The world between 3 GHz and 300 GHz: services and applications

The range between 3 GHz and 300 GHz is extremely crowded, with countless services and applications even occupying the same frequencies in many cases. This multipart article discusses how to bring order to this chaos, the issues to be monitored, and the role that systems from Rohde&Schwarz are playing for regulatory authorities and network operators.

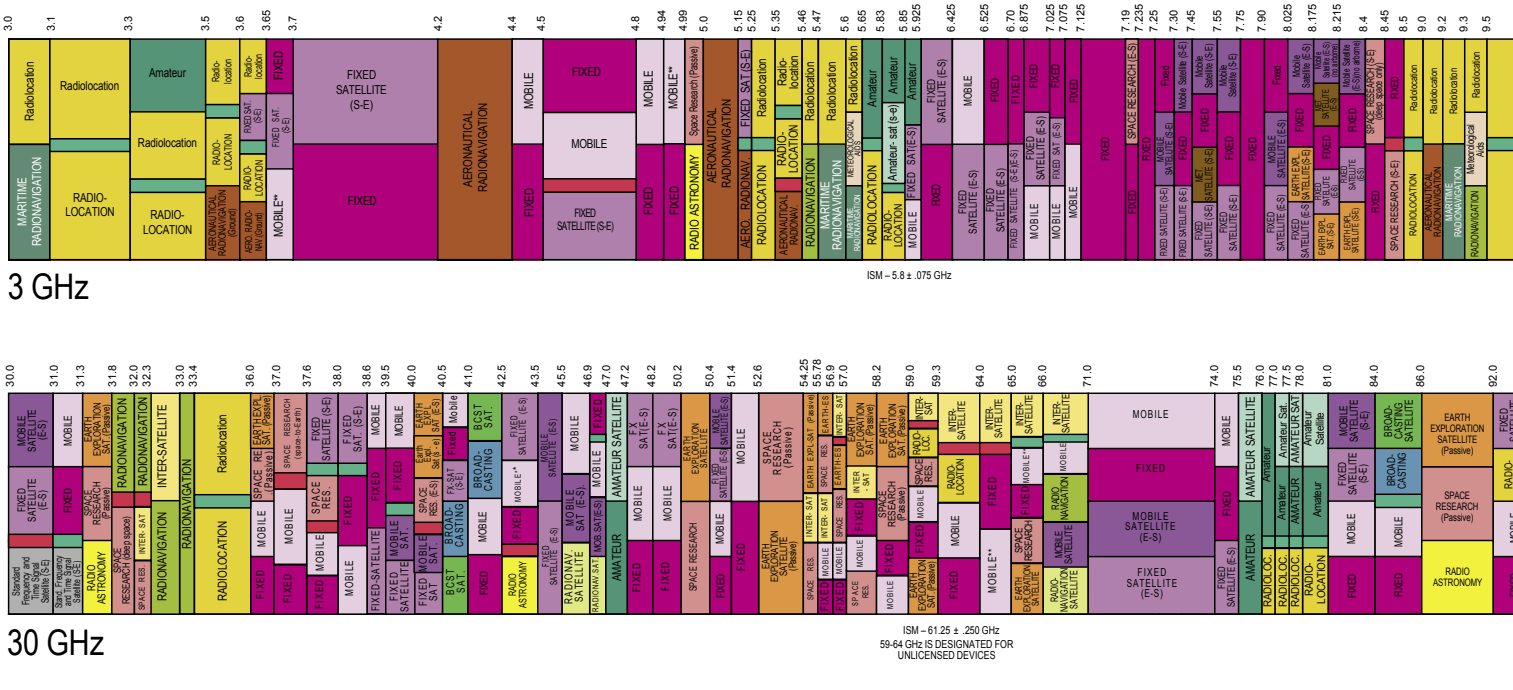
Bringing order to chaos — regulation makes it possible

