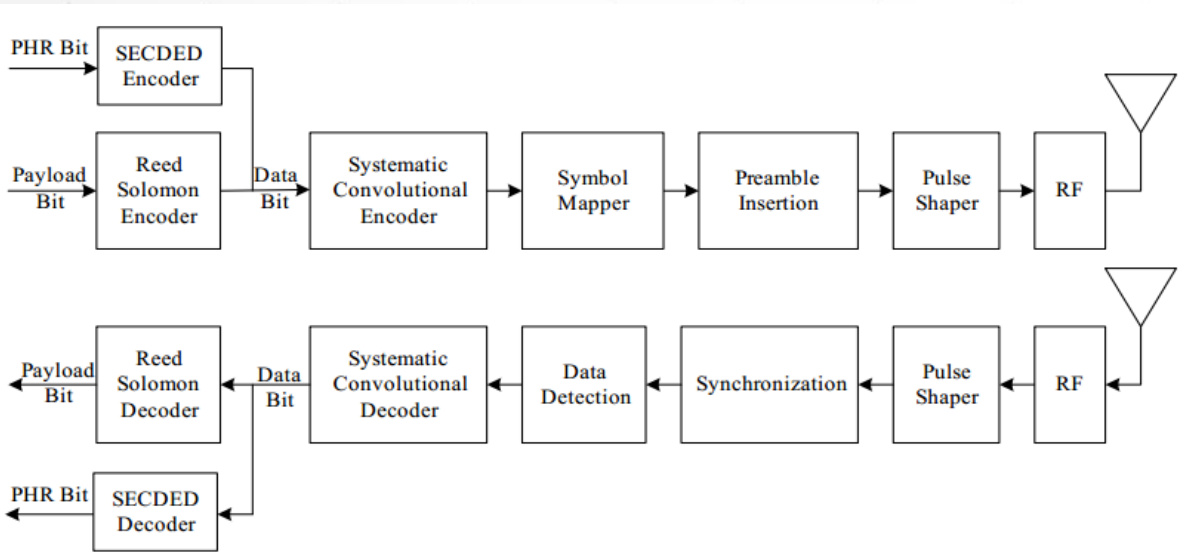
IEEE 802.15.4 HRP UWB PHY Waveform Creation

1. Overview

IEEE 802.15.4-2015 defined the HRP (High Rate Pulse Repetition Frequency) UWB (Ultra-wide Band) PHY (Physical Layer) with the feature of precision ranging, which can be employed in a **low-rate wireless personal area network** (**LR-WPAN**). The main objectives of a LR-WPAN are **ease of installation**, **reliable data transfer**, **extremely low cost**, and **a reasonable battery life**, while maintaining **a simple and flexible protocol**.

The HRP UWB PHY waveform generated from ***Keysight Signal Studio for IoT*** can be utilized to test UWB devices of users, such as the U1 chip in iPhone 11. The test solutions include **PER (Packet Error Rate), TOF (Time of Flight)** and **AOA (Angle of Arrival)** measurement and verification.

