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ROHDE&SCHWARZ

R&S®MR6000A: the first choice – and not just for the Airbus A400M transport aircraft

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The R&S®MR6000A airborne transceivers are already in operation in many military airborne platforms and will also be used in the A400M military transport aircraft in the future. As part of the A400M program, the transceivers successfully underwent the development processes described in RTCA/DO-178B (software) and RTCA/DO-254 (hardware) and meet the prerequisites for approval in line with civil avionics standards. During this work, it was also possible to further improve the technical parameters for the transceivers.

Civil standards – even for military transceivers

Above all, transceivers for military airborne platforms must provide reliable radio links that are protected against eavesdropping and / or jamming. Since airspace worldwide is used largely for civil purposes, military aircraft must also meet civil standards in order to fly in this airspace without restrictions.

This means that transceivers used in military applications must additionally meet civil standards, e.g. for communications with civil air traffic control (ATC). The civil requirements for airborne transceivers are oriented primarily toward ensuring the safety of the aircraft and of air traffic in general. Accordingly, every airborne transceiver is classified to find out how severely a possible malfunction would impact the aircraft's

Overview of the R&S®MR6000A transceiver

The R&S®MR6000A (FIG 1) is the best performing airborne transceiver in the R&S®M3AR product family. Its excellent characteristics make it suitable for applications in military and civil environments including all types of airborne platforms such as helicopters, transport aircraft, jets and unmanned aerial vehicles.

The R&S®MR6000A covers the frequency range from 30 MHz to 400 MHz and supports the NATO frequency hopping methods (TRANSEC) HAVE QUICK and SATURN. Integrated NATO encryption (COMSEC) is available as an option to protect voice and data transmissions against eavesdropping. The transceiver is interoperable with the NATO KY-58 and KY-100 encryption devices as well as the ED 4-2 and the R&S®MMC300 from Rohde&Schwarz. The proprietary Rohde&Schwarz R&S®SECOS waveform combines TRANSEC and COMSEC functionality in a single waveform and is also available for the R&S®MR6000A. R&S®SECOS can be installed on the transceiver in parallel with HAVE QUICK. Up to 200 presets can be stored in the radio with all of the information needed to operate a given waveform. The necessary radio circuits are then available for fast activation during the flight.

Accommodated in a housing that complies with the ARINC 600 standard, the R&S®MR6000A provides interfaces for connecting external devices such as an automatic direction finder (ADF), a Link 11 data terminal set (DTS), an improved data modem (IDM) or an external encryption device. If it is equipped with a cooling air intake, the transceiver can be operated continuously with full transmit power even at ambient temperatures of up to +71°.

FIG 1 The R&S®MR6000A transceiver from the R&S®M3AR product family.

FIG 2 The Airbus A400M transport aircraft.

safety. Severity definitions for safety assessment of cockpit equipment ranges from design assurance level A ("catastrophic"), which means that the aircraft's safety is directly affected, to level E ("no safety effect"). The most severe disruption that a transceiver can cause is the loss of communications with the air traffic controller. This case is classified as severity level C ("major"). See the blue box for more details.

Top functional safety – a continued challenge

The growing number of radio systems in today's advanced military airborne platforms increases the risk that the systems will mutually interfere with one another during simultaneous operation or experience a loss of sensitivity. This is why transceivers for military aircraft must function reliably even under extreme electromagnetic interference (EMI) and reception conditions.

Due to these growing military and above all civil challenges, Rohde&Schwarz has further optimized the R&S®MR6000A transceiver, especially by applying development processes in line with the civil avionics standards for software (RTCA/DO-178B, level C) and for hardware (RTCA/DO-254, design assurance level C). As part of these processes, the specific requirements for the software and hardware components are derived, starting from the equipment level, and then validated and verified. The validation involves a review of all requirements with respect to their reasonableness, completeness and consistency. The verification covers the requirements as well as the design, and encompasses reviews, technical analyses and in particular a number of explicit tests most of which are executed automatically. The tests must completely meet all requirements and cover the complete source code. All process steps are subject to permanent quality assurance in line with DO-178B/DO-254. This procedure minimizes the residual risk of malfunctions described in the specifications for level C failure classification.

