IEEE P802.22
Wireless RANs

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| Proposed resolution to comment no. 257: Part 2-Sensing methods for DVB-T |
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Abstract

This document presents spectrum sensing methods for TV signals of DVB-T Standard to partially resolve comment number 257 as listed in P802.22 D1 Sponsor Ballot Comments Database, IEEE 802.22-11-2r5.

**The Comment**

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No good sensing techniques seen for DVB-T, PAL, NTSC. We cannot neglect analog TVs, as those continue to be used in many countries.

Add easily implementable techniques for DVB-T, PAL, and NTSC. Actually, the energy detection method itself is not good enough in many cases. Modification may be needed to improve its performance. If needed, such contributions can be supplied from the commenter.

**Proposed Resolution:**

We propose the following text, equations and figures regarding DVB-T sensing be added in Annex C of P802.22 D1 to partially resolve the comment.

1. DVB-T Signal Specification

 The standard of DVB-T is developed by European Telecommunications Standards Union (ETSI) for the terrestrial broadcasting of digital TV. It is widely adopted by more than 30 countries.

The DVB-T uses orthogonal frequency division multiplexing (OFDM) modulation and is organized in frames. One DVB-T signal is a super frame consists of 4 consecutive frames, with each frame consisting of 68 OFDM symbols.

In DVB-T signals, some subcarriers, consists of around 10% of total subcarriers, are transmitted at a higher power by about 2.5dB compared to the other subcarriers. These boosted pilots include continual pilots (CP) and scatter pilots (SP). The CPs are placed at fixed sub-carrier locations and their locations do not vary from symbol to symbol, while the SPs are distributed at the positions if *k*-3×(*l* mod 4) (the operation ‘mod’ calculates the modulus after division) is divisible by 12, where *k* is the subcarrier location and *l* symbol number. In consequence, as shown in Fig.1, the pattern of boosted pilots (CPs and SPs) repeats every four OFDM symbols.

## The features of boosted pilot sub-carriers shown in the Fig.1 are exploited to achieve reliable detection of DVB-T signals. We generate a reference sequence by conducting inverse Fourier transform (IFFT) of a vector that is only composed of such pilot sub-carriers, defined as *sp*(t).

## The DVB-T signal is cycle with the period of 4*T* (*T*: one OFDM symbol duration). We then sample sp(t) over the 4*T*, as

 , n=0,1,…N-1 (1)

where 1/Tsp is the sampling rate.



1. Locations of scattered boosted sub-carriers in DVB-T OFDM symbols.

The horizontal axis represents the sub-carrier number (frequency) and the vertical axis represents the symbol number (time).

* 1. **Description of the sensing methods**

**1.2.1 Sensing method1: The improved cross correlation**

As shown in Fig.2, the sensing is achieved through following steps:

* + - 1. The received DVB-T signal that also contains noise is passed through RF front end and LNA;
			2. Above signal is sampled and converted to digital sequence (ADC);
			3. Frequency offset correction;
			4. Store above sequence in Buffer;
			5. Average the sequence for a cycle period (4*T*);
			6. Time offset correction;

The time offset correction finds the timing of the received DVB-T, i.e., same starting point of the DVB-T and the pilot sequence used as reference in latter step. Assuming the estimation result shows that the starting point locates between the *M*1-*th* sequence and the *M*2-*th* sequence (*M*2*≥M*1), i.e. range of Λ=[*M*1, *M*2], among the *N* DVB-T sequence of a cycle period (4*T*), a metric, *Γ*, is defined to express the time synchronization level, as

 . (2)

* + - 1. When the time synchronization level *Γ=*1*,* i.e. *M*1*=M*2, correlation is applied;

When the time synchronization level *Γ<*1*,* i.e. *M*2*>M*1, sliding correlation is applied over the window of [*M*1, *M*2], as

 , *m*= *M*1,…, *M*2 . (3)

where *x* is the DVB-T sequence, and find the maximum output among *M*2-*M*1+1 outputs.

the computation in (3) is called the selective sliding correlation here since the sliding window of [*M*1, *M*2] is selectively decided according to the achieved synchronization level in (2).

* + - 1. Compare either the correlation output or the peak selective correlation output with pre-decided threshold and judge presence/absence of TV signal: if the output is above the threshold, the presence of DVB-T signal is judged.



