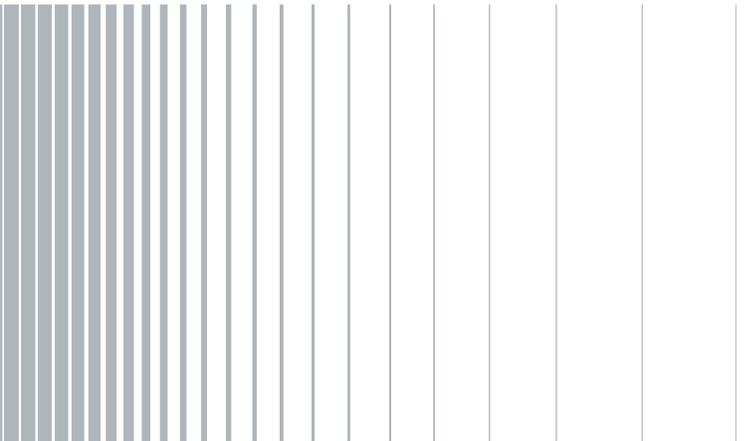


Go 2 Repack

An Expert Guide to Technology and Logistics



ROHDE & SCHWARZ



Executive Summary

In 2012, the Federal Communications Commission (FCC) was tasked with repacking the licensed broadcast spectrum to make room for wireless broadband. Now, with auctioning of the spectrum complete, the FCC estimates about 1,200 stations will be affected by the clearing of 84MHz of spectrum – and each of those stations will have a little more than three years to transition to their new channel assignments.

Similar to the analog-to-digital ATSC switch that ushered in the era of HDTV, the repacking offers some great opportunities for broadcasters. New transmission technologies can modernize existing facilities, and there is the promise of a new ATSC 3.0 digital broadcasting standard, which allows broadcasters to offer innovative programming and services using Internet Protocol (IP) to connect with computers and mobile devices. Now, broadcasters will have the technology to reach consumers who have changed their viewing habits to mobile over-the-top (OTT). That said, upgrading broadcast facilities is a complicated and expensive proposition, and affected stations will be racing against a 39-month clock to complete the transition.

In the last decade, the industry landscape has drastically changed. Several companies that were trusted during the analog-to-digital transition are no longer in business, the first generation of RF engineers has retired, and your engineering team has a new set of skills. The repacking checklist is extensive; every affected station needs to focus on permits, construction and installation, interim transmission facilities, coordination with other local broadcasters, RF systems, antenna and transmitter selection, and (of course) budgets.

Experts from Rohde & Schwarz, antenna manufacturers, RF consultants, and industry leaders have written this general “survival guide” to help you plan ahead for the process, keep your transition on track, and turn a long-term investment in RF equipment into new revenue streams for your station. We’ve included information about the repacking process and ATSC 3.0, as well as details about the latest antenna and transmitter technologies, so you can make the best equipment and infrastructure choices for your facility.

Good luck with your transition. We welcome you to contact us directly for more information about our products and services during this exciting yet challenging change.

Table of Contents

Repack: An Overview.....	3
Repack Impact on LPTV and Translators.....	3
Permits and Logistical Considerations.....	4
Transmitter Technology.....	5
Installation Prep.....	9
RF Systems: Plan To Replace.....	9
Antenna Selection: Repack and Beyond.....	10
ATSC 3.0 Antenna Decisions.....	12
Coverage: Defending the Footprint.....	12
ATSC 3.0: The New Standard.....	13

Repack: An Overview

By Graziano Casale, Account Manager, Broadcast & Media, Rohde & Schwarz

Since the Middle Class Tax Relief and Job Creation Act of 2012 empowered the FCC to “encourage a licensee to relinquish voluntarily some or all of its licensed spectrum usage rights” to make way for wireless broadband, the industry focus has shifted to the Incentive Auction. With the bidding now complete, we can move forward as an industry to make the 39-month repacking timeline as smooth and efficient as possible.

The Incentive Auction concluded at Stage 4 on Feb. 10, 2017, clearing 84 MHz of spectrum from channels 38-51 and selling 70 MHz paired in blocks of 10 MHz to wireless operators (see Figure 1). There will be 10 repack phases, with each station put into one of those phases and with staggered completion dates “to ease coordination issues and enable the Commission to track progress.” Phasing is also meant to prevent undue interference to broadcasters as they move.



Figure 1: New TV spectrum after FCC repacking.

Approximately 1,200 stations will be affected by the repack, according to the FCC. Once your station receives its Channel Assignment Public Notice (PN) via confidential letter from the FCC, you will have a 39-month window to complete its transition, though there is a waiver process for extenuating circumstances.

Within the first three months, you will need to determine how you will transition to your new channel assignment. During this time, your station must file a Construction Permit Application (FCC Form 2100) and provide an estimated cost of transition (Form 399). Throughout the three-month period, there will be a rush to provide the FCC with required information, so the more educated you are about your transmitter sites beforehand, the easier it will be to prepare the data.

Auction Winners

If your station participated in the Auction and is a Winner, the FCC will deliver the Auction Proceeds approximately 2-3 months after the Auction. They will roll bases after forward auction licenses are issued. Three months after the proceeds are received, the TV station must cease broadcasting and go off-the-air. If you participated in Channel Sharing, the cooperating stations must file the construction permits (CPs) within four months of receiving the auction proceeds and implement sharing within six months.

Repacked Stations

If your full power TV station is eligible for repacking, you will have three months to file a CP for a modified facility after receiving your reassignment PN from the FCC. After the FCC processes the initial applications, you will

have a window for Post Auction filing (channel changes or expanded facilities). The first window is for stations unable to meet the technical parameters in the reassignment PN, while the second window is for all other stations assignment to new channels.

Repack Impact on LPTV and Translators

By Michael Couzens, Vice President, Legal Affairs National Translator Association

If you are a low power television station or operate TV translators, the repacking rules are different. According to one estimate, there are 2,332 licensed TV translators and LPTVs assigned to channels 38-50, but non-Class A LPTV stations have no spectrum or compensation rights in the repacking. There are essentially in a wait-and-see-what’s-left pattern until the full power station musical chairs has been resolved.

The auction rules provide for a special displacement window to be opened for LPTV and TV translators once the full power stations have filed for their new channels.

However, LPTV stations must be constructed and licensed to participate in this window. If you only have a construction permit or are beginning anew with new applications (if permitted), your station will take a back seat to the full 39-month repacking project. If you have built or nearly built your facility, apply for your license as soon as possible.