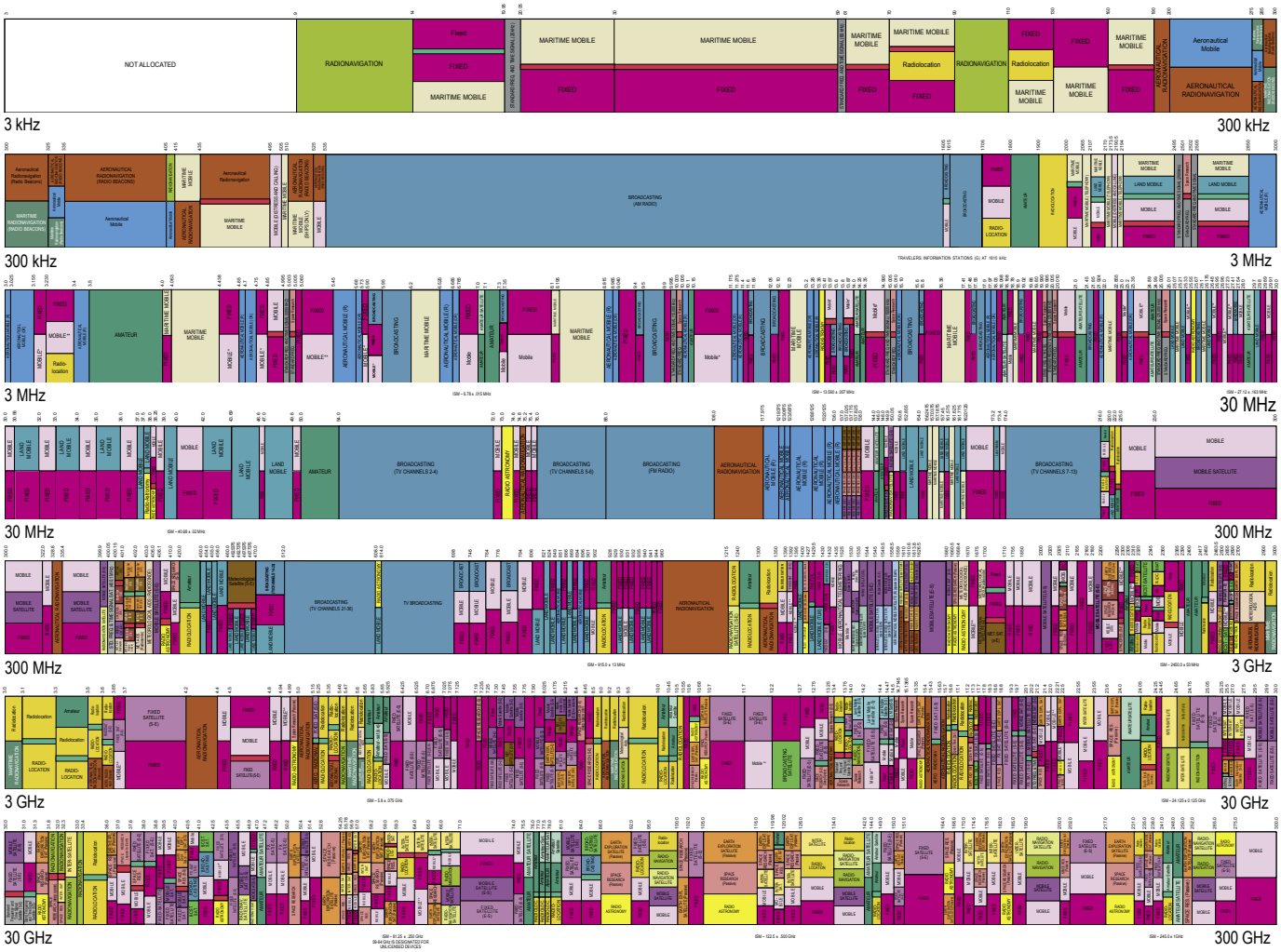
Without the strong hand of regulation, the world would surely sink into frequency chaos. National regulatory authorities manage allocation of the frequency spectrum within an international context through the International Telecommunication Union (ITU), which is a suborganization of the United Nations (UN) and has its headquarters in Geneva. The ITU divides the world into three regions and issues mandatory frequency allocations for all member states. See FIG 1 for an example.

