COVER STORY

Contactless Measurement of Vital Signs with Radar Sensors

BY BERND HETTICH, Product Marketing Manager, Infineon Technologies, and **SHUAI JIANG,** Master's Student, Technical University of Munich

The use of radar for monitoring vital signs has been researched for decades. The technology enables continuous contactless monitoring of heart and respiration rate while having low power consumption and a small PCB footprint. With innovative 60-GHz radar sensors, its use in consumer electronics is now becoming a reality.

In an aging society, health monitoring plays an increasingly important role. It is better to detect health problems at an earlier stage, thus avoiding hospital stays or at least shortening them as much as possible. People want to live a self-determined and independent life in their familiar surroundings into old age.

In addition, young people are interested in more personalized and self-determined medical services. With the ability to monitor health and fitness status at any time, it is possible to detect and take action against illnesses and stress at an early stage. Also, parents are doing everything to ensure that their children and infants are doing well so that they can react quickly if the worst should happen.

Many diseases can be detected early based on irregularities in cardiopulmonary data. New possibilities are emerging thanks to advances in technology. Since smartwatches were first launched, the combination of consumer electronics with digital health monitoring has become increasingly popular. This positive trend is also evident in the healthcare industry: **Figure 1** shows that investments in digital health have increased twentyfold in the past 10 years, with an extremely sharp increase in the recent past.[1]

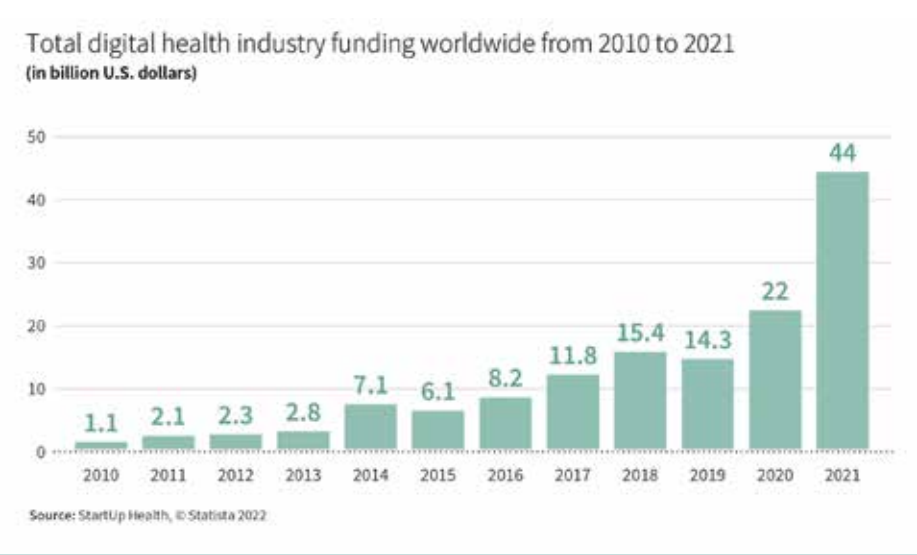

Figure 1: *Investments in the digital health industry have increased sharply in recent years.*

The most important vital signs that can be monitored include heartbeat and respiration rate. This information can be used to detect diseases like cardiovascular disease[2] or chronic obstructive pulmonary disease (COPD)[3] at an early stage. Similarly, diseases like sleep apnea can be detected through sleep monitoring.

Most technologies used today for tracking and monitoring require direct contact with the patient via such means as electrodes or skin contact with the sensor. This applies both to high-precision systems used in hospitals and to wearables from the consumer sector. These solutions either require cables, which restrict freedom of movement, or regular charging, which is inconvenient. Moreover, these methods are not suitable for people with allergies or skin injuries. Similarly, these contact-dependent measurements are often difficult for infants and seniors. Hence, the digital healthcare market needs a product that enables contactless and continuous user monitoring.

