An Introduction to Interference Hunting
White Paper

Much of what we do today depends upon having high-quality communication systems in place. Radio-frequency interference, in which RF energy degrades the performance of a RF communication system, can have a significant impact on the quality of experience of the end-user; and in some cases, lead to catastrophic results. As radio systems have evolved and become more complex, and as the number of interferers has steadily increased, the importance of interference hunting has grown significantly. In this white paper, we will explore the topic of interference hunting beginning with a broad overview of the topic and then leading to a more practical discussion on the different types of interferers, analysis of interferers and the tools that are often used in the field to perform interference hunting.

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Paul Denisowski
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1 THE CHANGING WIRELESS WORLD

For over one hundred years, radio frequency (RF) signals have been used for the transmission of information over both short and long distances. However, the last few decades have seen a fundamental shift in the nature of how these communications take place. Although two-way (or bidirectional) radio systems are as old as radio communication itself, the vast majority of radio transmissions were traditionally broadcast transmissions from commercial radio and television stations. These stations usually had large, well-positioned antennas structures and high transmit power levels that made reception of their signals relatively trouble-free within their defined service areas. Most issues with reception were primarily caused by propagation issues – too far from the station, indoor vs. outdoor receiving antennas, lightning or other atmospheric conditions, etc. The two-way radio systems were almost exclusively used for carrying analog voice signals. Along with the fact that the number of transmitters or other RF-generating devices at that time was relatively small, interference issues tended to be few and far between.

The widespread deployment of cellular communications systems in the 1990s marked a fundamental change in the nature of radio frequency communications. With this change, there were millions of small, portable transmitters communicating with thousands of larger, usually tower-based transmitters. Two-way radio communication had moved beyond military, government, public safety, and amateur radio and began to take on a more prominent role in our everyday lives. In most industrialized countries the number of cellular devices now exceeds the number of inhabitants; and even in developing countries it has become increasingly difficult to find individuals who do not use radio frequency devices on a daily basis.

A second fundamental shift occurred at roughly the same time: the need to be connected. The integration of RF communication into computing devices vastly increases both their usefulness and efficiency. The 802.11 (WiFi) family of protocols brought low-cost, standardized wireless connectivity to a wide variety of devices, and today it is not uncommon to find devices that support ONLY wireless connectivity. RF-based communication is now found in such diverse devices as security cameras, utility meters, vending machines, and medical equipment, as part of our ever growing wireless world.

In the last decade there have been additional developments in the wireless world and these have created the need for more effective and efficient communications. New applications require higher data rates, which in turn is driving the need for higher-order modulation schemes that require a “cleaner” RF environment. Since spectrum is limited, regulatory authorities have been advocating the reallocation of spectrum to newer technologies and services – something referred to as “spectrum refarming.” In addition, an ever-increasing number of subscribers have “cut the cord” and rely exclusively on radio-frequency technology for their voice and data connectivity. Wireless connectivity has quickly changed from a “nice to have” to a “must have.”

1.1 WHAT IS INTERFERENCE?

The term radio-frequency interference refers to situations in which the presence of RF energy degrades the normal operation of a wireless communications system. There is no specific level or frequency criterion that must be met in order for something to be considered interference. Signals that are service-affecting in one application may have no negative effect on other applications. Simply put, the definition of interference is a purely functional one: any radio frequency signal that has a negative impact on the ability to operate a wireless communications system can be considered interference.

1.2 EFFECTS OF INTERFERENCE

The effects of interference can vary tremendously depending on the characteristics of both the interferer and the affected system. In fact, the very first step in interference hunting is to detect the presence of interference. In some cases, poor system performance may be due to design issues rather than interference. Fortunately, there are certain common symptoms that can indicate the presence of interference. For example, in analog voice communications systems, interference is often immediately noticeable by users of the system in the form of noise, static, superimposed audio, and unexplained breaks in squelch.

In digitally modulated communications systems, the presence of interference is often not immediately obvious. Poor voice quality is one indication of possible interference, although voice quality can depend on a variety of factors. A more reliable indicator of interference in digital networks is dropped calls or lost connections. Low data throughput or high retransmission rates are also good indications that some form of interference may be present. Owning to the adaptive nature of many modern communications system, interference in digital networks can cause the system to revert to more robust transmission modes or lower-order modulation types; communication may still be possible, but with substantially degraded performance. Furthermore, the severity of these effects may not increase linearly with the level of interference. This type of “cliff effect” is seen in satellite television systems: the picture shows no visible degradation, or only occasional pixilation, until some threshold is reached after which the picture becomes completely unviewable or is lost entirely.