On January 19, the FCC (without notice) imposed an immediate freeze on the filing of any applications for LPTV and TV translator companion channels. As a result, these will not be addressed until the special displacement window. The freeze may not make much difference, except for isolated operators who never completed their DTV transition. (Some of these stations will certainly go out of business.)

In many cases, full power stations depend on extended terrestrial coverage over mountain ranges and in valleys via translators. This coverage is factored into their TV ratings, maps, and rate cards. Unfortunately, FCC planners did not adequately address these translators and their coverage during repacking. Consequently, rural residents in many states of the Inter-Mountain West will lose their only practical means of reception.

A study by the General Accountability Office, based on a survey conducted in Summer 2016, looked at possible LPTV repacking losses. Published last December, the report predicted substantial losses of niche programming by LPTV, including specialized cultural programs, foreign language, and tribal program services.

Single-site translator services with five, six, or even more transmission channels will be hard pressed to squeeze into the reduced band. Where translators are chained

from peak to peak, the repositioning will be even more daunting. Plus, while a fund of \$1.75 billion was set aside to compensate full power stations for their moving costs, no funds have been allocated for translator relocation costs.

Permits and Logistical Considerations

Congratulations, you're almost ready to file your initial Construction Permit (CP) and Schedule 399 Form with the FCC. Have you thought of everything? There are several filing "windows" associated with the auction that stations need to know, as well as several logistical issues your station may need to consider. The following guidelines will help you stay on schedule with the FCC and plan for potential technical difficulties.

Please note, some of the following guidelines may be subject to change as the repacking process evolves. Therefore, it is important to watch for updates from the FCC, industry leaders, manufacturers, and your legal and engineering advisors.

Construction Permit Filing

Within 90 days of the issuance of the Channel Assignment Public Notice, initial Construction Permits and Form 399 (proposed expenditures) must be filed in the License Management System (LMS) at the FCC. The first CP filing window is the one most often associated with the 90-day deadline. For this filing window, full power and most Class A stations will recreate their current "protected coverage" footprint with the station's *current antenna pattern on their newly assigned channel*. The CP should be filed concurrently with Form 399 prior to the end of the 90-day period following the Channel Assignment Public Notice.

All CPs of this nature are considered "minor changes," and the FCC has pledged to process these very quickly. The filing window applies to all UHF stations being repacked, as well as successful reverse auction winners that applied to move from UHF to VHF or from High-VHF to Low-VHF channels. A 1% increase in protected coverage or an increase that proposes *less than 0.5% increased interference* to other full power and Class A stations is allowed for this filing to still be considered a "minor change."

The second CP filing window begins once the FCC staff has completed its processing of initial CP applications, and will be solely for stations that are being repacked involuntarily. Priority will be given to stations that demonstrate they cannot construct facilities that meet the technical parameters specified in the Channel Assignment Public Notice. This filing will be considered a "major change" and would be for the following proposals:

- Request of a substitute or alternate channel other than the one assigned in the Channel Assignment Public Notice. Because stations are being repacked, the FCC does not anticipate

there will be many opportunities for an alternative channel.

- Requests for "expanded facilities," such as a change in coverage pattern or Effective Radiated Power (ERP). For example, in order to protect another station on the same channel or an adjacent channel, your original antenna pattern might be highly directional. As a result of the new channel assignments, your station might be permitted to change the pattern or become omnidirectional and serve a larger population. This would be considered "expanded facilities." If your station plans to file for an "expanded facility," this does not absolve you from the requirement to file a CP application and Form 399 budget estimate for construction of your originally assigned facility, and will not be reimbursed costs incurred over and above those required to construct the assigned facility.

An additional filing window will be offered to all other stations that are assigned new channels in the repacking process, or are winning UHF-to-VHF or high-VHF-to-low-VHF bidders to file for alternate channels or expanded facilities. Another filing window will be provided for displaced LPTV stations to file an application for any remaining channels in their markets after the initial filing windows have closed. At this writing, applications from LPTV stations will be accepted on a first-come, first-served basis.

What happens if you can't meet your construction deadline? The FCC has indicated it will allow stations to "seek a single extension of up to six months of their original construction deadline." However, if the six-month extension extends beyond the end of your station's "Broadcast Construction Period," your station may be required to stop broadcasting on your pre-repack channel and go off the air until the new facility is finished.

Your station must apply for an extension *prior to* 90 days before the end of your construction period. If you apply for an extension, you need to show you weren't able to complete construction as scheduled due to circumstances that were "either unforeseeable or beyond their control". Some examples include weather, tower lease disputes or zoning issues, unusual technical challenges, or the unavailability of a tower crew or equipment. Multiple and/or prolonged extensions will not be permitted.

Beyond the Filings

By now, most station groups and individual stations know what's needed to gather information for the Schedule 399 Form and file it. Remember, if it's too difficult to obtain a quote from a vendor, you can reference the cost in the updated Widelity Report Cost Catalog. Beyond quoting new antenna or transmitter purchases, as well as determining if your broadcast

tower needs strengthening, there are other details that are just as important for finalizing your budget.

- Do you need an interim facility? Perhaps your station needs some tower work or is on a shared or stacked antenna with other stations. How will you stay on the air while the work is being done?
- If you currently feed cable and satellite providers over the air, how will you keep your connection to them, especially if your interim or aux facility isn't as powerful and doesn't reach as far?
- If you share a tower, what is the "community" plan, and how does your station fit into the discussion?
- If your transmission facility is on a tower owned by others, does the tower owner have a repack plan? If so, what is it – and how does it impact your station?
- Are there FM stations on the tower? For the most part, FM stations don't get reimbursed by the government for any inconveniences they might suffer while TV stations are being reconfigured. Consequently, they may not be very happy with the process. Be sure to include them in all your planning, as they will probably have a say in when (and for how long) they can be powered off or run at reduced power while workers take care of the TV antennas. The same goes for FM and TV stations located on towers that are physically close to yours.
- Currently, the FCC has suggested that the repack will be performed in phases. All of the phases are scheduled to start at the same time (Day 0) and will finish at different times. The finish dates are dependent on how difficult each market is to transition. Does your market have a plan to finish within the allotted time?

How will the repack affect your viewers? Expect over-the-air viewers to be confused. The FCC requires stations to run informational PSAs and text crawls to address the public. PSAs must be at least 15 seconds long, closed-captioned, and include a "how-to" guide for changing channels. Text crawls need to be at least 60 consecutive seconds long. Stations are required to run crawls and/or PSAs in "every quarter of every day" (one in each of four, three-hour time blocks in a 24-hour period) and at least once during primetime programming. Cable or satellite viewers may have to "re-scan" their TV sets and cable boxes periodically as you go through phases of construction and are off the air for short periods of time.