1. Simplified block diagram of the improved cross correlation.

**1.2.2 Sensing method2: The combined signal feature detection and energy detection.**

 As shown in Fig.3, the sensing is achieved through following steps:

* + - 1. The received DVB-T signal that also contains noise is passed through RF front end and LNA;
			2. Above signal is sampled and converted to digital sequence (ADC);
			3. Frequency offset correction;
			4. Store above sequence in Buffer;
			5. Average the sequence for a cycle period (4*T*);
			6. the received DVB-T sequences are firstly multiplied with the pilot sequence generated in (2) and then their absolute products are integrated, as:

 (4)

* + - 1. Conduct computation of (4) for multiple times for multiple cycle periods of DVB-T sequences, by shifting the receiving time by a random interval, *τ*, and calculates the average value, as:

 (5)

Subjects to

 (6)

* + - 1. Compare the output in (5) with pre-decided threshold and judge presence/absence of DVB-T signal: if the output is above the threshold, the presence of DVB-T signal is judged.



1. Simplified block diagram of the combined signal feature detection and energy detection.
	1. **Simulation results**

For description simplicity, in Figures 4-6 and Table 1, we use The Proposed\_Syn to represent the improved cross correlation and The Proposed\_Asyn to represent the combined signal feature detection and energy detection.

In following, we will investigate the sensing time for achieving

***The Sensing Goal*: *PD*≥0.9 and *PFA*=0.01 at SNR=-20dB.**

* + 1. **Simulation results:using the DVB-T signal generator (SG) output data as source data*: 2K* mode DVB-T*,* TCP=T/32 (TCP is the cyclic prefix duration)**

The Clean RF DVB-T signals (SNR>30dB) generated by the SG are directly (frequency) down converted and sampled, the samples are further processed in Matlab to achieve low SNR.

1. In a 8MHz channel centered at 718MHz ;
2. Ave\_num: Averaged DVB-T signal block (with duration of 4*T*) number

Figures 4-5 show the Probability of detection (*PD* vs. SNR and the receiver operating characteristic (ROC) curves of The Proposed\_Syn (The improved cross correlation). To achieve ***The Sensing Goal***, as shown in Fig.4, in AWGN, The Proposed\_Syn at *Γ*=0.975 requires Ave\_num≥1; as shown in Fig.5, in one-path Rayleigh fading channel, The Proposed\_Syn requires Ave\_num≥5 at *Γ*=0.975 and Ave\_num≥2 at *Γ*=1.0.

 Fig.6 shows that The Proposed\_Asyn achieves *The Sensing Goal* with Ave\_num=4 & *κ*=1 in AWGN, with Ave\_num=25 & *κ*=1 or with Ave\_num=1 & *κ*=12 in Rayleigh fading channel. The increase of one Ave\_num leads to increasing at least 4*T* of the sensing time, while increase of *κ* alone does not change the sensing time. Therefore, in our sensing system the sensing performance is improved by increasing *κ* while fixing Ave\_num=1.



1. Probabilityvs. SNR: The Proposed\_Syn, *PFA*=0.01.



1. ROC curve: The Proposed\_Syn in one-path Rayleigh fading channel, SNR=-20dB.



1. ROC curve: The Proposed\_Asyn, SNR=-20dB, *PFA*=0.01.
	* 1. **Simulation results: the hardware sensing prototype outputs are used as source data: 8K mode DVB-T, TCP=T/8**

The RF DVB-T signals generated by SG are tuned to -120dBm using attenuators and then input into the hardware sensing prototype through a cable. The outputs from the A/D convertor of the hardware sensing prototype are used as source data in the Matlab simulation. Since the noise level of the prototype is around -100dBm/8MHz, SNR of the source data is around -20dB.

The Fig.7 verifies that the sensing performance is improved by increasing the ***κ*** defined in (5) and that ***The Sensing Goal*** is achieved when ***κ***≥16.



1. *Probability of detection* vs. ***κ***: The Proposed\_Asyn, SNR≈-20dB, *PFA*=0.1, Ave\_num=1.
	* 1. **Sensing performance summary**

Table 1: The sensing time for achieving the ***The Sensing Goal*: *PD*≥0.9 and *PFA*=0.01 at SNR=-20dB**



**References:**

1. C. Song, M. A. Rahman, R. Funada and H. Harada, "Robust Spectrum Sensing of DVB-T Signals," IEICE Technical Report, SR2010-63, pp. 161-168, Oct. 29, 2010.
2. ETSI EN 300 744 V1.6 .1 (2009-01), "Digital video broadcasting (DVB) ; framing structure, channel coding and modulation for digital terrestri al television ," ETSI, Tech. Rep., 2009.