactical anti-jam UHF radio system. It is the fielded NATO standard for jam resistant voice communications. Its technical characteristics are defined in STANAG 4246.

HAVE QUICK II radios may operate in either fixed frequency mode or anti-jam (AJ) mode. They can also be used with secure external voice equipment.

The HAVE QUICK II system provides resistance to EPM (ECCM) through the use of frequency hopping. There is no apparent pattern to the frequency hopping sequence and the frequencies appear to be randomly selected from the 225 MHz to 400 MHz band. To achieve communications in the AJ mode, HAVE QUICK II radios must hop from frequency to frequency in synchronization. This requires the use of the same frequency table, the same sequence of frequencies and common time information.

The AJ mode has a conferencing capability, but this is only available in non-secure mode.

To operate in the AJ mode, an HAVE QUICK II user must enter a communications net. A net is a unique hopping pattern defined by a combination of word of day (WOD), time of day (TOD) and net number. Net numbers are equivalent to channels in a conventional fixed frequency radio. Each net number selects a different frequency hopping sequence.

SATURN overview

SATURN, the second generation anti-jam tactical UHF radio for NATO, is the new generation, fast frequency hopping radio. Its technical characteristics are defined in STANAG 4372. SATURN radios are backwards interoperable with HAVE QUICK II radios. STANAG 4372 defines mandatory and optional modes for SATURN, which increases the flexibility of compliant implementations.

SATURN is a digital waveform that uses continuous-phase frequency shift keying modulation (MSK). SATURN provides improved EPM (ECCM) through fast frequency hopping. SATURN supports clear voice, secure voice and data with up to 16 kbit/s. It also supports NATO LINK 22 in UHF.

SATURN radios can monitor a fixed frequency while in hopping mode, which is called hailing. If a call comes in on this frequency, the operator receives an aural/visual indication and must then revert to this fixed frequency to communicate.

There are different ways to interrupt an existing transmission (break-in). This function operates in all modes of operation.
**R&S®SECOS**

**Waveform for use in fast airborne platforms as well as shipborne and vehicular applications**

In today’s communications scenarios, armed forces radio communications are vulnerable to intentional or unintentional eavesdropping and jamming. R&S®SECOS, the secure EPM communications system, was developed to counteract such activities.

R&S®SECOS can be deployed in secure fixed frequency and in frequency hopping mode. It was specifically designed to take advantage of the radios’ technical characteristics and therefore offers a very high range without compromising transmission quality. R&S®SECOS employs customized encryption. For voice operation, various speech codecs are available that can be selected as required.

R&S®SECOS allows simultaneous, collision-free operation of several R&S®SECOS frequency hopping networks so that multiple orthogonal R&S®SECOS communications networks can be operated nationwide in parallel without impacting system performance. R&S®SECOS supports point-to-point and broadcasting data transmission and uses forward error correction (FEC).

An integrated time division multiple access (TDMA) method makes it possible to create tactical data networks. The multistage TDMA concept enables automatic data exchange between different subscribers of an R&S®SECOS data network. Multiple TDMA data networks can be operated in parallel.

**Key facts**
- Secure voice and data communications
- Fully integrated in R&S®M3xR software defined radios
- Embedded customer unique encryption
- Fast, replay-proof, jam resistant synchronization schemes
- Orthogonal networking
- TDMA networking capability
- Easy waveform configuration
- Excellent voice quality

**Benefits and key features**
**Security**
- Proprietary, customer-specific algorithm for COMSEC, TRANSEC and waveform management
- Very high communications and management key diversity
- Supports different orthogonal hopping schemes
- Deception-proof due to inherent time authentication

**Electronic protection measures (EPM)**
- Frequency hopping
- Variable dwell times
- Selectable frequency range

**Robustness**
- Fast synchronization
- Autonomous time control
- Handles high bit error rates (BER) and high block error rates (BLER)

**Management tools**
- Control of all functions relevant to communications security
- Overall frequency planning and allocation
- Maintenance tool, e.g. to securely download radio waveforms
- Distribution of mission related R&S®SECOS keys and data within R&S®SECOS system

More information | www.rohde-schwarz.com
Rohde & Schwarz Cybersecurity is a leading IT security company that protects companies and public institutions around the world against cyberattacks. The company develops and produces technologically leading solutions for information and network security, including highly secure encryption solutions, cloud security, next generation firewalls and endpoint security. The portfolio also includes vulnerability scanners and firewalls for business-critical web applications and web services.

The award-winning and certified IT security solutions range from compact, all-in-one products to customized solutions for critical infrastructures. To prevent cyberattacks proactively, rather than reactively, our trusted IT solutions are developed according to the security-by-design approach. More than 500 people are employed at locations in Germany and France.

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<td>Fully ruggedized tactical crypto devices</td>
<td>ELCRODAT 4-2</td>
<td>Multimode multirole crypto device Encrypts and decrypts voice and data communications for all German and NATO security classifications</td>
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<td></td>
<td>R&amp;S®MMC3000</td>
<td>Multimode multirole crypto device Encrypts and decrypts voice and data communications at the highest security levels</td>
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Ruggedized HF/VHF/UHF and SatCom security for voice and data
The ELCRODAT 4-2 is a fully ruggedized tactical crypto device used to encrypt and decrypt voice and data communications for all German and NATO security classifications. TEMPEST-proof, it is interoperable with HF/VHF/UHF radio, satellite communications and line transmission equipment. It is perfectly suited for deployment on stationary and mobile platforms in rugged terrain and in naval and airborne environments.

The ELCRODAT 4-2 device supports simplex, half-duplex and duplex modes to satisfy the requirements of the widest range of digital and analog applications for both local and remote operation. The ELCRODAT 4-2 can be operated either with a control unit or the MIL-bus module. A customizable crypto algorithm provides the uniqueness and exclusivity needed for different national and coalition scenarios.

In data crypto mode, the device is seamlessly integrated into data transmission systems equipped with standard military interfaces (most standard military interfaces are supported). The vocoder used in voice mode optimizes speech clarity even in noisy transmissions. The flexible and future-ready design includes a protected software download process and a slot for an additional crypto board for upgrading the device to meet future requirements.

Key facts
- Voice and data encryption from the highest German security levels up to COSMIC TOP SECRET
- Protects HF/VHF/UHF, satellite communications and line transmission
- Fully rugged, tamper protected, TEMPEST-proof
- Stationary and mobile deployment in all military branches (army, navy, air force)

Benefits and key features
Dedicated operator interfaces for various applications
- Remote control software systems management interface
- MIL-bus communications systems management interface
- Control unit user interface
- Headset/intercom interface

Versatility through multiple traffic/operating modes and transmission methods
- Traffic modes according to operating modes and transmission methods
- Operating modes for voice and data transmissions
- Teletype for extremely reliable communications
- Synchronous and asynchronous transmissions over red and black interfaces

Comprehensive protection through elaborate security concept
- Audited production environment
- Hardware red-black separation and tamper protection

High quality of service and flexible operation with state-of-the-art technology
- High quality of service
- Flexible configuration
- Upgradeability

Wide selection of accessories simplifies commissioning and operation
- Configuration PC increases the efficiency and accuracy of the preset loading process
- Crypto ignition key (CIK) adds extra level of security and increases flexibility in deployment
- Mounting frame secures the device in physically demanding environments
- Seamlessly adjustable external power supply unit (110 V/240 V)
R&S®MMC3000 Multimode Multirole Crypto Device

In data crypto mode, the device is seamlessly integrated into data transmission systems equipped with standard military interfaces (most standard military interfaces are supported). The vocoder used in voice mode optimizes speech clarity even in noisy transmissions. The flexible and future-ready design includes a protected software download process and a slot for an additional crypto board for upgrading the device to meet future requirements.

The R&S®MMC3000 has a wide range of accessories to integrate the device in complex communications infrastructures. A security management system (R&S®SMS3000) is augmented by a data loading device (DLD), crypto ignition key (CIK), mounting frame, power supply unit and components for the remote operation of the control unit.

Benefits and key features

Dedicated operator interfaces for various applications
- Remote control software systems management interface
- MIL-bus communications systems management interface
- Control unit user interface
- Headset/intercom interface

Comprehensive protection through elaborate security concept
- Audited production environment
- Hardware red-black separation and tamper protection
- Secure key generation and management

Versatility through multiple traffic/operating modes and transmission methods
- Traffic modes according to operating modes and transmission methods
- Operating modes for voice and data transmissions
- Teletype for extremely reliable communications
- Ready for transmissions over IP
- Synchronous and asynchronous transmissions over red and black interfaces

Wide selection of accessories simplifies commissioning and operation
- Configuration PC increases the efficiency and accuracy of the preset loading process
- Crypto ignition key (CIK) adds extra level of security and increases flexibility in deployment
- Mounting frame secures the device in physically demanding environments
- R&S®GP3000 data loading device (DLD) enables key distribution to geographically dispersed units
- Seamlessly adjustable external power supply unit (110 V/240 V)

Ruggedized HF/VHF/UHF and SatCom security for voice and data

The R&S®MMC3000 is a fully ruggedized tactical crypto device used to encrypt and decrypt voice and data communications at the highest security levels. TEMPEST-proof, it is interoperable with HF/VHF/UHF radio, satellite communications and line transmission equipment. It is perfectly suited for deployment on stationary and mobile platforms in rugged terrain and in naval and airborne environments.

The R&S®MMC3000 is based on the ELCRODAT 4-2. The ELCRODAT 4-2 is approved for communications up to NATO COSMIC TOP SECRET. It has been a proven key component in the field of highly secure communications and helps safeguard interoperability between NATO nations. The R&S®MMC3000 does not contain NATO crypto algorithms but complies with the high standards regarding robustness, flexibility and security.

The R&S®MMC3000 device supports simplex, half-duplex and duplex modes to satisfy the requirements of the widest range of digital and analog applications for both local and remote operation. The R&S®MMC3000 can be operated either with a control unit or the MIL-bus module. A customizable crypto algorithm provides the uniqueness and exclusivity needed for different national and coalition scenarios.
ATC direction finding
Chapter 5
ATC direction finding

High reputation in precision and reliability
Rohde & Schwarz has been developing and manufacturing traffic control direction finders for ATC and vessel traffic service (VTS) for more than 50 years. During this time the well-known R&S®PA family of traffic control direction finders based on the Doppler DF method gained a high reputation for their precision and reliability. Some R&S®PA100 direction finders are still in operation after more than 20 years.