Transmitter Technology

**By Olaf Farhrenkroog, Technical Sales Manager
Rohde & Schwarz**

The repacking will displace many TV stations from their current frequencies to new ones, even if the originals are not in the cleared range. Changing the frequency of a high-power TV station is a very complex task that requires careful advanced planning.

In some cases, it will be more economical to exchange the complete transmitter rather than retuning the existing tube-based transmitter. If the last transmitter you installed was purchased as a result the digital transition, you might be surprised at how amplifier technology has advanced in the last decade. What seemed impossible back then has become the dominant solution for high-power broadcast transmitters. Transistor-based, solid-state transmitters have knocked traditional MSDC-IOT transmitters out of the market. Here are some important considerations when considering a new transmitter.

Amplifier Technology

The first milestone for this paradigm shift was the successful implementation of the Doherty principle in high-power broadcast amplifiers. Compared to standard solid-state transmitters, the level of efficiency is 10-15%

Doherty Principle

The principle itself dates back to 1936, when William H. Doherty applied it to a two-tube amplifier. Key to the efficiency increase is the separated amplification of the peak and average power signals by using a peak and a main amplifier. The main amplifier operates as a normal broadcast amplifier until it backs off. When it reaches the back-off point, the amplifier constantly works in saturation. The peak amplifier then joins the main amplifier in amplifying the peak signals. The main and peak amplifier outputs combine to produce the final output power.

higher. The resulting power efficiency (AC to RF) at the system level reaches up to 43% in ATSC (UHF) and 50% in VHF band III, including cooling, which put solid-state transmitters on par with MSDC-IOT transmitters. The second milestone toward displacing IOT transmitters was an adequate TPO of the amplifiers for supporting even the most powerful TV stations. Current 50V LDMOS transistors have enabled a dramatic increase of output power compared to the levels in 2006. Transmitters with up to 106kW ATSC UHF have been realized in a very compact form factor, impressively proving the scalability of the platform from 1kW to 100+kW.

When determining the power level of your new transmitter, consider the upcoming adoption of ATSC 3.0. This change to an OFDM modulation poses a challenge to some transmitter designs, resulting in a



Figure 2: R&S THU9evo with 106kW TPO (ATSC).

much reduced available output power. To be safe, select your new transmitter based on OFDM power ratings (e.g. DVB-T2). Another influence on your transmitter's TPO is the potential need for a circular polarized antenna to properly support the mobile applications of the ATSC 3.0 standard. Changing from a planar polarization to a full circular polarized can require up to 50% higher TPO from the transmitter.

Amplifier technology is the crucial component in determining the cost of ownership, especially for high-power transmitter stations. While the efficiency figures at nominal power are important, most transmitters operate at reduced output power, which is why it is important to also verify the system efficiency at 10%, 25% or even 30% reduced output power. Ideally, you can measure these values at a comparable TV station to review real-world numbers. Conventional transmitters experience a significant reduction in efficiency at reduced power. Intelligently designed amplifiers allow optimizing efficiency at reduced power levels, maintaining the projected cost savings in your specific application.

To ensure that your transmitter is operating at optimum efficiency at all times, Rohde & Schwarz offers a software-based Efficiency Optimization tool. It adjusts several parameters of the amplifiers while monitoring the signal quality at the transmitter output, finding the sweet spot of best efficiency vs. influencing quality. Many networks operate several transmitters in various frequencies. Even transmitters installed during the repack might be required to start at the "old" frequency before changing to the new frequency. Therefore, it's essential your new transmitter supports all UHF frequencies up to 700 MHz (CH 51) with a single

hardware platform amplifier, tunable without any soldering to any frequency.

Wide Band Doherty vs. Classic Two-Way Doherty

Some of today's transmitter designs promote a so-called wide-band Doherty implementation. Introduced by the main supplier of broadcast related power transistors, the design has the goal of overcoming the frequency selectivity of the Doherty Principle.

The initial attempt of having one transistor design for the whole UHF frequency band (470-790 MHz) was rejected due to very poor efficiency. Instead, three frequency bands are available in three different transistors. You can't convert a transistor to a different frequency band; you need to physically replace them because of the basic differences in the layout structure.

As a single ended transistor, this amplifier has no cancellation of the even harmonics. The second harmonic in particular can have a relatively high power level, which requires strong harmonic filtering at the transmitter output with higher losses and less efficiency. Another unwanted effect of this harmonic filtering is a strong reflection through the combining network back to the transistors. When you combine networks, it causes harmonic reflections to distribute stress unevenly on the transistors. Depending on the implementation, an increase in transistor failures can result from this additional stress, reducing reliability and increasing maintenance cost.

The so-called wide band Doherty solutions are mostly adapting the reference design of the chip manufacturer. In contrast, Rohde & Schwarz has developed and mastered its proprietary two-way Doherty solution. Starting with our first Doherty amplifiers in 2012, R&S has pioneered this solution, which provides the highest efficiency of any Doherty implementation over the whole UHF frequency band.

There is only one hardware platform for all frequency ranges, simplifying spare part handling for various transmitters/stations. By means of metal jumpers, the appropriate Doherty frequency band is selected and automatically detected by the amplifier. With its symmetrical push-pull amplifier, the even harmonics cancel out in the balun-combining network, which reduces demands for harmonic filtering at the transmitter output and results in lower losses. Stressful reflection of power back to the transistors is avoided, while the reliability of the amplifier is significantly improved.

Liquid Cooling Systems

Despite great advances, transmitters are still producing a lot of waste heat that needs to be removed reliably and cost efficiently. The majority of a transmitter's waste heat is caused by the components in the amplifier that create the output power, namely the transistors and power supplies. The power transistors generate great heat in a very small spot in the amplifier. Multiple transistors have to be cooled evenly and reliably.

A liquid cooling system transfers the heat load to a water-based coolant. As an experienced RF expert, you might have concerns about bringing water even close to high voltages. After all, pipe-based liquid cooling systems in the power amplifier are challenged to provide even cooling to all power components, and even little mechanical impacts on the pipes can cause tiny leakages that could result in major failures.

