IR-UWB for Precise Ranging and Localization

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The appearance of UWB radios in mobile devices developed by the world's leading manufacturers has opened the door to new applications and business opportunities. CSEM and 3db Access have worked together for more than 7 years on the development of UWB technology for the automotive industry and are now working on a front-end IP that will provide widespread connectivity and compatibility with mobile devices, while assuring state-of-the-art efficiency and low power performance that maximizes the autonomy of battery powered devices.

Ultra-wideband technology (UWB), although present for several decades, came back into focus in the past year. This sudden rise of popularity was fueled by the announcements made by Apple and Samsung that impulse radio (IR) UWB devices will be used in their new smartphones. The key feature of IR-UWB is the capability to provide highly precise distance measurements that could otherwise not be attained with radios commonly found in mobile devices, such as WiFi or Bluetooth. At the moment it is the only technology that can provide secure access (for cars or smart doors and mobile transactions) and enables applications such as personnel tracking in warehouses, augmented reality, or various healthcare and medical applications.

The centimeter-level precision is enabled by extremely short pulses, in the order of 2 ns long, that provide a very fine resolution in time or equivalently, but also result in very large transmitter signal bandwidth (> 500 MHz). The IEEE 802.15.4z standard, released in August 2020, introduced several enhancements to the PHY layer targeting the improvements of integrity, accuracy and security. Two UWB standards are defined today:

- Low-rate pulse UWB PHY (LRP)
- High-rate pulse UWB PHY (HRP)

The HRP is generally more complex and power-hungry but promises higher data-rates and better precision. As such it was adopted for widespread use in smartphones. The high complexity of the HRP is a consequence of the short time between consecutive pulses, which results in inter-pulse interference (IPI) in environments with strong multi-path propagation. Battling the IPI requires heavy digital signal processing and use of specific codes that result in a silicon area that is more than 5 times larger than for similar LRP radios. With the 4 MHz maximum pulse rate of the LRP, typical delay spread of indoor and outdoor channels is shorter than the time between pulses, effectively eliminating the IPI problem and allowing for a significant reduction of power. As a result, the LRP is much more suited for battery powered devices like wearables, key fobs and trackers.

The 7 years long collaboration between CSEM and 3db Access resulted in the first industrial LRP UWB solution that operates in the 6-9 GHz band. The 3DB6830 is currently on the market, integrated in products for secure keyless car access. It achieves 10-15 times lower peak power consumption than similar HRP solutions from competitors. At the same time, it achieves a link budget of more than 90 dB, assuring a minimum range of 120 m in line-of-sight scenarios and guarantees a precision better than 10 cm [1]. Other existing solutions either consume an order of magnitude more power for the similar performance, or they can only achieve a link budget of less than 80 dB.

Recently, the HRP has been selected as the new standard for devices integrated in smartphones. The choice was made based on the expected performance of HRP and knowing that power consumption is not a limiting factor. To address the new market, collaboration between CSEM and 3db continues through an Innosuisse-supported project. The aim of the project is to develop a novel, dual-mode HRP and LRP compatible solution that provides widespread connectivity to commercial devices, together with long autonomy and secure ranging.

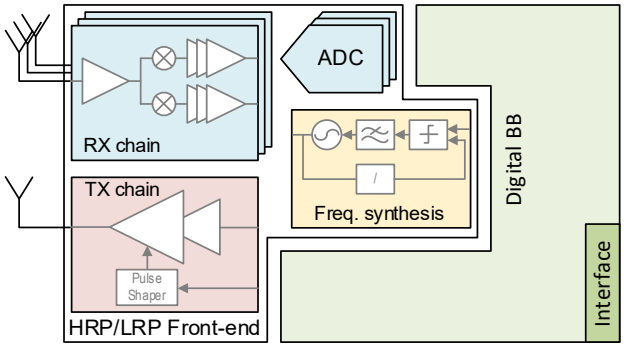

Figure 1: Next generation UWB radio.

The new LRP and HRP compatible RF analog front-end, co-developed by CSEM and 3db, will support different modulations (BPSK, FSK, PPM), channel frequencies, data-rates, and pulse durations. CSEM designed the fast frequency synthesizer, which covers the entire 6-9 GHz band, supports fast frequency switching for the LRP FSK, and provides a coherent, low phase noise carrier signal for the HRP BPSK modulation. The transmitter itself must be able to accommodate a wide range of output power levels, to conform to spectrum limitations and provide a maximum link budget for different pulse rates. A fully integrated solution is targeted, with the quartz crystal and decoupling capacitors being the only needed external components, further reducing the bill of materials, and lowering the price of the product. Integrated, distributed power management will help reduce on-chip coupling and improve performance and consumption of the final product. The TSMC 22 nm technology node has been selected for implementation. The choice is driven by price, reliability as well as performance of the logic circuits needed for the complex combined LRP/HRP digital baseband. To provide support for direction finding and angle of arrival, the future UWB transceiver will contain two or more independent receiver chains. In this way, the targeted transceiver will cover a full range of future applications, while assuring compatibility with a large number of devices.

[1] D. Barras, "Indoor Localization using IR-UWB," CSEM Scientific and Technical Report (2016) 122.