ADVANTAGES OF RADAR TECHNOLOGY

A radar sensor enables continuous and contactless monitoring of both heartbeat and respiration rate. It also allows the recording of long-term vital data without the user being consciously aware of this all the time. This will not only help doctors make accurate diagnoses but reduce the hygiene risks to patients. Therefore, radar's vital-sensing capabilities promise to solve many of the challenges of today's healthcare industry.

But how does vital sensing work with radar technology? The radar transceiver transmits a low-energy RF signal via its Tx antenna

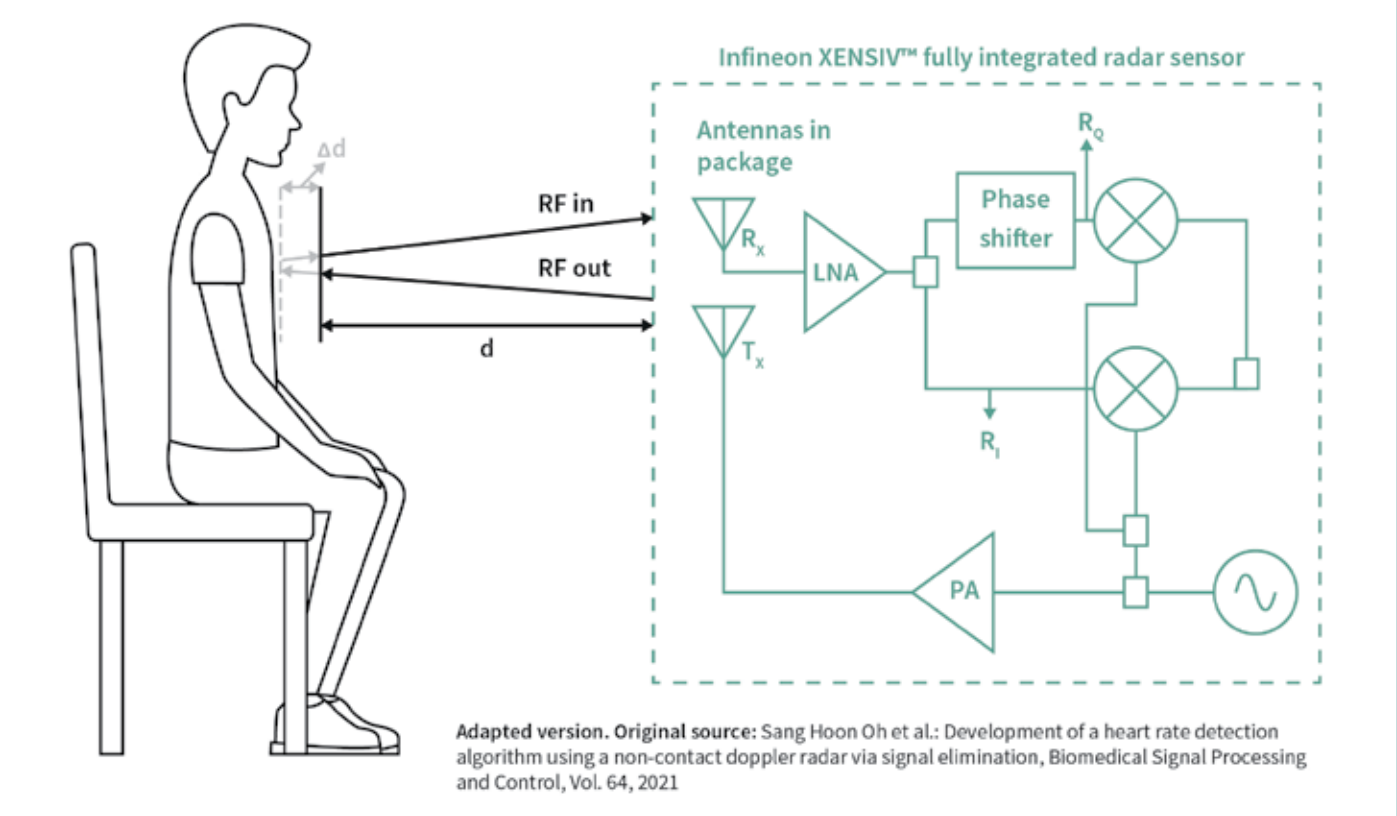

Figure 2: *Operating principle of radar technology for vital sensing*

and receives the reflected signal via the Rx antenna (**Figure 2**). Generally, moving targets result in a Doppler shift, which can be measured by comparing the transmitted and the received signals. This allows detection of the tiny movements of the chest caused by breathing and the heartbeat with highly sensitive sensors like the Infineon XENSIV™ 60-GHz radar sensors. Thanks to advanced algorithms, the heartbeat and respiration rate can be extracted accurately from the signal. This can also satisfy the requirements for medical certification.

In the context of vital sensing, radar technology has five major advantages over previous technologies: It is unobtrusive, robust, anonymous, energy-efficient and small.

Unobtrusive

For vital sensing, radar technology has the advantage that it hardly affects the patient. The only requirement is that the user remains within a certain distance of the device, typically within 1.5 meters. Preferably, the user's chest needs to be oriented toward the sensor, but this is not mandatory. Because radar can detect through non-conductive materials, people can wear any kind of clothing or cover themselves with a thin blanket. The same feature gives engineers of radar-based devices almost free choice in the material and shape of the housings to meet the design requirements of consumers.