In 2008, Rohde & Schwarz introduced the R&S®DDF04E, the first wideband digital direction finder for traffic control applications. Now, for the first time, bearings could be taken on multiple frequency channels in parallel in the entire frequency range of interest with the same high level of system DF accuracy and sensitivity with a single DF antenna and DF unit.

Based on the success of R&S®DDF04E, in 2017 Rohde & Schwarz introduced the first wideband DDF for traffic control with a 20 MHz realtime bandwidth. The R&S®DF-ATC-S ATC DF system family covers the entire VHF ATC frequency range in a single measurement step and other VHF/UHF channels quasi-simultaneously with a single weatherproof DF unit. This increases the mean time between failure (MTBF) and significantly simplifies installation at airports.

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<td>Direction finding system</td>
<td>R&amp;S®DF-ATC-S</td>
<td>Air traffic control direction finding system</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Direction finding system specially designed for ATC controllers to get accurate DF results</td>
<td></td>
</tr>
</tbody>
</table>
Accurate and reliable direction finding for civil and military air traffic control

The R&S®DF-ATC-S air traffic control DF system solution provides accurate and reliable direction finding for both civil and military airports. The R&S®DF-ATC-S system enables ATC controllers to accurately determine the direction to the aircraft on the basis of its radio transmissions. The DF results are used to convey to the pilot the magnetic heading toward the airport (QDM) and can be shown on additional radar or map displays. This helps to reduce call-sign confusion and to identify responses from wrong aircraft. The increased safety makes it possible to handle more flights per hour by reducing the time gaps between consecutive flights.

Possible configurations range from small airport DF systems with up to two frequency channels in the VHF aviation band to powerful systems with up to 32 frequency channels in parallel for seamless coverage of the frequency range from 118 MHz to 450 MHz. Future-proof 8.33 kHz channel spacing in the VHF aviation band is included.

The R&S®DF-ATC-S standard configurations are complete systems for integrators and ATC authorities and include all required components. The new solution will replace the current ATC DF system based on the R&S®DDF04E digital direction finder for air traffic control.

Key facts

- Helps to instantaneously identify which aircraft is transmitting to reduce misunderstandings and call-sign confusion
- Increases safety and situational awareness, which allows more flights per hour
- Seamless coverage of a wide frequency range from 117.975 MHz to 450 MHz with only one DF antenna
- Up to 32 frequency channels in parallel, with up to 28 channels inside and up to four channels outside the VHF airband, configurable at control GUI
- 8.33 kHz and 25 kHz channel spacing
- Result outputs on radar displays and in traffic management systems via a TCP/IP interface or RS-232 (optional)
- Optimized control software for ATC operators
Benefits and key features

Standard system configurations

- Four standard configurations to match the requirements of different airports
- Each standard configuration provides an all-in-one solution and is optimized for simple deployment and reliable operation
- Detailed documentation, installation, operating and maintenance manuals
- One partner for the complete ATC DF system including masts, installation support, training and maintenance

One solution for all frequency channels with high DF accuracy and sensitivity

- Parallel direction finding on up to 28 VHF airband frequency channels from 117.975 MHz to 137 MHz, plus four out-of-band VHF airband frequency channels up to 450 MHz for simultaneously monitoring all important distress frequencies
- DF accuracy and measurement speed are equally high for all frequency channels
- R&S®ADD095 VHF DF antenna features a high level of DF accuracy, sensitivity and outstanding immunity to reflections
- Compact R&S®ADD317 VHF/UHF DF antenna optimized for semi-mobile scenarios
- Excellent large-signal immunity due to sophisticated preselection and extremely linear receivers

Ergonomic operation and easy configuration

- Optimized graphical user interface specially designed to meet the requirements of ATC controllers
- Switching between different frequency channels with a fingertip

- Easy configuration of the number of channels and frequencies being monitored
- Different user rights for system users and administrators to restrict system configuration changes
- Support of day and night view

Designed for easy maintenance

- Monitoring of system status and built-in self-test routines
- SNMP interface for integration into monitoring system
- Logging of system messages and DF results

Standard system configurations

Standard system configurations as all-in-one solutions are defined to match the requirements of different customers and airports. Each solution comes with all required system components, complete set of documentation and few options e.g. antenna mast, obstruction lights or UPS. System setup and internal tests are executed before delivery to the customer for simple deployment, low maintenance effort and reliable operation. Installation support, training and maintenance can be provided.

Central component of each configuration is the compact and weatherproof outdoor R&S®DFU300 direction finder unit including DF system server, temperature control, power supply, GPS and Ethernet switch. Together with the DF antenna it is installed at the antenna site. Outdoor UPS, antenna mast and obstruction lights can be added as required.

Each configuration includes at least one high-contrast touch panel PC with the control software for administration and operation, plus one TTL-to-LAN converter for ground transmission suppression (GTS) for installation in...
the ATC tower or control room. GTS is used to support the air traffic controller by suppressing all bearings of their own radio transmissions.

Standard LAN network products shall be used to connect the R&S®DFU300 with the control and administration panels. If required, adapters for LAN to fiber or DSL converters can be added to handle long distances between the DF antenna site and the ATC tower.

Connection to customer-specific traffic management systems and/or radar displays also runs via LAN (TCP/IP). Alternatively, RS-232 interfaces are available for connecting radar displays.

The table below provides a comparison of the standard configurations and its capabilities followed by a short summary of each system configuration.

<table>
<thead>
<tr>
<th>Features and options</th>
<th>R&amp;S® DF-ATC-S1 standard ATC DF system</th>
<th>R&amp;S® DF-ATC-S2 standard plus ATC DF system</th>
<th>R&amp;S® DF-ATC-S3 high-end ATC DF system</th>
<th>R&amp;S® DF-ATC-S4 high-availability ATC DF system</th>
</tr>
</thead>
<tbody>
<tr>
<td>VHF aviation channels, 117.975 MHz to 137 MHz</td>
<td>2</td>
<td>up to 4</td>
<td>up to 28</td>
<td>up to 28</td>
</tr>
<tr>
<td>Frequency range</td>
<td>117.975 MHz to 137 MHz</td>
<td>117.975 MHz to 450 MHz</td>
<td>117.975 MHz to 450 MHz</td>
<td>117.975 MHz to 450 MHz</td>
</tr>
<tr>
<td>Channel spacing</td>
<td>8.33 kHz/25 kHz</td>
<td>8.33 kHz/25 kHz</td>
<td>8.33 kHz/25 kHz</td>
<td>8.33 kHz/25 kHz</td>
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<tr>
<td>Out-of-band channels, 137 MHz to 450 MHz</td>
<td>not supported</td>
<td>on request</td>
<td>up to 4</td>
<td>up to 4</td>
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<tr>
<td>System DF sensitivity ¹</td>
<td>3 µV/m</td>
<td>5 µV/m</td>
<td>2 µV/m</td>
<td>2 µV/m</td>
</tr>
<tr>
<td>System DF accuracy ²</td>
<td>typ. 1° RMS</td>
<td>typ. 1° RMS</td>
<td>typ. 0.5° RMS</td>
<td>typ. 0.5° RMS</td>
</tr>
<tr>
<td>Immunity to reflections</td>
<td>medium</td>
<td>medium</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>R&amp;S®DFU300 direction finder unit</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2 (spare DF unit with dual network support)</td>
</tr>
<tr>
<td>Direction finding antenna</td>
<td>R&amp;S®ADD317 (traffic red)</td>
<td>R&amp;S®ADD317 (traffic red)</td>
<td>R&amp;S®ADD095 (traffic red)</td>
<td>R&amp;S®ADD095 (traffic red)</td>
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<tr>
<td>Integration kit</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>DF control touch panel</td>
<td>1</td>
<td>1</td>
<td>1 (optionally more)</td>
<td>1 (optionally more)</td>
</tr>
<tr>
<td>Administrator touch panel PC</td>
<td>optional</td>
<td>optional</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Data interface for DF measurement result</td>
<td>not supported</td>
<td>not supported</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>TTL converter for GTS</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Antenna mast, height: 5 m, with obstruction lights, red/white painting and ladder</td>
<td>optional ³</td>
<td>optional ³</td>
<td>optional</td>
<td>optional</td>
</tr>
<tr>
<td>Outdoor UPS</td>
<td>optional</td>
<td>optional</td>
<td>optional</td>
<td>optional</td>
</tr>
</tbody>
</table>

¹ Maximum number of supported VHF airband channels provisioned and 1 s integration time.
² Measurement in reflection-free environment. The RMS error is calculated from the bearings of evenly distributed samples versus azimuth and frequency.
³ R&S®DF-ATC-M1 contains the galvanized antenna mast, R&S®DF-ATC-M1L adds obstruction lights, red/white painting and ladder.

**System components**

**R&S®DFU300 compact and weatherproof ATC direction finder**

The main component of the R&S®DFU300 is an accurate digital direction finder based on the correlative interferometer DF method. Along with its integrated control PC, power supply and Ethernet switch, the direction finder is accommodated in a compact weatherproof housing. The integrated temperature control system features active heating and cooling so that the R&S®DFU300 can be used across a wide temperature range.

Thanks to its GPS module, the R&S®DFU300 knows its exact geographic position and has an accurate time source. For communications with control panel PCs and airport radar systems, an Ethernet interface is provided to connect to the airport LAN.
R&S®ADD317 VHF/UHF DF antenna
- Stationary narrow-aperture DF antenna covering the frequency range from 117.975 MHz to 450 MHz
- Multi-element DF antenna with five elements
- Integrated lightning protection with lightning rod; no impact on DF accuracy
- Optional antenna mast specifically designed for R&S®ADD317 at airports
  - Mast height: 5 m
  - Obstruction lights, red/white painting and ladder can be added

R&S®ADD095 VHF DF antenna
- Seamless coverage of a wide frequency range from 117.975 MHz to 450 MHz with only one DF antenna
- Wide-aperture DF antenna with nine antenna elements for high DF accuracy, sensitivity and immunity to reflections
- Integrated lightning protection with lightning rod; no impact on DF accuracy
- Optional antenna mast specifically designed for R&S®ADD095 at airports
  - Mast height: 5 m
  - Obstruction lights, red/white painting and ladder

TTL converter for ground transmission suppression
The TTL converter box has 16 input channels to be connected with the airport radiocommunications system. The DF ATC control software allows operators to configure for each input the corresponding frequency to be blanked as soon as it is used for their own transmissions. The control box is connected over Ethernet to the DF ATC control software.