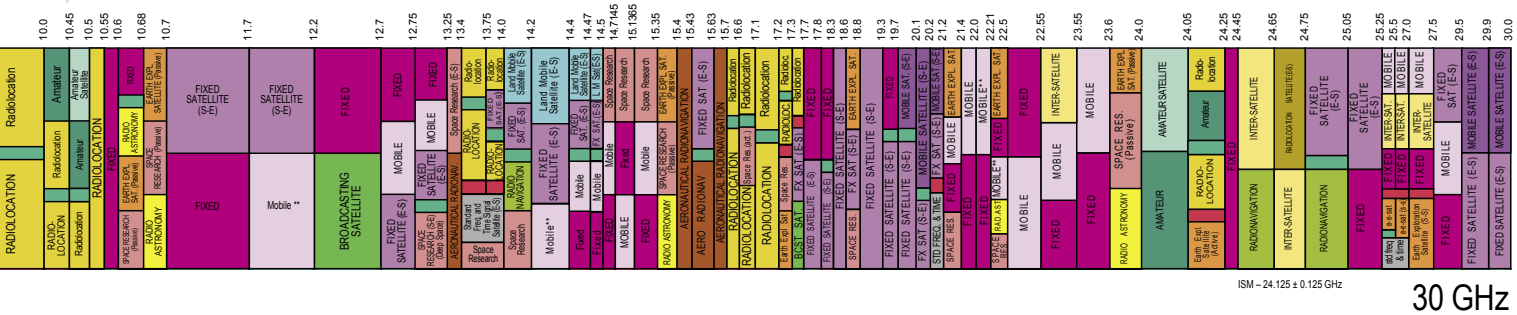
Services and applications in the frequency range from 3 GHz to 300 GHz

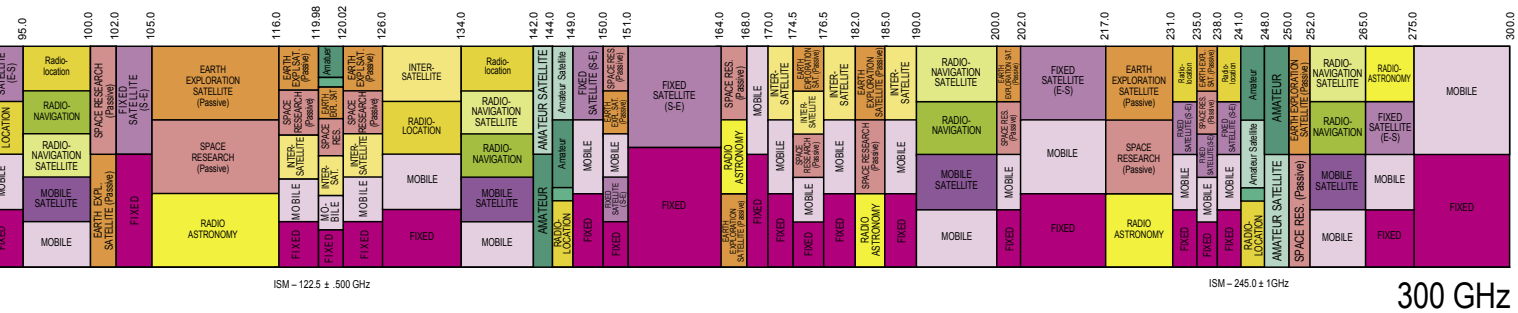
Within the ITU regions, the frequency spectrum between 9 kHz and 275 GHz is allocated to different services, e. g. "fixed", "aeronautical", "satellites", and "space" (FIG 2). The actual services are divided into applications in which the usable frequency ranges are defined for the end users. Examples of applications include WLAN/WPAN, WiFi, WiPro, WiMAX™, radar (civil, military), radio broadcasting and television (satellite) as well as traffic telematics. There are more than 200 different applications which are combined into application groups for the sake of clarity.

FIG 1 Densely occupied: The example illustrating national frequency allocation between 9 kHz and 300 GHz on the right (top) shows just how extensively the frequency bands are used and how many different services must be accommodated. The detail below shows the range between 3 GHz and 300 GHz.




3 kHz
300 kHz
300 kHz
3 MHz
3 MHz
30 MHz
30 MHz
300 MHz
300 MHz
3 GHz
3 GHz
30 GHz
30 GHz
300 GHz


ISM – 24.125 ± 0.125 GHz
30 GHz


ISM – 122.5 ± .500 GHz
ISM – 245.0 ± 1GHz
300 GHz

The frequency spectrum between 9 kHz and 3 GHz is completely occupied, which means that new services or services that need more bandwidth must use the range above 3 GHz in order to meet requirements for bandwidth, data rate, reliability, and interference-free transmission in the RF field.