2 WHAT IS INTERFERENCE HUNTING?

In some cases it's possible to compensate for interference without actually shutting down the interferer. For example, the use of shielding or filters, changing antenna orientation, changing frequencies, etc. can be used to limit the effects of the interfering signal as seen at the affected device. However, in the vast majority of cases the only way to eliminate the interfering signal is to identify, locate, and disable it. The process by which an interfering signal is identified and located is called interference hunting.

As mentioned above, the first step in interference hunting is recognizing that interference is, in fact, present. A related and equally important task is analysis of the behavior, spectral characteristics, and (if possible) content of the interfering signal. There are some interfering signals than can be identified and located by analysis alone. For example, if interference is being caused by an analog audio transmission, demodulating and listening to the content of the transmission may yield information (such as call signs) that indicates its source. Even if such a precise identification cannot be made, analyzing the spectrum and behavior of an interferer can provide valuable clues for further investigation, e. g. if we see the distinctive pattern produced by cable television leakage, we can concentrate our efforts on cable infrastructure near the affected location.

But even when analysis of the interferer gives us a strong indication as to its origins, it is almost always necessary to identify the precise location of the device generating the interference. This is the second and most challenging component in interference hunting, namely radiolocation or direction finding. No matter how much information we have about the nature of the interferer or its general location, resolving interference almost always requires physically disabling (powering off) the source of the interference. Given the large number of both intentional and unintentional sources of RF energy in populated areas, trying to resolve interference by "process of elimination" (i.e. turn off devices one by one until the interference stops) is neither efficient nor practical. The vast majority of time and effort in interference hunting occurs during the direction finding stage, and this is an area in which the proper selection of tools and techniques has a tremendous impact on successfully resolving an interference issue in a timely manner.

2.1 SPECTRUM REGULATION

In most countries around the world, spectrum is assigned or allocated by a governmental regulatory authority, such as the Federal Communications Commission

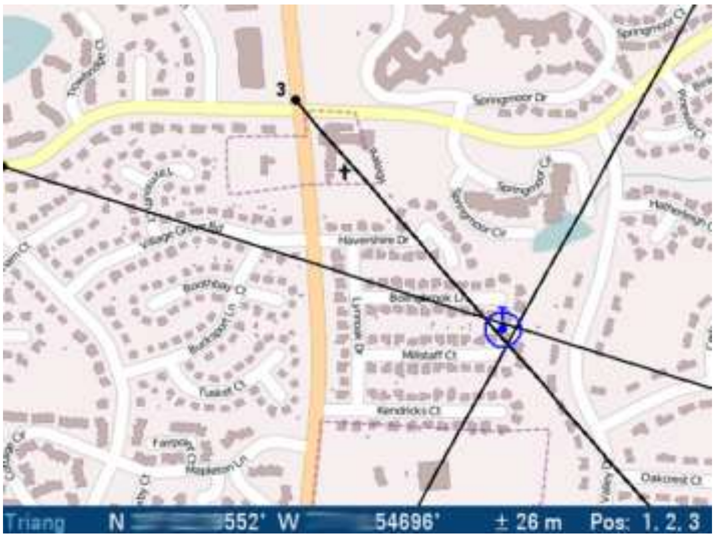
(FCC) in the United States. Although there are some frequencies and frequency bands (regions of spectrum) that can be more or less freely used by anyone, the vast majority of spectrum is licensed, i.e. allocated to a primary user or service. For non-governmental or non-military applications, the cost for obtaining these licenses can vary tremendously, ranging from nominal administrative fees up to hundreds of millions of dollars.

Although in recent years there has been a tendency to see frequency licensing as simply a means of generating revenue, the true value in licensing spectrum is that it grants the licensee the authority to treat all other signals within that frequency range as unauthorized interference and to take appropriate steps to resolve it. Despite the fact that legal authority over radio-frequency operations typically rests with the responsible regulatory authority (the FCC in the United States), it is often the spectrum licensees themselves who are involved in the detection, location, and resolution of interference issues within their frequencies.

