RESEARCH NEWS

Remote sensing with satellite mega-constellations

Avalanche Detection Using Passive Radar

In winter, avalanches pose the biggest danger in mountains. Avalanche monitoring is therefore of critical importance to ensure the safety of people and infrastructure. Researchers at the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR are breaking new ground in avalanche detection. Passive radar — which uses signals from the new Starlink and OneWeb satellite mega-constellations — enables them to detect whether avalanches have actually been triggered after controlled detonations, even in remote regions without terrestrial infrastructure. In a feasibility study, the researchers proved that satellite mega-constellations are suitable for avalanche detection.

Every winter, the risk of avalanches in the mountains rises as the amount of snow increases. One of the protective measures to reduce the risk to people and infrastructure is to carry out controlled, artificial detonations. These detonations trigger the release of huge masses of snow, which thunder down into the valley along a predetermined path. But the question remains: Was the avalanche actually triggered as planned? It is essential to confirm this factor. To do this, the affected area must be monitored in a targeted manner — regardless of the visibility and prevailing weather conditions. This task is currently performed using mechanical wires that break when the avalanche starts, or by helicopters that monitor the area during the detonation. Many cases also involve the use of radar technologies which enable continuous remote monitoring in all weather conditions. However, all of these solutions present major disadvantages: Mechanical wires, for example, have to be re-tensioned after every avalanche, possibly putting technicians at risk, while helicopters can only fly in good weather conditions and active radar technologies require transmission licenses.

Passive radar for operation in remote regions

This is where passive radar could be a suitable alternative for avalanche monitoring. Unlike conventional active radar, passive radar is a positioning technology that does not emit electromagnetic energy but uses radio or mobile communication signals. What's more, it does not emit radar beams that are reflected by an object and then deflected back to the receiver. Instead, it uses beams that are already present. Passive radar is not only cost-effective, energy-saving and easy to install — another advantage is that it can also be operated without transmission licenses. "As passive radar does not require transmitting antenna and needs fewer components, it is cheaper and easier to put into operation. It can easily be set up without a license," says Dr. Diego Cristallini, Group Leader at Fraunhofer FHR. The problem, however, is that radio signals are usually not

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available in remote mountain regions. This means that Dr. Cristallini and his team have to rely on signals from the OneWeb or Starlink satellite mega-constellations with fixed-satellite services (FSS), which are available around the world. These satellite networks are intended to provide broadband coverage anywhere on Earth. In a feasibility study commissioned by ESA-ESTEC (European Space Research and Technology Centre), researchers are investigating whether Starlink and OneWeb are suitable for avalanche detection and, more specifically, whether they are actually capable of detecting and confirming an avalanche after a detonation.

Stationary passive radar enables SAR images

"Satellite links are always used when terrestrial networks are unavailable, overloaded or disrupted. Like OneWeb, Starlink is a LEO (low Earth orbit) satellite service. This means that a large number of satellites circle the Earth in a low orbit. This proximity is advantageous in terms of latency, as the distance from the ground to the satellite and back is only a few hundred kilometers," explains Dr. Cristallini. The large number of Starlink satellites enables continuous radar images of the Earth's surface: As soon as a satellite disappears on the horizon, a new one appears, producing two-dimensional images of the area that are easy to interpret. "We're talking here about SAR (synthetic aperture radar), which allows images of remote mountain regions to be recorded that go far beyond detection." The satellite mega-constellations are permanently available as a signal source. The electromagnetic signals are sent into the mountain regions from different angles, rendering areas visible that would otherwise be obscured when using just one transmitter.

Using the topographical data of a mountain, Dr. Cristallini and his team have developed a simulation environment that has allowed them to simulate avalanches and analyze whether they can be detected using the Starlink signals. To test the promising simulation results in practice, the researchers have also used their passive radar system to detect small and controlled landslides in a former basalt mine on the Rhine near the German town of Remagen. These landslides occur when an excavator pours its load into the still-gaping hole. "Both the simulations and the practical test have shown that passive radar with signals from satellite mega-constellations is suitable for detecting and confirming avalanches," summarizes Dr. Cristallini.

Fig. 1 Practical tests in a former basalt mine: The right-hand receiver antenna of the passive radar is aligned with a Starlink satellite, while the left-hand receiver antenna points toward the controlled landslide.