Rohde&Schwarz presented the European Aviation Safety Agency (EASA) with the required verification that the specified development processes had been used in order to obtain civil approval of the R&S®MR6000A for the Airbus A400M transport aircraft (FIG 2).

Failure classification for equipment used in aircraft

The certification specification for large aeroplanes (CS-25) issued by the European Aviation Safety Agency (EASA) describes the potential consequences of failures in different categories on the aircraft, passengers and crew as well as their allowed probability of occurrence. This failure classification system is applied to each piece of equipment to be used in an aircraft in order to evaluate its risk potential. Based on the classification, the development process for an airborne transceiver is defined in line with the RTCA/DO-178B and RTCA/DO-254 standards.

The R&S®MR6000A has a failure classification of "major" and is subject to design assurance level C since even if there is a complete failure of radiocommunications with air traffic control, the aircraft can still land safely with the aid of the navigation system. This landing procedure must follow a specified series of steps and would entail significant additional burden on the crew in an emergency situation.

The Radio Technical Commission for Aeronautics (RTCA) is a non-profit organization with headquarters in Washington, D.C. (USA). It prepares recommendations for communications, navigation as well as monitoring of air traffic management.

High immunity to cosmic radiation

High-energy ionizing neutrons can cause disruptions in electronic components that lead to software errors, thereby potentially endangering the operation of a transceiver. Cosmic radiation increases with altitude and reaches its maximum at an altitude of approx. 18000 m (60 000 ft). The R&S®MR6000A is highly immune to such radiation, making it a good choice for safe, reliable operation in transport aircraft and jets. Only functional impairments that have a very low probability of occurrence are tolerated. Such impairments are normally measured in failures per flight hour. Based on the standards mentioned above, a value of $\leq 10^{-5}$ has been specified for the R&S®MR6000A.

Excellent RF parameters

The RF parameters of airborne transceivers must meet extremely demanding requirements to ensure reliable transmission and reception. Besides high sensitivity and selectivity, the receiver's large-signal immunity is also crucial. This applies especially under challenging conditions such as parallel radio operation on the same platform or in the vicinity of powerful broadcast transmitters. The interfering signals that occur in such a scenario should have a relatively low influence on the effective usable sensitivity.

Robust protection against strong external signals

At low altitudes, airborne transceivers are commonly exposed via their antennas to high field strengths produced by broadcast transmitters or radar equipment. The radios must not be damaged even in the presence of an interference level amounting to a few watts at the antenna. Moreover, they must still provide adequate sensitivity under the influence of interfering signals exhibiting a few hundred milliwatts of power at the receiver input. Of course, immunity to high frequency (HF) and VHF FM audio broadcasting is also very important.

The R&S®MR6000A transceiver has demonstrated its immunity to all of these interference types. FIG 3 shows the effective usable sensitivity of the transceiver under the influence of an HF interfering signal with a level of +25 dBm during reception in the VHF/UHF range from 118 MHz to 399.975 MHz. Thanks to the integrated highpass filter which suppresses HF interfering signals, a sensitivity of about 1 µV (–107 dBm) is achieved.

FIG 4 illustrates the effect of the FM immunity filter used in the R&S®MR6000A to suppress radiated signals from VHF FM audio broadcast transmitters. Even with an interference level of 2 W (+33 dBm), the 5 µV (–93 dBm) receiver sensitivity specified in the ICAO and EUROCAE standards is still met with a large margin. The sensitivity is an important factor that affects the audio quality and achievable range.

In practice, however, high sensitivity is available without limitations only if the radio exhibits both appropriate large-signal suppression capability and selectivity. In addition to the