Touch panel PC with control software
The ATC DF control software for ATC operators and administrators is installed on a touch panel PC to allow system control via the touchscreen. Mouse and keyboard are not required but can be used optionally. The touch panel PC runs under Windows 10 operating system and has a display size of 10.1" with 1280 x 800 resolution. It has adjustable brightness, a wide viewing angle and anti-glare surface for improved readability in brightly illuminated environments. At night or in a dark environment, the software’s night view can be activated.

Data interface for DF measurement results
All DF results from the ATC system are provided in real-time to external systems over a TCP interface. The external system can be a radar system, map display or any other system in which DF results are of interest. Details such as frequency, timestamp, azimuth and elevation value, overhead pass (OHP) flag and ground transmission suppression (GTS) flag are available for all configured frequency channels.
Chapter 6
C-UAV, analysis and disruption

Modular drone defense systems
Commercial drones represent a serious security risk to major public events, but also to sensitive infrastructures and facilities such as industrial testing grounds, large industrial plants, German Armed Forces properties and correctional facilities. A particular risk is the unauthorized use of such drones for espionage, provocation or even criminal and terrorist purposes.

Since early 2015, ESG Elektroniksystem- und Logistik-GmbH, Rohde & Schwarz GmbH & Co. KG and Diehl Defence GmbH have been cooperating and working intensively on a joint solution to counter these threats. The resulting solution includes different sensors and appropriate effectors as well as a command and control system. The modular drone countering solution consists of the following components:

- R&S®ARDRONIS radio-controlled drone identification and countering system
- ESG’s TARANIS® command and control system
- Diehl HPEMcounterUAS electromagnetic pulse sources
- Other optional sensors such as cameras and radars

The cooperation ensured effective protection against the unauthorized use of commercial drones and thus against an omnipresent security risk during the 2015 G7 summit in Germany. Following its successful debut, the solution ensured the safety of other major events such as the visit of the US President to the Hanover Fair.

ESG’s TARANIS® command and control system
The solution addresses the complexity of drone threats with a hierarchal approach, offering a modular solution that is scalable and customizable using equipment relevant to the given scenario.

In the context of protection against drones, ESG’s state-of-the-art TARANIS® command and control system can be connected to various numbers of sensors that detect drones and/or their remote control as well as to effectors that counter the immanent drone threat.

Due to the flexible, mobile data connections, sensors and effectors can be placed anywhere and the situational picture can be distributed to stationary or mobile operators.

R&S®ARDRONIS radio-controlled drone identification and countering system (described in this brochure)
R&S®ARDRONIS focuses on the remote control radio link of commercial drones. The subsystem can detect and identify the drone and take bearings on the remote controller even before the drones take off. Its ability to distinguish the remote control signals from other emissions within the same frequency band makes it highly reliable. R&S®ARDRONIS alerts security personnel early on so they can respond to the potential threat in a timely manner.

R&S®ARDRONIS can also disrupt the drones’ remote control radio links. It exactly matches the transmissions on the remote control signal and does not interfere with other radio links. No longer controllable by their pilots, the drones are forced into failsafe mode.

Diehl HPEMcounterUAS electromagnetic pulse sources
The Diehl HPEMcounterUAS source directly impacts the semiconductors of the control electronics inside commercial drones by means of electromagnetic pulses. Whether flying autonomously or radio-controlled, the drone becomes inoperable upon impact of HPEM pulses.

If navigation methods like inertial navigation, infrared homing, optical flow, home on jam, simultaneous localization and mapping are used, jammers cannot affect the drone. In such cases, the HPEM can affect the control electronics, regardless of the control method, and immediately disable the drone.
Protective measures can only be taken after a threat is detected. To effectively counter the threat, early warnings are critical – every second counts. When R&S®ARDRONIS detects commercial drone activity, it automatically classifies the type of drone signal, determines the direction of the drone and its pilot, and (on command) disrupts the radio control link to prevent the drone from reaching its target.

R&S®ARDRONIS displays concise information about the threat and continuously updates a map view that indicates the direction of the drone and its pilot. A predefined list of contacts can immediately be notified about the threat and R&S®ARDRONIS can also record the remote control (RC) signal as evidence. The proprietary Rohde & Schwarz ARDRONIS control center (ACC) software displays the results from several remote sensors. Using ACC, security forces can localize the threats, deploy countermeasures and have the best chance of intercepting the illegal pilot.

Through repeated involvement in protecting high-profile events and high-ranking VIPs, R&S®ARDRONIS has proven to be a valuable asset for the security services involved. Rohde & Schwarz has thereby established a global benchmark in counter-drone solutions.

R&S®ARDRONIS – detecting, localizing and disrupting RC drones
The majority of commercial remote controlled drones are controlled (uplink) via frequency hopping spread spectrum (FHSS), an advanced frequency agile waveform. Another family of drones is controlled (uplink) via WLAN. Signals transmitted from the drones (downlink) are typically FHSS, wideband or WLAN signals.

R&S®ARDRONIS combines leading Rohde & Schwarz sensors to form a reliable, high-performance solution for securing a predefined airspace against drones. Highly sensitive antennas and monitoring receivers collect RC drone signals.

For FHSS-controlled drones:
- R&S®ARDRONIS compares the measured signals with an extensive library of drone profiles. This “monitor and match” process provides reliable early warning of any threats in the coverage area.
- R&S®ARDRONIS direction finding (DF) ability delivers two critical parameters: the direction of the operator (RC signal DF) and the direction of the drone itself (telemetry or video downlink signal DF).
- R&S®ARDRONIS makes it possible to trigger effective countermeasures. The integrated jammer disrupts the targeted drones with minimum disturbance to other signals in the same frequency band.
For WLAN-controlled drones:
- R&S®ARDRONIS can detect the drone
- R&S®ARDRONIS optionally can use sectorial WLAN antennas to provide sectorial directional information
- R&S®ARDRONIS makes it possible to trigger effective countermeasures. The WLAN link between the remote control and the drone can be disrupted

Basic R&S®ARDRONIS packages
Thanks to the automated workflows, R&S®ARDRONIS is an optimized solution that effectively and reliably detects, localizes and disrupts FHSS-controlled drones and their remote controls, all within a few seconds. Four R&S®ARDRONIS packages were designed to meet users’ specific technical requirements:
- R&S®ARDRONIS Detection (R&S®ARDRONIS-I)
- R&S®ARDRONIS Direction (R&S®ARDRONIS-D)
- R&S®ARDRONIS Disruption (R&S®ARDRONIS-R)
- R&S®ARDRONIS Protection (R&S®ARDRONIS-P)

Benefits for all basic packages
- Early warning of drone activity
- Accurate classification of drone type
- Threat alerts based on profile matches
- Recording of signals to secure evidence
- Intelligence from intercepted video signals
- Threat notification to predefined persons/teams
- Field-proven counter-drone system
- System integration via open interfaces
- Multisensor wide area monitoring via ACC

Additional benefits
- Direction finding of drones and their pilots (for R&S®ARDRONIS-D and R&S®ARDRONIS-P)
- Disruption of RC links, on command (for R&S®ARDRONIS-R and R&S®ARDRONIS-P)
- Localization of drones and their pilots via ACC (for multiple R&S®ARDRONIS-D and R&S®ARDRONIS-P)
- Central control of remote jammers via ACC (for multiple R&S®ARDRONIS-R and R&S®ARDRONIS-P)

Additional option for handling WLAN-controlled drones
Each basic R&S®ARDRONIS package can be extended with options to additionally support detection of WLAN drone activity, classification of WLAN drone type, WLAN downlink video interception and WLAN disruption

Key features
- Early warning
  - Early warning is the key to countering any threat. R&S®ARDRONIS can detect RC activity even before drones take off. Early warning alone often ensures an effective response, including jamming and pilot interception
- Direction finding (DF) for FHSS-controlled drones
  - Direction information gives security personnel a real tactical advantage. Direction and localization enable a fast, effective response to the drone and the pilot
- Active countermeasures for FHSS-controlled drones
  - A choice of jamming modes enables an appropriate response to single or multiple threats
- Situational awareness
  - Continuous reporting of drone activity on all relevant frequencies within a large coverage area provides situational awareness
- Accurate classification of FHSS-controlled drones
  - Reliable detection and measurement of the RC signal followed by automatic matching of RC parameters with the built-in profile library
- Automatic threat alert
  - The automatic threat alert means R&S®ARDRONIS can be operated with minimal training. When a signal is classified as a threat, the operator is immediately alerted via the user interface
- Immediate built-in notification
  - Immediate built-in notification can be triggered manually or automatically. Key players can be informed about threats quickly and efficiently without distracting the operator from the current situation
- Video interception
  - R&S®ARDRONIS is able to intercept and visualize various common formats. Security staff can see what the drone pilot sees, which can be advantageous both during and after a drone-related incident
- Securing of evidence
  - Decoding the video signal and recording the RC signal of a drone allows security staff to collect valuable evidence that can be used to prove that a drone pilot participated in illegal activities
- Wide area monitoring and protection
  - ACC enables wide area protection by providing an overview of all detection and direction data from remote sensors, map-based threat localization and immediate access to active countermeasures
- Detection and disruption of WLAN-controlled drones
  - The R&S®ARDRONIS packages can optionally be extended with additional sensor equipment that handles WLAN-controlled drones
- Open interface
  - An open interface enables integration into multivendor and multisensor solutions, making R&S®ARDRONIS particularly attractive to integrators
Flexible deployment
C-UAV, analysis and disruption

R&S®ARDRONIS can be deployed as a fixed installation to cover a specific area, as a semi-mobile solution providing temporary cover or as a fully portable solution enabling ad hoc security. Modular design translates easily into custom solutions and is especially beneficial for portable systems.

Powerful, compact and portable setup
R&S®ARDRONIS precisely matches users’ specific requirements thanks to its fully modular and configurable design.

Plug & play concept
The plug & play concept quickly deploys R&S®ARDRONIS devices and configurations with little user intervention. The equipment and notebook (optional) come preconfigured (IP address, software/firmware installation).

R&S®ARDRONIS-I setup
R&S®ARDRONIS-I is ideal for users interested in drone detection and classification, i.e. monitoring of drone activity in a specific area. It is relatively small, compact and can be quickly set up. For portable use, a transport case with a compartment for the R&S®ARDRONIS-I application (antenna, receiver, notebook and accessories) is included.

