Handheld Spectrum Analyzer R&S®FSH 3

Put to the test on board the International Space Station ISS

The R&S®FSH 3 (FIG 1) from Rohde & Schwarz is a high-end spectrum analyzer in handheld design that features low weight, minimum power consumption and outstanding RF performance [*]. It is currently being used on board the International Space Station (ISS) for distance-to-fault (DTF) measurements.

FIG 1 The R&S®FSH 3 with VSWR bridge for vector reflection measurements.

Time signal system in the test phase

The global transmission services (GTS) system is a new system for the worldwide transmission of time signals to receivers on the ground, such as watches or clocks in vehicles. It is currently being tested as part of a pilot experiment on board the ISS (FIG 2). This is the first commercial experiment aboard the space station. Once the test phase has been completed, the GTS system is to be transferred to an operator company. Owing to a recently developed cryptographic modulation, further services such as vehicle theft protection or the tracking of specific items (e.g. containers or stolen goods) can also be implemented.

The GTS system consists of an active phased array antenna outside the ISS and an electronics unit inside the Russian service module, the space capsule, where the experiments are conducted. The electronics unit contains a highly stable crystal oscillator, transmitters for the UHF and L band and a controller which generates the transmission signals via software in realtime. This unit is directly controlled and measured from a special ground station in Stuttgart; otherwise, the controller functions autonomously. It also ensures correct antenna control which compensates the significant differences in free-space attenuation between the nadir and horizon direction by means of a specially designed directional pattern.

The antenna was installed in Moscow in December 1998 before the service module was launched. In summer 2000, the electronics unit was delivered by means of a Progress space transporter and installed by the crew (FIG 3).

Needed – a featherweight high-tech analyzer

However, when the electronics unit was initially put into operation in February 2002, it exhibited deviations from the precalculated receive field strength on the ground. Nevertheless, the telemetry performed both on board the ISS and via the ground station exhibited nominal values. One of the possible reasons for this deviation may have been two RF wiring harnesses that had already been installed prior to the launch and that had been in space for two years. The harnesses with a total length of 29 m are routed via special vacuum-tight coaxial ducts from the interior of the service module to the outside. Thus, they are partially outside the space station in the orbit vacuum, which makes them rather difficult to check.

When an onboard multimeter was used, only short circuits or cable breaks were able to be eliminated as possible causes of deviation. To measure the RF characteristics, it was thus crucial to procure a lightweight mobile device that offered battery operation and could be remote-controlled via a laptop – in other words, an instrument such as the Handheld Spectrum Analyzer R&S®FSH 3. Since laptops are part of the basic equipment on board the space station, "all" that needed to be done was to transport the 2 kg analyzer to the space station: With each kilogram costing US$ 20 000, every gram counts!

Photo: NASA

FIG 3
Cosmonaut Deschurow installs the electronics unit for the GTS system.