STEPS IN INTERFERENCE HUNTING

Generally speaking there are several steps involved in interference hunting, the first of which is to determine whether or not interference is actually present. There are many cases in which problems with radio communications systems are caused by things such as poor design or planning, equipment malfunction, equipment misconfiguration, user error, etc. As mentioned earlier, dropped calls in a cellular network may be due to radio frequency interference, but may also be due to insufficient coverage, capacity issues, and network or user equipment issues. The crackling sounds heard in a handheld radio may be external interference or may be a loose speaker wire. Before one begins interference hunting, it is important to be reasonably sure that external interference is present and to have some idea as to the spectral characteristics of the interfering signal.

Once the presence of interference is suspected, the next step is to identify the general geographical area in which interference is occurring. In some cases this information is actually provided by the affected system itself, such as a cellular base station that reports unusually high received signal strength or failed calls in a given sector. User reports of no or poor



reception/connectivity can also help determine the affected geographical area. The diameter of this area will vary depending on things such as type of service, terrain, and propagation but tends to be on the order of several kilometers.

Field work can be started once this general geographic area has been identified. In the interest of efficiency, a vehicle is commonly driven around the affected area in an attempt to further define the possible location of the interferer. Vehicle-mounted automatic direction finding and/or drive-test systems can be used in this phase, although handheld antennas and portable instruments are also effective tools. If the interfering signal is visible over larger distances, bearings and triangulation may be used to estimate the interferer's position. The goal in this stage is to narrow down the search location to a walkable area such as a city block, group of buildings, etc.

In almost all cases, resolution of interference means identifying the specific device that is creating the interference and resolving it; hence the final step in interference hunting involves walking around the suspected interferer location and making measurements using a handheld instrument and directional antenna. Here, the usual methodology is to scan or sweep buildings or structures, concentrating on those devices that are known radio frequency emitters (such as antennas, electronic devices, etc.). Unlike the first two steps, this step frequently requires physical access to private property or premises.

2.2 INTERFERENCE HUNTING TOOLS

Although different techniques used in the various stages of interference hunting, all of these steps require the use of an instrument which can detect, measure, and display radio frequency spectrum, as well as an antenna which can effectively receive signals at the frequencies of interest. The two most common instruments that are used in interference hunting are spectrum analyzers and monitoring receivers.

Spectrum analyzers use a so-called heterodyne or swept architecture. The input signal in question is converted to an intermediate frequency using a mixer, and a local oscillator provides the mix frequency. The intermediate signal is then swept past a fixed-tuned filter (the resolution bandwidth), logarithmically amplified and passed to the display.

Monitoring receivers, on the other hand, digitize the input signal and then apply a Fast Fourier Transform (FFT) to generate the displayed spectrum. As a result, monitoring receivers are substantially faster and more sensitive than swept spectrum analyzers.

Since almost all interference hunting involves a walking/sweeping stage, it is important that instruments used in interference hunting are (1) battery-powered, (2) portable, and (3) reasonably rugged. Other important features of these instruments are their (4) ability to graphically provide information both in spectrum and waterfall (spectrogram) representations, (5) spectrum and audio recording capability, (6) audio demodulation, (7) internal mapping, and (8) the ability to provide tone-based measurements of RF levels (similar to the way in which a metal detector works).

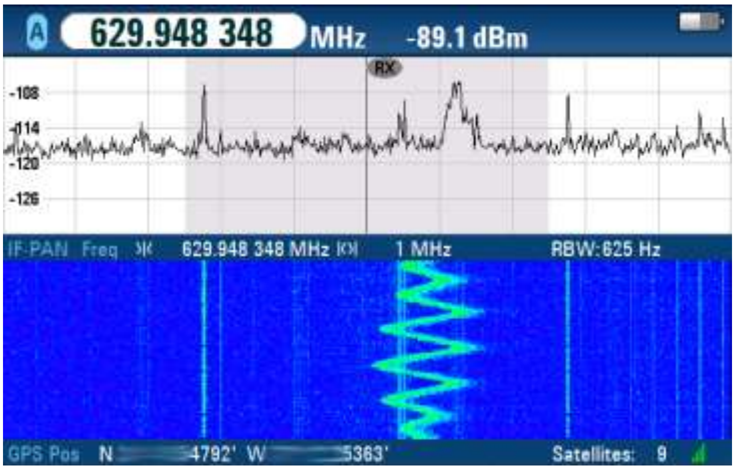
The other indispensable tools in interference hunting are antennas. In order to effectively detect an interfering signal, we need either an antenna which is matched to the frequency of interest, or a wideband antenna which is capable of efficiently receiving signals at a wide range of frequencies. Although omnidirectional antennas are often used in the "driving around" stage of interference hunting, location of interference sources requires the use of a directional antenna; an antenna which receives signals in one direction better than others. In most cases these directional antennas are handheld yagi, log-periodic, or dipole antennas, and the direction to the interference source is determined based on signal strength as determined when the signal is strongest when the directional antenna is pointed towards the signal source.