Main components
- R&S®HE600 active omnidirectional receiving antenna
- R&S®EB500 monitoring receiver

R&S®ARDRONIS-D setup
R&S®ARDRONIS-D effectively and reliably detects and determines the direction of RC signals in the shortest possible time. R&S®ARDRONIS-D is a key component of the overall R&S®ARDRONIS solution. The combination of a reliable detection result and precise bearing line overlaid on a detailed local map provides many benefits to security personnel. For easy transport and deployment, the system includes an INCAS box with a compartment for the R&S®ARDRONIS-D application (direction finder and notebook).

Main components
- R&S®ADDx multichannel DF antennas
- R&S®DDF550 wideband direction finder

Active approach: R&S®ARDRONIS-R setup
R&S®ARDRONIS-R comes with the R&S®WSE wideband smart exciter to detect, classify and disrupt RC signals. The R&S®WSE can disrupt drone control signals in a specific frequency band. For easy transport and deployment, the system includes a compact INCAS box for the R&S®ARDRONIS-R application (R&S®WSE, R&S®WSE-RTA, R&S®SGT100A and LAN switch).

Main components
- R&S®WSE wideband smart exciter
- R&S®SGT100A SGMA vector RF source
**Active approach: R&S®ARDRONIS-P setup**

R&S®ARDRONIS-P comes with the R&S®WSE wideband smart exciter to detect, classify and disrupt RC signals. R&S®ARDRONIS-P enables classification, direction finding and countermeasures for RC drones. It contains an additional R&S®DDF550 that determines the direction of drone pilots and drones. The R&S®WSE can disrupt drone control signals in a specific frequency band while the R&S®DDF550 simultaneously looks for more RC drone signals in other frequency bands. For easy transport and deployment, the system includes an INCAS box with a compact configuration for the R&S®ARDRONIS-P application (R&S®WSE, R&S®DDF550, R&S®SGT100A and LAN switch).

**Main components**
- R&S®WSE wideband smart exciter and R&S®WSE-RTA Rx/Tx switch and amplifier
- R&S®SGT100A SGMA vector RF source
- R&S®ADDx multichannel DF antennas
- R&S®DDF550 wideband direction finder

**R&S®ARDRONIS-WF setup**

The R&S®ARDN-WF, together with a connected WLAN antenna, provides WLAN drone RC signal detection, WLAN video interception (optional) and WLAN drone countermeasures (optional):
- Multiple R&S®ARDN-WF boxes can be added to the basic R&S®ARDRONIS packages to cover the requested area with WLAN drone detection and countermeasures
- The ACC software running on a central computer controls all R&S®ARDRONIS remote installations connected via LAN

**Configuration for R&S®ARDRONIS-P**

[Image of R&S®ARDRONIS-P configuration]

**Configuration for R&S®ARDRONIS-R** (can be configured with either an RX/TX omnidirectional or directional antenna)

[Image of R&S®ARDRONIS-R configuration]

**Configuration of sensor for WLAN reception: R&S®ARDN-WF outdoor PC, R&S®ANT-DDO omnidirectional WLAN antenna**

[Image of R&S®ARDN-WF configuration]

**Training courses**

R&S®ARDRONIS training courses are a combination of classroom-based theory lessons and practical exercises. They cover the most important topics that must be understood in order to effectively counter threats from drones. The courses provide participants with the necessary knowledge to understand the security threats posed by drones and how to use key functions such as detection, direction finding and countermeasures. All courses are instructor-led with an interactive approach. The instructor uses a mixture of question and answer sessions, continuous assessment and a final exam to ensure effective knowledge transfer.
State-of-the-art interference hunting solutions
Chapter 7
State-of-the-art interference hunting solutions

Your requirements
Radio interferences can degrade or even disrupt ATC radiocommunications and important navigational aids used in avionics. This opposes a serious threat to safety and can result in a temporary close-down of the airport. The number of reports about cases of radio interference on airports worldwide increased significantly in recent years.

Various types of radio interference sources were detected on airports already, such as:
- faulty or poorly shielded electronic devices
- incorrectly set electronic devices
- imported electronic devices, which are not compliant with local regulations
- portable jammers for GPS and/or cellular networks

Consequently, it is necessary to quickly locate the object, building, or the specific room within a building, from which the radio interference originates. Most airports are located in or nearby built-up areas, hence multi-path wave propagation is typical.

Our solution: accurate portable direction finder
If radio interference occurs continuously or frequently, using a mobile direction finder is the quickest way to locate the interference source.

Within minutes, the compact DF system based on the R&S®DDF007 portable direction finder can turn a normal vehicle into a mobile DF covering the frequency range from 20 MHz to 6 GHz. This vehicle makes it possible to find the right object or building in a timely manner. In addition, during the drive, the R&S®MobileLocator software (included in R&S®RA-LOC) automatically locates the source of interference with a high degree of accuracy.

Our solution: automatic homing software
In urban environments, reflections are unavoidable. As a result, the direction finder does not always point steadily in the direction of the transmitter, but often in other directions. Extending the averaging time brings no advantage, because incorporating incorrect bearings into the averaging would significantly deteriorate the overall results.

The R&S®MobileLocator software uses a multitude of bearings to calculate a radiolocation result step by step and displays this result on a map using the R&S®MapView geographic information software. For every location within a definable area, the software continuously calculates the probability of the transmitter being at that location. This probability is then indicated in different colors. If a sufficiently high number of individual results is available, R&S®Mobile Locator calculates the transmitter’s location.

<table>
<thead>
<tr>
<th>Type</th>
<th>Designation</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portable direction finder</td>
<td>R&amp;S®DDF007</td>
<td>Portable direction finder</td>
<td>58</td>
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<tr>
<td></td>
<td>R&amp;S®MobileLocator</td>
<td>Mobile locator software</td>
<td>59</td>
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<tr>
<td>Portable receiver</td>
<td>R&amp;S®PR100</td>
<td>Portable receiver</td>
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<td>Accessories for interference hunting systems</td>
<td>R&amp;S®ADDx07</td>
<td>DF antennas</td>
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<tr>
<td></td>
<td>R&amp;S®HE400</td>
<td>Handheld directional antenna</td>
<td>61</td>
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</table>
State-of-the-art interference hunting solutions

R&S®DDF007 Portable Direction Finder

Full range of functions in a handheld format
The R&S®DDF007 portable direction finder has an integrated, fast wideband receiver that covers a very wide frequency range. The battery-operated unit relies on high-precision DF methods. The R&S®DDF007 is used in conjunction with compact DF antennas, making it ideal for all applications that call for a powerful yet handy direction finder. The DF system consists of the R&S®DDF007 portable direction finder and a compact DF antenna (R&S®ADD107, R&S®ADD207 or R&S®ADD307). The DF antennas come with an integrated GPS module, an electronic compass and an optional magnet mount vehicle adapter. Installing the portable direction finder in a commercial vehicle takes no more than a few minutes.

The direction finder’s integrated wideband receiver offers ample functionality for signal detection and display, including a panorama scan function (optional) for the fast scanning of wide frequency ranges and a fast spectrogram (waterfall) display.

To identify individual rooms within the building, the portable R&S®HE400 active directional antenna is connected to the R&S®DDF007 instead of the DF antenna.

Key facts
- Wide frequency range from 20 MHz to 6 GHz (DF mode) and 9 kHz to 7.5 GHz (receive mode)
- High-precision correlative interferometer DF method (f > 173 MHz)
- Integrated, fast wideband receiver with optional panorama scan for fast scanning of wide frequency ranges
- Compact, multi-element DF antennas with integrated GPS module and electronic compass; optional magnet mount adapter for quick-and-easy antenna installation on a vehicle roof
- Automatic location of the transmitter’s position
- Generation of an interference search report with all relevant information
- Straightforward and easy-to-use user interface

Benefits and key features

**Integrated, fast wideband receiver**
- Detailed IF spectrum display at high bandwidths
- Fast spectrum monitoring
- Demodulation of wideband signals
- Signal analysis in receive mode (option)
- Polychrome spectrum to distinguish superimposed, pulsed signals (option)
- Occupied bandwidth measurement

**High-precision DF method**
- Correlative interferometer DF method
- Watson-Watt DF method (for R&S®ADD107 below 173 MHz)

**Integrated map display (option)**
- Integration of OpenStreetMap (OSM) digital maps
- Triangulation-based radiolocation

**High-resolution IF spectrum**
- All details visible in DF mode

**Control and system software**
- R&S®DF7-CTL control software
- R&S®RAMON software components (options)

**Innovative, compact DF antennas and accessories**
- Multi-element DF antennas
- Integrated GPS module and electronic compass
- Vehicle adapter with magnet mount (option)
- Lightweight wooden tripod (option)
- Transportation bag and DF antenna backpack (options)

**Homing in on a transmitter**
- Locating a transmitter at close range
- Frequency range extendable up to 18 GHz
**R&S®MobileLocator**

**Advanced interference hunting and emitter location**
R&S®MobileLocator detects and automatically locates a transmitter from a moving DF vehicle. This does not require special skills or experience on the part of the operator. Within minutes, the compact DF system based on the R&S®DDF007 portable direction finder can turn a commercial vehicle into a DF platform. In combination with other Rohde & Schwarz direction finders, R&S®MobileLocator can also be used in dedicated DF vehicles and helicopters.

The R&S®MobileLocator software, which is part of the R&S®RA-LOC radiolocation software module, uses intelligent averaging to continuously calculate the primary DF direction. It merges multiple results from different positions to provide a single location result (running fix).

**Broad scope of application**
R&S®MobileLocator was developed for automatic location of fixed frequency signals in urban areas. The signal does not have to be continuously active as long as a sufficient number of signal bearings are taken. R&S®MobileLocator is not designed to locate push-to-talk (PTT) networks or frequency agile signals.

**Key facts**
- Fast, easy installation in commercial vehicles
- Optimized for interference hunting in urban areas (multipath propagation)
- Automatic location of the transmitter’s position
- Generation of an interference search report with all relevant information
- Straightforward and easy-to-use user interface

**Benefits and key features**

**Easy to transport, easy to set up**
- Simple system configuration
- Support for laptops and tablets
- Fast setup in commercial vehicles

**Comprehensive, optimized system software**
- Complete system software package
- Optimized web-based user interface for touchscreen operations
- Wide variety of expansion options

**Straightforward interference search and signal monitoring**
- Panorama scan for quick overview of all signal activity
- Signal demodulation and audio recording
- Spectrum display in realtime bandwidth for detailed signal monitoring

**Automated interference hunting**
- Typical interference signals
- Automatic collection and evaluation of DF results
- Homing in on a transmitter
- Report generation with all relevant information

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R&S®MobileLocator control software on a laptop or tablet. Display of the current position with vehicle heading, DF spectrum and level versus time, together with the heat map for interference hunting.
R&S®PR100 Portable Receiver

On-site radiomonitoring from 9 kHz to 7.5 GHz
The R&S®PR100 portable receiver has been specifically designed for radiomonitoring applications in the field. The receiver’s functions and control concept have been optimized for monitoring tasks. In addition, it can be used for a variety of other applications.