FIGs 1 and 2 illustrate the basic problem: Since frequency is a limited resource and worldwide demand for it is huge, frequencies are commonly allocated to multiple services. Interference and impairments affecting individual frequency users are therefore more or less inevitable. This becomes even more apparent if the individual services are combined into main groups and their allocation is plotted on the frequency axis, as shown in FIG 3. It is no surprise that mutual impairments or interference can occur (FIG 4). It is also not enough to simply have the individual frequencies exclusively allocated on a planned basis by national regulatory authorities. Instead, these authorities must additionally create measurement capabilities to make it possible to regulate the frequency spectrum between 3 GHz and 300 GHz. This includes localizing the sources of interference when they occur and documenting them so they can be eliminated.

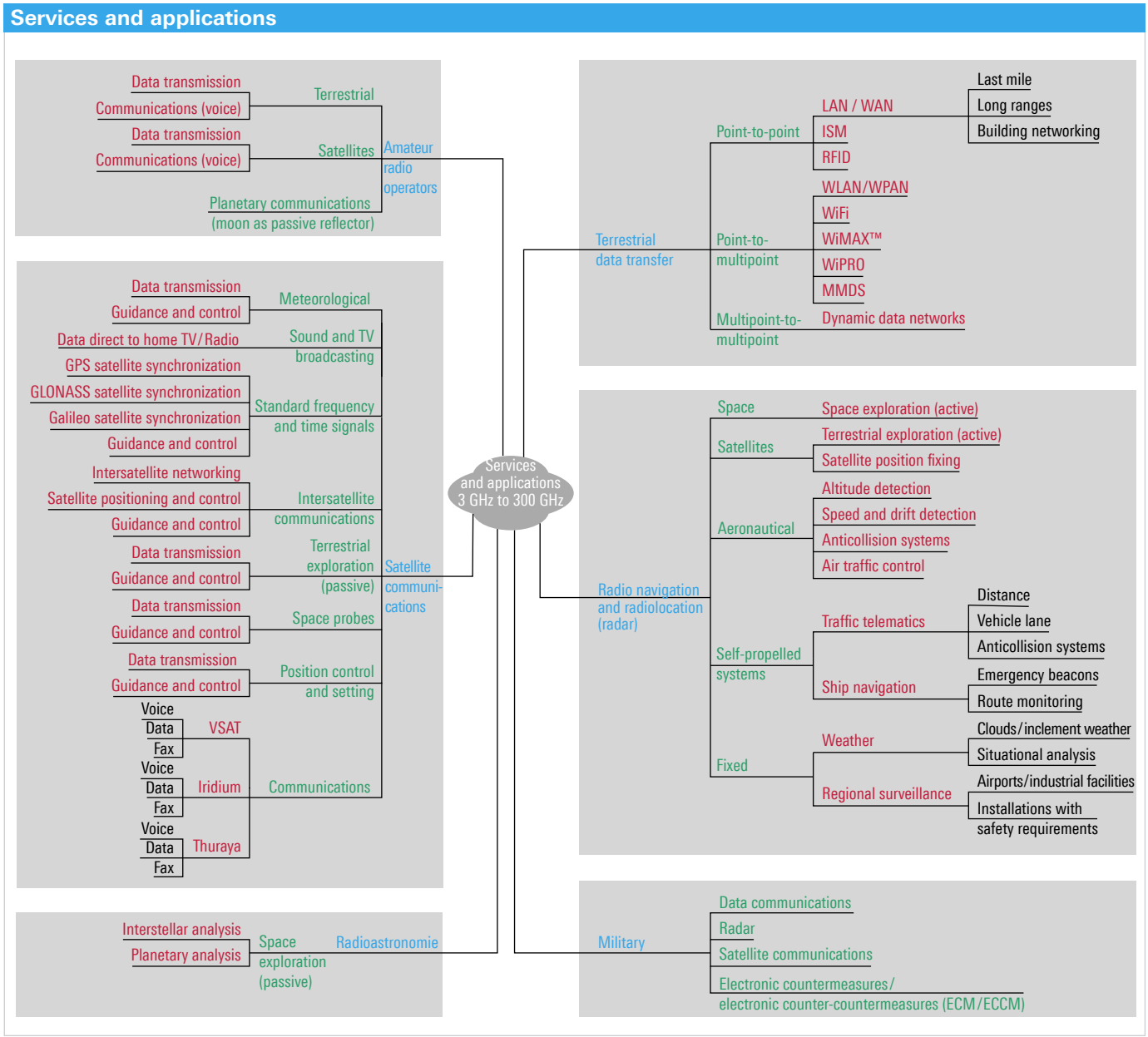


FIG 2 Main groups of services (blue), services (green), and application groups (red and black) in the frequency range from 3 GHz to 300 GHz.

Typical monitoring systems

The national regulatory authorities use the following typical monitoring systems in the frequency range from 9 kHz to 3 GHz:

- Fixed monitoring systems (FMS) (manned or unmanned)
- Mobile monitoring systems (MMS) (manned), installed on mobile platforms, e.g. in vehicles
- Portable monitoring systems (PMS) based on handheld equipment
- Universal monitoring systems (UMS) (unmanned), which are permanent, e.g. installed on roofs but also mobile or transportable
- Transportable monitoring systems (TMS) (manned), installed for temporary use

Starting at 3 GHz: monitoring limited to line-of-sight links

