Infineon Smart Speaker Solutions

Advanced Sensing Capabilities for smart speakers enabled by radar sensors

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Introduction

In Star Wars®, the Force®[1] enables people to feel the presence of someone that they cannot see. A very useful skill that is now real albeit for smart speakers being able to similarly sense the presence of someone – not with the Force but by using radar sensors. And radar does not mean a big rotating antenna but everything, including the tiny, non-moving, built-in antenna, is now available as a thin device less than a quarter the size of a fingernail. This is so small and needs such little power that it can be integrated into almost any device to enable it to 'see' adding many new smart features for product differentiation.

A key benefit of being able to detect if people are nearby is that provides sophisticated power saving for electronic devices because it enables them to drop down into deep sleep mode with almost no power usage, leaving just the radar sensor on sentinel duty that needs very little power. As the sensor can also detect the range of a person, it can elevate the device through the wake stages as they approach to be ready for instant use. This approach can save a lot of power that rapidly mounts up if every device in a house or office can do this as it reduces energy consumption by only delivering high energy use services such as heating, music, or lighting only when there is someone actually present.

This and other innovative features in smart speakers, such as sensing how many people are nearby, where they are and how they are moving, are discussed in this article along with the great sensitivity of radar sensors that can detect even the smallest of movements such as breathing, heartbeat and other vital signs.

With smart speakers becoming the central control hubs of smart houses and smart offices, presence detection enabled by a radar sensor allows OEMs to provide advanced, innovative features to differentiate their products in this highly competitive and rapidly growing market segment. Also, with the huge numbers of smart speakers being produced, the cumulative power reduction of the smart speaker and their connected IoT edge devices from the inclusion of radar sensors will make a great impact on carbon footprint reduction.

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[1] Star Wars and The Force are registered trademarks of Lucasfilm Limited

1. Smart Speaker: Definition and growth potential?

It is categorised as a type of loudspeaker and a VUI (Voice User Interface) with hands-free activation usually by a key or wake word of an integrated virtual assistant that provides intuitive interaction to access almost anything on the Web. This is an extremely user-friendly device that enables people to have their own personal voice assistant to help organise their busy lives, play the music they want, control other devices, tell them the latest news and the weather forecast, and search the Internet for answers to questions. Most of these could be done via typing on a computer or smartphone, but the convenience of using a VUI is compelling as it is intuitive, hands-free and can be done from anywhere in the room when doing something else.

The excellent user experience and usefulness of smart speakers is expanding their use outside the house, where they can control a smart home, into offices where they deliver similar benefits to create smart offices. This almost exponential growth can be seen in the Voice Assistant Platform Forecasts from SAR Insight & Consulting, which predicts that global shipments of smart speakers will grow to almost 200 million units per year by 2026. The installed base is forecast to almost double from 415 million units in 2021 to 798 million units by 2026, representing a CAGR (Compound Annual Growth Rate) of 14%. Total cumulated revenues are expected to top US$80 Billion from 2014 to 2026. To put the explosive growth in perspective, in 2015, global sales revenue was a mere US$0.2 Billion. Not bad for a product category that did not even exist before November 2014 and indicates that these forecasts could turn out to be much lower than in reality as this is a very hot growth area.