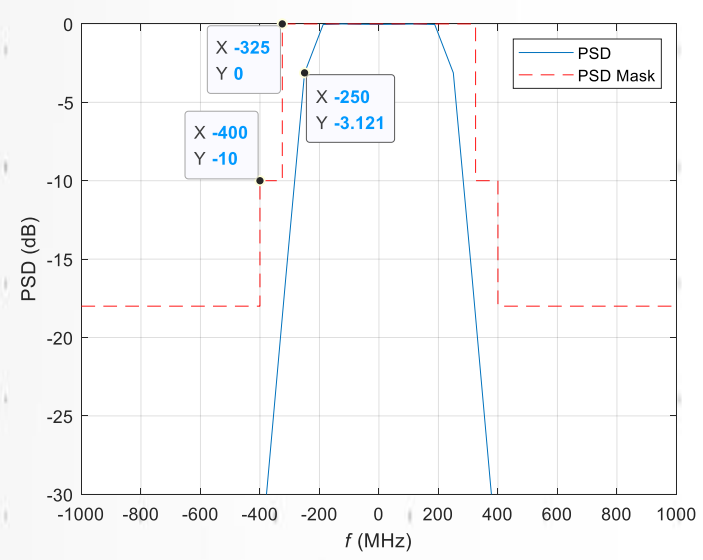
2. Signal Flow and Pulse Shape Design

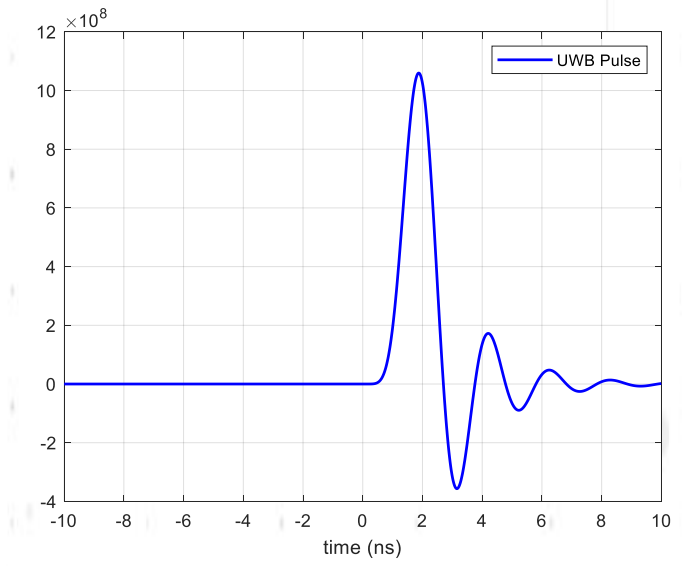


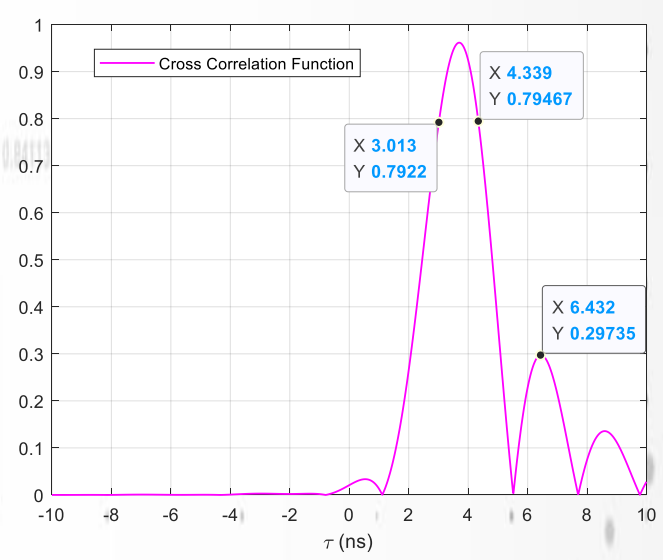
HRP UWB PHY Signal Flow

The signal formats of HRP UWB PHY and HRP-ERDEV (Enhanced Ranging Device) PHY are respectively defined in IEEE 802.15.4-2015 and IEEE 802.15.4z (Draft 2019).

But the design of **the pulse shape** is open to developers. To meet the **PSD (Power Spectral Density) mas**k and **Cross-correlation mask**, the **8 order Butterworth pulse** is designed as follows.







8 order Butterworth pulse with the cutoff frequency of 500MHz

$$\boldsymbol{p(x) = 2\varepsilon(t)\Omega_c \sum_{k=0}^{3} e^{a_{p_k} t}(a_{k_k} cosb_{p_k} t - b_{k_k} sinb_{p_k} t)}$$

Where, $\Omega_c = 2\pi f_c$

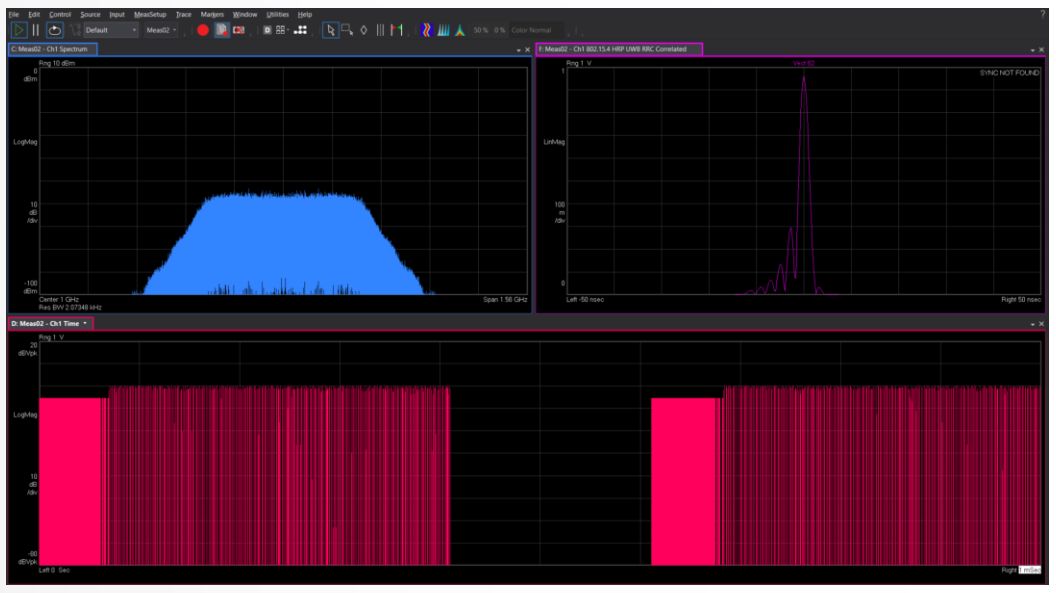
$$\{a_{p_k}\} = \Omega_c\{cos\frac{9}{16}\pi, cos\frac{11}{16}\pi, cos\frac{13}{16}\pi, cos\frac{15}{16}\pi\}$$
$$= \Omega_c\{-0.1951 \quad -0.5556 \quad -0.8315 \quad -0.9808\}$$