Due to the propagation conditions that prevail in the frequency range from 3 GHz to 300 GHz (radio links are basically limited to line-of-sight communications), fixed monitoring systems (FMS) are not useful for detecting interference due to their limited range. Mobile monitoring systems (MMS) are also usable only to a limited extent unless they are situated at an exposed location. Moreover, the typically very low transmitted power levels of spurious emissions in this frequency band limit the range of conventional microwave monitoring systems.

Despite all of these challenges, Rohde&Schwarz offers monitoring systems that are well suited to handling the special propagation and background conditions encountered in the microwave range. By using system components that are specially configured to meet these requirements, the monitoring range that is achieved is twice as large as that of competing products.

Main groups of services

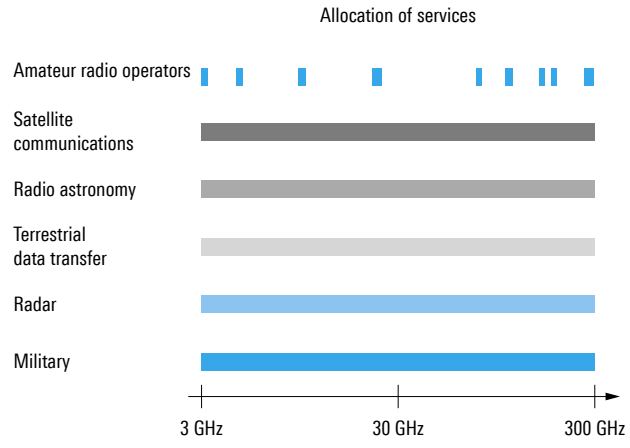


FIG 3 Combination of the services into main groups and allocation vs. frequency clearly shows the multiple allocations.

Customized: systems from Rohde&Schwarz

The highly specialized test and monitoring systems developed by Rohde&Schwarz cover practically all of the possible applications and can be used to find and document interference sources quickly and reliably.

Portable monitoring systems (9 kHz to 18 GHz)

Portable systems are used to identify nearby transmitters, meaning at a distance of a few meters to several hundred meters depending on the frequency range, e.g. in buildings, on roofs, or in hard-to-access places.

For a system that is small, light in weight, and easy to carry, the R&S®PR100 portable receiver is recommended for the range between 9 kHz and 7.5 GHz with the R&S®HE300 directional antennas (FIG 5). A frequency extension is under

FIG 4 Through simultaneous usage of very different applications in identical frequency bands, significant mutual impairment or interference can occur.