In sophisticated cooling solutions, the coolant is encapsulated into a non-ferrous metal cooling plate with no chance of water escaping the coolant circuit. Non-ferrous metal is a prerequisite for a trouble-free liquid cooling system. The use of copper-based materials in the cooling circuit can cause galvanic corrosion in the system – and depending on the severity, leakages can result out of this corrosion.

Properly designed cooling systems use only stainless steel, aluminum, and plastic (isolating) materials. The coolant in the system is mixed with antifreeze and corrosion inhibitors. A mixture of roughly 60% water and 40% glycol are suitable for most applications, unless your station is exposed to severe environmental conditions.

It's also easy to overlook cooling the power supplies, but it's another important consideration. For example, if you have a 50kW TPO transmitter with 42% (AC to RF) system efficiency, it will consume about 119kW of electrical power. Not all of this will feed AC/DC power supplies, but for the ease of this estimate, we assume it will. Today's power supplies typically provide roughly 90% efficiency. If the power supplies are not cooled, this results in a heat load into the room of 11.9kW. In other words, you have eight fan heaters in the room at full power, even in the summer.

Based on this example, it is clear this heat should be dissipated with a reliable liquid cooling system, which avoids putting a load on the air conditioning system and increasing your operations cost. The avoidance of fans in the power supplies also reduces your maintenance costs for the transmitter.

In general, your cooling system should include dual, fully redundant pumps and fans. That way, if one should fail, you still maintain continuous operation of your transmitter. This redundancy requirement results in an oversized cooling system for normal operation, which is

why it's mandatory to have temperature-controlled fans in the system. Otherwise, the coolant can cool down below the dew point in the station and cause condensation inside the transmitter.

Today's liquid cooling systems last for the lifetime of the transmitter and require almost no maintenance. The pumps and fans operate below nominal power, which reduces the mechanical stress of the units, so no preventive exchange is required. Pressurized closed loop cooling systems also avoid the ingress of oxygen into the system. Along with the avoidance of copper-based metals, this helps avoid the deterioration of the coolant, eliminating the need for regular coolant replacements. Only annual checks of filling and pH-levels of the coolant are required.

Station Dummy Load

Most transmitter stations have a dummy load installed that can handle the nominal TPO of the transmitter. Many tube-based transmitters have a cooling system that provides sufficient capacity for cooling a water column load or a RF combiner. With efficiency optimized solid-state transmitters, this spare capacity is no longer available, and the water column load requires a separate solution.

Rohde & Schwarz offers a solution based on this proven cooling system for the transmitters, with a redundant pump unit and heat exchanger for outside installation. The advantage is the full removal of waste heat out of the transmitter room via the liquid cooling system. Spare part commonality with the transmitters simplifies logistics and reduces maintenance costs.

ATSC 3.0 Readiness

All eyes are currently on the repack and the clearance of the upper frequencies. When looking for new transmitter in this clearance event, however, you should consider the expected transition from ATSC to ATSC 3.0. While the adoption in U.S. markets will take some time, most broadcasters expect it to happen. The new standard will enable mobile applications, targeted advertising, pay TV business models, and much higher data rates.

Any new transmitter you install during the repack should be easily upgradeable to the new standard, once it has been adopted by the FCC. The change to ATSC 3.0 will encompass more than just the exciter. We already discussed that some transmitters will experience a substantial reduction in available output power when moving from 8VSB (ATSC) to an OFDM (ATSC 3.0) modulation. This is why you should select a new transmitter based on the OFDM TPO rating.

The mobile applications of ATSC 3.0 might also require a change in the polarization of the transmit antenna. Consequently, you might want a higher TPO of the transmitter, which has to be carefully planned. Some RF components like band pass filters, antennas, or dummy

loads have a different rating for 8VSB compared to OFDM. Also, these components of your system should be ready for the anticipated change to the new standard.

In South Korea, the first networks have been under installation since late 2016. Rohde & Schwarz installed the first SFN network for a private broadcasting company with THU9 liquid cooled transmitters. The early rollout of the network is focused on the upcoming Winter Olympics in PyeonChang in 2018.

Temporary Transmitter System

Once you select a new transmitter, RF system, antenna, and other ancillary components, you need to address the installation period. Such a comprehensive rebuild easily adds up to a construction period of at least four weeks. During that time, the station has to stay on the air, not only for the business considerations but because of the FCC's licensing requirements. The setup of a temporary transmitting system becomes inevitable and adds to the complexity of the project.

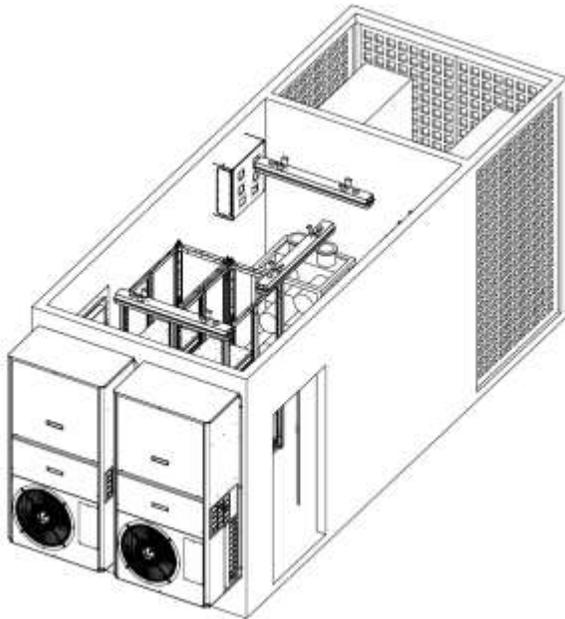


Figure 3: Transportable transmitter system.

What are your options for a temporary system? Many stations are limited by available floor space, or the air conditioning doesn't allow any additional heat load to the room. Plus, an air-cooled temporary transmitter might fall short on output power. During construction, additional space is desperately needed, so more equipment is only going to get in the way. Are you willing to rely on your clunky backup transmitter? Does it even work?

More than likely, your best option is a dedicated, fully transportable temporary transmitter. It is a complete transmitter system, easily and quickly deployable on site. Just add power, the transport stream input, and a connection to the existing antenna to stay on the air.

The output power has to be high enough for high-power sites to function as an adequate backup. For many broadcasters, a temporary reduction of up to -3 dB in output power is acceptable. For transmitter stations with a 50kW main transmitter, it sets the expectation to at least 25kW output power.

Any temporary transmitter has to be equipped with complete thermal management. Heat dissipated by the transmitter and supplemental equipment has to be effectively guided out of the facility. Reliability expectations demand a fully redundant cooling system for the setup. Because the existing RF system at most station needs replacing as well, the temporary transmitter should be fitted with a FCC-compliant mask filter.