Robust

In addition, radar sensor functionality is barely impacted by surrounding conditions. For example, it continues to function reliably regardless of whether it is completely dark or very bright in the room or whether it is dusty, foggy or humid. Hence, a radar sensor does not interfere with people's daily lives. Thanks to advanced signal processing, the sensor can also differentiate between human and non-human targets, so small pets and other sources of signal clutter can be ignored.

Anonymous

The radar device analyzes only the modified echo of the signal it emits itself and is therefore not dependent on any external signals. As a result, radar does not collect any personal data, such as images, sounds or videos. Thus, radar-based health-monitoring devices can be continuously used at home and in private spaces without users having to fear violations of their privacy.

Energy-efficient

The low power consumption of only a few milliwatts makes it possible to use the radar 24/7. Additionally, the typically radiated power is

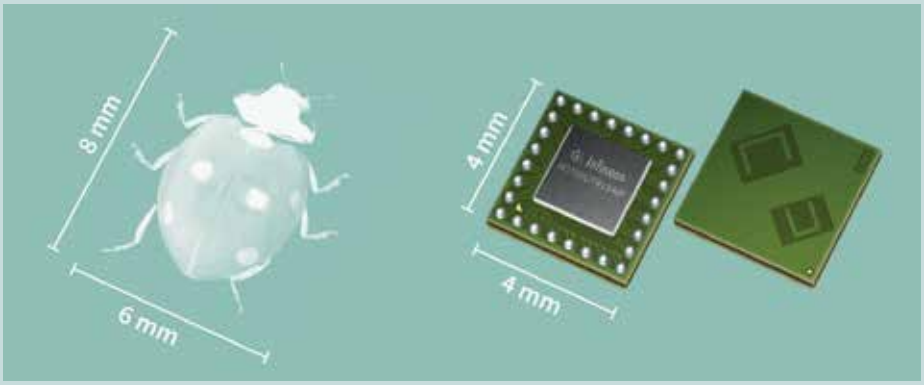

Figure 3: *At 4 × 4 mm, the Infineon BGT60UTR11AIP is the smallest 60-GHz radar sensor on the market.*

about 10 dBm or even less. This is very low compared with a 5G smartphone, for example, which typically can have about 20-dBm radiated power. The radiation from the radar sensor has no adverse effect on humans.[4]

Small

A radar chip also has a very compact size. At 4.05 × 4.05 mm, Infineon's BGT60UTR11AIP (**Figure 3**) is the smallest 60-GHz radar sensor with integrated antennas on the market.[5] Sensors like this can be easily integrated into consumer electronics, where they provide a huge increase of functionality. Applications include smart hubs, laptops, tablets, smart TVs and many other smart-home devices.