The global market for Smart Speaker

Source: SAR Insight, Voice Assistant Platform Forecasts, February 2021
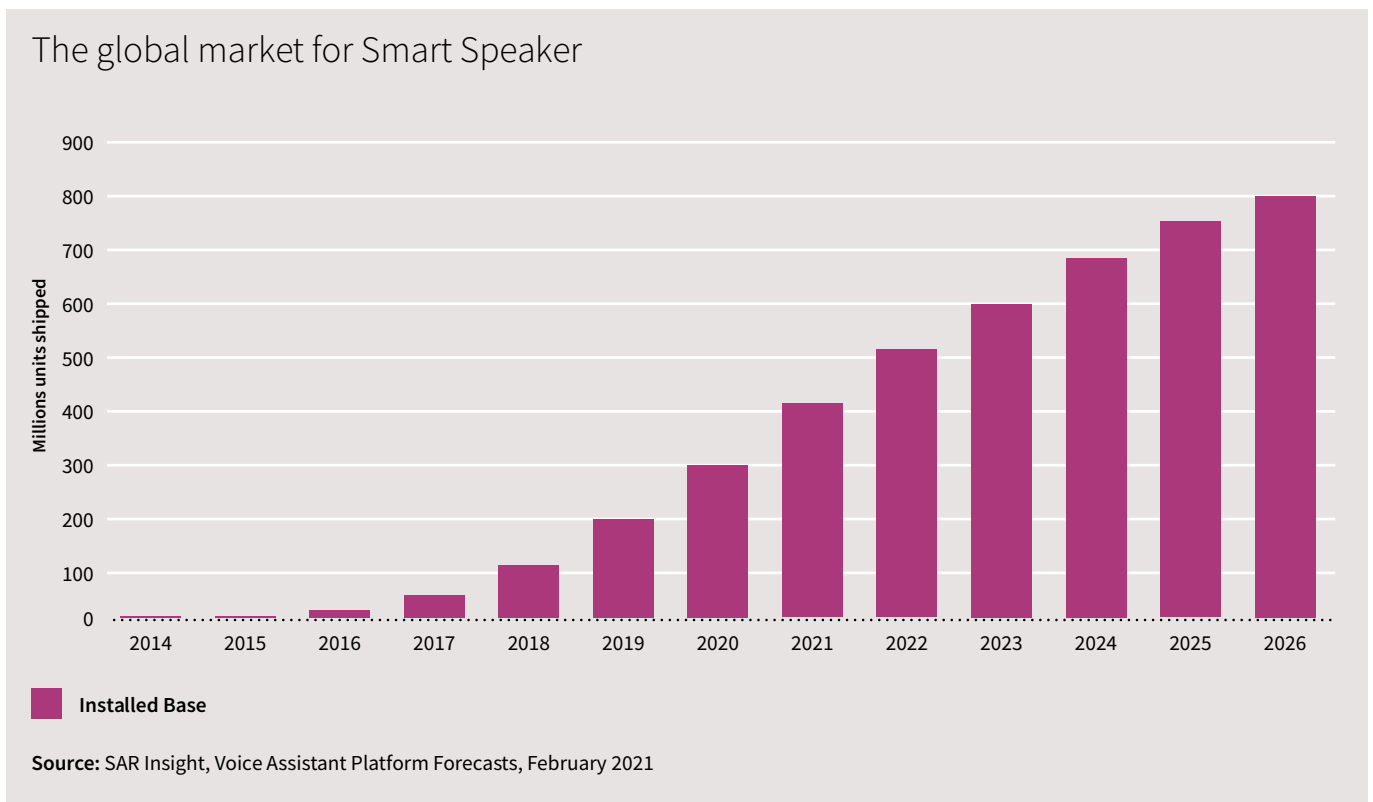
How to benefit from this huge growth potential?

The voice is the normal way to communicate between humans and so a VUI is a very natural way to control a smart speaker. Ways to make VUI even better and differentiate your designs with better sensitivity and other features are discussed in a companion paper entitled [Essential Parts and Innovative Features in smart speakers' Design.](#)

As with many new device categories become mainstream, the market starts to flood with products that are virtually identical and a race begins with many OEMs cutting prices to win market share often sacrificing quality in this race to the price bottom.

A far better path is to offer the purchaser a better user experience as most customers will value this and are prepared to pay for useful features that the basic, less expensive (or budget-friendly) models do not have.

Incorporating a radar sensor enables the next generation of smart speakers to be created with new features to excite and interest customers to buy these models and even upgrade to them over existing devices.

2. Beyond voice: Giving smart speakers another fundamental aspect of human interaction

If you go one step back from the human-to-human conversation, you see the person approaching and that initiates the voice interaction. Similarly, at the end, you see them leaving and you know that the interaction has finished. If interaction involves a group of several people, you can see them coming and going and where they are all the time. Effectively, this enables you to focus your attention and resources according to changing circumstances.

Transposing this sense of awareness to a smart speaker, a radar sensor provides the motion and presence detection that we use our eyes for. Radar can sense movement and its direction within a hemispherical volume with a radius of up to 5 meters or more depending on the radar sensor utilized. Thus, it senses people approaching and leaving plus where they are in the hemisphere and can track where each of them is moving.

Humans communicate by waving and gesturing to others; a radar sensor provides the same ability to interact through gestures as it is sensitive enough detect such movements. In fact, its sensitivity is so good that it can be used to detect the movement of a chest when breathing and even 'seeing' the pulse of a heartbeat under the skin which is even better than a human eye!

