Low-noise amplifiers aboard the Arctic Weather Satellite

September 17 2024

Artificial impression of the Arctic Weather Satellite in its orbit at an altitude of approx. 600 km. Credit: ESA/Mlabspace

The Arctic Weather Satellite (AWS) of the European Space Agency (ESA) was sent on its journey to a polar orbit 600 km above the Earth on August 16, 2024. On board: four low-noise amplifiers (LNAs) from the Fraunhofer Institute for Applied Solid State Physics IAF in Freiburg. They are essential components of the passive microwave radiometer with

which the AWS measures temperature and humidity in the Arctic more precisely than ever before. This should contribute to a better understanding of both the Arctic and the climate change that is particularly visible in it.

If the mission is successful, ESA plans to launch a global constellation of identical small satellites into space to enable more precise and shorter-term weather forecasts (nowcasting) and climate observations on a global scale.

The task of LNAs in technical systems is to improve the quality of incoming signals. As their name suggests, they amplify weak signals while causing as little background noise as possible so that signals can be more easily detected and analyzed. In this way, LNAs increase the sensitivity of systems.

"The more powerful a low-noise amplifier is, the more accurately and reliably a system can collect data. They play a major role in satellite-based Earth observation, as the microwave radiation that reaches the satellite radiometer is very weak," explains Dr. Fabian Thome, Deputy Head of Business Unit High Frequency Electronics at Fraunhofer IAF.

"It is a great confirmation and motivation that we are contributing to better research into the Arctic and its effects on the global climate with our LNAs."

Contributing LNAs for frequency ranges around 54, 89 and 170 GHz to the AWS radiometer

The AWS microwave radiometer consists of a rotating antenna that picks up the natural microwave radiation emitted by the Earth's surface and transmits it to four feedhorns and four receivers.

The antenna and receiver each belong to one of four groups comprising a total of 19 channels, which together cover a frequency spectrum of 50 to 325 GHz: Eight channels with frequencies from 50 to 58 GHz measure temperature, one channel at 89 GHz detects clouds, another at 165.5 GHz both clouds and humidity, five channels between 176 and 182 GHz are only responsible for humidity, while finally four channels at 325 GHz plus/minus 1.2 to 6.6 GHz measure humidity and also detect clouds.

With this technical equipment, the radiometer is able to create high-resolution vertical humidity and temperature profiles under all weather conditions.

Fraunhofer IAF has provided a total of four LNAs for three of the four channel groups: one module for the frequency range around 54 GHz, two identical modules for 89 GHz, which were connected in series for greater overall amplification, and one module for the 170 GHz range.

The researchers have enhanced proven technologies based on the compound semiconductor indium gallium arsenide (InGaAs) and realized metamorphic high-electron-mobility transistors (mHEMTs) for monolithic microwave integrated circuits (MMICs).

InGaAs mHEMT technology for MMICs

"Fraunhofer IAF is a world leader in the development of transistors and circuits for satellite-based radiometry systems. Our modules define the state of the art in many performance areas," emphasizes Thome.

This can also be seen exemplarily in the AWS radiometer modules: In tests, the LNA for the frequency range around 54 GHz achieved a noise figure of 1.0 to 1.2 dB with a gain of 31 to 28 dB, thus significantly improving the state of the art. With noise figures of 1.9–2.3 dB at 23–25

dB gain (89 GHz) and 3.3–4.1 dB at 25–30 dB gain, the other AWS LNAs are exactly in the range of the current state of the art.

In developing the modules, the researchers worked closely with the direct client ACC Omnisys (AAC Clyde Space) from Sweden, which built the radiometer system for OHB Sweden and ESA.

Fraunhofer IAF was able to use its research infrastructure and the expertise of its employees along the entire value chain in the development and production of the modules. Teams from the fields of microelectronics, epitaxy, technology and precision mechanics worked closely together and carried out all the key steps from circuit design to material growth, processing and measurement as well as process technology, separation, assembly technology through to module construction and integration until the LNA modules were ready for use.

