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**Wireless Personal Area Networks**

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# ANNEX I Ranging for TVWS WPAN PHYs

1. Introduction

This annex describes a ranging mechanism for TVWS WPAN standard. The geo-location requirements for TVWS specify that accuracy of a geo-location capability to determine its geographical coordinates is +/- 50 meters for Mode II fixed and personal/portable devices. Mode I device may also require location capability. In order to incorporate these requirements, exploiting GPS receiver for TBVDs will be a solution. However, GPS is not 100 % available such as indoors, urban canyons and GPS jamming/spoofing attack environments. Moreover, battery-powered Mode I devices may not equip with GPS receiver. Therefore, it is well motivated to provide optional RF localization in TVWS WPAN standard.

1. General

The ranging mechanism for TVWS WPAN PHYs is basically same as that of UWB PHY, shown in Annex E of IEEE Std 802.15.4-2011. Similar to UWB PHY, A TVWS WPAN frame with the ranging bit set in the PHR is called a ranging frame (RFRAME). The critical instant in this RFRAME is the start of PHR for both FSK and OFDM PHYs, called as the ranging marker (RMARKER). In the two-way ranging technique, ranging counter values in the ranging originator are captured upon RMARKER departure and arrival, while ranging counter values at the ranging responder are captured upon RMARKER arrival and departure. In this ranging counter operation, the exact timing of RMARKER for any RFRAME transmission can be easily achieved. However, the timing of RMARKER arrival at the receiver that determines the ranging performance is susceptible to noise, signal bandwidth, and operation clock. As a result, a main issue in TVWS WPAN based ranging is how to obtain the accurate arrival time of FSK and OFDM signals.

The technique for achieving this signal arrival time is beyond the scope of this standard, but it is helpful to discuss a typical approach for TVWS WPAN PHYs, e.g., FSK and OFDM PHYs. In the following, the time of arrival (ToA) estimation for OFDM PHY and the symbol transition timing (STT) estimation for FSK PHY are briefly described.

1. ToA Estimation for OFDM PHY

The conventional autocorrelation-based schemes can be used for ToA estimation in OFDM PHY since the STF and LTF sequences in SHR show a good autocorrelation property.

1. STT Estimation for FSK PHY

Generally, the FSK system has not been used for accurate ranging due to its narrowband characteristics. However, the accuracy of +/- 50 meters in TVWS enables FSK-based ranging to assist a geo-location capability of TVBDs. Different from the UWB and OFDM PHYs that exploit a correlation property of preamble sequence, the timing of RMARKER arrival in FSK system can be obtained from STT estimation during preamble, whose sequence is multiple repetitions of “01010101.”

One of approaches for STT estimation is to use the phase difference vector of the received FSK signal. The phase of FSK signal is increasing and decreasing according to time and experiences changeover at every symbol duration during preamble. Therefore, the phase difference vector between the received signal and its delayed signal shows phase transition, from which symbol transition time can be estimated. Since the TVWS WPAN FSK PHY allows the applications to specify preambles 4-1000 long, large number of preambles involved in STT estimation enables ranging performance enhancement due to suppressed noise.