Get the Most out of UWB

When it comes to mobility, where something is and where it is going are among the most powerful pieces of information a system can have. That principle applies to vehicles on the road — but it also applies to the driver, the passengers and any vulnerable road users nearby, such as pedestrians and bicyclists.

Ultra-wideband (UWB) has emerged as a promising wireless technology for determining the locations of objects with precision in certain applications. The biggest game changer is the inclusion of UWB support in major smartphones, which allows a vehicle system to know the locations of the people carrying them.

As OEMs look to take advantage of this trend and include more UWB devices in their vehicles, optimizing those systems for cost and maximum effectiveness will be crucial — as will moving beyond using UWB simply for phone-as-a-key applications to enable a range of potential features.

LOCATION, LOCATION, LOCATION

UWB-enabled devices use frequent, low-power pulses of radio waves over a wide swath of the electromagnetic spectrum — a bandwidth of more than 500 MHz — to communicate with other UWB devices. In the early 2000s, companies considered UWB for data-transfer applications, mainly between consumer electronics devices, but performance was lower than initially expected.

However, it turns out that UWB excels in precision locating, which has made it very relevant to mobile devices.

A system could try to determine the distance of a device using other wireless technologies, such as Bluetooth or Wi-Fi, by looking at signal strength. But that approach has limitations. A poor signal does not necessarily mean that an object is far away; it could also mean that another object is causing interference. For example, the 2.4 GHz spectrum used by Bluetooth does not travel well through water and thus has trouble transmitting through a human body. As a result, such technologies would only be able to accurately determine range within a few meters.

In contrast, UWB looks at time of flight to determine the distance of an object — that is, it measures the time it takes for a signal to go from one device to another. Because it works over a wide band of frequencies, it avoids interference issues that might be associated with a particular narrow band.

When a vehicle has multiple UWB transceivers, it can use a localization algorithm to correlate data from them and determine the location of a nearby UWB device, with an accuracy of ±10 cm (4 in.) – and it can do so with a range of up to 300 m, depending on the power level used.

Other wireless technologies lack this kind of location precision or range. For example, phones use near-field communication to enable contactless payments, but the range is extremely short, at 4 cm. And GPS lacks precision — particularly if there is interference — with accuracy measured in meters.

PHONE AS A KEY

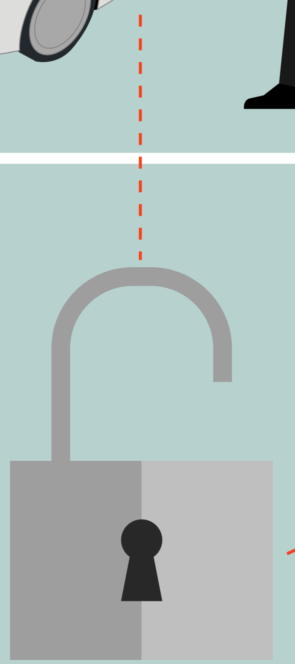
The first application for UWB in automotive is using a phone as a key to unlock a vehicle, since the latest smartphones now include UWB support. If a vehicle can see that a verified and linked phone is approaching it, the vehicle can potentially unlock the doors, start up and take other actions. This ability to recognize the approaching key before someone touches the door handle eliminates the “wall effect” of other wireless technologies, where the system is too slow to authenticate the key and unlock the door — resulting in the user having to pull on a handle multiple times to open the door, as if there were a wall obstructing access.

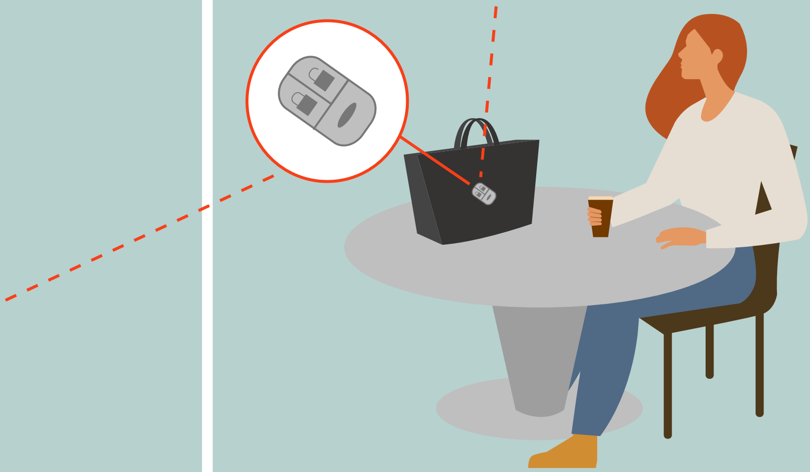
Today’s key fobs often use low-frequency (LF) radio transmissions. In addition to lacking the precision location capabilities of UWB, the LF technology in those fobs has a range of just 1 or 2 meters, or up to 8 meters in some cases – although it can determine if a fob is inside or outside of a vehicle with an accuracy of ±10 cm, in keeping with standards set by Thatcham Research.