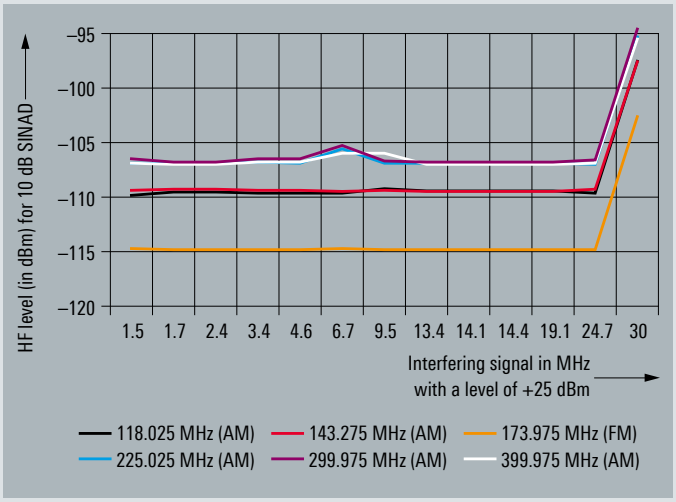

FIG 3 Even with an interference level of 25 dBm in the HF range (1.5 MHz to 24 MHz), the sensitivity of the R&S®MR6000A transceiver in the VHF / UHF frequency range is barely affected.

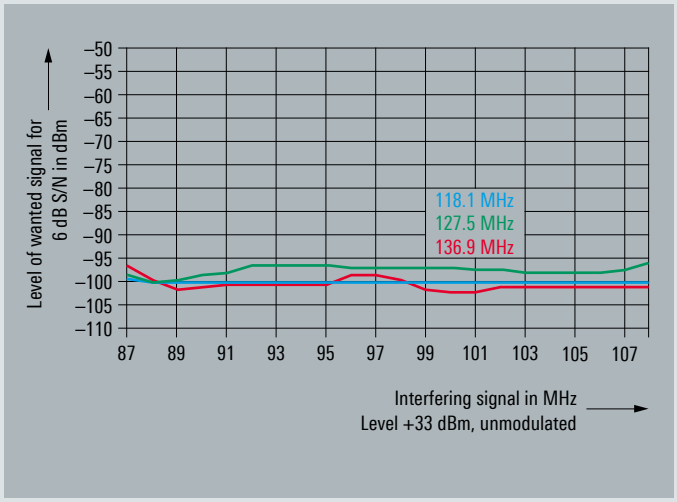

FIG 4 With its integrated FM immunity filter, the R&S®MR6000A ensures effective usable sensitivity in line with the EUROCAE ED-23C civil standard even in the presence of very strong VHF FM audio broadcast transmitter signals (2 W) and enables a range of approx. 370 km (approx. 200 NM).

above-mentioned integrated filters to protect against HF and VHF FM signals, the R&S®MR6000A also has built-in frequency-agile co-site filters that are capable of effectively suppressing interfering signals in the same frequency band.

High intermodulation suppression in the VHF band

If several interfering signals occur simultaneously, the receiver's dynamic range and linearity become very important. In case of insufficient linearity, undesired receiver phenomena will occur due to third order intermodulation products. If two or more interfering signals with an equidistant frequency spacing from the wanted receive channel are present at the receiver's antenna, an undesired receiving effect will occur which superimposes the interfering signals on the actual receiving channel. Such situations occur frequently in the VHF ATC band due to the heavy usage of channels, especially around civil airports.

Thanks to the careful design of the frontend receiver circuitry and the level plan, the R&S®MR6000A transceiver provides suppression of intermodulation products in the VHF band of about 85 dB (FIG 5).

Crossmodulation immunity against strong AM interfering signals

Crossmodulation occurs whenever a strong interfering signal with amplitude modulation (AM) overdrives the receiver's input amplifiers or first mixer. Problematic crosstalk effects of this type are largely independent of the strength of the wanted signal. Such effects also occur when the aircraft is close to the called ATC station. The R&S®MR6000A easily manages such challenges since it was developed based on the ARINC 716 US standard which specifies high crossmodulation immunity for VHF airborne transceivers. Accordingly, the transceiver tolerates interfering signals at a level of +10 dBm, for example, with an offset of 500 kHz from the receive frequency, exceeding the standard´s requirements by far (FIG 6).

Inherent spurious signals: every radio is tested

Inherent spurious signals occur due to the different digital clocks used in a transceiver and manifest themselves as a whistling sound in the audio output during reception of weak signals. Such inherent spurious signals can be reduced to just a few potential frequencies using shielding techniques, printed circuit designs that are optimized for EMC considerations and carefully selected clock frequencies. During production, Rohde&Schwarz tests each of its R&S®MR6000A radios at these critical frequencies to ensure that the radios delivered to customers do not have any blocked receive channel.

