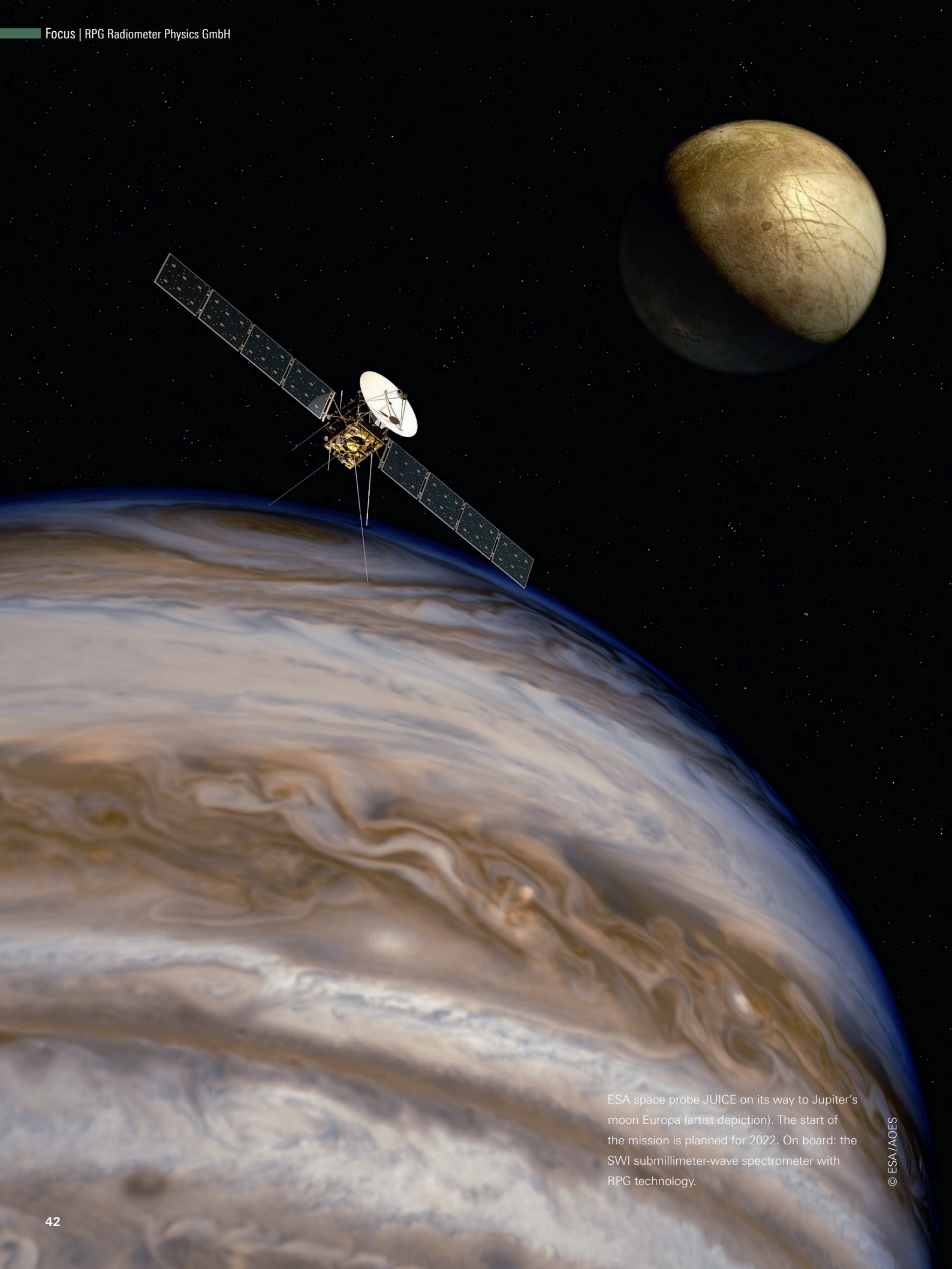


ESA space probe JUICE on its way to Jupiter's moon Europa (artist depiction). The start of the mission is planned for 2022. On board: the SWI submillimeter-wave spectrometer with RPG technology.

High up, far away

The research objects typically associated with products from Rohde & Schwarz subsidiary RPG Radiometer Physics can be found by looking up into the sky; however, a telescope is often required.