Examples of applications used in parallel	Possible consequences
Simultaneous usage of satellite downlink frequencies and terrestrial WiFi systems at 3.7 GHz in the C band	Failure of satellite communications
Impairment of civil air traffic control radar by microwave link systems	Possible impairment of aviation safety
Defective VSAT terminals disrupt terrestrial microwave link systems	Failure of communications systems
Impairment of satellite TV reception at 12 GHz in the Ku band due to terrestrial microwave link systems	Failure of TV transmission
Automatic anti-collision systems aboard vehicles are disrupted by satellite uplink signals or by microwave link systems used for data transmission	Impairment of vehicle safety

development for this receiver using the R&S®HF907 double-ridged waveguide horn antenna (DC to 18 GHz). It expands the portable monitoring system to include searching for VSAT transmitters or microwave links at close range, for example.

Universal monitoring systems (100 kHz to 18 GHz)
Universal monitoring systems are used to automatically monitor the spectrum in a range between a few meters and a few kilometers, depending on the frequency range, and to clearly identify any emissions. Such systems can also be used for automatic long-term spectrum monitoring, automatic measurement of band occupancy or identification of unused frequencies, which can then be reallocated by the regulatory authorities. Rohde&Schwarz offers the universal R&S®UMS1x0 monitoring systems for such applications (FIGs 6 and 7). These systems can be mounted on roofs or masts, for example, to provide a relatively large coverage range for signal interception. For details on the versatility of the R&S®UMS100 monitoring systems, read the article starting on page 76.

Transportable monitoring systems (9 kHz to 300 GHz)
These systems are designed for short-term local use and can clearly identify transmissions in a range between a few meters and a few kilometers, depending on the frequency range. For the frequency range from 9 kHz to 26.5 GHz (expandable up to 300 GHz), Rohde&Schwarz offers the R&S®TMS500 microwave monitoring systems (FIG 9) which can be transported by two persons.

They can be set up, e.g. on roofs, balconies or ridges, meaning any elevated location where a large signal interception range can be achieved. When installed in vehicles, the range increases and universal applications are possible.

At frequencies above 26.5 GHz, all of the components have a high insertion loss. Microwave converters are required for measurements at such high frequencies. Rohde&Schwarz offers converters that have been specially optimized for this application area. They have special filters, mixers, and amplifiers directly in the antenna to help ensure that the converter output frequency is below 26.5 GHz. This technique provides compensation for the cable losses that occur between the antenna and the receiver. To provide for the frequency stability of the monitoring system, the microwave converters are linked to the R&S®TMS500 using a 10 MHz reference frequency.

Five different microwave converters suitable for outside usage along with the associated antennas are available to extend the frequency range of the R&S®TMS500 transportable microwave monitoring systems (FIG 8):

R&S®MW-40	26.5 GHz to 40 GHz
R&S®MW-58	40 GHz to 58 GHz
R&S®MW-75	58 GHz to 75 GHz
R&S®MW-90	75 GHz to 90 GHz
R&S®MW-110	90 GHz to 110 GHz

FIG 5 The R&S®PR100 portable receiver with the R&S®HE300 antennas.

Module for 9 kHz to 20 MHz.

Module for 20 MHz to 200 MHz.

Module for 200 MHz to 500 MHz.

Module for 500 MHz to 7500 MHz.

Customer-specific frequency expansions up to 300 GHz are available on request.

Using the converters allows the R&S®TMS500 monitoring system to operate in its frequency range from 9 kHz to 26.5 GHz without any modification. Expansion is also possible at a later time by purchasing converters. The frequency ranges that are used do not have to be directly adjacent to one another.

Integration into higher-ranking measurement systems and frequency-allocation systems

The microwave monitoring systems from Rohde&Schwarz can be independently operated as separate systems. They can also be seamlessly integrated into existing spectrum monitoring systems by using the R&S®ARGUS software. R&S®ARGUS also allows them to be integrated into spectrum management systems so that, for example, the universal R&S®UMS1xx monitoring systems can be used for automatic monitoring of the frequency spectrum or for determining band occupancy.

Outlook

Additional articles are planned which will discuss the frequency range from 3 GHz to 300 GHz in particular:

- Wave propagation and measurement capabilities
- Professional system design
- Interaction between spectrum management and spectrum monitoring

Michael Braun

FIG 6 R&S®UMS100 monitoring system (100 kHz to 6 GHz).

FIG 7 R&S®UMS180 monitoring system (10 MHz to 18 GHz).

FIG 8 R&S®MW-40 microwave converter.

FIG 9 R&S®TMS500 transportable monitoring system.