Thus, adding a radar sensor enables a smart speaker to add the sense of 'sight' to its sense of 'hearing', making interactions even more intuitive and natural.

What about other ways of adding 'sight'?

The options are a PIR sensor, an ultrasonic sensor or a camera. Let's look at each one of these in turn and their drawbacks.

Within low-end motion detection sensors our new BGT60LTR11AIP is a smart, cost-effective and highly sensitive solution.

	60 GHz Radar	PIR	Ultra-sonic	ToF	Camera
	BGT60LTR11AIP	www.polin.de	www.mouser.com	IRS1125A	www.vision-systems.com
Detection range	yellow	orange	orange	green	green
Solution size	green	orange	green	green	purple
Power consumption	yellow	green	green	yellow	orange
Environmental robustness	green	orange	yellow	green	green
Sensitivity	green	orange	green	orange	yellow
Computing complexity	green	green	green	orange	orange
Design flexibility	orange	purple	purple	purple	purple
Sensor price	yellow	green	green	orange	orange
Price/Detected Area	green	green	yellow	yellow	orange

PIR (Passive Infra-Red) sensor

As the name says, this is a passive detector of infra-red radiation coming off a target. Humans in a warm room become hard to distinguish from the background. Similarly, a human can be undetectable in a thick jacket at the ambient cold temperature of the surroundings that leaves little non-ambient area of the human for the PIR to detect. It also needs a lens above the sensor which is large and obtrusive when trying to design an elegant speaker.

The PIR sensor does not have good sensitivity especially in radial direction, i.e., if you are directly walking towards or away from it -- as anyone knows who has had to stand in front of an automatic door waving and waving at the sensor to be detected. It is a binary device in that it is triggered when it detects the presence of a moving IR source and so the door will also open if someone just walks by it. The range is determined by the model with basic ones sensing around 2 m and higher-end versions going up to 8 m.

Ultrasonic sensor

In this case, the sensor sends out an ultra-high frequency sound and listens for the echoes of this from targets in the same way the bats do. As they provide distance information to the target, their major use is as parking sensors for cars to warn that an object is near the bumper. In a domestic setting, fabrics easily absorb these frequencies and prevent sound being reflected back to the sensor reducing its ability to 'see'. As a tiny loudspeaker is needed for the sound, this is a point of weakness that must be protected from dust and liquids and requires careful design to make it discrete. Lastly, ultrasonics need careful calibration and interfacing with a microcontroller by an experienced technician when they are being designed into a device.

Camera

A camera would seem like a good way to provide the ability to 'see' but there are major drawbacks to this. The biggest one being privacy as the camera would be watching all the time which also means a very visible lens to be incorporated into the device design. Other drawbacks include the need to have ambient light and a backup light source at night time, and complex algorithms on a powerful CPU to process the images to extract actionable information such as the movement of people. Both of these need considerable amounts of power which is not consistent with creating 'green' products. Besides that, it is by far the most expensive solution.

3. The radar sensor: Overcoming these drawbacks

The first advantage is that it is mounted inside the device on the motherboard, just like a standard IC package, so it does not any special protection so no dome and no grill to interfere with the device's external design as radar 'sees' through non-conductive surfaces. The privacy concern of a camera is also removed as no lens is required and there are no images of people.

The second advantage is that it is self-contained active device as it generates pulses at 60 GHz and "listens" for their reflection. Unlike ultrasonics, these signals are not absorbed by fabrics and there is no requirement for the ambient light that a camera needs not an IR-emitting body for a PIR sensor.

The third advantage is adjustability as a 60 GHz radar sensor can have a detection range as far as 15m and a sensitivity so good that it can 'see' a pulse beating just beneath the skin. It therefore also 'see' gestures without the need for a camera opening up new HMI options. A 24 GHz radar sensor can 'see' even further – up to 100m or more.

The fourth advantage is that it can detect direction of movement. Thus, it can 'see' if a person is approaching or leaving or just walking past and respond accordingly. What's more it can detect and distinguish between several people or 'targets' and track their movements in space.

The fifth advantage is the ease of integration into a new design as, generally, no special calibration or setup is required. An example of when that would be needed is in a device that is subject to vibration but, as this is a periodical movement, it can be cancelled out with smart algorithms.