Committed to R&D

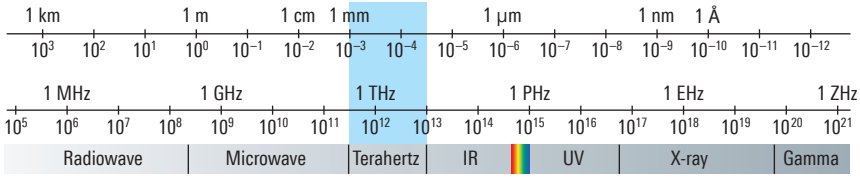
The roots of the company residing in a new building in Meckenheim near Bonn are, one might say, extraterrestrial. The fact that the company is located in Bonn is no coincidence. It logically follows from the proximity to the Max Planck Institute for Radio Astronomy, where RPG founder Dr. Peter Zimmermann worked for over 20 years. Working on the Microwave Limb Sounder Project at NASA's Jet Propulsion Laboratory in subsequent years brought him in close contact with technology for researching the earth's atmosphere using submillimeter waves, and laid the foundation for starting his own company in 1991. In the early years, the company concentrated on developing mixers and local oscillators up to 1 THz and integrating them into receiver systems. The soon-to-come transition to building entire radiometers (see box) was obvious and consistent with RPG's technological focus. The company and its product line grew with the increasing market demand for further applications in the exotic and difficult-to-master frequency range, to which RPG had dedicated itself. Meteorological measuring instruments are still a mainstay of the company's portfolio today. In addition to passive solutions (radiometers and scintillometers), RPG now also offers active weather scanners such as cloud radar systems. A second business field has carried on the company founder's passion for space exploration since he passed the baton to his successor in 2002. RPG subsystems were and are installed on important satellites and probes operated by ESA, NASA and other national space agencies. R&D efforts for key upcoming projects such as ESA's (large photo) Jupiter Icy Moons Explorer (JUICE) mission are well underway. The company's third pillar brings the focus back to earth – and to Rohde & Schwarz. Those who have committed themselves to mastering the entire radio spectrum must think beyond 100 GHz. They have to rise to the Terahertz challenge. Considering the physical and technical pitfalls that this frequency range represents for developers, however, it made sense to cooperate with a company that feels at home with the subject matter. Initial joint test and measurement projects extended the frequency range of Rohde & Schwarz network analyzers and signal generators into the triple-digit Gigahertz range. To secure the know-how of the RPG experts for the future, Rohde & Schwarz started purchasing company shares in 2006 and ultimately became its majority holder in 2010. The two companies have cooperated intensively on test and measurement projects ever since.

There are various reasons why the Terahertz range will never have the wide-base market significance of microwave technology. It does, however, cover exclusive R&D niches and offer concepts for applications in medicine, materials science, industrial sensor technology, security and communications technology that make a thorough exploration of this range appear an attractive option.

What is a radiometer?

Radiometers are instruments for measuring the radiance of electromagnetic waves. At the core of RPG instruments are ultrasensitive receiver modules that measure sky radiation in the microwave range (~3 GHz to 660 GHz). The power of the radiation emitted in this range must be amplified significantly (60 dB) before it can be detected in separate receive channels. These channels are positioned so that the absorption spectrum of the air components water and oxygen is captured. This information enables researchers to derive temperature and moisture distribution data along the measurement path.

The electromagnetic spectrum



The Terahertz (or submillimeter-wave) range between the microwave and infrared regions of the spectrum marks the transition from electronics to optics.

Weather reconnaissance from the ground

Microwave remote sensing instruments is a key business field for RPG. The company focuses on developing ground-based measuring instruments for remote atmospheric sensing. In contrast to balloon-based measurements, remote sensing means measurements are not taken on site. Instead, researchers analyze radiation emitted by items under test, in this case, the atmosphere. This could be naturally occurring thermal emission from air molecules, for example. Radiometers are based on this passive principle of measurement. Alternatively, active radar can also be used to measure the radiation reflected by rain and clouds. Both product groups work in the high microwave range, as the atmosphere is partially transparent in this range. This means the entire atmospheric column can generally be observed, even in cloudy or rainy conditions. The microwave radiometer is the most widely used instrument for this purpose. It can determine vertical temperature and humidity distribution from the ground up to an altitude of 10 km. This atmospheric layer, the troposphere, is where weather is made. Vertical temperature and humidity profiles are of great importance to weather prediction. Weather services around the world use weather balloons to collect this data. However, the cost of sending up such balloons is so high that usually only two can be launched each day. This is where radiometers can help. They provide temperature and humidity profiles once a minute, enabling meteorologists to reliably capture atmospheric changes, especially in the layers close to the ground. The data collected can be used as input parameters for weather forecasting models. Radiometers are increasingly being combined into networks for this purpose. The objective is to do away with weather balloons for numerical weather prediction and improve forecasting quality.