BRINGING HEALTH MONITORING TO THE SMART HOME

The lessons of the pandemic have prompted people to realize the importance of knowing their health status and preventing potential diseases. Likewise, advances in machine learning are enabling the functionalities of sensor technology to be exploited to the maximum. As a result, radar technology is increasingly entering the smart home for health monitoring.

Continuous recording of vital data means it can be easily shared with the user's physician to make an accurate diagnosis. Thanks to artificial intelligence, analysis of the recorded data and trends over time allows early detection of diseases. Symptoms of already known or suspected diseases like sleep apnea can be identified, recorded and easily shared with the patient's doctor. Also, in the event or risk of respiratory arrest, an emergency medical service can be alerted automatically and in time.

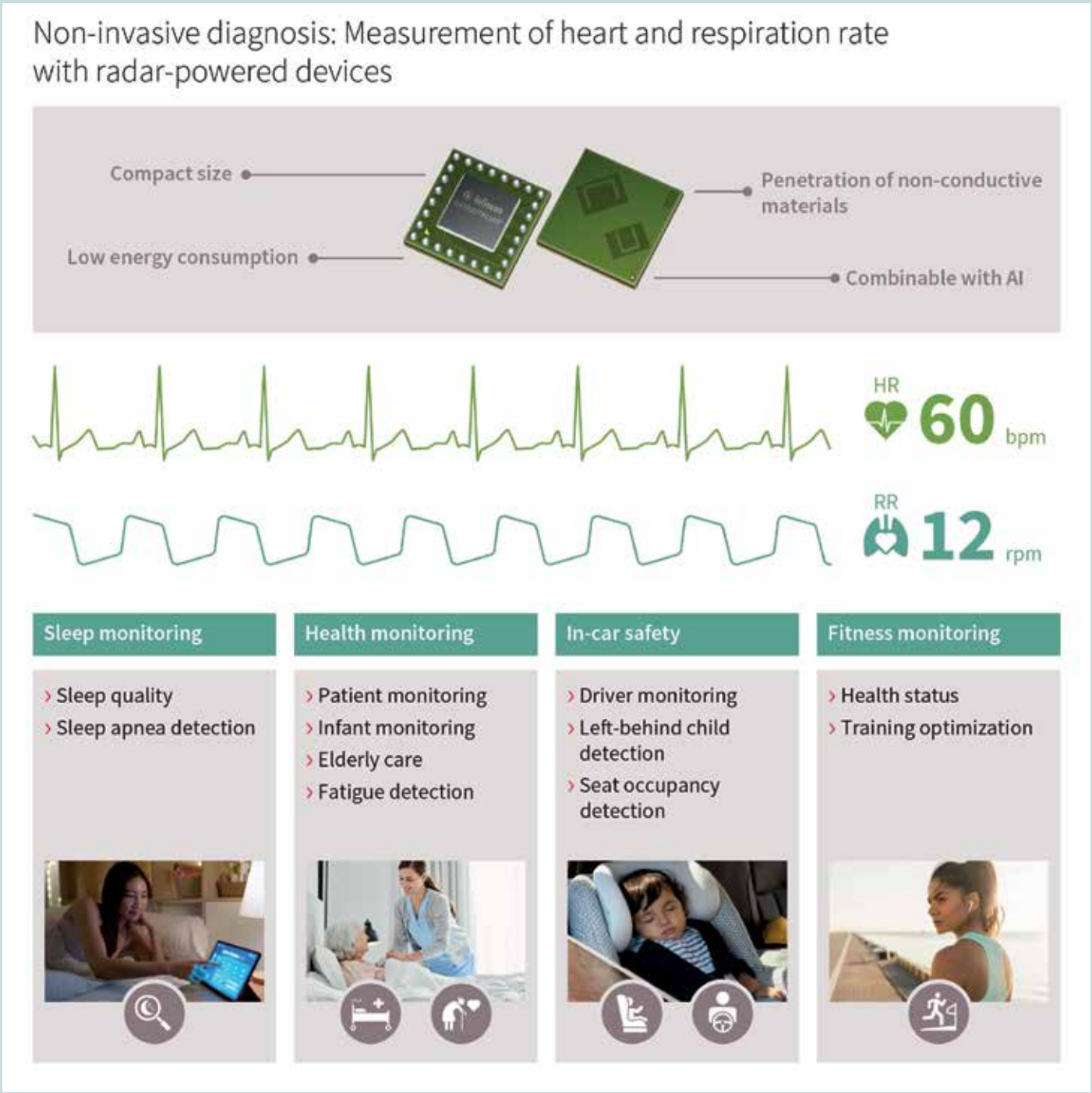

Figure 4: *Potential applications of radar for vital sensing*

These benefits allow elderly and sick people in particular to lead a self-determined life. But parents also benefit from the technology, as infants and newborns especially are difficult to monitor with conventional systems. This is where radar sensing can really prove its worth, whether it be monitoring for signs of sudden infant death syndrome or monitoring premature or seriously ill infants.

But it is not only sleeping individuals who can be monitored via radar. Thanks to the compact size of the radar chip, radar sensors can be integrated directly into almost all kinds of smart-home devices, including smart TVs, laptops or lamps. This allows the sensor to monitor the heartbeat and breathing rate of people who are asleep, watching TV, working on a laptop or reading with the aid of a smart lamp. Radar technology can also immediately detect a heart attack and trigger an appropriate emergency call. When integrated into a motor vehicle, it can instruct driver-assistance systems to bring the car to a safe stop. Furthermore, radar sensors could be used to detect signs of fatigue and remind people to take a break from work or driving.

At the same time, radar sensors enable other features beyond pulse and respiration monitoring (**Figure 4**). For example, they can be used for fall detection, and there is promising ongoing research into the use of radar to measure blood pressure. Because radar technology enables simultaneous detection of micro motion, speed and direction, radar-equipped products can use this information to support more sophisticated applications beyond vital sensing. A radar sensor can also be used for robust human-presence detection, for example, to switch a TV or laptop to energy-saving mode while no one is sitting in front of it. Gesture control as well as tracking the position of multiple people in a room can also be implemented.