The R&S®PR100 operates in a wide frequency range from 9 kHz to 7.5 GHz. Whether used for monitoring emissions, detecting interference or locating miniature transmitters, the receiver always combines high mobility with maximum operating ease. The receiver and the R&S®HE400 active directional antenna together form a compact receiving system. The receiver can also be used in conjunction with other antennas, e.g. broadband omnidirectional antennas.

Despite its compact design, the R&S®PR100 offers a wide range of functions otherwise available only in equipment in higher price segments. Its favorable price/performance ratio makes it an indispensable instrument for all radiomonitoring tasks where high mobility and cost-efficiency are crucial.

Featuring compact size and low weight, the R&S®PR100 is ideal for use in places that cannot be accessed with a vehicle. Its low power consumption allows the receiver to operate for up to four hours on a single battery charge. The lithium-ion battery can be exchanged in a matter of seconds without any tools. The current instrument settings are automatically written to the internal memory when the receiver is switched off.

Key facts
- Fast panorama scan across the entire frequency range from 9 kHz to 7.5 GHz
- 10 MHz IF spectrum and demodulation with bandwidths from 150 Hz to 500 kHz
- Spectrum and spectrogram (waterfall) display on 6.5” color screen
- Storage of measurement data to receiver’s built-in SD card
- LAN interface for remote control and data output
- Ergonomic and rugged design for portable use
- Low weight: 3.5 kg including battery
- Manual location of emissions with the R&S®HE400 active directional antenna (9 kHz to 7.5 GHz)
- Automatic location of emissions with direction finding algorithms (20 MHz to 6 GHz)
- Display of digital maps on the R&S®PR100; triangulation based on multiple, manually or automatically determined DF results

Benefits and key features
Interference detection and location in professional radio networks
- Reliable detection of radio interference caused, for example, by defective electronic equipment
- Fast and effective elimination of interference sources, e.g. at airports

Triangulation to locate signal sources in manual/automatic DF mode
- Manual direction finding of a signal source with the R&S®HE400 active directional antenna
- Automatic direction finding of a signal source with the R&S®PR100-DF option
- Triangulation based on multiple, manually/automatically determined DF results
- Display of results on a digital map loaded in the R&S®PR100

Detection of pulsed signals and superimposed transmission
- Capture of short-duration pulses, such as radar emissions
- Wide IF bandwidth for analysis of short-duration pulses and pulse packets
- Polychrome spectrum display for indicating relative signal occupancy

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<td><strong>R&amp;S® HE400 Handheld Directional Antenna</strong></td>
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Test and measurement for terrestrial navigation aids

Chapter 8

Test and measurement for terrestrial navigation aids

Civil aviation and military operations depend on accurate distance, location and direction measuring systems to ensure public safety and military mission success. Failures of these systems may place lives at immediate risk. Terrestrial air navigation systems such as landing systems and en-route navigation systems require unique test and measurement capabilities.

With demonstrated experience in this field, Rohde & Schwarz provides test solutions that cover every need – from design, development and production to operational maintenance.

Terrestrial navigation systems are subject to regular inspection and maintenance in the field. For these measurements, Rohde & Schwarz offers complete laboratory quality measurement solutions in portable, lightweight, weather-protected, battery-powered form factors:

- Ground and flight inspection of terrestrial navigation signals with lightweight instruments that offer a high degree of accuracy and fast measurement speeds
- Spectrum and signal analysis in development, production and maintenance
- Signal generation and simulation for accurate and repeatable test signals needed for receiver testing and calibration
- Power measurements using standalone sensors that can be operated with a laptop and require only simple test setups, yet deliver highly accurate measurement results
- Easy-to-use handheld cable and antenna analyzer for setup and maintenance of antenna sites

Terrestrial air navigation – application overview

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<thead>
<tr>
<th>Application</th>
<th>ILS</th>
<th>VOR</th>
<th>MB</th>
<th>GBAS</th>
<th>DME</th>
<th>TACAN</th>
<th>ATC</th>
<th>COM</th>
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R&S®EVSF1000
VHF/UHF Nav/Flight Analyzer

Efficient flight inspection of terrestrial navigation and communications systems
The R&S®EVSF1000 is a signal level and modulation analyzer for installation in flight inspection aircraft. It performs measurements on ILS, GBAS, VOR and marker beacon ground stations during startup, maintenance and servicing and analyzes air traffic control communications (ATC COM) signals. The instrument's mechanical and electrical design and high sensitivity make it ideal for state-of-the-art flight inspection. In addition, the R&S®EVSF1000 performs specialized, drone-based measurements on terrestrial navigation systems.

As an integral component of a modern flight inspection system on board an aircraft, the R&S®EVSF1000 delivers precise, high-sensitivity analyses in the frequency range from 70 MHz to 410 MHz.

Virtual screen of the R&S®EVSF1000

Key facts
- Precise, reproducible analyses on ILS, GBAS, VOR and marker beacon ground systems (in line with ICAO Doc 8071 and ICAO Annex 10)
- High measurement rate, at 100 data records/s
- Analysis of ATC COM signals
- High sensitivity for coverage measurements
- Compact, robust design
- Two identical signal processing units for simultaneous localizer and glidepath measurements

Excellent performance for state-of-the-art flight inspection systems
- Level measurements with utmost accuracy
- Outstanding input sensitivity, efficient preselector
- Precision modulation analysis in realtime
- Reliable measurement of identifier parameters

Highly customizable for specific tasks
- Simultaneous analysis of course and clearance signals (R&S®EVSG-K1)
- Detailed analysis of VOR and marker beacon signals (R&S®EVSG-K2, R&S®EVSG-K3)
- Testing of ground-based augmentation systems (GBAS/SCAT-I) for satellite navigation (R&S®EVSG-K4, R&S®EVSG-K5)
- Integrated data recording
- High measurement rate
- RF spectrum analysis (R&S®EVSG-K10)
- AF spectrum analysis (R&S®EVSG-K11)

Tailored to flight inspection applications
- Integration into flight inspection aircraft (R&S®EVSF1-B4)
- Reliable bridging of short-term interruptions in the on-board power supply
- Detailed analyses in line with ICAO requirements
- Compact, robust, lightweight
R&S®EVSG1000
VHF/UHF Airnav/Com Analyzer

Efficient servicing of air navigation and communications systems
The R&S®EVSG1000 is a portable signal level and modulation analyzer specifically designed for commissioning and servicing ILS, GBAS, VOR and marker beacon ground stations and for analyzing air traffic control communications (ATC COM) signals. The instrument’s high accuracy and measurement speed, robust mechanical design and integrated battery make it ideal for high-precision measurements in the field.

Key facts
- High-precision analysis of ILS, GBAS, VOR and marker beacon ground systems (in line with ICAO Doc 8071 and ICAO Annex 10)
- Analysis of ATC COM signals
- High dynamic range of >130 dB, precise level and modulation depth measurements
- Spectrum preview and detailed analysis options in the frequency and time domain
- Extremely compact, with integratable battery
- Dynamic measurements at up to 100 data records/s in high measurement rate mode
- Simultaneous analysis of course and clearance signals on dual-frequency (2F) ILS systems

Unique measurement functions for high-precision, efficient ground inspection
- Level measurements with utmost accuracy
- Outstanding input sensitivity, efficient preselector
- Precision modulation analysis in realtime
- Reliable measurement of identifier parameters
- AF signal analysis via the LF input

User-friendly design and application-specific extras
- Intuitive operation via straightforward GUI
- Detailed analyses in line with ICAO requirements
- Simple remote operation via standard interfaces
- Trigger and synchronization functions
- Easy maintenance, repair and service

Software options for customized analysis
- Simultaneous analysis of course and clearance signals (R&S®EVSG-K1)
- Detailed analysis of VOR and marker beacon signals (R&S®EVSG-K2, R&S®EVSG-K3)
- Testing of ground-based augmentation systems (GBAS/SCAT) for satellite navigation (R&S®EVSG-K4, R&S®EVSG-K5)
- ATC communications signal analysis (R&S®EVSG-K6)
- Integrated data recording (R&S®EVSG-K21)
- High measurement rate (R&S®EVSG-K22)
- RF spectrum analysis (R&S®EVSG-K10)
- AF spectrum analysis (R&S®EVSG-K11)
- AF time domain analysis (R&S®EVSG-K12)

Hardware options and accessories
- Compact, robust, lightweight
- Battery-powered field measurements (R&S®EVSG-B3)
- Weather and transit protection for mobile use (R&S®EVSG-Z1)
- Safe transport in a hard-shell transport case (R&S®EVSG-Z2)
- ILS/VOR test antenna (R&S®EVSG-Z3) with carrying bag

VOR measurement (R&S®EVSG-K2 option)

![VOR measurement](image)

ILS measurements with R&S®EVSG-Z3 ILS/VOR test antenna

![ILS measurements](image)
R&S®EDS300 DME/Pulse Analyzer

Precise distance and pulse analysis for ground and air measurements
The R&S®EDS300 is a level and modulation analyzer designed for installing and maintaining pulsed, terrestrial navigation services. Its high sensitivity and compact design make the R&S®EDS300 ideal for conducting field measurements on the ground and in the air. The DME/pulse analyzer also features trigger and synchronization capabilities for easy integration into test vehicles and flight inspection systems.