The primary drawback of LF, however, is that it is less secure. Car thieves can use a man-in-the-middle attack to compromise LF-based keyless entry systems (see diagram). If the thieves can get between the vehicle and its owner, they can use specialized equipment to relay the signal from the vehicle to the key fob to fool the vehicle into thinking the fob is next to it and unlock the doors.

1 A thief stands close to the vehicle and uses a device to transmit signals to another thief.

2 The second thief gets as close to the key fob as possible with another device.





4 The vehicle, detecting the signal from the first thief's device, unlocks the door.

3 The second thief transmits the signal from the fob to the first thief's device.

UWB's approach of using time of flight to measure distance helps protect the system from this kind of attack, given that it would be much more difficult for the attacker to mimic a response.

The momentum behind phone-as-a-key functionality is impressive. Modern smartphones are already on board with the technology: UWB appeared in the Apple iPhone 11 in 2019 and in the Samsung Galaxy S21 in 2021. Meanwhile, the Car Connectivity Consortium is establishing standards for the future of vehicle-to-smartphone connectivity, including its Digital Key specification for ensuring interoperability among phone-as-a-key implementations based on UWB. The group has brought together dozens of companies, including many OEMs; suppliers such as Aptiv; and Apple, Samsung and seven other phone manufacturers.

Phone-as-a-key technology enables interesting features. For example, since it can detect when an authorized phone is approaching a vehicle, OEMs could design their vehicles to respond to the approach with personalized welcome lighting or sounds.

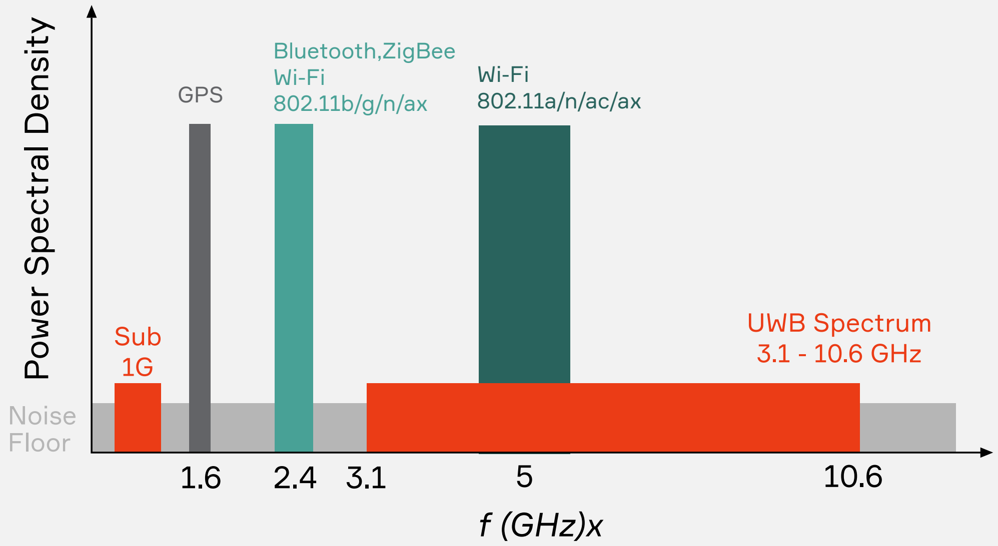
It also enables virtual key sharing. For example, a driver could send a virtual key to a friend's smartphone, allowing that friend to unlock the vehicle for a period of time. Likewise, a car rental company could send a virtual key to a customer's smartphone instead of providing a physical key fob.

OPTIMIZING UWB DEPLOYMENT

Adding UWB capabilities to vehicles will take careful planning to ensure the best performance at the lowest cost. The primary challenge is in the number of UWB nodes required, particularly as OEMs struggle to find available space within today's vehicles, which are already jam-packed with electronic devices, sensors, actuators and much more.

LOW AND WIDE

UWB uses low-power transmissions over a very wide band of wireless spectrum.



There must be three UWB nodes on the vehicle to determine the position of an approaching smartphone, and a vehicle will often have eight to 12 nodes to cover all angles around the vehicle and also locate a device within the vehicle itself. A typical node is fairly compact in size, but it requires power and data lines to function.

One way to solve the space problem is to up-integrate the UWB nodes into equipment that will already be on the vehicle. For example, Aptiv has patented technology that combines corner radars with UWB nodes; this has the potential to consolidate at least four of the nodes with radar sensors that will be on the vehicle anyway.

Another approach is to optimize the locations of the UWB nodes that are used. Aptiv is developing sophisticated algorithms, based on simulations at the vehicle level, to determine the places that UWB nodes could be placed in the vehicle for maximum effect. For example, an OEM might identify many available locations, and simulations could help designers figure out which combination of locations would provide the most robust coverage.

