**IEEE P802.15**

**Wireless Personal Area Networks**

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# ANNEX S

# Ranging considerations for operation in TVWS

1. Introduction

This annex describes a ranging mechanism for the TVWS WPAN standard. The geo-location requirements for TVWS specify that the accuracy of a geo-location capability to determine its geographical coordinates is +/- 50 meters for Mode II fixed and personal/portable devices. Mode I devices may also require location capability. It may be possible to provide a geo-location capability by incorporating a GPS receiver on a device. However, the GPS service may not always be available in some situations, such as when the receiver is inside a buildings or urban canyon, or is under attack through jamming or spoofing. Moreover, battery-powered Mode I devices may not be equipped with GPS receiver. Therefore, it is advisable to provide optional RF localization in TVWS WPAN standard.

1. General

The ranging mechanism for TVWS WPAN PHYs is basically the same as that of the UWB PHY, shown in Annex E of IEEE Std 802.15.4-2011. Similar to the 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 the PHR for both FSK and OFDM PHYs, known 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 determined. However, the timing of the RMARKER arrival at the receiver that determines the ranging performance is susceptible to noise, signal bandwidth, and clock frequency tolerance. As a result, a major 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 symbol transition timing (STT) estimation for the FSK PHY and the time of arrival (ToA) estimation for the OFDM PHY and are briefly described.

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 TV band devices. Unlike the UWB and OFDM PHYs that use a correlation property of the preamble sequence, the timing of the RMARKER arrival in an FSK system can be obtained from STT estimation during the preamble, whose sequence is multiple repetitions of “01010101.”

One approach for STT estimation is to use the phase difference vector of the received FSK signal. The phase of the FSK signal experiences inflection point at every symbol during preamble. Therefore, the phase difference vector between the received signal and its delayed signal shows a phase transition, from which the symbol transition time can be estimated. Since the TVWS WPAN FSK PHY allows applications to specify the variable length of preamble symbols, e. g., 4-1000 bytes, ranging performance can be enhanced by increasing the number of preamble symbols involved in STT estimation.

1. ToA Estimation for OFDM PHY

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