One option, as illustrated in Figure 3, is a transportable transmitter system fitted in a 20-foot customized container. The high power density of current transmitters makes it possible to fit a dual cabinet transmitter with approximately 30kW TPO after band pass filter within the container.

The fully redundant cooling system with pumps and heat exchangers are installed in the container for quick deployment. Inside the container, the environmental conditions are controlled with redundant air conditioning units and a heating element. Integrated electrical power distribution helps facilitate deployment, while the output signal can be monitored from a TV set inside the container. The interface to the antenna system is an industry standard 6 1/8" EIA flange on the side of the container.

With its compact form factor, this temporary setup can be easily transported by truck to the transmitter site and deployed next to the antenna mast or in proximity of the existing transmitter building. Figure 4 illustrates the standard workflow for the repack with such a temporary transmitter system.

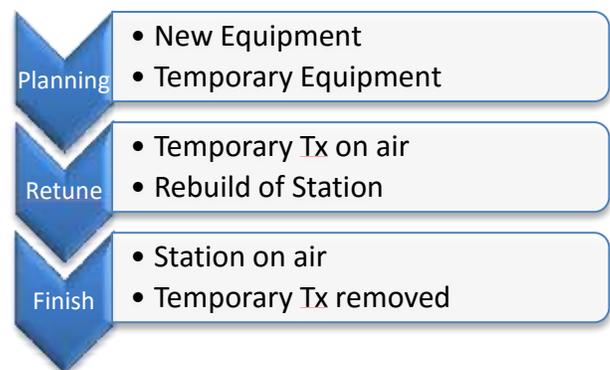


Figure 4: Standard workflow with temporary transmitter system.

The transmitter in such a temporary system is a standard high efficiency, liquid cooled transmitter. Deployment as a permanent transmitter at a station is possible as well, re-using all the installed equipment except for the container itself. You can also keep the temporary setup as a disaster recovery solution in case of a catastrophic failure at a main station.

Supplier Reliability

Investing in a new transmitter during the repack requires careful consideration. The new equipment will be in service for at least 10 years – and will be directly responsible for creating your company’s revenue. Continuous supply of spare parts, services, and training is a prerequisite for fulfilling this requirement over extended periods. This is why it is important for you consider the reliability and stability of the equipment supplier.

For more than 80 years, Rohde & Schwarz has been a privately owned company group. Our first R&S FM transmitter went on air on February 28, 1949, and was the first FM transmitter in Germany. Since then, R&S has set standards in technology and quality, continuously developing leading edge transmitters for TV and audio broadcast.

Rohde & Schwarz is among the technology and market leaders in all of its business fields, including wireless communications, EMC, test and measurement, and radio signal monitoring and analysis. The high level of manufacturing depth within the company enables complete control over product quality and capacity. More than 3,000 highly trained experts in manufacturing ensure sufficient production capacities, addressing market needs in our various business fields.

Installation Prep

**By Ted Collora, Senior Vice President
Hanson Professional Services, Inc.**

RF consultants, facilities engineers, hardware manufacturers, and installers are about to get very, very busy. Proper planning for the repacking will save your TV station time and money, so it’s important to start gathering information as soon as possible.

New hardware should be at the top of your list, including antennas (main, aux, and/or interim), transmission line, RF filters, and combiners. Your plan should also address the need for an interim facility, identify any temporary equipment or structures required, approximate layout during and after the transition, check capacities of electrical and cooling utilities and identify any required upgrades, and schedule equipment removal with minimal disruption of service.

Remember, interim facilities may become permanent facilities, with old facilities either decommissioned or

used as backup. Identify any equipment that is obsolete or no longer needed and prepare a disposal plan.

Any required construction documents and local construction permits should be identified and sufficient time allocated for documentation development, submittals, and local permit approvals. Beyond permit fees, your estimated transition cost should include consulting fees, building modifications, antennas, transmission line, transmitters, RF filters and switching, combiners, monitoring, hardware installation, and any necessary tower work.

To more accurately estimate costs, your station will need to consider the available space for new and/or interim facilities, as well as your inventory of current hardware. You may need to make room by moving (or removing) existing equipment and/or obtaining an interim or permanent structure. Your inventory should also include information about which items are channel dependent and which can be used for any channel (or broadband).

RF Systems: Plan To Replace

**By Dan Fallon, Senior RF Engineer
Dielectric**

RF systems are installed between the transmitter output and the gas barrier that feeds the transmission line to the antenna. They vary in size and scope, but usually monitor output power, filter the transmitter output to assure mask compliance, combine the power of multiple transmitter cabinets, provide a load to perform transmitter proof and testing, and switch between main/aux transmitters or main/aux antennas. Typically, RF systems are purchased through the transmitter OEM.

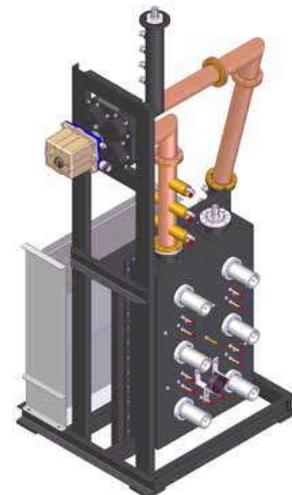


Figure 5: RF patch panel.

While there are some broadband or re-tunable components in an RF system, the practicalities of changing a channel in a single overnight period prohibits re-tuning most of them. Coaxial switches and patch

panels are the two broadband components that may be easy to change. If two different transmitters are used to accomplish a channel change, or two different transmission lines are used, either a switch or patch panel can accomplish the switch with minimal off-air time. Waveguide switches tend to be more band limited. WR1500 switches are the only ones that span the pre- and post-repack channel ranges – these should be swept with a network analyzer to determine suitability at the new channel.

Virtually all mask filters will have to be replaced, as about 90% of the mask filters deployed during the DTV transition are single channel. Even if you have filters that are band-tunable, you should plan to have a second filter tuned and ready to be swapped. The scheduling and cost of getting a qualified technician on site to re-tune a filter during an overnight channel change make having a second one available a more realistic option.

The size of a new mask filter has to be considered. Newer band-tunable mask filters are available for up to 60kW input power, and are generally much smaller than the older dual mode cylindrical waveguide filters.