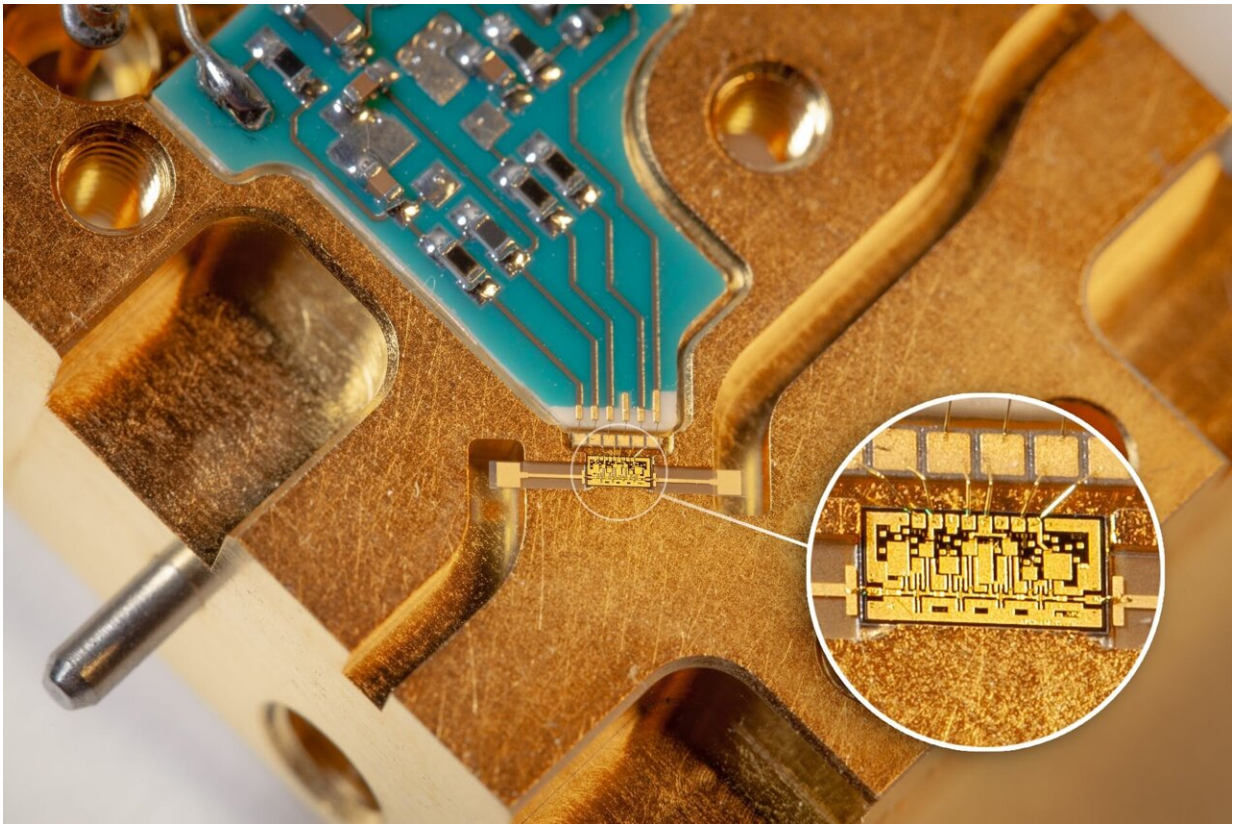
An initial qualification of the modules for use in space also took place at the institute before the hardware was handed over for receiver integration.

AWS and EPS-Sterna: New Space for more precise weather forecasts, nowcasting and climate monitoring

The AWS mission is to collect more precise weather data in the Arctic for the first time, which will enable short-term forecasts for the polar region—including so-called nowcasting, which refers to forecasts for the next few hours.

As the Arctic has a strong influence on global weather, the data also enables better global weather forecasts. This also applies to the climate: climate change is progressing faster in the Arctic than in other regions of the world. At the same time, changes in the Arctic have an impact on the

global climate due to feedback effects.



Close-up of the 89 GHz LNA MMIC integrated into the respective AWS microwave radiometer LNA module. Credit: Fraunhofer IAF

If successful, an entire constellation of identical small satellites will follow the AWS: the EUMETSAT Polar System—Sterna (EPS-Sterna). The plan is to have six satellites in three different orbits at the same time to collect long-term weather data from the polar regions.

The satellite set will be renewed three times, so that a total of 18 satellites will be used during the time of the mission. Two satellites are planned as replacements. The first of six EPS-Sterna satellites is due to

be launched in 2029.

With this project, ESA is pursuing the New Space approach for the first time. New Space is characterized by projects being carried out in the shortest possible time with significantly fewer resources.

In the case of AWS, whose total mass is only 150 kg, only three years passed from project start to rocket launch, during which a fraction of the cost was incurred compared to previous projects. Further advantages of New Space are the greater resilience of constellations—the failure of a satellite in the network can be compensated for or replaced quickly and cheaply—and the flexibility of missions, which can be extended or shortened if necessary, without consuming large amounts of resources.

From September 24 to 26, 2024, Fraunhofer IAF will present exhibits of the LNA modules installed in the AWS radiometer as well as other high-frequency electronics from the application areas of satellite communications, mobile communications or low-temperature measurement technology at this year's European Microwave Week (EuMW) in Paris (booth: 202K).

More information:

- ESA website on AWS
- Electronic circuits at Fraunhofer IAF
- Fraunhofer IAF at EuMW 2024
- Publication Dr. Laurenz John: Low-Noise Amplifiers for the Arctic Weather Satellite

Provided by Fraunhofer Institute for Applied Solid State Physics