Automotive Manufacturing Testing for Ultra-wideband (UWB) Digital Key

Overview

Passive Keyless Entry (PKE) and Passive Entry Passive Start (PEPS) systems allow drivers to unlock their car and start it without having to ever physically get the key out of their pocket. Due to their popularity, these systems have expanded from the luxury car segment to becoming an expected feature equipped in all new cars. However, relay attacks have shown the vulnerabilities of the technologies used in today's PKE systems. Car thieves can hack them by using relatively inexpensive and readily available tools.

The CCC (Connectivity Car Consortium) for the Digital Key 3.0 standard has adopted a combination of Bluetooth Low Energy, UWB and NFC technologies to power the next generation PKE and PEPS systems. This decision makes sense, as UWB brings both high accuracy location awareness and the level of security needed to prevent malicious attacks. Beyond keyless entry, new use cases will be unlocked as phone manufacturers start embedding this technology into their next generation phones. New applications like key sharing or key transfer for car sharing, car rental, or corporate fleets will become possible and secure.

Why UWB?

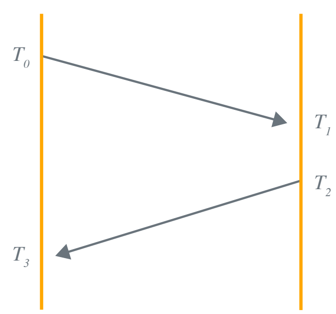
UWB combines high accuracy positioning (achieving centimeter level accuracy) and security, and therefore is the technology of choice for future PKE and PEPS applications. Based on the IEEE 802.15.4z standard, UWB uses a distance measurement technique called Time-of-Flight (ToF). As its name indicates, this method uses the RF signal's travel time between devices to measure distance. Angle of Arrival (AoA) adds another layer of spatial awareness by determining the direction of arrival of the signal. Compared to other technologies relying on measured signal strength to evaluate distance, UWB provides a higher degree of accuracy and security.

Accuracy

The UWB communication consists of a message exchange between the UWB Keyfob (also called Tag) and the UWB Anchor on-board the car. The Time-of-Flight measurement uses specific fields in the UWB messages as timestamps to calculate distance. UWB uses very short pulses (in the order of nanoseconds) of low-energy signal with a wide bandwidth (> 500 MHz). The large channel bandwidth and short pulse make this technology very robust in a multipath environment with sources of interference from reflection or refraction, compared to narrowband signals. Additionally, UWB operates over a wide frequency range (3.1 to 10.6 GHz) and therefore can select operation on a channel away from interferences created by Bluetooth or Wi-Fi systems co-located in the car.

Security

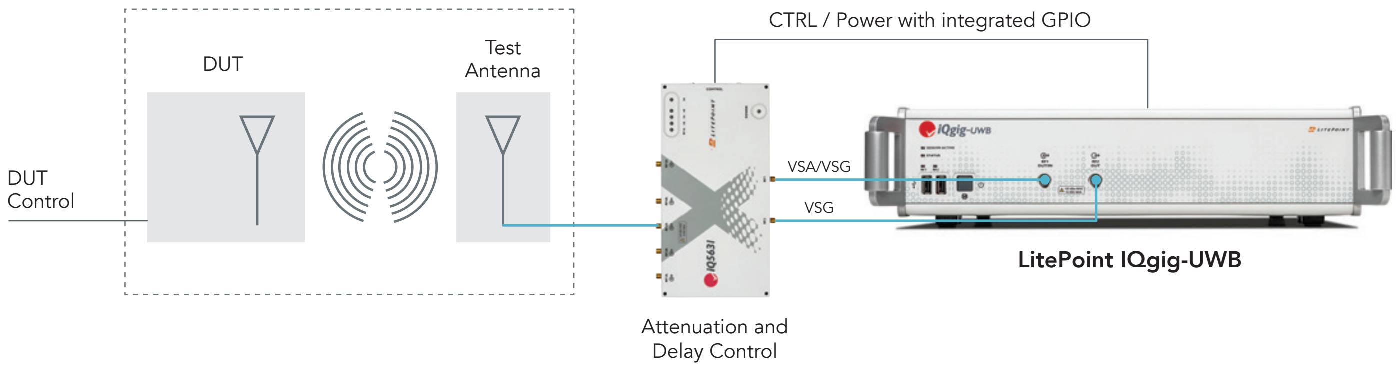
PKE technologies relying on measurement of signal strength to evaluate distance can be easily subjected to relay/man-in-the-middle attacks, where the communication from the valid key is spoofed by amplifying its signal strength and tricking the receiver into believing that the key is nearby. UWB is natively immune to these type of attacks, because its distance measurement is based on time. A relay/replay attack will add latency to the message transmission and therefore would achieve the opposite effect, by indicating that the key is further away from the receiver. The IEEE 802.15.4z standard further adds a layer of security by using a scrambled timestamp sequence (STS) at the PHY layer. It adds a cryptographic timestamp to ensure protection from decoding or manipulation by 3rd parties.



$$T_2 - T_1 = Reply$$
$$T_3 - T_0 = RTT$$
$$ToF = \frac{RTT - Reply}{2}$$
$$Distance = ToF * speed\ of\ light$$

Manufacturing testing of UWB

UWB technology brings new challenges to the manufacturing environment. Validation of DUT performance encompasses traditional power and frequency transmitter and receiver tests, and additionally brings a new dimension with the need to calibrate and measure delay. **A ± 100 ps error in ToF measurement results in ± 3 cm position accuracy. DUT calibration and validation on the manufacturing line is critical to ensure consistent device-to-device performance and ultimately guarantee the end customer experience.** Therefore, the test solution needs to deliver a ToF measurement mechanism with a precision that is an order of magnitude better than the DUT to ensure accuracy. **LitePoint's UWB solution is the first purpose-build UWB tester that can ensure a high-accuracy trigger mechanism for ToF validation with picosecond level precision.** The following section describes the key areas for complete coverage during manufacturing testing of UWB Keyfobs and Anchors located in a car.