There are also special direction finding antennas which, when connected to a special direction-finding receiver, can be used to automatically calculate the direction or bearing towards a signal source. These systems may be based on a variety of direction finding methodologies (Doppler, Watson-Watt, TDOA, Correlative Interferometry, etc.) and are either always mounted on a vehicle or set up in a fixed location. In many cases these systems are able to automatically determine an interferer’s location within a radius of several dozen meters.

Perhaps the most important tool in interference hunting is knowledge of radio frequency principles, propagation, signals, and spectral allocations. Having the right tools, a familiarity with the signals normally found in a given region of spectrum, and knowledge of the characteristics of common interferers, is essential in identifying and resolving interference issues quickly and efficiently.

3 ANALYZING INTERFERENCE

Analyzing suspecting interferers is important for a number of reasons, not the least of which is confirming that a received signal is actually interference. Moreover, a detailed analysis of an interfering signal can provide vital clues as to its source and even its location. For example, if our interfering signal consists of a regular, contiguous pattern of 6 MHz wide “haystacks” of almost identical amplitude, it is extremely likely that this signal is egress from a cable television system, and our efforts can be focused on examining cable-related infrastructure and devices.



There are several different ways of analyzing interference, and often interference hunting requires a combination of these different analysis methods. The most basic method for analyzing interference is visual inspection of the spectrum. The traditional method for displaying spectrum is a graph of amplitude vs. frequency. In a waterfall or spectrogram display, the vertical axis represents time and different colors are used to show amplitude. This type of display is extremely useful in analyzing intermittent or variable frequency signals. For most interference hunting applications, the simultaneous display of both spectrum and waterfall provides the user with the optimal mix of information. Additional numerical data can be obtained using markers and lines.

Content analysis is another powerful tool in analyzing interference generated by modulated sources, since the demodulated information can sometimes be used to identify the source of the signal. One example is wireless microphones operating at frequencies reserved for other services. Demodulating and listening to the audio information can provide a wealth of information regarding the microphone’s location. Broadcasters and licensed services are normally required to transmit their identification or call signs at regular intervals, and once this call sign is obtained, the licensee’s contact information can be looked up in the FCC database. Demodulation of digital signals is also possible but typically requires more advanced tools. Note however that in some cases even digital signals can be identified by audio demodulation, such as recognizing the distinctive sound of an FSK modulated paging transmission.

Another useful analysis method for analyzing interference is behavior or pattern analysis. Interference sources may be continuous in nature (that is, always "on"), while others may be intermittent over shorter or longer periods of time. Knowing that a given type of interference only occurs during home football games at night is a powerful indicator of where that interference might be coming from. Similarly, problems that only occur when it rains or is very windy suggest outdoor sources. One should always look for possible correlation between interference and other events, no matter how unrelated those events may seem.

Other useful capabilities in analyzing intermittent interference include the ability to remotely access and control an instrument, the ability to trigger and collect information when "interesting" events occur, and the ability to record spectral data over a long period of time for later analysis. Spending hours staring at a screen and hoping to catch an intermittent interferer is not an effective (nor particularly popular) interference hunting methodology.

3.1 COMMON INTERFERENCE TYPES

While the variety of interference sources is almost endless, a large number of (especially narrowband) interferers often share common characteristics. An awareness of these frequently reoccurring "themes" can save substantial amounts of time and effort when investigating potential interference sources.

The term noise can be used in a very broad sense to refer to any interfering signals. As mentioned above, almost anything powered by electricity is a potential source of unintentional and undesirable radio frequency signals. In some cases it is useful to differentiate between noise created by electrical systems and noise created by electronic systems. Electrical noise sources tend to be wide (many megahertz wide) and may be periodic in frequency and/or time. Examples of this are emissions from electric motors, welding equipment, vehicle ignition systems, electrical fences, faulty transformers/ballasts, etc. In contrast, noise from electronic sources, sometimes also referred to as "spurious emissions" or "spurs", are usually much narrower (less than one megahertz wide) and tend to be continuous, although in some cases they may vary in frequency, i.e. be oscillating or drifting. It is fairly safe to say that almost all consumer and commercial electronics radiate spurious emissions at numerous frequencies; it is the level of these emissions that determines whether or not they are truly sources of interference.