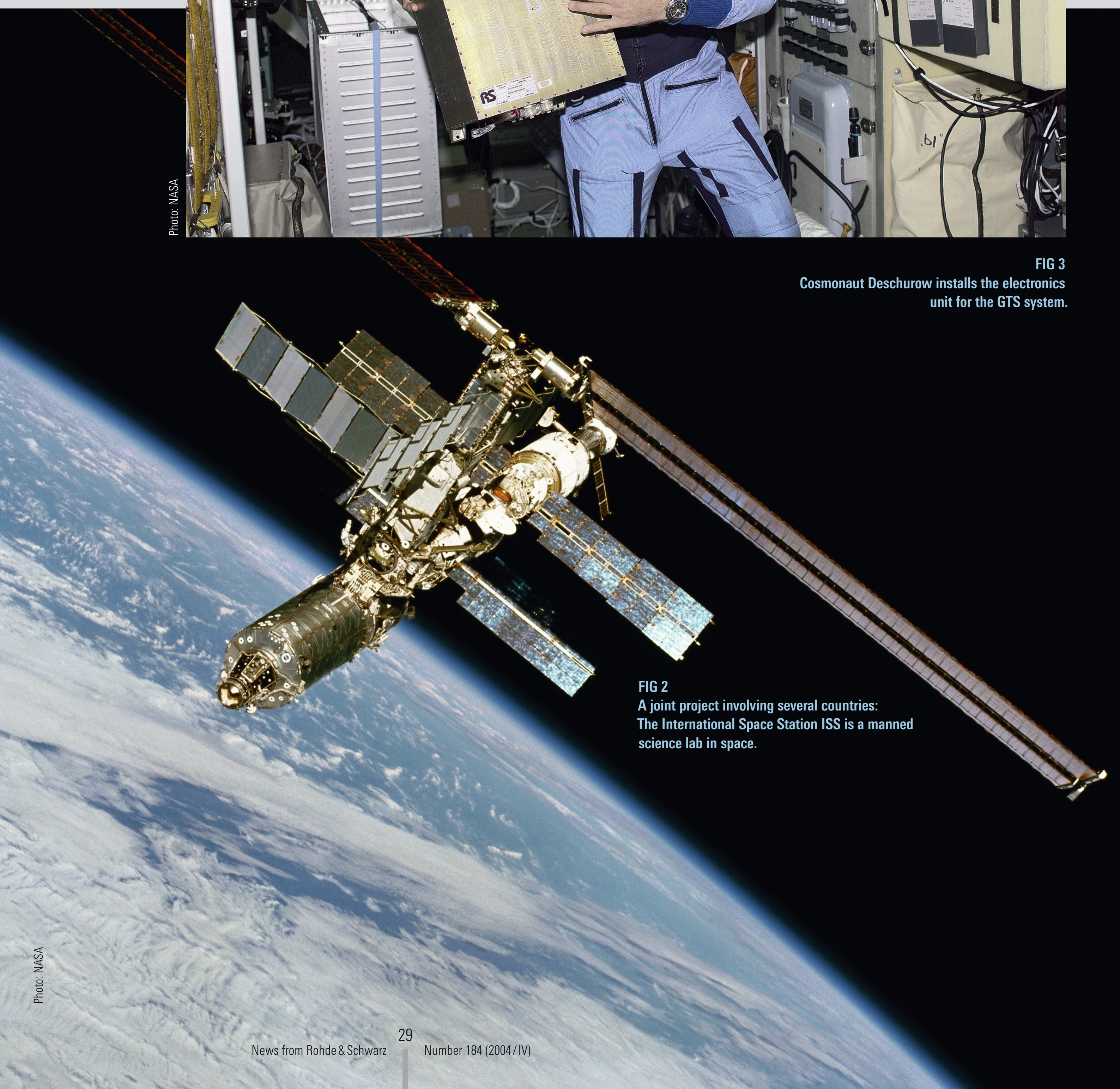

FIG 2
A joint project involving several countries: The International Space Station ISS is a manned science lab in space.

Photo: NASA

Moreover, a number of questions had to be clarified: Would the R&S®FSH 3 withstand the extreme stress it is subjected to when being transported into orbit? Would its electronics work even under the increased radiation exposure at an altitude of 400 km? Would the spectrum analyzer meet the ISS security requirements so that it would neither endanger the crew nor interfere with onboard electronics? The most important and pressing question, however, was: Would the R&S®FSH 3 be able to accurately measure the cables which are almost 30 m in length and outfitted with various connectors, or is the cable loss too high?

To answer these questions, the entire setup was simulated in Moscow with the aid of the phantom flight antenna model and the ground simulator of the service module. The R&S®FSH 3 was set to distance-to-fault measurement mode, and the cables were tested. The measurement was a complete success: Despite the considerable cable lengths, the spectrum analyzer was able to display even the delay differences between the phase shifter elements in the active antenna and thus passed this first test for such an unusually sophisticated application with flying colors.

Off to the "gym"

Next, the R&S®FSH 3 had to be prepared for launch and for operation on the space station. As is usual with commercial off-the-shelf (COTS) products, the safety experts completely dismantled the instrument and subjected it to a thorough inspection. In particular, materials containing PVC and electrolytic capacitors might endanger the astronauts and must therefore be replaced. However, since there was no viable alternative for the capacitors in the switching power supply, they were encapsulated in Teflon sleeves together with absorbent material. The rechargeable batteries were removed and replaced by a special power supply for matching the ISS power supply. Finally, the interior facings of the housing were completely covered with self-adhesive aluminum foil to meet fire protection requirements. Thus modified, the R&S®FSH 3 once again immediately functioned without any problems even though the firmware had not been designed for operation without rechargeable batteries (FIG 4).

Thoroughly tested

The next challenge the R&S®FSH 3 had to face were mechanical vibration tests. Again, the analyzer excelled because the quality standards at Rohde & Schwarz are so demanding that no further mechanical tests were necessary. When EMC and radiated emission were tested, the values measured were minimal and not significant enough to jeopardize the electronics on board the ISS. Thus, no further shielding was necessary.

Finally, thermal and vacuum tests had to be performed because such exceptional stress does not occur when the R&S®FSH 3 is used on earth. The spectrum analyzer was subjected to a temperature range of –50 °C to +50 °C in a climatic chamber, simulating the extreme conditions that can occur during launch from Russia's Baikonur space center. Since a pressure loss might also occur in the Progress transport capsule, the instrument had to pass the corresponding tests. The R&S®FSH 3 easily withstood vacuums up to 400 mbar in a tank.

To ensure that the instrument would not emit any toxic substances, it was wrapped in polyethylene foam rubber and subjected to an outgassing test in a high-temperature-resistant bag for 72 hours. The spectrum analyzer excelled once again and was finally granted launch permission. In December 2003, it was handed over to the Russian partner company RSC Energia, which transported it together with the Progress capsule to the ISS in February 2004.