Key facts
- High-precision measurement of DME and TACAN systems on the ground and in the air (in line with ICAO Doc. 8071, ICAO Annex 10, STANAG 5034 and MIL-STD 291C)
- Total peak level deviation < 1 dB
- Receiver acquisition sensitivity –97 dBm
- 0.01 NM distance measurement uncertainty down to –80 dBm
- 0.2° TACAN bearing deviation for input levels ≥ –80 dBm
- Detailed automated pulse shape analysis
- Multi-DME mode for measuring up to ten DME stations quasi-simultaneously, i.e. within 50 ms (R&S®EDS-K5)
- Synchronization via GPS, trigger and remote interfaces

Measurement functions for regular verification of pulsed navigation signals
- High-precision distance and level measurements on DME ground stations
- Accurate analysis of military TACAN stations
- High dynamic range of 105 dB
- Detailed analysis in line with ICAO requirements, STANAG and MIL-STD

Expanded functionality and adaptation using hardware and software options
- Precise distance measurements on the ground and in the air
- High-performance multi-DME mode for measuring up to ten DME stations
- Simultaneous measurement of two different signals using an additional RX unit
- Low-power interrogator for ground measurements with variable output power
- Flight inspection with integrated high-power interrogator
- Modulation and signal analysis of TACAN ground stations (500 W peak power)
- Detailed pulse shape analysis on DME systems
- GPS-based measurements

User-friendly design and application-specific extras
- Compact, robust design for stationary and mobile applications
- Remote control via LAN interface
- Easy measurement data transfer via USB data logger
- Various synchronization capabilities for integration into existing flight inspection systems
- Maintenance, repair and service

GPS-based measurements using R&S®EDS-K3

R&S®EDS-Z2 rugged wheeled transport case
R&S® EDST300 TACAN/DME Station Tester

Maintenance checks and signal-in-space analysis on TACAN and DME stations
The R&S® EDST300 TACAN/DME station tester is an analyzer designed for commissioning, testing and servicing pulsed terrestrial navigation systems. Its wide dynamic range and compact design make the R&S® EDST300 ideal especially for wired and field measurements on TACAN and DME ground stations.

Key facts
- High-precision TX/RX measurements on TACAN and DME systems (in line with ICAO Annex 10, ICAO Doc. 8071, MIL-STD-291C and STANAG 5034)
- All required measurements with a single instrument
- High dynamic range (110 dB) and precise peak power measurements
- Precise, efficient measurement of characteristic TACAN/DME parameters (main delay < 50 ns, bearing < 0.2°)
- Detailed, automated time domain analysis
- Extremely compact with internal battery

Commissioning and regular maintenance checking of TACAN and DME ground stations
- Precise on-channel peak power and frequency measurements

The R&S® EDST300 TACAN/DME station tester with R&S® EDST-Z1 test antenna (960 MHz to 1215 MHz)

- Analysis of TACAN/DME spectrum
- Detailed analysis of TACAN bursts
- Automated pulse shape analysis
- Detailed analysis of station identifier
- Efficient on-channel sensitivity measurement
- Interrogation loading test
- Adjacent-channel measurement and decoder rejection
- High-precision measurement of reply delay and reply delay variation

Signal-in-space analysis on TACAN and DME stations
- Efficient analysis in the field
- High dynamic range
- Modulation and signal analysis on TACAN ground stations
- Site environment analysis
- Battery-operated field measurements

User-friendly design and application-specific extras
- Detailed analysis in line with relevant standards
- Compact, robust design for stationary and mobile applications
- Remote control via LAN interface
- Exporting measurement data via USB data logger
- Power measurements using an external power sensor
- Maintenance, repair and service

Peak power measurements with level correction

Analysis of main and auxiliary reference bursts (MRB, ARB)
R&S®FSW Signal and Spectrum Analyzer

Setting standards in RF performance and usability
Users in the aerospace and defense (A&D) sector and developers of future, wideband communications systems will find plenty of reasons why the R&S®FSW is the right solution for their T&M requirements. With phase noise unparalleled among signal and spectrum analyzers, the R&S®FSW facilitates, for example, the development of oscillators intended for use in radar systems.

The R&S®FSW offers up to 2 GHz analysis bandwidth for measuring wideband-modulated or frequency agile signals. Rapid identification of spurious emissions, low phase noise, extensive pulse analysis functions and wide analysis bandwidth make the R&S®FSW signal and spectrum analyzer an essential tool in the development and production of radar systems.

Key facts
- Unmatched phase noise – ideal for measuring oscillators for radar and communications applications
- Fast identification and analysis of spurious emissions
- Low phase noise for oscillator measurements
- Pulse parameter measurements at the touch of a key
- Detection of wideband frequency hopping signals
- Analysis of short pulse rise and fall times
- Excellent dynamic range for spurious measurements thanks to low DANL
- Harmonic measurements made easy – due to integrated highpass filters
- High sensitivity even at low frequencies
- High level measurement accuracy
- Unparalleled dynamic range up to 1 GHz with separate receive path
- Ultrawideband filters in sweep mode
- Large I/Q memory depth for seamless recording of long signal sequences
- MultiView: multiple results at a glance
- Multiple measurement applications can be run and displayed in parallel
- High measurement rates and fast sweep times with sweep rates of up to 1000 sweep/s

R&S®FSW-K15 VOR/ILS Measurements

Precise VOR and ILS modulation analysis for calibration, development, production and service
The R&S®FSW-K15 option adds VOR/ILS analysis to the R&S®FSW. It extends the R&S®FSW analyzer’s calibration capabilities to include VOR/ILS signal generators (for example R&S®SMBV100A with R&S®SMBV-K151/-K152) and navigation/ramp testers (for example R&S®CMA).

With the R&S®FSW and the R&S®FSW-K15 option, such instruments can be calibrated by a single box without the need for an additional VOR/ILS tester. The R&S®FSW-K15 is designed to replace the R&S®FS-K15 option for the R&S®FSMR, R&S®FSU and R&S®FSQ. It offers the same function set for VOR/ILS analysis, adds some features and has the same uncertainty specification as the R&S®FS-K15.

Key facts
- Low measurement uncertainty for
  • ILS difference in the depth of modulation (DDM)
  • VOR phase
  • Modulation parameters of single signal components such as 90/150 Hz tones, 30 Hz/9.96 kHz subcarriers
- All measurement parameters and spectrum overview at a glance
- Selective distortion measurements for all AM and FM components of VOR and ILS signals
- Identifier measurement and Morse code indication (1020 Hz)
- Easy to operate: user simply has to select between VOR and ILS
The R&S®FSH Handheld Spectrum Analyzer

R&S®FSH can perform any of these tasks quickly, reliably and with high measurement accuracy.

**Key facts**

- Frequency range from 9 kHz to 3.6/8/13.6/20 GHz
- High sensitivity < −141 dBm (1 Hz), with preamplifier < −161 dBm (1 Hz)
- 20 MHz demodulation bandwidth
- Low measurement uncertainty (< 1 dB)
- Measurement functions for all important measurement tasks related to the startup and maintenance of transmitter systems
- Internal tracking generator and VSWR bridge with built-in DC voltage supply (bias)
- Vector voltmeter
- Two-port network analyzer
- Easy operation with user-configurable automatic test sequences (wizard)
- Brilliant color display, easy to read even under poor lighting conditions
- Easy-to-replace Lithium-ion battery for uninterrupted operation up to 4.5 hours
- Easy handling due to low weight (3 kg with battery) and easy-to-reach function keys
- Rugged, splash-proof housing for rough work in the field

R&S®FSH can perform any of these tasks quickly, reliably and with high measurement accuracy.

**Key facts**

- Frequency range from 9 kHz to 3.6 GHz or 8 GHz
- 100 dB (typ.) dynamic range for filter and antenna isolation measurements
- Factory calibration over entire frequency range
- Built-in DC voltage supply (bias) for active components such as amplifiers
- Power meter option
- Easy operation with user-configurable automatic test sequences (wizard)
- Brilliant color display, easy to read even under poor lighting conditions
- Easy-to-replace Lithium-ion battery for uninterrupted operation up to 4.5 hours
- Easy handling due to low weight (3 kg with battery) and easy-to-reach function keys
- Rugged, splash-proof housing for rough work in the field

The all-in-one handheld platform

The R&S®FSH is a handheld spectrum analyzer – and depending on the model and the options installed – a power meter, a cable and antenna tester and a two-port vector network analyzer in a single device. Its ruggedized housing, low weight and easy operation make it indispensable for outdoor work. It provides the most important RF analysis functions to solve daily routine measurement tasks. The R&S®FSH can perform any of these tasks quickly, reliably and with high measurement accuracy.

**Key facts**

- Frequency range from 100 kHz to 3.6 GHz or 8 GHz
- 100 dB (typ.) dynamic range for filter and antenna isolation measurements
- Factory calibration over entire frequency range
- Built-in DC voltage supply (bias) for active components such as amplifiers
- Power meter option
- Easy operation with user-configurable automatic test sequences (wizard)
- Brilliant color display, easy to read even under poor lighting conditions
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- Rugged, splash-proof housing for rough work in the field

R&S®ZVH Cable and Antenna Analyzer

R&S®ZVH performs fast, reliable and highly accurate measurements. Even in its basic configuration, the R&S®ZVH detects cable faults, measures the matching of filters and amplifiers and checks the loss of cable connections – the three most important tasks involved in setting up transmitter systems and putting them into operation. For further measurements such as the isolation between transmit and receive antennas or the output power of output amplifiers, suitable options are available. Using the R&S®ZVHView software, test reports can be generated in just a few simple operating steps.

**Key facts**

- Frequency range from 100 kHz to 3.6 GHz or 8 GHz
- 100 dB (typ.) dynamic range for filter and antenna isolation measurements
- Factory calibration over entire frequency range
- Built-in DC voltage supply (bias) for active components such as amplifiers
- Power meter option
- Easy operation with user-configurable automatic test sequences (wizard)
- Brilliant color display, easy to read even under poor lighting conditions
- Easy-to-replace Lithium-ion battery for uninterrupted operation up to 4.5 hours
- Easy handling due to low weight (3 kg with battery) and easy-to-reach function keys
- Rugged, splash-proof housing for rough work in the field

The benchmark for efficiency in the field

The R&S®ZVH cable and antenna analyzer is rugged, handy and designed for use in the field. Its low weight and simple operation make it indispensable for anyone who needs an efficient measuring instrument for installaing and maintaining outdoor antenna systems. The R&S®ZVH cable and antenna analyzer performs fast, reliable and highly accurate measurements. Even in its basic configuration, the R&S®ZVH detects cable faults, measures the matching of filters and amplifiers and checks the loss of cable connections – the three most important tasks involved in setting up transmitter systems and putting them into operation. For further measurements such as the isolation between transmit and receive antennas or the output power of output amplifiers, suitable options are available. Using the R&S®ZVHView software, test reports can be generated in just a few simple operating steps.