Along with improved localization algorithms in the UWB nodes themselves, this approach could result in one or more nodes being identified as unnecessary and thus eliminated from the design, saving cost and weight.

MORE TO COME

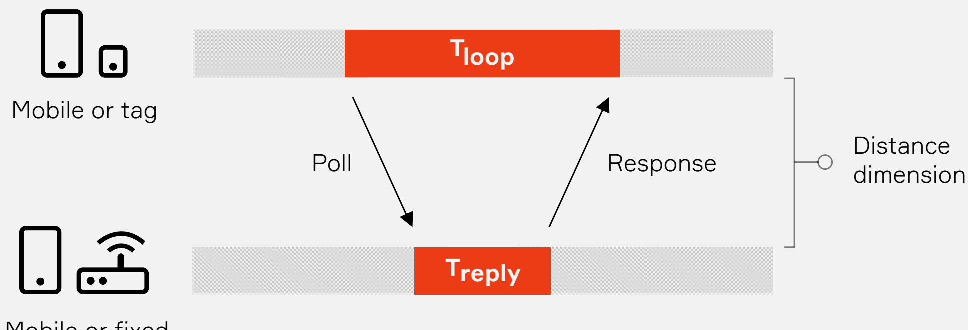
Once a vehicle is equipped with UWB sensors, many new capabilities are possible beyond phone-as-a-key functionality. These capabilities stem from knowing several pieces of information with precision: where a phone is, whose phone it is, how that phone is moving, and the location of other UWB transceivers in relation to the vehicle.

Opening a liftgate

A vehicle could use UWB as a mechanism to enable opening a liftgate. The vehicle could detect that an authorized user was standing behind the vehicle, and if the user moved in a predetermined way (perhaps by taking a step toward the liftgate, and then away again), that would signal to the vehicle that the liftgate should open.

DISTANCE DETERMINATION

UWB devices determine the distance to another device by measuring the time it takes for a poll and response to travel to that device.



$$\text{Time of flight} = \frac{T_{loop} - T_{reply}}{2}$$

Identifying the driver

When a driver was inside the vehicle, the system would be able to detect that the person's phone was in the driver's seat or in the console next to it. It could then communicate to the phone that its owner was likely driving the vehicle, and the phone could enter a driver mode that would limit distractions. In contrast, the passengers' phones in the vehicle would be in different locations; the system would detect that as well and could let the phones know that their owners were not driving. This could help prevent phones from entering driver mode based simply on their velocity.

Locating vulnerable road users

Using UWB with phones that are not known to the vehicle could be useful too. While a vehicle was being driven, UWB could detect the exact location of phones in the pockets of bicyclists or pedestrians nearby, providing that information to the advanced driver-assistance system. The system could use the data as an input to its sensor fusion capability, comparing it with radar scans and camera images.

Assisting with parking

Vehicles would be able to communicate with UWB transceivers that were not in phones as well, which opens up some interesting possibilities. For example, if a parking garage placed UWB nodes along its walls, those nodes could let the vehicle know with precision where it was within the garage, enabling more precise automated parking. A driver could pull up to the entrance, get out, and let the vehicle communicate with the garage computer to identify an available space and drive to it. An automated system using UWB could potentially allow vehicles to park very close to one another — say, within 30 cm, too narrow to open a door — and maximize use of space in the garage.

Aligning with wireless charging stations

Likewise, UWB could help with localization when it comes to wireless charging stations for electric vehicles. With wireless stations, the vehicle has to be positioned just right to ensure that it is well aligned with the station to get the most efficient charging rate. If the station were equipped with UWB, an automated vehicle could ensure that it pulled up to the station in exactly the right spot.

GAME CHANGER

Engineers have really just scratched the surface when it comes to the best use cases for UWB. But with the technology becoming ubiquitous in the smartphones that nearly everyone carries, the time is right for OEMs to optimize their vehicle architectures to incorporate UWB and to develop innovations that take advantage of the technology in ways that will make people's lives easier.

ABOUT THE AUTHOR

Todd P. Oman
Global Innovation & Continuous Improvement Methodologies Manager,
Advanced Engineering

Todd Oman drives innovation, optimized designs and continuous improvement using a range of tools acquired with Master Black Belts in Six Sigma and Design for Six Sigma. Todd began his career in 1981 with the organization that would become Aptiv, rising through several roles in semiconductor product development, test development and manufacturing engineering. In his role in advanced engineering, he has designed technologies for packaging high-power semiconductor devices, developed product concepts for vehicle access, and led Aptiv's Connectivity & Security business pursuits for North America. His work has led to 23 patents and several pending. Todd has served as vice president of technical programs for the Indiana chapter of the Surface Mount Technology Association.

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