In the meantime, the procedure for installing the R&S®FSH View software and for performing the measurements had been transmitted to the ISS crew. The big day finally came on 18 March: The R&S®FSH 3 was installed and was ready to perform its first measurements (FIG 5).

A shooting star

As expected, the R&S®FSH 3 functioned smoothly despite the increase in radiation exposure. The measured data was transferred from the spectrum analyzer to the ISS telemetry system via laptop and transmitted to the ground station for evaluation on 22 March 2004. The distance-to-fault measurement revealed everything: The discontinuities of the cable connections were clearly visible, as were two other spikes in the diagram that could not be replicated during the ground simulation (FIG 6). These interferences seem to be at least part of the reason for the reduced signal quality and are currently being analyzed in detail. Until final clarification, the R&S®FSH 3 will remain on board the ISS. Then it will be sent back on a Progress transporter only to burn up as a shooting star when reentering the earth's atmosphere.

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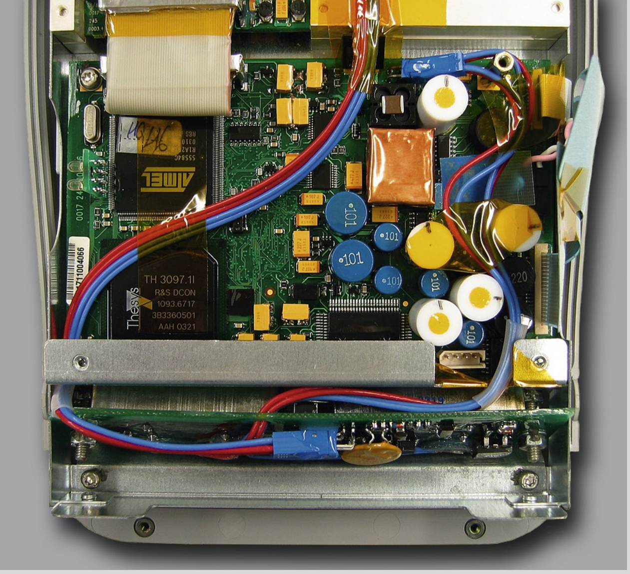


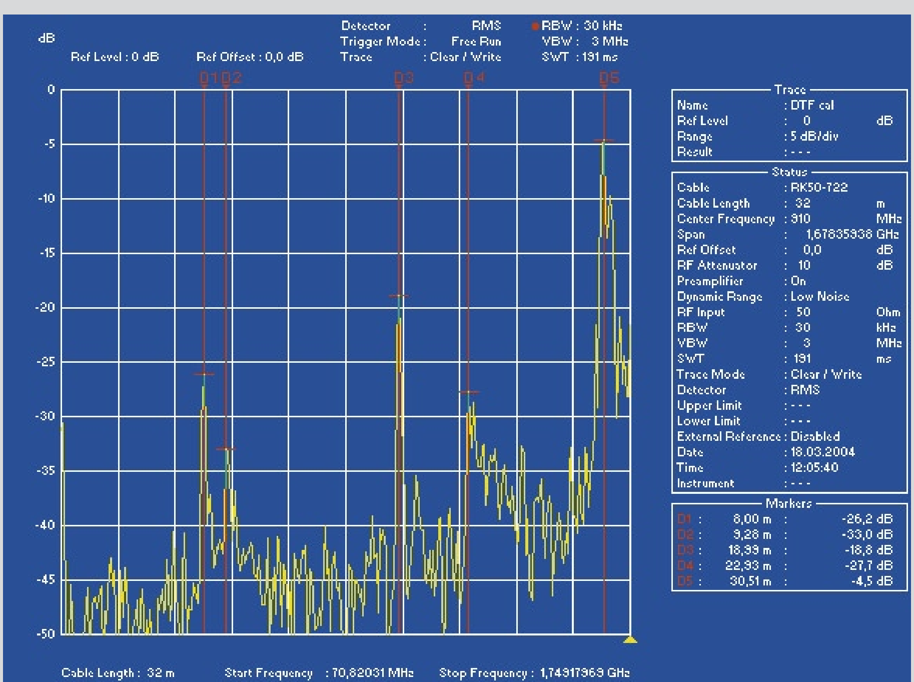
Photo: TZ Raumfahrt

FIG 4 Ready for a trip to space: the R&S®FSH3 after modification. Especially materials containing PVC and electrolytic capacitors could endanger the astronauts and thus had to be replaced.

FIG 5
After strenuous tests and a long journey, the R&S®FSH3 finally reached the ISS, where measurements then began.

Photo: RSCE

FIG 6
Results of the DTF measurement: cable discontinuity (marker D1); unwanted faults (marker D2 and D4); duct from space station to the antenna outside (marker D3); antenna (marker D5).



More information and data sheet at
www.rohde-schwarz.com
(search term: FSH3)

REFERENCES

[*] Handheld Spectrum Analyzer R&S®FSH3: Numerous expansions and a new model. News from Rohde & Schwarz (2004) No. 181, pp 32–35