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R&S®SMBV100B Vector Signal Generator

**Perfect combination of performance and usability**
The R&S®SMBV100B vector signal generator combines superior performance characteristics such as high output power, wide modulation bandwidth and excellent signal quality. With a frequency range from 8 kHz to 6 GHz, the instrument covers all important RF bands for digital wireless communications. The wide RF modulation bandwidth of up to 500 MHz satisfies the challenging requirements of fourth and fifth generation communications standards. In A&D applications, the wide bandwidth allows the generation of complex pulsed signals.

**Key facts**
- Frequency range from 8 kHz to 3 GHz or 6 GHz
- Ultra high output power up to +34 dBm
- 500 MHz modulation bandwidth with perfect accuracy
- Excellent EVM and ACPR results up to high power levels
- Internal signal generation for all major digital communication standards
- Fully-fledged GNSS simulator for GPS, Glonass and Galileo
- Convenient operation via 7" touchscreen

The R&S®SMA100B RF and microwave signal generator delivers maximum performance without compromise. It provides purest output signals while maintaining the highest output power level, far outpacing the competition. As the world’s leading signal generator, it can handle the most demanding component, module and system T&M tasks in the RF semiconductor, wireless communications and aerospace and defense industries.

**Key facts**
- Frequency range from 8 kHz to 3 GHz, 6 GHz, 12.75 GHz, 20 GHz, 31.8 GHz, 40 GHz, 50 GHz and 67 GHz (overrange up to 72 GHz)
- Excellent SSB phase noise of –152 dBc (typ.) at 1 GHz and –132 dBc (typ.) at 10 GHz, each at 10 kHz offset
- Virtually no wideband noise (–162 dBc (meas.) at 10 GHz and 30 MHz offset)
- Maximum output power exceeds 30 dBm across wide frequency ranges
- Exceptionally low harmonics
- Flexible size: 2 HU or 3 HU housing: 3 HU with larger 7" display and multiple front panel connectors
- State-of-the-art GUI with touch display

In many test setups, such as for RF component verification, it is important to provide signals at high power levels. The R&S®SMBV100B offers best-in-class signal quality up to very high power levels. No extra amplifier is needed, which simplifies the test setup.

With the additional R&S®SMBVB-K151 ILS, R&S®SMBVB-K153 VOR and R&S®SMBVB-K151 DME options, the R&S®SMBV100B vector signal generator can be used for avionic measurement applications.

R&S®SMA100B
RF and Microwave Signal Generator

**Performance leadership without compromise**
The R&S®SMA100B RF and microwave signal generator delivers maximum performance without compromise. It provides purest output signals while maintaining the highest output power level, far outpacing the competition. As the world’s leading signal generator, it can handle the most demanding component, module and system T&M tasks in the RF semiconductor, wireless communications and aerospace and defense industries.

The R&S®SMA100B covers all fields of application, from research and development to production, service and maintenance. To meet the specific needs of any given application, the base unit’s already excellent performance can be improved with options.

When equipped with the R&S®SMAB-K25 option, the R&S®SMA100B can generate avionics signals (VOR/ILS) in accordance with ICAO standards. Due to its low modulation error and very high level accuracy, the R&S®SMA100B with the R&S®SMAB-K25 is the optimal high-precision VOR/ILS signal source for testing avionics receivers.
The reference in radio testing

The R&S®CMA180 is a radiocommunications tester for radio systems that operate in the 100 kHz to 3 GHz range. Its technology is based fully on digital signal processing and advanced computing. Intuitive operation and efficient measurement capabilities make the R&S®CMA180 an indispensable tool for performing radio measurements.

The R&S®CMA180 demodulates and modulates all common analog RF signals, making it ideal for testing transmitters and receivers. For receiver tests, audio signals from the internal generators or from external sources can be modulated onto the RF carrier. The audio signals demodulated by the device under test (DUT) are fed into the R&S®CMA180 via analog or digital inputs and then analyzed. For transmitter tests, the R&S®CMA180 demodulates the received signal and measures the demodulated audio signal and the RF signal. The test set now also incorporates a digital signal generator and analyzer that can be used to carry out digital receiver and transmitter measurements.

Applications in the R&S®CMA180 frequency range

Using the ARB generator, users can play back nearly any type of signal. These signals can be generated with MATLAB® or R&S®WinIQSIM2™, including proprietary waveforms from software defined radios (SDR), and then loaded into the R&S®CMA180 and replayed. The advanced and efficient user interface makes it easy to learn to use the R&S®CMA180. Users can quickly reach all settings and easily perform measurements. Measurement results are clearly and conveniently displayed.

The optional ILS, VOR and marker beacon generator as well as VoIP support in line with EUROCAE ED-137B make the R&S®CMA180 invaluable for air traffic control (ATC) and radio navigation.

The R&S®CMA180 can be powered by batteries, making it independent and portable. Results are displayed in a straightforward manner, and the graphical user interface is easy to operate.

Key facts

- Frequency range from 100 kHz to 3 GHz
- Analog modulation and demodulation (CW, AM, FM)
- Up to 150 W peak input power and up to 100 W continuous input power
- Signal level for receiver measurements can be lowered to –140 dBm
- Integrated audio generators
- Audio quality tests (SINAD, THD, SNR)
- Integrated sweeping spectrum analyzer, tracking generator and scope
- Use of R&S®NRP and R&S®NRT power sensors, no configuration required
- I/O recorder and ARB generator
- Digital signal analysis
- ILS, VOR and marker beacon generator
- VoIP in line with EUROCAE ED-137B for ATC radios
- Digital receiver and transmitter measurements
Security scanners
Airport security checks, security at public events

The R&S®QPS is a state-of-the-art millimeterwave security scanner that automatically detects potentially dangerous items carried on the body or in clothing. The scanner can be used for airport security checks, security at public events with a high threat potential and access control at security-related facilities.

The R&S®QPS security scanner delivers high-precision and efficient security control while ensuring an unobtrusive and uncomplicated experience for scanned persons. It consists of a flat panel with thousands of transmitters that emit extremely low-power millimeterwaves in very short succession and just as many receivers that record high-resolution 3D information. Persons being scanned stand squarely in front or between the panels as if facing a mirror, holding their arms slightly away from their bodies.

The detection software uses machine-trained algorithms to search for conspicuous objects of all material types. The scanner searches for anomalies indicating unusual objects rather than for certain items, enabling it to discover unknown and new threats.

The R&S®QPS is designed for implicit privacy. Rather than generating photographic images, it evaluates physical information. Detected locations of interest are marked on a symbolic body graphic.

The R&S®QPS poses no health hazard whatsoever. It operates on frequencies similar to those of a vehicle distance warning system. The transmitted power at the scanned person’s location is almost undetectable and several orders of magnitude lower than mobile phone emissions.

Detection characteristics
- Detection of all types of potentially dangerous objects (metal, ceramic, plastic, liquid)
- Outstanding body coverage, complete head, shoulder and leg illumination
- High system resolution, bandwidth and dynamic range for high detection performance and minimum false alarms
- Certified by the European Civil Aviation Conference (ECAC)

Benefits for operating company
- Flat form with low weight and high positioning flexibility
- Escape routes through the lanes remain open
- Low fire load
- Reliable, quiet continuous operation
- Insensitive to temperature fluctuations
- Low maintenance costs due to stable calibration and no moving parts
- Integration into local networks
- Software updates to meet future requirements

Benefits for operators
- Simple touchscreen operation
- Unobstructed view of arriving passengers
- Direct access to passengers before scanning
- No obstacles for wheelchair users

Benefits for scanned persons
- Open, transparent scanning environment, no booth
- Easy to hold body posture; not necessary to raise arms
- Extremely short scan time
- Not necessary to change position
Safe, high-resolution radio frequency security screening

People screening at airports, borders, high-security facilities and in other environments requires a balance between security effectiveness and respect for the privacy of individuals being screened. R&S®QPS quick personnel security scanners deliver high-performance threat and contraband detection designed specifically to protect personal privacy and minimize intrusive secondary screening measures.

The R&S®QPS product series provides high-resolution security scanning and was specifically designed to promote faster, more effective and comfortable people screening at security checkpoints.

Your task

Security operations have long demanded higher performance technology to support efficient checkpoint operations with the ability to detect an expanding range of threats and prohibited items. The challenge faced by screening systems is not simply accuracy but safety. While we want powerful systems that effectively detect threats, these same mechanisms must not harm the people who are scanned. A prime concern would be unhealthy exposure to ionizing radiation.

Rohde & Schwarz solution

Low-power, non-ionizing millimeterwave scanning

R&S®QPS technology operates in the millimeterwave range of the electromagnetic spectrum, similar to the frequencies used by vehicle parking sensors. The systems produce no ionizing radiation and their output power is less than a fraction of the output power of a mobile phone. The waves and energy emitted by the R&S®QPS travel through clothing, but do not penetrate the body. Instead, the waves “bounce back” and are combined to create an avatar with indicators showing where items have been detected within clothing.

R&S®QPS systems do not penetrate the skin and do not disrupt the atomic structures of cells or DNA like X-rays and other types of ionizing radiation do. Safe for pregnant women and for individuals with hip/knee replacements, metal pins or other orthopedic implants, the R&S®QPS eliminates the need for special screening.

The open design of the R&S®QPS provides an unobstructed view of security screening operations.

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**Screening time for the R&S®QPS**

<table>
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<th>Scan time</th>
<th>Computer analysis</th>
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<tr>
<td>0 s</td>
<td>&lt; 0.1 s</td>
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<tr>
<td></td>
<td>2.5 s</td>
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</table>

After stepping onto the scanner’s footprints and slightly raising your arms away from your side as shown on the panel, the operator presses the scan button. The screening process seems nearly instantaneous to both the passenger and operator.

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**Increased throughput**

Up to four additional resolution stations may be added.
No interference danger
Millions of patients worldwide rely on cardiac pacemakers and defibrillators to keep their hearts beating regularly. R&S®QPS technology has been tested by third-party labs and it has been conclusively demonstrated that its extremely low power is safe for human exposure. In fact, at the surface of the panels, the power of a single R&S®QPS scan is 40,000 times below the limit permitted by the International Council on Non-Ionizing Radiation Protection (ICNIRP). It is 500,000 times lower than permitted levels for the scan volume of the system. R&S®QPS systems process takes only 64 ms, which is 5 times faster than the blink of an eye. With electromagnetic energy over 1000 times less than the power emitted by a modern mobile phone, one million R&S®QPS scans causes less exposure than one minute of talking on a mobile phone, making the R&S®QPS safe for both the security operator and individuals being screened.