If switching from an IOT to solid-state transmitter, the RF system can become much simpler. Combining IOT cabinets has traditionally been done using a “magic-tee” combiner, typically a waveguide component. It is large and needs to be wired to a controller to accomplish the switching. Combining solid-state cabinets is typically done with hybrids. Except for very high powers, these are broadband coaxial components that are much smaller than their waveguide counterparts.

Planning for ATSC 3.0 at the new transmission facility? Your new components must be ready to handle the high peak-to-average power ratio (PAPR) of ATSC 3.0 and the wider occupied bandwidth. This should not be an issue for new components, as manufacturers are designing to ATSC 3.0 requirements. However, older eight pole mask filters should be swept to determine if their bandwidth is wide enough for the ATSC 3.0 signal. If vertical polarization is planned either immediately or in the future, the additional power should be planned into the RF system.

Antenna Selection: Repack and Beyond

**By Dave Benco, Director of Television Sales
Electronics Research, Inc.**

Your station’s TV antenna is a passive device that accepts full power (TPO) from the transmitter, usually attenuated through filters and transmission line, and radiates/focuses the RF signal toward a targeted area or

population to a permitted level, or field strength. The focusing effect, or gain, of the antenna results in the station achieving its effective radiated power (ERP) as licensed by the FCC.

Selecting an antenna for your repacked facility is a complex decision that involves many disciplines of engineering and project management. This guide is meant to help engineers understand the different areas and trade-offs that are critical when selecting a television antenna to complete a spectrum repack project.

There are a variety of options available to produce the desired RF pattern and coverage. Choosing the one that is right for your station will require attention to the RF performance specifications such as beam tilt, null fill, elevation and azimuth patterns, and polarization.

Mechanical characteristics also need to be considered. Overall length, weight, shape, and wind load of the antenna will be important factors in your decision. Finally, changing your antenna will require you to perform a structural analysis of your tower to ensure that the proposed load can be supported within applicable building codes and with adequate safety factors. Once all these factors have been considered and the antenna is manufactured, tower installation can begin.

Slot Antennas

There are two basic types of television transmitting antennas for High Band VHF and UHF, the panel antenna and the coaxial slot antenna. Choosing one or the other is based on the unique characteristics of these antennas and their differing construction.

Today, the slot antenna is the most common antenna type in use for television broadcasting. Its design is based on a cylindrical conducting material with slots cut into it for the purpose of coupling the RF energy to the atmosphere. The location and number of these slots generally determine the antenna pattern and gain specifications. Slot antennas are specific to one (or sometimes two) RF channels, because the length of the antenna and the location of the slots are based on the operating frequency.

In general, lower channels have longer wavelengths and therefore require longer antennas. This is of particular concern when you are moving from a higher channel to a lower channel, because the new antenna will require additional length to maintain the same gain. If the additional length is not available due to antenna aperture restrictions or overall tower height constraints, the gain must be reduced on the lower channel.



Figure 6: Slot antenna.

Slot antennas can be produced to generate a pattern to a customer's specification. This pattern should be verified in an appropriate anechoic chamber to ensure compliance with the desired spec, as well as to verify the arrangement of any pattern shaping elements used to achieve the pattern. The antenna is completely enclosed in a radome to protect it from the elements, and the radome can be pressurized to further protect the radiating elements from the effects of atmospheric moisture. Pressurized slot antennas have been known to operate for decades without any sign of corrosion to the radiating elements or the mechanical structure of the antenna.

Compared to panel antennas, slot antennas offer several advantages. They are typically capable of a wider variety of custom patterns in both horizontal polarization as well as elliptical polarization. Slot antenna construction is relatively simple, with far fewer cables and connectors than a panel antenna, which results in a very dependable design with few potential points of failure. Plus, the slot antenna places less wind load on the tower structure than a panel antenna of similar performance.

Pattern Performance and Null Fill

When you choose a slot antenna, it is important to be aware of the differences in elevation pattern. As the elevation pattern becomes more "focused," or higher in gain, the nulls (low points) in the pattern become more pronounced. These nulls can mean that population near the tower may not receive sufficient signal to achieve reception.

Some center-fed slot designs – so called because they are fed at the center of the vertical length of the antenna – exhibit significant, deep nulls due to the physics of the antenna architecture. When deploying a center-fed slot antenna, you will often find options to reduce the gain of the antenna to achieve "null fill" and reduce the deep notches in the elevation pattern. This can result in increased transmitter power requirements and antenna

length to achieve the same gain performance as an end-fed design.

Many slot antennas use an end-fed architecture for smoother elevation patterns and naturally occurring heavy null fill, especially at higher gains. End-fed designs are also capable of greater electrical beam tilt without a reduction gain, which results in higher signal levels within the close in coverage area when combined with the increased null fill. In general, end-fed antennas provide a smoother elevation pattern and more consistent coverage, especially for higher gain applications.

Panel Antennas

Panel antennas consist of an array of paddle-type radiators enclosed in radomes and arranged in a specific pattern to achieve the desired pattern and gain performance. The main advantage of the panel array is that it is broadband. However, the pattern of the antenna changes with frequency, so the different channels will not have *exactly* the same patterns, especially for complex pattern and high gain designs.

Available for both top and side-mount applications, panel antennas are typically much higher in wind load

than slot antennas. They can provide a unique benefit in the event that multiple stations with the same (or very similar) patterns need to use the same aperture on the tower. Because panel antennas use a complex feed system to supply each panel in the array, and a separate system is required to feed V-pol radiating elements within each radome, the addition of V-pol greatly increases the complexity of the antenna.

Structural Concerns and Polarization

Full power TV antennas are large, heavy loads to place on your tower. The analysis of the tower structure is critical to ensure it can support not only the load of the antenna, but also any other rigging and fixtures required to complete the work to install the antenna. Slot antennas can be more than 50 feet long and weigh more than 5 tons, and are often put in place using a gin pole, which is a device used in construction of tall towers for stacking tower sections.

Wind is another concern in tower design and analysis. The structural design of the panel antenna is particularly

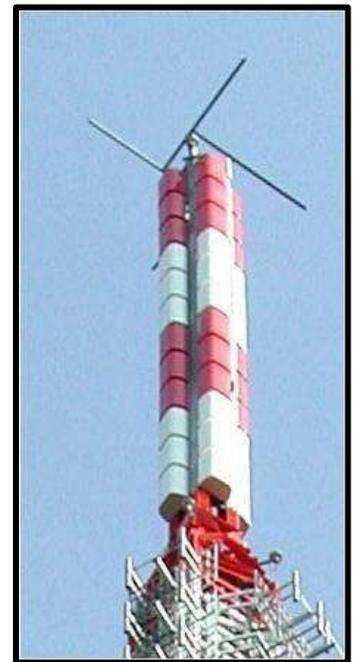


Figure 7: Panel antenna.

important because of the great wind load associated with it. The structure that holds the individual panels in the array needs to have sufficient strength to support the panels, withstand the wind (based on the location of the tower), and provide appropriate mounting points for attachment to the tower. Your local building code will specify the standard to which your tower needs to be evaluated (TIA 222 G is the current version of the tower construction standard).