A great deal of uncertainty in weather forecasting, however, comes from poor registration of clouds and precipitation. This is the point where passive radiometry reaches its limits and the reason why RPG developed a cloud radar system that measures cloud distribution with high accuracy. Besides applications for numerical weather prediction, the instrument also provides valuable findings for cloud research. Only by understanding the processes taking place inside clouds is it possible to predict how they will form and develop.

RPG's portfolio in the remote sensing sector covers more than the earth's atmosphere. Microwave radiometers can also be used for observations of the solid earth, e. g. for soil moisture measurements. Another instrument that comes into play here is the scintillometer. It measures the heat flux between the ground and atmosphere. A portion of this heat flux is directly linked to the transfer of moisture between the ground and atmosphere. This makes these measurements useful, especially for water management experts. Such data is helpful for tasks such as optimizing irrigation strategies, assessing forest fire hazards and monitoring water reservoirs.

Beyond the atmosphere

The RPG space activities division is responsible for exploration from the sky. For years, this division has developed microwave and millimeter-wave front-ends and components for ultrasensitive T&M equipment on satellites and space probes. Once more, the focus lies on atmospheric research instruments, be they for earth or other planets and moons. The above-mentioned JUICE mission is an example of an extraterrestrial program. It is the first large-class mission in ESA's Cosmic Vision 2015 – 2025 planning period. The probe is expected to reach Jupiter in 2030 and will use the most powerful analysis tools ever sent to the outer solar system to dissect the planet and three of its four large (Galilean) moons over the course of many years. The SWI submillimeter-wave spectrometer will be one of the ten instruments employed on this mission. Its task will be to record the atmospheric temperature profile of Jupiter, determine the composition and dynamics of the planet's stratosphere and troposphere and analyze the exospheres and surfaces of its icy moons. The SWI uses a 30 cm antenna for this purpose and operates in the frequency ranges between 1080 GHz and 1275 GHz as well as 530 GHz and 601 GHz. RPG has completed preliminary studies for the instrument and is currently developing RF component prototypes.

The meteorological operational satellite (MetOp) program is an important satellite project with RPG involvement. ESA is implementing this programm on behalf of the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). The MetOp satellites are the first European weather satellites in polar orbit. They fly at low altitude (800 km) to deliver high-resolution measurement data on air and water temperature, humidity, wind speed and ozone concentration. This information enhances data provided by the very high flying European Meteosat satellites in geostationary orbit. The program includes multiple phases extending out to 2030. The first satellites are already in orbit (MetOp-A and -B), and MetOp-C is expected to follow in 2017. RPG is already working on the second generation of these satellites (MetOp-SG), which will carry instruments that are significantly more powerful. Three instruments will be distributed between two satellites and are expected to provide a significantly more broadband examination of the microwave and millimeter-wave ranges in particular (18 GHz to 229 GHz and 183 GHz to 664 GHz). The MetOp-SG orbiters will operate in pairs, flying the same orbit in short succession with different equipment on each. RPG has carried out preliminary studies for all three instruments (microwave sounder, microwave imager and ice cloud imager) and is now developing and manufacturing key components such as downconverters, mixers,

frequency multipliers and complete frontends. The company is currently beginning to produce prototypes of the instrument qualification models.

On this project and others, ESA, as a European organization, attaches great importance to key components coming from Europe and being developed

The RPG remote sensing product line:
Radiometers in the French-Italian Dome Concordia Antarctic station (center left), in the climate observation station of the Italian energy and environmental agency ENEA on Lampedusa (bottom left), at the European Southern Observatory in Chile's Atacama Desert (top right); cloud radar (center right) and scintillometer.

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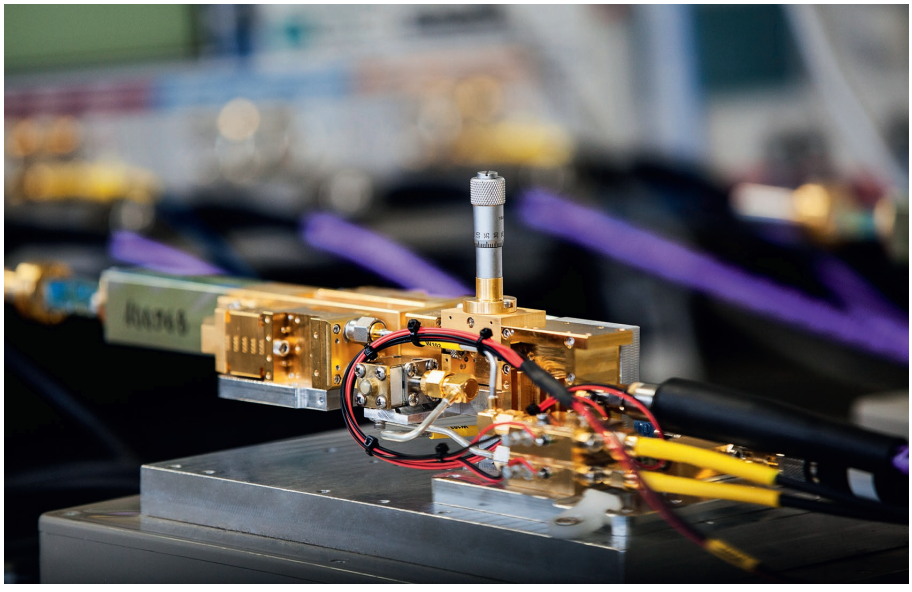