Harmonics are a normal by-product of almost all radio-frequency transmitters. A harmonic is simply a copy of the original (or "fundamental") signal appearing at whole number multiples of the original frequency. For example, a transmitter operating at 155 MHz can produce harmonics at 310 MHz, 465 MHz, etc. Although the level of harmonics normally decreases as the frequency increases, a surprisingly large number of narrowband interferers have turned out to be harmonics of signals operating at lower frequencies. Wideband harmonics are much less common. A good rule of thumb is to always check whether a narrowband interferer is a harmonic. Since the fundamental signal is almost always significantly stronger than its harmonics, it is often easier to track down the fundamental itself.

Intermodulation results from two or more signals appearing in a nonlinear circuit. Sum and difference frequencies can be created from the mixing of fundamentals and harmonics, and these intermodulation products can occur at frequencies substantially removed from their component signals. Because intermodulation involves the mixing of multiple signals, it will only occur when all component signals are present. This type of intermodulation is commonly seen when high-power transmitters share an antenna, feedline, or tower system, providing the close proximity and power levels needed for the signals to mix.

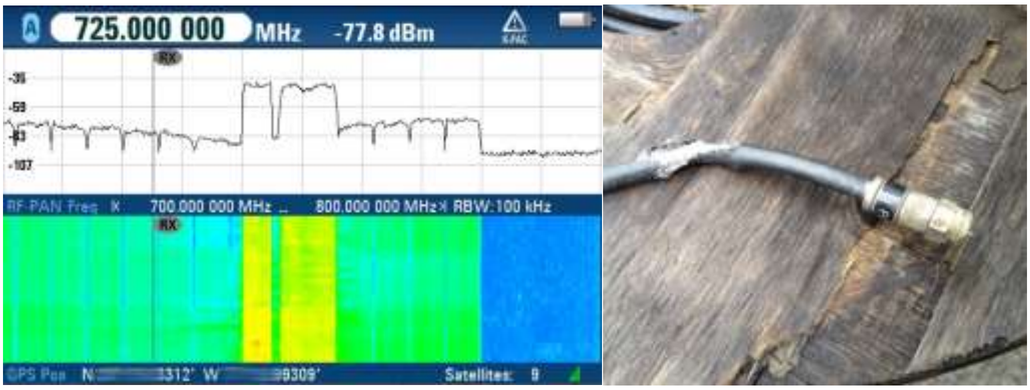
Another form of intermodulation is external rectification, also called the “rusty bolt effect.” A junction between two pieces of metal can create a rectifier (diode), especially when corrosion is present, resulting in spurious signals that are then radiated by metallic elements in this junction. Towers and guy lines are common culprits since they can rust, have long metal elements, and are close to powerful transmitters. Utility poles/wires, metal fences, and gutters are also prime suspects. Bonding and grounding are the most common remedies for this type of interference.

3.2 SPECIFIC INTERFERENCE TYPES

In the same way that there are some common themes in interference sources, there are also a number of systems and devices which generate interference. In some applications, such as cellular telephony, these “well-known” issues can represent a substantial percentage of interference sources.

Bidirectional amplifiers (also called cell phone repeaters or signal boosters) are devices used to extend cellular coverage within buildings or in other areas with poor reception. As the name implies, they operate by amplifying and retransmitting both downlink and uplink signals and are generally not a source of interference when properly installed and operated. They most commonly cause interference when there is insufficient physical separation between the so-called serving and donor antennas, leading to a feedback loop that substantially increases the noise floor over the entire uplink band (typically a range of 30-40 MHz). The presence of a small yagi or directional antenna on a building roof, or the panel or dome type indoor antennas are good visual clues as to the presence of a bidirectional amplifier.