ATSC 3.0 Antenna Decisions

By Cory Edwards, Sales Manager
Dielectric

If your station decides to move forward with ATSC 3.0, will you use a new or existing antenna? If you're staying with your existing antenna, you need to make sure it can handle the higher peak power expected from ATSC 3.0 modulation. This is not typically a problem, but be sure to verify it with the antenna manufacturer.

There are several more decisions if you're investing in a new antenna, starting with the addition of vertical polarization (V-pol). A station's ERP is based only on horizontal polarization. Adding a vertical component to the signal allows the broadcaster to get more power to the receive antenna. The increase in received signal strength (RSS) in a high fade environment has been measured at more than 5 dB for H/V ratios between 80/20 and 50/50.

The RSS increase is due to more than just stronger signal power. During propagation to the receive antenna, the signal will experience both reflection and diffraction around objects. This changes the relative polarization of the signal at the antenna, which causes fades in reception. Adding vertical polarization to the broadcast signal mitigates these fades, resulting in a significant improvement in reception for both indoor and small receive antennas. If your plan is to use the ATSC 3.0 option to broadcast to mobile receivers, adding V-pol to your broadcast signal should be considered a must.

V-pol can be added to either panel or coaxial slot antennas. If adding to a slot, a vertical dipole can be added external to the slot. If there are several slots, dipoles can be added to all of them to mimic the H-pol pattern or to a single row to make a more directional V-pol pattern. The amount of extra transmitter power required will depend on the ratio chosen (80/20 vs. 50/50) and whether or not the V-pol pattern is directional. In any case, adding V-pol to slot antenna is a decision that needs to be made at the time of purchase, because it can't be modified once the antenna is in place.

There are two choices if V-pol is added to a panel antenna – either a fixed H/V ratio for all channels on the panel or an “adaptive polarization” approach that allows each broadcaster to choose their own ratio. Typically, it

would begin with H-pol only and then add V-pol in the future.

Another set of ATSC 3.0 antenna options focuses on high bit rate delivery to indoor receivers (4K or high capacity download). An option called “future fill” allows you to install an antenna now for your standard pattern (for replication), then convert it on the tower to a high null fill pattern.

Coverage: Defending the Footprint

By Casey Joseph, Vice President of Sales and Business Development, LS Telcom

As the majority of the 600MHz band is prepared for use by the incoming wireless operators, hundreds of over-the-air (OTA) broadcasters currently occupying the UHF channels in the target spectrum are being repacked into the lower portion of the UHF band. Key to a successful transition of channels and sequencing of the repack are appropriate coverage prediction and planning.

For the broadcaster, the footprint of the network is the key to your customer base, so it's very important to maintain a similar footprint as you transition between channels (see Figure 8). Establishing your current footprint involves measuring existing equipment and the propagation modelling of the network as a baseline. When the new channel is established, the baseline coverage previously calculated can be compared to the new channel footprint to assure your customer base is maintained. Planning tools should be leveraged that can incorporate flexibility in multiple data points, including multiple propagation models and custom antenna patterns, with the target to create a pattern as close to the actual coverage representation as possible.



Figure 8: Field strength coverage.

In addition to propagation modelling, before and after antenna measurements can be taken at the transmission tower to further refine the coverage modelling and provide a post-installation validation of the transmission pattern. This additional input can provide further refinement and optimization of the installed system.

Interference Mitigation

A successful repacking has to be carefully prepared and organized, with particular attention to the frequency plan to avoid inter-service interference, as well as

interference to other services on a local, national, and international basis. This means coordinating your investigations and negotiations with bordering broadcasters is essential to ensure a smooth transition. The close adjacency between the broadcast band and the mobile service band in particular should be validated for out-of-band interference or overloading, which might appear and significantly impact the reception of terrestrial TV broadcasting.

Basically, the frequency of a radio signal has a strong impact to the physical behaviour of the electromagnetic signal. From the wave propagation point of view, the use of lower frequency generally results in larger coverage as well as better performance regarding diffraction, which results in less shadowing behind obstacles. Also, wall penetration performance is better in lower frequency ranges.

On the transmitter site, a frequency change requires retuning the transmitter and adjusting the filter and combiner according to the new frequency. You should also consider how the feeder cable loss and radiation patterns of the transmitting antenna (assuming the antenna is broadband) also change, which could contribute to changing coverage. The domestic receiving installation might also be impacted to the frequency change because of frequency dependency of the receiving antenna.

Planning for the ATSC 3.0 Future

To meet the new spectrum requirements, it's necessary to upgrade to more efficient transmission standards and encoders to guarantee the current number and quality of programs can still be accomplished by a lower number of transmission channels. More programs and/or better video resolution and frame rates might even be possible.

The next generation of terrestrial digital TV broadcasting, ATSC 3.0, offers numerous possibilities to increase the capacity per multiplex and consequently the number of programs per channel beyond what was offered in ATSC 1.0. The use of the highly robust, multi-carrier multiplexing (OFDM), efficient FEC (Forward Error Correction), and SFN (Single Frequency Networks) capabilities allow engineers to design spectrum-efficient networks and offer more programming flexibility.

Apart from the transmission standard, the source coding technique is also relevant. Today's most state-of-the-art compression standard is HEVC (High Efficient Video Coding), which performs twofold efficient compared to MPEG-4 and fourfold compared to MPEG-2. With better compression performance, more and higher quality programs can be accommodated in one multiplex.

To rise to all these challenges, a professional network planning tool is absolutely essential to coordinate the repacking, as well as plan your channel in the very best manner to satisfy coverage and capacity requirements.

Professional network planning saves time and money while preventing problems. Specifically, it ensures optimized CAPEX and OPEX, analyses multiple options to optimize implementation, minimizes self-interference for SFN implementation, and helps you avoid interference between ATSC 3.0 and other services. It also analyses national and international coordination requirements, as well as bi- or multilateral agreements.