Suppression of undesired spurious reception

Spurious reception arises due to mixing effects in the receiver, causing undesired reception of signals at a different frequency than the one selected on the receiver. Using careful receiver design and optimum selection of the intermediate frequencies, Rohde&Schwarz has met its ambitious goal

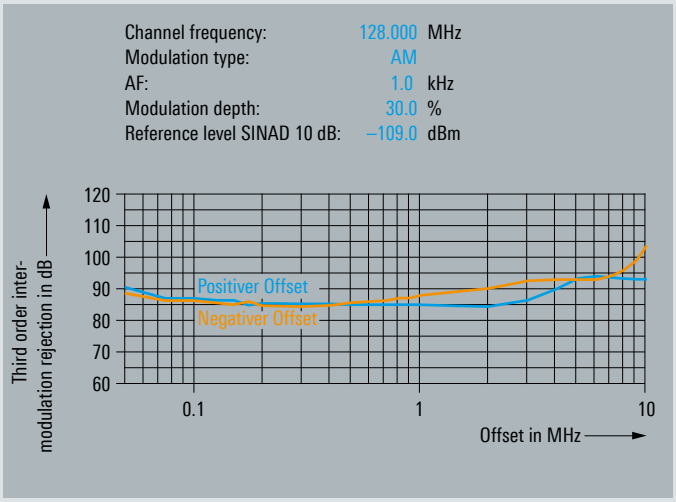

FIG 5 Third order intermodulation rejection at a receive frequency of 128 MHz.

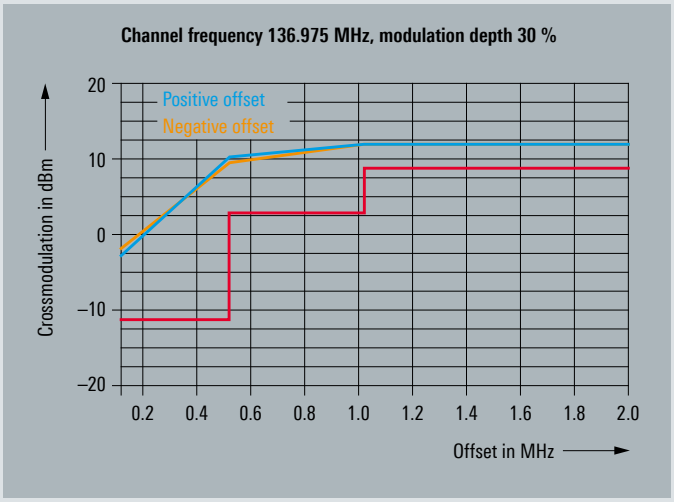

FIG 6 Crossmodulation immunity: The red curve shows the requirements from the VHF ARINC 716 standard while the two other curves represent the behavior of the R&S®MR6000A transceiver.

of 100 dB spurious response suppression with only a few discrete exceptions which are specified in the data sheet. As a consequence, the R&S®MR6000A transceiver provides excellent suppression of undesired spurious response reception even in the presence of strong interfering signals.

Low transmitter phase noise reduces co-site interference

If several transceivers are used simultaneously in an aircraft (co-site operation), there is a risk of mutual interference. For example, this is true especially on large airborne platforms used for air surveillance. More than 20 radio systems can be installed on such a platform. Phase noise produced by one transmitter can desensitize the receivers, making them less sensitive, which reduces the available range for voice and data modes. Accordingly, the phase noise and broadband noise behavior of transmitters far away from the carrier must be minimized.

In this area too, the R&S®MR6000A transceivers offer impressive performance since their integrated co-site filters – which are also effective during frequency hopping – considerably reduce the transmitter's broadband noise. This means that the noise power density at an offset of 10 MHz from the carrier is only about –174 dBc (1 Hz) (FIG 7).