RADAR SENSORS AT WORK

With its XENSIV™ 60-GHz radar sensors like the BGT60UTR11AIP or BGT60TR13C, Infineon provides developers with everything they need to incorporate vital sensing into their designs. Infineon has many years of experience in the automotive and industrial radar market and was one of the pioneers in using radar for vital sensing in consumer electronics.

The range of high-quality and reliable products is reinforced with strong support, which is provided for the software as well as hardware design and testing of customer products. All in all, product engineers save time in development and can provide high-quality end products.

Infineon's customers and partners are already successfully using Infineon's radar sensors in their vital-sensing products. For example, Swiss company Sleepiz offers a medically certified device for sleep monitoring (see **sidebar**). Furthermore, Google's Nest Hub 2 is using Infineon's radar sensor to detect vital signs during sleep as an additional feature.

CONCLUSION

With radar technology, it is possible to build consumer-oriented products that take smart devices to a whole new level, introducing smart healthcare to the mass market. Radar is the only contactless technology that can continuously and anonymously monitor heartbeat and respiration rate.

Radar sensors bring vital sensing to the consumer electronics and healthcare markets. From surveillance of premature infants to early disease detection to monitoring the health and medical condition of the elderly, radar enables low-power and accurate vital sensing at any time of life. ■

Analyzing Sleep and Detecting Sleep Apnea

Sleepiz's goal is to detect diseases like sleep apnea to prevent further health effects like heart problems or diabetes. As an associated partner of Infineon and as part of its product offering, the company is also selling its algorithm for robust heartbeat and respiration rate detection with Infineon's XENSIV™ 60-GHz radar sensor to other customers in order to facilitate and jumpstart their vital-sensing development.

Figure 5: *Sleep disorders like apnea can be detected through analysis of vital signs like respiration rate and heartbeat with devices powered by Infineon's XENSIV™ 60-GHz radar sensors.*

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