Compact radar takes an inside view

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The W-band radar is equipped with a 3-channel antenna with dielectric lenses. Credit: Fraunhofer IAF

The human eye cannot see through wood, paper, or plastic. But a compact radar with a modular design now makes it possible to see the invisible: The millimeter wave sensor penetrates non-transparent material. It transmits signals at frequencies between 75 and 110 GHz and can be applied in a broad range of areas, from flight safety and logistics to industrial sensor technology and medical technology. Fraunhofer researchers are presenting a prototype of the radar at this year's Hannover Messe, which is set to take place from April 8 to April 12.

The mountain rescue helicopter is moving very slowly and carefully toward to the scene of an accident. A few minutes ago, two snow-shoers placed an emergency call to the base. One of two men was injured and unable to walk back down the mountain. Very carefully, the pilot begins to land. This is a risky maneuver, as freshly fallen snow makes the approach difficult. The rotor downwash causes the soft, loose snow to swirl upward. Within seconds, a cloud of snow surrounds the helicopter. In whiteouts like these, pilots lose their reference points and cannot tell whether the helicopter is moving upward or downward. Such difficult landing maneuvers will soon be issue of the past: researchers at the Fraunhofer Institute for Applied Solid State Physics IAF, for Manufacturing Engineering and Automation IPA, and for Reliability and Microintegration IZM are working together to develop a radar that can provide landing support in all ambient conditions. Whether in snow clouds, dust, or fog, the radar is capable of measuring exact heights and distances to the ground. This radar works with millimeter waves at frequencies of 75 to 110 GHz, usually known as the W-band. Even in situations of difficult visibility, it can identify small objects at a range of up to 3 kilometers. In contrast to optical sensors, the millimeter wave sensor is capable of penetrating all dielectrical, non-metallic and non-transparent materials, such as clothing, plastic surfaces, paper, wood, or even snow and fog.

This makes the W-band radar suitable for a broad range of applications, from traffic controls and medical technology to logistics and industrial sensor technology. This includes, for instance, the monitoring of container ports or manufacturing processes. "The W-band radar can be used in any situation where other sensor technologies in manufacturing processes have failed because of high temperatures or limited visibility.

Just to name one example, it can be used as a filling level sensor in flour silos: a great deal of dust forms when they are being filled," says Dr. Axel Hülsmann, an engineer at IAF. And the device has other advantages as well: in contrast to x-ray scanners, it does not pose a health hazard, and it works with short-wave beams in the millimeter range. It has a transmission power of 10 milliwatts, compared with the 1000-milliwatt range of a mobile phone.

About the size of a cigarette box

Existing radar systems, which are based on ceramic substrates, are expensive, large, and weigh four to five kilograms. This limits where they can be deployed, and they are mainly used for military applications. In contrast, the new system that Fraunhofer researchers have developed has a modular design and is cost-effective. In addition, it is more energy efficient, has a higher resolution, and can be universally applied. The new technology presents no problems when required to address frequencies exceeding 100 GHz.

Thanks to the short wave-lengths of approximately three millimeters, the W-band radar is compact in size. The complete system, which is made of gallium arsenide semiconductor technology, is about the size of a cigarette box. In addition to handling digital signal traffic, the box contains a high-frequency module, a signal processor, as well as a transmission and reception antenna with dielectric lenses. "Since we are using a dielectric antenna, the angle of aperture can be freely selected. This means recorded data can cover a close-up of large surfaces just as easily as small, far away objects," says Hülsmann. This makes it possible to monitor a fence that is several hundred meters long, like the ones at Hamburg's container port. "When there is fog, as is often the case at Hamburg's port on the Elbe River, security cameras are unable to deliver high-resolution images. This is why the authorities often patrol with dog units when the weather is bad," the researcher explains.

Using bats as role models

But how does the millimeter wave sensor work? "In principle, our system can be compared with that of a bat. When bats emit ultrasonic signals, echoes bounce back from walls, branches, moths, and gnats. The bats use these echoes to determine what obstacles lay ahead, and the echoes allow them to distinguish between obstacles and prey. If nothing were in the way, there would be no echo. So they see with their ears," explains Hülsmann. "Our radar emits signals that are reflected by the objects under observation. With the help of numerical algorithms, the signals transmitted and received can be compared to one another. And this comparison makes it possible to determine the distance, size, thickness, and speed of the object. If the object does not move, the signal remains unchanged." The measured data can be transferred to a PC via a USB interface. Connection to other existing systems, for instance via CAN-BUS interfaces, is also possible.

A prototype of the W-band radar will be presented for the first time at this year's Hannover Messe, which is set to take place between April 8 and April 12. The researchers will be on hand at the joint Fraunhofer trade show booth, Stand 18 in Hall 2. To demonstrate the filling level sensor function, fog partly fills the space between two concentrically placed water columns; the inner column contains water. While an optical sensor would be "fooled" to measure only the height of the fog, the radar penetrates the mist and reliably calculates the actual water level. The system is expected to be ready for market in two years. By then, experts aim to be able to apply a multi-channel radar to detect not only the distance and speed of objects, but also their exact position.

More information: They will be located at Stand D18 in Hall 2.

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