ATSC 3.0: The New Standard

By Jerry Fritz, Executive Vice President for Strategic and Legal Affairs, ONE Media

Although the United States completed its conversion from analog broadcasting just nine years ago, its new ATSC digital standard was based on technology and business assumptions made in 1995. Since then, dramatic improvements have been made in everything from computing capacity to flat and mobile monitors. Television *transmissions*, however, have been stuck with a standard set more than 20 years ago – with no improvements.

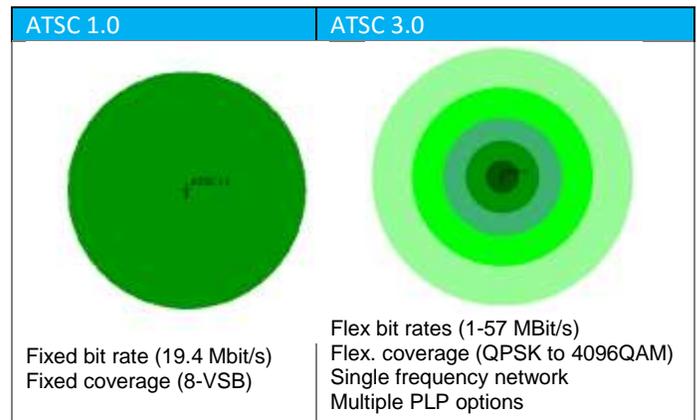


Figure 9: Physical layer differences.

The original ATSC standard is unable to transmit anything other than TV programs. It doesn't use Internet Protocol (IP), for example, so it can't integrate with other computer screens. It also doesn't work well indoors, can't support mobile or pedestrian use, and is severely constricted to a limited number of channels with less than ideal audio and video quality.

As content distributors take advantage of the latest technologies to reach viewers, television service continues to evolve. ATSC 3.0, a new version of the digital standard, is designed to integrate television distribution with computer devices using IP. While not backward compatible with the original ATSC, this next-generation TV standard is the bridge that connects broadcast protocol with the internet. Broadcasters will now be able to offer innovative services that can be provided and dynamically assigned in real time. New opportunities include:

- Access to unlimited viewing via mobile devices such as tablets and smartphones;
- Visually stunning pictures on large-screen televisions with superior, robust indoor reception;
- Geo-targeted and personalized programming, advertising, and subscription services;
- Multiple streams of synchronized content;
- Advanced emergency alerts with rich media maps and video transmitted in multiple languages; and
- Innovative datacasting, including non-television services such as automotive and IoT service capability.

The complete ATSC 3.0 standard is scheduled to be fully formalized in Q1 2017. It is really a compilation of 23 separate standards, all aggregated under the A/300 designation. As illustrated in the chart provided by the ATSC (Figure 10), all standards are either finalized or in the pipeline to be completed in 2017. The essential transmission piece – the so-called “bootstrap” signaling capability (A/321) – is pending before the FCC, awaiting approval via a rulemaking proceeding. With approval expected by Q3 2017, television licensees will have the option to upgrade their transmission facilities and take advantage of the new standard’s capabilities.



Figure 10: A progress chart of ATSC 3.0 standards.

Unlike the analog-to-digital transition, no new channels are being allocated by the FCC for a slow deployment. The industry will install this new technology in parallel with continued transmission of their existing digital standard in a voluntary, market-based approach. Some broadcasters in each market will deploy ATSC 3.0, while

others will continue to transmit using the current ATSC standard. This plan allows broadcasters in each market to share channels and simulcast their respective signals, so viewers can receive local programming in both the current and new DTV formats.

Transmission of both ATSC and ATSC 3.0 programming will be required for some time, because the new ATSC 3.0 standard is not backward compatible. As a result, TVs, tablets, phones, and other devices without a new 3.0 chipset will only receive original ATSC signals. However, ATSC 3.0 “gateway” devices in homes and cars will enable legacy devices through standard Wi-Fi connections, accelerating the acceptance of the new standard. Original ATSC transmissions will be phased out as the deployment progresses and new devices include 3.0 chips. With respect to receivers in the market, 4K TVs sold in South Korea already include the ATSC 3.0 tuner, while U.S. deployment will likely begin in 2018.

Cooperative sharing agreements between broadcasters will be developed, and deployment will occur simultaneously with the spectrum auction repack. Because many stations will be assigned to new channels and will require new transmission facilities, it makes sense to upgrade transmitters that are ATSC 3.0 capable during the repack. Plus, the ATSC 3.0 upgrade will enable stations that require replacement transmitters to tap into the \$1.75 billion reimbursement fund established by the government to facilitate the repack.

With enhanced television and non-TV data services enabled, business development will be limited only by entrepreneurial imagination. Broadcasters will be empowered to both grow their existing television businesses and explore new data delivery opportunities, such as automobile telematics, distance learning, building maintenance, e-book distribution, digital signage support, multi-channel pay bundles, and computer operating system upgrades. Plus, partnerships with big-data distributors offer potential benefits to broadcasters by leasing out “excess” channel capacity.

Special Thanks To:



Dielectric

ERI®



LS telcom

ONEMedia
OPEN NETWORK ENABLED

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 79 88

customersupport.la@rohde-schwarz.com

Asia Pacific

+65 65 13 04 88

customersupport.asia@rohde-schwarz.com

China

+86 800 810 82 28 | +86 400 650 58 96

customersupport.china@rohde-schwarz.com

Sustainable product design

Environmental compatibility and eco-footprint

Energy efficiency and low emissions

Longevity and optimized total cost of ownership

Certified Quality Management

ISO 9001

Certified Environmental Management

ISO 14001

This and the supplied programs may only be used subject to the conditions of use set forth in the download area of the Rohde & Schwarz website.

R&S® is a registered trademark of Rohde & Schwarz GmbH & Co. KG; Trade names are trademarks of the owners.

Rohde & Schwarz

The Rohde & Schwarz electronics group offers innovative solutions in the following business fields: test and measurement, broadcast and media, secure communications, cybersecurity, radiomonitoring and radiolocation. Founded more than 80 years ago, this independent company has an extensive sales and service network and is present in more than 70 countries.

The electronics group is among the world market leaders in its established business fields. The company is headquartered in Munich, Germany. It also has regional headquarters in Singapore and Columbia, Maryland, USA, to manage its operations in these regions.

Rohde & Schwarz USA, Inc.

6821 Benjamin Franklin Drive | Columbia, MD, 21046

Phone + 1 410 910-7800 | Email: info@rsa.rohde-schwarz.com

www.rohde-schwarz.com/tx9