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RESEARCH NEWS

Microwave amplifiers improve weather prediction

Highly-sensitive tracking nose in space

In the coming years, the European Space Agency (ESA) will be launching a series of new weather satellites that will be able to measure important meteorological data, such as precipitation, water vapor or temperature, better than ever before. The heart of these measuring devices consists of extremely sensitive microwave amplifiers that were developed at the Fraunhofer Institute for Applied Solid State Physics IAF. These can perceive even very weak signals from the environment, which are important for more accurate weather predictions.

Among meteorologists, there is the joke that the weather of tomorrow can be predicted most safely when assuming that it will be the same as today. The common belief is that this would be true in many cases. Of course, meteorologists today no longer rely on this not-so-serious rule of thumb. For weather predictions, they rather rely on computer simulations which are fed with thousands of pieces of measurement data. For some decades, such data have mainly been supplied by satellites that use sensitive sensors to measure the temperature or the precipitation on earth. The better these sensors are, the more accurate the measured values and, therefore, also the weather predictions. In the next years, the European Space Agency (ESA) will, therefore, be launching the second generation of its MetOp weather satellites (Meteorological Operational Satellites), six in all, which are equipped with state-of-the-art measurement technology. A total of EUR 1.4 billion has been earmarked for the construction of the second-generation MetOp satellites – launch and operation not included.

Measurements in the upper atmosphere

With the satellites, small but very fine technological components from the Fraunhofer Institute for Applied Solid State Physics IAF in Freiburg – highly precise amplifiers that measure microwave radiation – will also be launched. This radiation is emitted from every single object, every surface – similar to how a body radiates heat, which can be seen in the infrared image. The amplifiers are calibrated to microwave frequencies because these provide important meteorological information: they capture microwaves emitted by water vapor, rain, fog or ice crystals – particularly also from the ice crystals in the cirrus clouds high up in the atmosphere, which are believed to have an important effect on the climate and weather. Thanks to the microwave radiation, it is also possible to reach very precise conclusions about the temperature on the ground.

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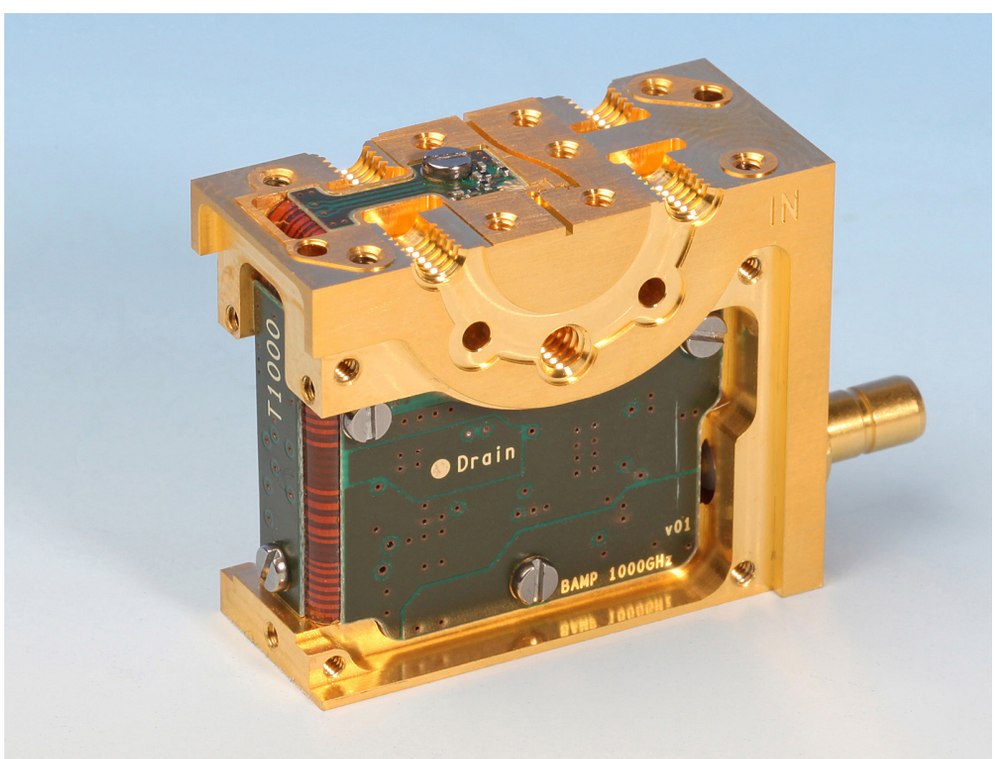
The signals received by the microwave antennas of the satellites are extremely weak, though. They are only a few nanowatts strong. In order to be able to detect these microwave signals with any degree of reliability, amplifiers are needed. The amplifiers from the Fraunhofer IAF have proven to be ideal. "The core of these amplifiers is a transistor from the semiconductor material indium gallium arsenide," says Dr. Michael Schlechtweg, who heads the High Frequency Electronic business unit at the Fraunhofer IAF. "A characteristic of this material is that it is very easily traversed by electrons, even if the electric field that drives the electrons is very small." Accordingly, the electrons in the transistor are already set in motion by very weak microwave signals, which makes the transistor extremely sensitive. "Thanks to the microwave circuits developed by the Fraunhofer IAF, the MetOp satellite will be able to determine temperature, water vapor and type of precipitation even more precisely in the future. This increases the reliability of the weather forecast," explains ESA Project Manager Ville Kangas. However, transistors made of the conventional semiconductor material silicon would be far too insensitive.

Making the smallest electrodes with high accuracy

It is not the indium gallium arsenide alone which makes the amplifiers so sensitive. Their small size also contributes to this. The electrodes of the transistors are just 50 to 35 nanometers (millionths of a millimeter) long. Only then are tiny electron currents or signals measurable. "This extreme sensitivity and small size are the result of 25 years of research," Michael Schlechtweg explains. "During this time, we have developed a highly accurate manufacturing process in which the amplifier circuits are built in 150 production steps. We form the electrodes with an electron beam. Only a very few companies worldwide are able to do this with such a degree of precision."

On the MetOp satellite, the amplifiers are used in three different microwave instruments which measure different things – precipitation, water vapor, ice crystals or the temperature. For this purpose, the experts working with Schlechtweg had to produce different sensors, each of which is calibrated to the corresponding microwave frequency – in concrete terms, there are five frequency bands between 54 and 243 gigahertz. As Schlechtweg explains, a value of 243 gigahertz is a considerable value, since, the higher the frequency, the more powerful the amplifier has to be. The components of the Fraunhofer IAF are this powerful. And they have impressed not only the ESA. A US company has recently inquired about them. It is therefore also possible that the microwave amplifiers from the IAF will be launched on board US satellites.



Amplifier module: The low-noise, high-sensitivity microwave amplifiers of the Fraunhofer IAF can already detect signals of only a few nanowatts. They are based on the semiconductor material indium gallium arsenide. © Fraunhofer IAF | Picture in color and printing quality: www.fraunhofer.de/en/press