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[Home](#) > [A low-cost, finger-nail sized radar](#) > A low-cost, finger-nail sized radar

A low-cost, finger-nail sized radar

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[1]

EU-funded researchers have squeezed radar technology into a low-cost fingernail-sized chip package that promises to lead to a new range of distance and motion sensing applications. The novel device could have important uses in the automotive industry, as well as mobile devices, robotics and other applications.

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Developed in the 'Silicon-based ultra-compact cost-efficient system design for mm-wave sensors' ([Success](#) [2]) project, the device is the most complete silicon-based 'system-on-chip' (SoC) package for radar operating at high frequencies beyond 100 GHz.

'As far as I know, this is the smallest complete radar system in the world,' says Prof. Christoph Scheytt, who is coordinating the project on behalf of IHP in Frankfurt, Germany. 'There are other chips working at frequencies beyond 100 GHz addressing radar sensing, but this is the highest level of integration that has ever been achieved in silicon.'

Measuring just 8 mm by 8 mm, the chip package is the culmination of three years of research by nine academic and industrial partners across Europe, supported by EUR 3 million in funding from the European Commission. The team drew on expertise from every part of the microelectronic development chain to develop the groundbreaking technology, which is expected to be put to use in commercial applications in the near future.

Operating at 120 GHz - corresponding to a wavelength of about 2.5 mm - the chip uses the run time of the waves to calculate the distance of an object up to around three metres away with an accuracy of less than one millimetre. It can also detect moving objects and calculate their velocity using the Doppler effect.

From a commercial perspective, the technology is also extremely cheap: manufactured on an industrial scale, each complete miniature radar would cost around one euro, the project partners

estimate.

That gives it the potential to replace ultrasonic sensors for object and pedestrian detection in vehicles, to be used for automatic door control systems, to measure vibration or distance inside machines, for robotics applications and a wide range of other uses. It could even find its way into cell phones.

To develop the miniaturised radar system, the team had to overcome a range of technical challenges, not least integrating and ensuring the reliability of the tiny antenna.

'In this area, size matters a lot,' Prof. Scheytt notes. 'The main motivation for using high frequencies rather than lower ones is that the antennas can be smaller.'

While an FM radio has an antenna that's about one metre long and a WiFi router's antennas are about 10 cm in length, at mm-Wave frequencies (between 30 GHz and 300 GHz) the antennas can also be at the millimetre scale. Given the increasing miniaturisation of modern devices - from cell phones to robotics components - working in the millimetre range is therefore a significant advantage.

A novel substrate to solve attenuation

However, at high frequencies unwanted electromagnetic radiation and high attenuation are serious problems. 'The higher you go in frequency the more the wiring radiates: modelling this interface was a big challenge,' the project coordinator says.

The Success team addressed the issue through precise modelling, a novel technique for antenna integration, and using a polyamide substrate for the antenna.

'The project partners researched and tested a lot of different substrates for the antenna to find one that was the least lossy. Then they used a technique to print the antenna on it and connect it through solder bumps,' Prof. Scheytt explains. 'The antenna itself is planar, meaning it is mounted flat on top of the chip. This is completely different to the packaging technology of other millimetre-wave systems, which usually have bulky antennas with tube-like conductors. The advantage is that the whole "system-in-package" is a lot smaller.'

Another issue with high frequency devices is testing that they work as they are designed to. Current testing techniques are expensive and ill-suited to the high-volume testing necessary if the device is to be manufactured commercially. To address this, the Success team took the unusual step of including self-testing features built in to the chip package.

'Built-in self-testing is quite common for cell-phone chips that work at much lower frequencies, but it is something quite novel for millimetre-wave chips,' Prof. Scheytt says. 'Our industrial partners put a lot of emphasis on including this as it makes no sense to have a chip that can be manufactured for a euro and then have to spend 30 or 40 euro to test each one.'

The built-in test features enable technicians to easily and cheaply test if the antenna is connected correctly, the transmit power of the device and if it is operating in the right frequency range. And, because there is no radio frequency interface to deal with, integration onto a printed circuit board is similarly cheap and easy.

'Since all the high-frequency circuitry is in the package you have only low-frequency interfaces to work with,' Prof. Scheytt notes.

He points out that an application engineer can handle the chip, because it is a standard surface-mount package, in much the same way they would fit an ultrasonic sensor or microcontroller.

'Users can solder the chip onto their standard circuit boards and receive low-frequency signals that can be processed without difficulty,' says Prof. Thomas Zwick, head of IHE at the Karlsruhe Institute of Technology (KIT), a project partner.

The different partners in the Success consortium are now looking to use the technology commercially. Bosch, for example, is investigating deployment possibilities, seeing major potential for low-cost radar operating at high frequencies, while other partners, such as Silicon Radar in Germany, Selmic in Finland and Hightec in Switzerland are also expected to incorporate the work carried out in Success into their industrial processes.

Success received research funding under the European Union's Seventh Framework Programme (FP7).

Links to projects on CORDIS:

- [FP7 on CORDIS](#) [3]
- [Success project factsheet on CORDIS](#) [4]

Other links:

- [European Commission's Digital Agenda website](#) [5]

Contact:

Newsroom Item Type:

- [Projects news and results](#) [6]

Around Europe & the World:

- [Germany](#) [7]

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Links

- [1] https://ec.europa.eu/digital-agenda/sites/digital-agenda/files/newsroom/satellite_subchapter_492x158ps_3762.jpg
- [2] <http://www.success-project.eu/>
- [3] http://cordis.europa.eu/fp7/home_en.html
- [4] http://cordis.europa.eu/projects/rcn/93756_en.html
- [5] http://ec.europa.eu/information_society/digital-agenda/index_en.htm
- [6] <https://ec.europa.eu/digital-agenda/en/newsroom/all/projects-news-and-results>
- [7] <https://ec.europa.eu/digital-agenda/en/country/germany>