1) https://www.escardio.org/The-ESC/Press-Office/Press-releases/security-millimetre-wave-body-scanner-safe-for-patients-with-pacemakers-and-defibrillators European Society of Cardiology, ESC Congress – August, 2018 report presented by Dr Carsten Lennerz, German Heart Centre Munich, Technical University of Munich and German Centre for Cardiovascular Research (DZHK)

High-frequency millimeterwave yields high resolution detection
The R&S®QPS operates at a higher frequency range and delivers substantially improved performance and detection capability than currently deployed legacy AIT technology. With a resolution of 1.9 mm (smaller than the size of a match head), R&S®QPS technology can detect small quantities of contraband, threat material and anomalies. This increased eAIT performance addresses the well documented performance challenges of older AIT systems and supports mission critical security screening at airports, borders, buildings and in loss prevention applications where the detection of many different and smaller objects is required.

Simple installation and minimal maintenance keeps lines moving
The R&S®QPS can be installed, relocated or packed up in less than half a day. Once setup is complete, power is established by a switch on the back of each panel. Within just three minutes of power-on, the system is operational. Aside from an on-site preventive maintenance check every six months, the system is virtually maintenance-free. Initial setup and commissioning typically take less than three hours, since calibration and configuration setup are performed at the factory.

Visit the R&S®QPS Learning Center at www.rohde-schwarz.com/QPS
# Service and support

With a dedicated, global service network and 24-hour availability, Rohde & Schwarz offers its customers comprehensive support worldwide.

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Service and support

With a dedicated, global service network and 24-hour availability, Rohde & Schwarz offers its customers comprehensive support worldwide.

Support offerings range from detailed consultation before during and after purchase to application support, product upgrades in the form of software updates, repair and maintenance services, customized spare parts packages, seminars and customized training courses. We attach great value to the technical expertise of our local sales engineers, who answer customer questions personally and in detail.

Rohde & Schwarz products are used in demanding applications where reliability is as important as accuracy. High equipment availability is vital in production for ensuring continuous, profitable operation. Our services are designed to maintain both high availability and high accuracy over the long term in order to protect our customers’ investments. Most of our equipment is platform-based to allow adaption to changed requirements and new technologies, even after years of service.

Service that adds value
- Worldwide
- Local and personalized
- Customized and flexible
- Uncompromising quality
- Long-term dependability
Integrated logistics support (ILS) provides standardized, disciplined management of all technical logistics activities to ensure operational reliability and maintenance and achieve predefined performance characteristics. ILS enables customers to use resources in a plannable, cost-efficient manner over the entire lifecycle of a product.

Rohde & Schwarz provides a holistic approach in consideration of the general and established standards (MIL-STDs, IEEE, DEF, etc.) and specifications (ASD/AIA). The Rohde & Schwarz ILS department with the experts is continuously improving by central management of all ILS topics over all divisions and market segments within the company.

**Integrated Logistic Support Goals**

ILS includes planning and directing the identification and development of logistics support and system requirements for the Communication System with the aim to create systems that last longer and require less support. Therefore, ILS addresses several aspects of supportability not only during the project phase, but also throughout the whole lifecycle of the system. The main goals are:

- Reduce system life cycle costs by attacking the main operation and support cost drivers during system design
- Improve systems readiness/availability to meet the systems mission requirements
- Identify system life cycle logistics resource requirements

To reach the goals, Rohde & Schwarz is planning and executing holistic ILS strategies. The ILS approach consists of planning and conducting a number of disciplines, which correlate one with another to assure full system availability. Rohde & Schwarz is planning each element of ILS in coordination with the system engineering and is therefore able to simplify the maintainability of products and systems.
Purpose and scope
Rohde & Schwarz provides a full range of system lifecycle, maintenance and operational system support services for the communications system. As such, Rohde & Schwarz is able to act as single point of accountability for the business and technical elements of the in-service support program, including the achievement of established system operational and equipment availability criteria, ensuring system worthiness, and ensuring the long-term sustainability and cost effectiveness of the systems support.

- Very high level of system-support from a quality, responsiveness and cost-effectiveness perspective
- Equipment management and support that takes a holistic view of technical supportability across the mission systems. Rohde & Schwarz will ensure that short-term operational availability of equipment is addressed while also considering the systems 15+ years expected life cycle
- Application of integrated and pro-active measures by Rohde & Schwarz to ensure that the communications system continues to be reliable and supportable through a rigorous supportability and obsolescence management program
- Fully managed and optimized supply chain
- Continuous availability of mission system design authority capability to support the customer’s new or evolving operational requirements
The main aspiration of Rohde & Schwarz is to deliver high-reliability, high-availability radio communications solutions that support the operational effectiveness and security of the armed forces during missions. Every system and every device requires expert maintenance to ensure its availability in missions throughout the entire product lifecycle and useful life. It may be crucial to your success to perform part of the maintenance work yourself – directly and flexibly using the infrastructure of our own organization and the know-how of your staff.

This is why Rohde & Schwarz has developed the service partner program. As a service partner of Rohde & Schwarz, you are able to service your Rohde & Schwarz communications systems on your own. The scope of services is tailored to your requirements and expectations.

The Rohde & Schwarz service partner program lets you benefit from a flexible service concept that ensures the availability of your devices and makes use of your own staff and infrastructure.

As a Rohde & Schwarz service partner, you have access to the following services

**R&S®UCS radio test equipment**
The R&S®UCS test equipment enables you to self-service your transceivers, meeting the highest quality, convenience and cost-efficiency requirements. The test equipment will be selected according to the required scope of servicing.

**Training**
Various Rohde & Schwarz training modules empower your staff to service your transceivers on their own. Depending on the type of service partner agreement, you can use different training modules.

**Software updates**
As our partner you will receive all software updates that you need for preventive and corrective maintenance.

**Spare parts**
A local pool of spare parts tailored to your requirements enables you to immediately perform preventive and corrective maintenance. This pool will be replenished when necessary.

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**Service partner program**

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<th>End user</th>
<th>Replacement units</th>
<th>Conformance testing</th>
<th>Replacement of modules</th>
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<td>Examples</td>
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<td>Service partner/self-maintainer</td>
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You can choose the service level that meets your special requirements and also combine your expertise with that of Rohde & Schwarz.
Service performed by Rohde & Schwarz according to your requirements
If necessary, we will support and combine your own service activities with our authorized service partners or our central service organization in Germany. Depending on the required turnaround time, customized measures such as a reserved pool of spare parts can be arranged.

Fast troubleshooting using a reference system at Rohde & Schwarz
Our service partners use the same test systems as Rohde & Schwarz. We are therefore able to reproduce any errors or problems on our reference system to help you solve the problem, quickly and competently.

Service notes
Rohde & Schwarz incorporates technical advances into its products and improves them throughout their entire life-cycle. As a service partner you benefit from this development. You will receive service notes that inform you about modifications and innovations.

Regular review meetings
Use this opportunity to get evaluations and assessments for the new software and hardware features of your test system. Discuss all maintenance issues that come up with regard to your radios. Take a close look at the spare parts logistics for your equipment. Consult the technical experts from Rohde & Schwarz and clarify open questions.
R&S®UCS Radio Test Equipment

**Comprehensive radio checking**
The radio test sets are based on the R&S®UCS test system family. The platform is used in Rohde & Schwarz production and repair facilities and ensures high performance during testing and the availability of up-to-date test software. Training packages adapted to the operators’ current skill levels are also available.

**R&S®I-level test equipment**
For I-level testing according to the manufacturers’ specifications, Rohde & Schwarz offers a radio-specific R&S®UCS version allowing for a full performance or standard test. In case customers are content with a restricted testing scope and are willing to accept the risk of potential test gaps after I-level maintenance, they can opt for a radio-specific smaller test system like the R&S®UCS-Compact.

**R&S®O-level test equipment**
The R&S®UCS-Lite fulfills the specific requirements for comprehensive testing of basic radio functionality which is needed for O-level maintenance. Main radio functional tests during scheduled maintenance with typical tasks such as battery replacement or storage life tests are covered by the system (functional check).

The test set includes all required radio-specific cabling so that it can be quickly and easily connected to the radio. A dedicated transport case is available for ease of transportation and protection against mechanical damage.

**R&S test equipment for SKD (semi knocked down) production**
Apart from the test systems for I-level und O-level maintenance Rohde & Schwarz also offers a production test system for SKD production which has the highest levels of test depth.

**Features and benefits**

**Mobile and adaptable to specific requirements**
- Ready to test various types of radios (airborne, stationary/shipborne, tactical)
- Supplied extension sets for quick and easy connections to the radio
- Scalable to requested test depth
- Modular system configuration to enable future extensions
- Transportable and robust 19" aluminum racks (R&S®UCS-Base and R&S®UCS-Compact)

**Basic setup and operation**
- Easy to operate
- Fast and automatic test procedures

**Support of maintenance and on-site repair**
(R&S®UCS-Base)
- Precise error identification
- Verification after module replacement

<table>
<thead>
<tr>
<th></th>
<th>Production</th>
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<tr>
<td><strong>Test instruction to be followed</strong></td>
<td>Test instruction (factory final testing)</td>
<td>Performance test (full scope)</td>
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<tr>
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<td>Performance test (reduced scope)</td>
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<td>Resulting statement of compliance</td>
<td>All measured values are within the data sheet specifications</td>
<td>All measured values out of a reduced scope are within the data sheet specifications</td>
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**All radios with EPM (ECCM) functionality (R&S® M3xR, R&S® SDxR)**

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<tr>
<th></th>
<th>R&amp;S®UCS-Production</th>
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1) R&S®M3SR Series4400: some testing restrictions may apply.
Comprehensive performance testing of radios
- In-depth functional and verification testing (R&S®UCS-Base)
- Detailed functional testing (R&S®UCS-Compact)
- Comprehensive testing of basic radio functionality (R&S®UCS-Lite)

- User-selectable scope of testing
- Full control of system status
- Integrated, versatile test report tool
- Export functionality for test data
- Test data available for statistical analysis

R&S®UCS-Production
For SKD production and I-level testing (for radio R&S®M3SR Series4400). Dedicated test and measurement instruments + universal switch unit

R&S®UCS-Base
For I-level testing. Dedicated test and measurement instruments + universal switch unit

R&S®UCS-Compact
For customer defined I-level testing. R&S®CMA180 radio test set + universal switch unit

R&S®UCS-Light
For O-level testing. R&S®CMA180 radio test set + adaption set
Global sales and service locations

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Rohde & Schwarz

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- Environmental compatibility and eco-footprint
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