$$\{b_{p_k}\} = \Omega_c\{sin\frac{9}{16}\pi, sin\frac{11}{16}\pi, \ sin\frac{13}{16}\pi, sin\frac{15}{16}\pi\}$$
$$= \Omega_c\{0.9808 \quad 0.8315 \quad 0.5556 \quad 0.1951\}$$

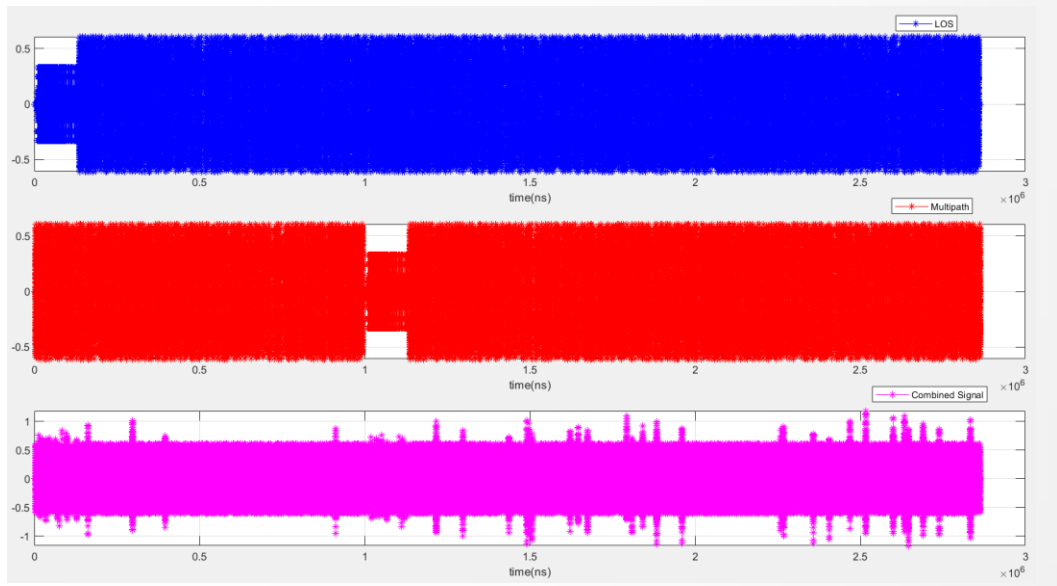
$$\{a_{k_k}\} = \{0.2940, \quad 0.3468, \ -4.2087, \quad 3.5679\}$$

$$\{b_{k_k}\} = \{-0.1964, 1.7433, \ -0.8372, \ -5.3398\}$$

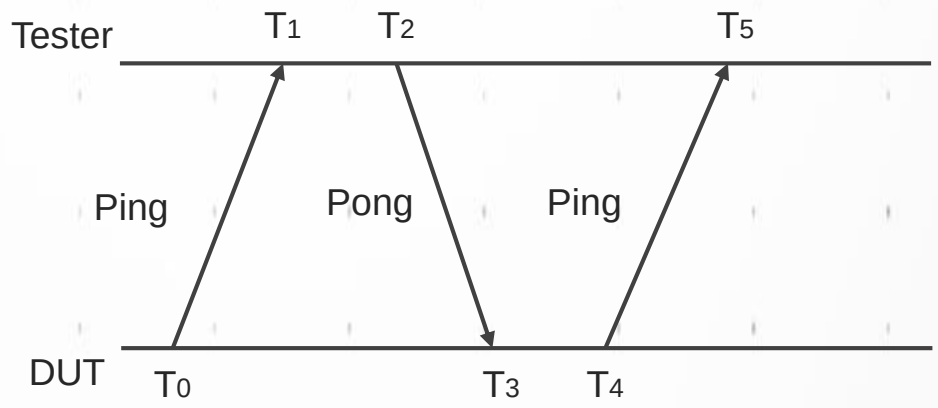
3. UWB Test Solutions



Waveform Generation and PER Measurements



Multipath Measurements



$$\frac{(T_3-T_0)(T_5-T_2)-(T_2-T_1)(T_4-T_2)}{T_4+T_5-T_0-T_1}$$

TOF Measurements and Verification Combined with E7760A Wideband Transceiver (In Progress)

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