High transmit power under real-world conditions

Antennas usually exhibit some degree of mismatch to the 50 Ω impedance used in aircraft installations. This depends on the antenna bandwidth, for example. As a result, the voltage standing wave ratio (VSWR) of aircraft antennas is typically in the range from 1.5 to 2.5, which means that the airborne transceiver's output stage is terminated by an unmatched load impedance. Depending on the phase angle (cable length), the transmitter's efficiency will be degraded, the current drain will increase and the output power will decrease.

The R&S®MR6000A has a specified transmit power of 20 W AM (carrier) and 30 W FM. The power output stage has a large margin and was designed to be highly insensitive to the load impedance. FIG 8 shows the results from a measurement in the VHF range. It can be seen that the radio outputs approx. 20 W RF power over the entire frequency range even with a VSWR of 3.

Summary

The R&S®MR6000A airborne transceiver in the ARINC 600 housing combines excellent RF parameters, compliance with civil specifications and top functional safety even under extreme environmental conditions in a single unit. The transceiver meets the most demanding requirements and is well suited for use in all kinds of military platforms. Moreover, the civil approval for this airborne transceiver allows corresponding certification of the aircraft by civil aviation authorities. The R&S®MR6000A is already in use in helicopters (e.g. CH-53) and jets (e.g. Tornado) and will also be installed in the Airbus A400M transport aircraft in the future.

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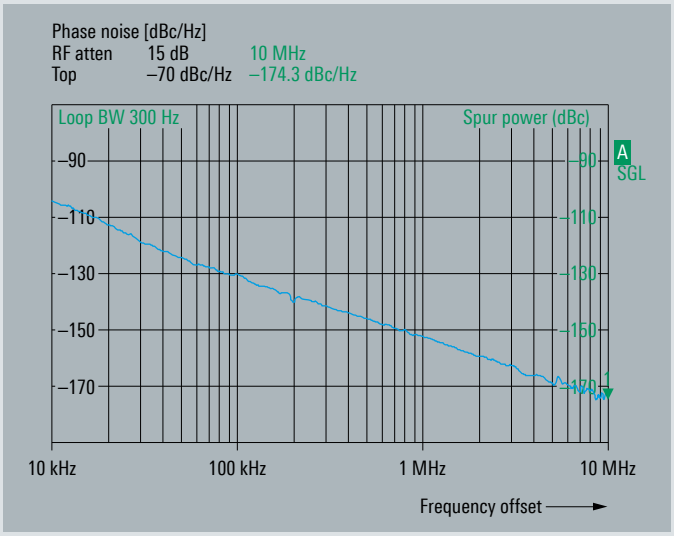

FIG 7 Transmitter phase noise during operation at 284 MHz: A value of –130 dBc (1 Hz) is obtained at a 100 kHz offset and –174 dBc (1 Hz) at a 10 MHz offset.

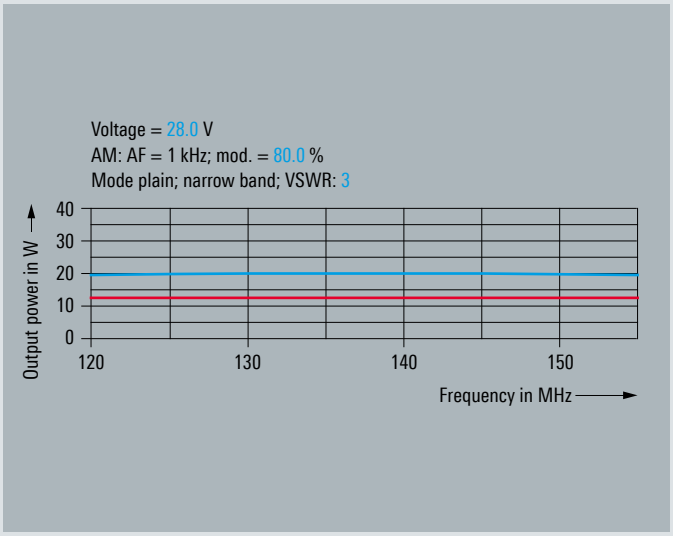

FIG 8 Even at a VSWR of 3, the R&S®MR6000A's transmit power remains at approx. 20 W (blue line) which is well over the specified limit (red).

The R&S®M3AR airborne radio family.

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