Lastly and most importantly, it is low power at only a few mW and for some chips under certain settings even below 1 mW. It can also reduce the power consumption of the rest of the device, by using it as a sentinel watching for the approaching presence of someone to automatically wake up the rest of the device from a deep sleep, power saving mode. And similarly reverse the process to automatically save power ("vacancy detection").

4. What new features does a radar sensor offer to a smart speaker design?

Adding a radar sensor can improve the user experience by sensing the presence and location of a person enabling the smart speaker to intelligently 'listen' using an array of microphones to focus in on their location. This helps eliminate noise to ensure better listening for more accurate response to voice commands or to focus in on whoever is talking in a room of several people on a conference call for improved clarity. Similarly, intelligent 'speaking' by ensuring that the music volume stays consistent as the person moves around the room with beamforming from an array of loudspeakers to direct the sound to them.

Because it can detect the direction of movement (angle of arrival), the smart speaker is now aware that someone is approaching so that it can power up the VUI and internet connection to be ready to listen for commands. There is now no longer a need for a 'wake up' word.

If also controlling the room's lighting, this is turned on as the person comes within range (even through a closed door) so no fumbling for the light switch. Similarly, it can power down if there is no one around such as when someone leaves so it automatically turns off the music as well as connected devices such as TV, lighting, air conditioning and heating. All of which helps save energy.

A radar sensor can detect 'real presence'. A PIR or camera could be fooled into turning off the lights in the situation of a person falling asleep in a chair and hardly moving. A radar sensor can see the chest movement of breathing and know that there really is someone still present.

Adding health monitoring features

The amazing sensitivity of a radar sensor enables smart speakers to have new features for health monitoring. This is an exciting new area that address the growing awareness of the importance of health monitoring as can be seen by fitness trackers and the features built into smart watches such as exercise, sleep and heart monitoring.

Thanks to a radar sensor's sensitivity, which can even detect a pulse in a wrist, there are now many health monitoring opportunities that can be designed into a smart speaker with a radar sensor to add user value with hardly any impact on the system costs as these are all in software.

People know that a good night's sleep is vital to health and there are several ways to monitor this such as wearing a smart watch at night but when are you going to charge it? Having your smartphone resting on the mattress to detect movement is another method but that just shows how much you move at night which is not really a good measure of quality of sleep. And totally fails when there are two people in the bed! The radar sensor can detect the breathing and the heart rate which gives a very good indication of the quality of nocturnal rest and the various types such as awake, light sleep and deep sleep. Thanks to the radar sensor's multi-target tracking ability, the two targets can be separated as well as the sleep quality of each person tracked.

Other health-monitoring, value adds of a radar-enabled smart speaker include fall detection, unobtrusive monitoring of elderly people who unexpectedly change their daily routines so that they can be checked in case of a problem, monitoring of respiration rate, irregularities in heart rate patterns as an early warning of a possible problem, and even coughing or snoring. All of which can be done automatically eliminating the problem when the elderly person forgets to wear the monitoring device. These features could also be used to design a really intelligent baby monitor that keeps a watchful 'eye' open all night that the baby is alright as well as the usual 'listening' of standard baby monitoring.

Summary

Adding a radar sensor to your next smart speaker design not only adds a wealth of new features to differentiate your product but also makes it 'greener' by reducing power consumption of the speaker itself and the devices it controls to become a significantly important way to cut energy usage in homes and offices.

According to Statista, there will be more than 500 million smart homes worldwide by 2025. Rather than all these additional devices increasing the world's demand of energy, by making them really smarter and implementing presence detection, they can actually cut energy demand by turning themselves and associated devices straight into deep, energy-saving mode when no-one is present with just the radar sensor in sentinel mode with its tiny power need of only a few mW. The regular standby mode of many electronic devices can be quite significant and by dropping them into deep sleep mode waiting to be awoken by the smart speaker could save a country the output of one or more power stations!

So, when designing your next smart speaker, it is important to have a trusted supplier that understands this application area with products that have been optimised for use in it along with system knowledge and partners to assist with design to ensure low risk, fast time to market.

This is vital not only for your first model to make it stand out in this increasingly crowded marketplace but also for your subsequent designs where Infineon's expert knowledge of new use cases and what new features can be added is crucially important to differentiate your products and gain market share.

Further information on Infineon's comprehensive range of solutions for smart speaker design can be found at:
www.infineon.com/smart-speaker