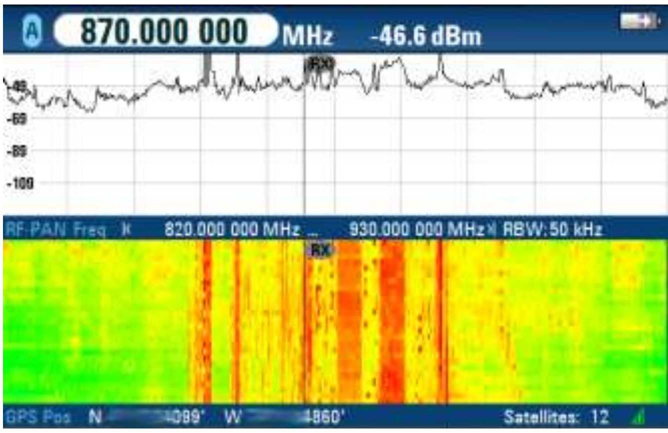
Cable egress (or “leakage”) occurs when the radio-frequency signals used in cable television systems escape from the shielded cables and devices that carry them. Since the frequencies used in cable television systems can extend up to 1 GHz in some areas, there can be an overlap with many commercial, government, and cellular services. The most common cause of egress is the presence of physical faults in the cable infrastructure such as cracked/damaged cables, faulty splices, unterminated connectors, and loose amplifier and tap housings. Fortunately, cable egress is very easy to diagnose due to its regular, continuous pattern of 6 MHz wide channels.



Wireless microphones are often used by clubs, organizations, schools, churches, etc. and most commonly transmit analog, narrow-band FM signals. Problems can occur when these microphones are operated outside of their allowed frequency ranges. This sometimes is caused by the use of microphones designed for use in countries with different frequency allocations, but it can also result from spectrum refarming (i.e. people continuing to use microphones in spectrum that has been reallocated, such as 700 MHz in the United States). Wireless microphone can also be very powerful transmitters for their size. As mentioned above, audio demodulation is an excellent way of tracking down interference from wireless microphones.

There are also cases of deliberate interference, in which someone intentionally interferes with radio-frequency communications. Unfortunately there are many cases of individuals making unauthorized, harassing, or misleading (e.g. false distress calls) transmissions on public safety, government, commercial, and amateur radio frequencies. These transmissions are often analog modulated voice signals but are also usually intermittent in nature, making it very difficult to locate the source. Recording the content of these transmissions is very important in the event that legal action needs to be taken.

The other most common source of deliberate interference is jammers: devices designed to limit or deny the ability to use a certain frequency range by raising the noise floor to an extremely high level (typically around -50 dBm in the affected area). Jammers are often designed to affect particular services (GPS, WiFi, etc.) and/or frequency bands (850 MHz, 1900 MHz, etc.) but often create issues for services and frequencies well outside of their target range. In order to be effective, a jammer must generate a wide, strong, continuous signal, and this makes it relatively easy to identify and locate them. Physically most jammers have multiple antennas (one per target service/band) but may also be disguised as everyday objects.



It is important to keep in mind, although most individuals and organizations are very cooperative in helping to resolve interference issues, persons engaged in deliberate interference will often go to great lengths to disguise and deny their activities.

4 CONCLUSION

The rapid rise in both the prevalence and the importance of radio-frequency communications has increased the importance of interference hunting as a means to identify and resolve interference issues as quickly and efficiently as possible. While there is tremendous variation in the types and sources of radio-frequency interference, knowledge of common causes and characteristics, together with the use of appropriate tools and techniques, greatly increases the probability of locating and resolving these issues.

About Rohde & Schwarz

Rohde & Schwarz is an independent group of companies specializing in electronics. It is a leading supplier of solutions in the fields of test and measurement, broadcasting, radiomonitoring and radiolocation, as well as secure communications. Established more than 75 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. Company headquarters are in Munich, Germany.

Regional contact

Europe, Africa, Middle East
+49 89 4129 12345
customersupport@rohde-schwarz.com

North America
1-888-TEST-RSA (1-888-837-8772)
customer.support@rsa.rohde-schwarz.com

Latin America
+1-410-910-7988
customersupport.la@rohde-schwarz.com

Asia/Pacific
+65 65 13 04 88
customersupport.asia@rohde-schwarz.com

China
+86-800-810-8228 /+86-400-650-5896
customersupport.china@rohde-schwarz.com

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Rohde & Schwarz GmbH & Co. KG
Mühldorfstraße 15 | D - 81671 München
Phone + 49 89 4129 - 0 | Fax + 49 89 4129 – 13777

www.rohde-schwarz.com