with European expertise. Until recently, this would have been possible only to a limited extent in the field of millimeter-wave technology. European companies lacked the ability to produce the semiconductor devices needed to generate millimeter waves of sufficient power. However, initiatives such as the EU-sponsored Millimetre-wave Integrated Diode and Amplifier Sources (MIDAS) project and a similar ESA program have meanwhile borne fruit. Several European semiconductor manufacturers now have the capability to produce the required circuits based on GaAs Schottky technology. The main advantage of the European solution is the close interlinking of system developers and technology experts, which has now become possible (US manufacturers were not able to enter into such close partnerships for technology policy reasons). This provides RPG with deep insight into the process data of its partners. The company can use this information to draft its own highly precise circuit layouts.

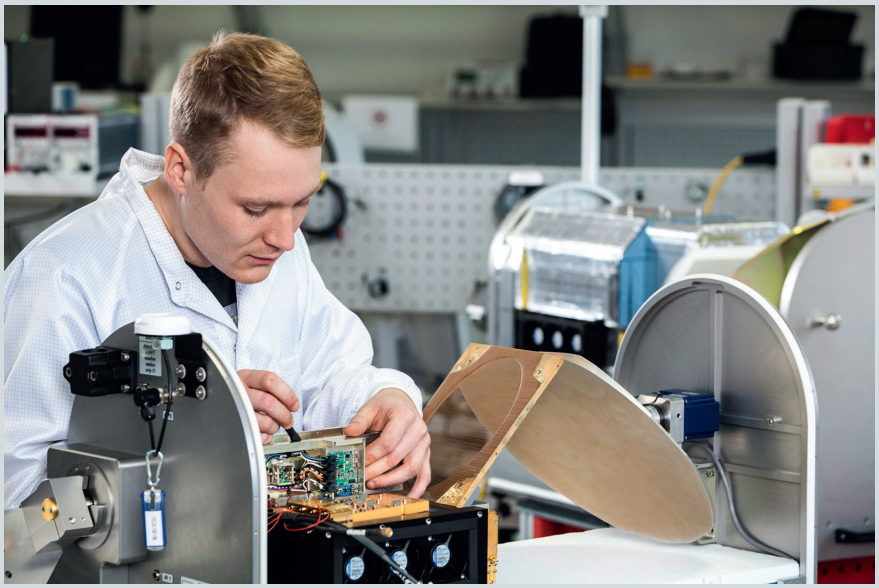
Top: The MetOp-SG weather satellites are expected to replace the current MetOp-A/B/C generation starting in 2020 (photo: ESA). Center and bottom: The new R&S®ZCx frequency converters developed and produced by RPG enable users to conduct network analysis in the millimeter-wave range with unprecedented operating convenience.

Back to earth

The advances in millimeter-wave semiconductor technology also have a productive impact on the third pillar of RPG's portfolio. This focuses on the development and manufacturing of millimeter-wave components in general as are required for a diverse range of tasks in research and industry. These components typically include mixers, frequency multipliers, antennas and connection elements but also amplifiers and entire spectrometers and, last but not least, T&M equipment accessories produced by RPG for Rohde&Schwarz. The most recent product in the last category is a new generation of network analysis frequency converters that deliver 10 dB to 15 dB higher output power than previous models (power being the critical issue in this frequency range, as mentioned above) and offer new possibilities for characterizing active components.

RPG manufactures all its products at its own facilities, as this is the only way to ensure the desired level of quality. The use of RPG instruments at renowned scientific institutions is proof that this quality is well known and valued throughout the demanding research community (as shown by the small selection of photographs on page 45).

Volker Bach



One of the prime addresses for millimeter and submillimeter-wave technology in Europe: RPG Radiometer Physics GmbH, Meckenheim near Bonn, Werner-von-Siemens-Strasse 4, http://www.radiometer-physics.de.