Crystal Calibration (CFO Offset Calibration)

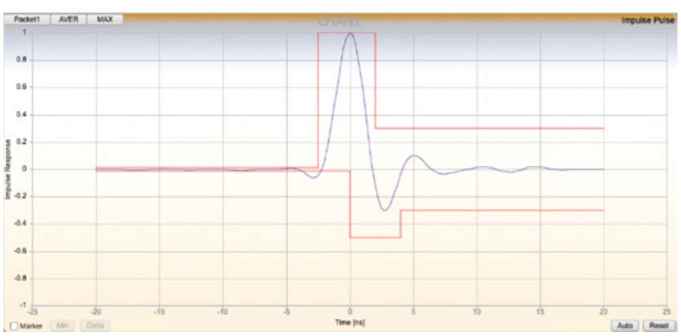
Crystal calibration is generally the first step performed in manufacturing testing. This calibration trims the crystal tuning capacitors and reduce the crystal's initial frequency offset error to within a few ppm from the tester's reference clock. This step is critical to ensure ToF accuracy and improves receiver sensitivity by minimizing CFO error. Crystal calibration requires a high performance tester clock reference.

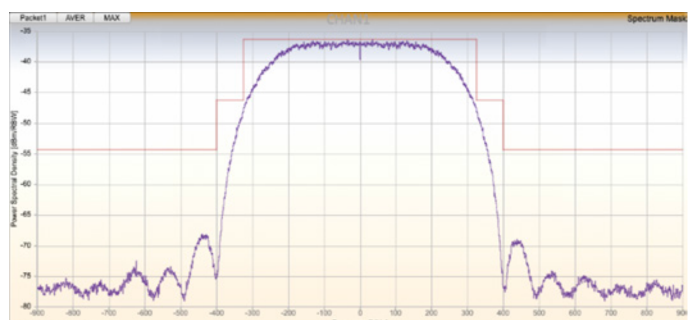
Transmitter Power Calibration

UWB is regulated to transmit at a very low power level. The FCC sets the limit at -41.3 dBm/MHz radiated power (RMS). TX power calibration ensures compliance to FCC limits or other regulatory domains. To achieve the highest range performance, this optimization ensures that the DUT gain can be maximized while still remaining compliant with regulatory limits and account for device-to-device variations. This calibration requires the tester to support 500 MHz to 1 GHz of bandwidth.

Transmitter Testing

Transmitter verification uses the previously calibrated DUT's TX signal to verify modulation quality metrics and spectral emissions conformance. It provides metrics that can be used to detect manufacturing defects, such as component or soldering errors, as well as limit issues due to component tolerances. For ensuring interoperability and performance, metrics and limits related to UWB pulse shape and different pulse parameters are defined in IEEE 802.15.4z or can be industry consortium specific.





Receiver Testing

Packet Error Rate (PER) testing is performed to ensure that a minimum sensitivity level is met for the different data rates. Typically, limits are set in such a way to guarantee that the DUT will achieve less than 1% PER at a specific received input signal. This test can be done with a power sweep or at a fixed minimal level to guarantee performance.

Antenna Delay (ToF) Calibration and Verification

RF front-end, antenna delay and device-to-device variations are the largest factors influencing the accuracy of the ToF mechanism and ultimately the device's ranging accuracy. Automotive applications require a high level of accuracy (± 10 cm) and therefore calibration of the ToF delay needs to be conducted on each DUT. A calibrated setup with a tester capable to run two-way ranging in keyfob and anchor mode with a high accuracy should be used to provide the best calibration and verification.

The LitePoint Advantage

While still an emerging technology, UWB is now transitioning from the lab to volume production. **Car and electronic automotive manufacturers are ramping up UWB for their next generation PKE and PEPS systems and they are faced with the need to find a test solution that can evolve from DVT to the manufacturing floor while providing the test coverage and reliability required for the automotive industry.**

As a solution provider, LitePoint has been working with the leading UWB chipset providers to develop a reference test platform that is purpose-build for UWB testing. LitePoint's IQgig-UWB™ is a complete RF PHY test solution with all signal generation, analysis, and processing contained in a single, robust instrument. The integrated VSG and VSA enable comprehensive transmitter and receiver testing with close to 2 GHz instantaneous signal bandwidth. IQgig-UWB has a precision trigger and response mechanism to enable accurate Time-of-Flight measurements with picosecond level precision, and combines with the IQ5631 Power and Delay Control Module (PDCM) to enable receiver sensitivity testing below -100 dBm and AoA testing with up to 80 ps configurable delay.

Working with the leading UWB chip manufacturers, LitePoint provides turnkey solutions that integrates optimized test and calibration routines. With Integrated DUT and tester control IQfact+™ application software provides quick and reliable results for both calibration and verification.

For more information on LitePoint's UWB test solutions visit the following pages:

https://www.litepoint.com/products/iqgig-uwb/
https://www.litepoint.com/uwb/

For more information on LitePoint's Bluetooth LE test solutions visit the following pages:

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