Analysis of DVB-T2 Signal for Exploitation by Passive Coherent Location System

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***Abstract*—The paper describes basic analysis and research of actual topics dedicated to exploitation of DVB-T2 transmitters by a Passive Coherent Location system (PCL system). The PCL system is based on bistatic radars. The target detection in bistatic radar is solved by computation of the Cross Ambiguity function. The paper focuses on description of structure and various parameters of the DVB-T2 signal and its influence on the shape of Cross Ambiguity Function.**

***Keywords*—passive radar system, bistatic radar, signal processing, DVB-T2, ambiguity function**

I. Introduction

The Passive Coherent Location system is a modern radar system based on the bistatic radars [1], [2], [3], [8]. The bistatic radar is a radar with separate receiver and transmitter parts. The principle of the bistatic radar is very well known since the period of the Second World War. History of bistatic radar is described in [5], [6]. The broader expansion of the bistatic radars, and radar systems based on them, come with development of the digital signal processor speed, advanced algorithm in signal processing area, and last but not least with parallel processing techniques in programming due to very high computation demands for real-time signal processing. The principle of the PCL systems is based on exploiting of the broadcast transmitters which already exist in the environment. The first PCL system exploit analog broadcast services as AM, FM or analog TV [6], [7]. The second generation of PCL systems was based on digitization of the broadcast services as DVB-T, and rarely GSM [9-13].

The DVB-T broadcast services will be, in the near future, replaced by a new generation of the broadcast services based on DVB-T2 standard that is very different in comparison to the previous DVB-T standard. The start of the DVB-T2 broadcast service is planned for 2020 in the Czech Republic. The current/future PCL system needs to reflect this new broadcasting standard. The topic about developing/an upgrade of the PCL system that exploits DVB-T2 transmitters, is very real. The detailed information about the principle of the PCL system, bistatic radars, scheme of the DVB-T signal and its influence on the target detection capabilities are published in papers [14], [15] and not will be further discussed.

The target detection on the PCL system is based on the computation of the Cross Ambiguity function (CA function). The CA function is defined in discrete form by formula

$$CAF(m,k) = \sum_{n=0}^{N-1} s_T^*[n] s_R[n+m] e^{\left(\frac{j2\pi kn}{N}\right)}, \qquad (1)$$

where $CAF(m,k)$ is output from the discrete CA function, m is time delay of the target, k is Doppler shift of the target, $s_T^*[n]$ is complex conjugate discrete direct path signal, $s_R[n+m]$ is time delayed discrete reflected signal, j is imaginary unit and N is total number of samples.

The maxima of the CA function should correspond with detected targets. The output parameters of the CA function do not correspond to the position in the Cartesian coordination system. But, the output corresponds to time delay and Doppler shift of the target. From the output parameters of the CA function, it is possible to compute position of targets in Cartesian coordinate system (from time delay) and speed of the target (from Doppler shift) by target association techniques [16], [17], [18].

The determination of influence of the DVB-T signal is possibly shown by computation of the ambiguity function. The ambiguity function is computed by the same formula as in (1) only, the reflected signal $s_R[n+m]$ is replaced by transmitted signal $s_T[n+m]$ (equivalent of autocorrelation function).

In the previous research, was found a strong influence of parameters of DVB-T signal on output shape of the ambiguity function. Output contains a lot of local maxima caused by parameters of the DVB-T signal (guard interval, different pilot carriers, number of symbols, etc.). The analysis is presented in [14], [15]. For the previous research a DVB-T generator was develop that strictly follow the norm ETSI EN 300 744 V1.6.1 [19]. Due to significant difference between DVB-T and DVB-T2 signal a new DVB-T2 generator will be developed for deep analysis that corresponds to norm ETSI EN 302 755 V1.4.1 [20]. The architecture of the generator will be modular and proceed from DVB-T2 block scheme. In the next chapter of paper, the DVB-T2 signal is briefly described. Due to increasing complexity of the DVB-T2 format we expect presence of the more maxima related to DVB-T2 signal.

The results show present only preliminary research. The detailed analysis will be part of future work that is described in chapter Conclusion.

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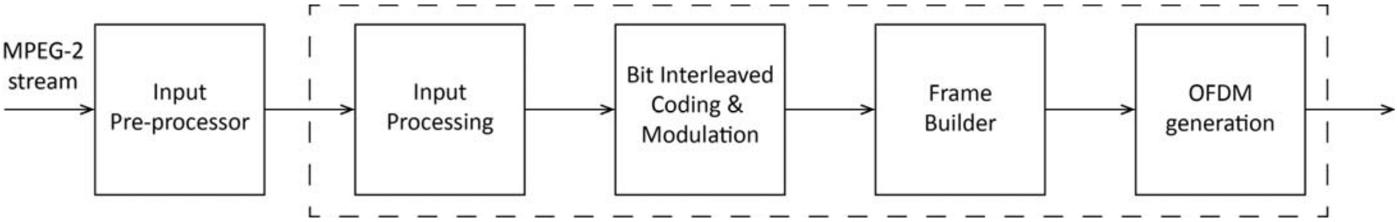

Fig. 1. Block scheme of the DVB-T2.

II. Analysis of DVB-T2 Signal

The DVB-T2 standard is described in norm ETSI EN 302 755, whose last version is 1.4.1 [20]. The base block diagram is shown in Fig.1. Each block presents a comprehensive part of DVB-T2 consisting of several other block diagrams that are all described in norm. This part of paper will be focused on a basic description of DVB-T2 signal generation, input parameters and parameters of DVB-T2 signal related to PCL signal processing. The input data is one or more MPEG-2 transport streams. The base structure of DVB-T2 data streams are based on packet data structure (data frames).

(1) Input pre-processor(s)

Input pre-processor(s) is not part of a T2 frame and may include conversion or de-multiplexer of MPEG-2 transport streams to streams suitable for the T2 frame.

(2) Input processing

Input processing is a block which contains several other parts corresponding to MPEG-2 input data preparation divided into data fields. Headers are put to individual data fields and corresponding CRC code for protection. The input processing includes: input interfaces, CRC-8 encoder, header insertion and scrambler. From the point of view of PCL processing, only “data rearrangement” does not have an influence the output of the CA function.

(3) Bit Interleaved Coding & Modulation (BIC&M)

Block scheme of BIC&M is shown in Fig. 2. BIC&M includes error protection coding (BCH and LDPC coding), bit interleaver which correspond to “randomization” of input data, “demux bits to cells” that split data to sub-streams. The number of sub-streams depends on used modulation. The grey part in Fig. 2 corresponds to mapping of cells for used modulation and subsequent rotation of constellation diagram (optional parameter). The used modulation in DVB-T2 are BPSK, DBPSK, QPSK, 16-QAM, 64-QAM, 256-QAM. Each modulation passes through normalization process.

For individual modulation type we used a different rotation angle and normalization factor. The summarization is shown in Tab. 1. f_q, z_q is a constellation point before and after normalization.

TABLE I. Type of Modulation in DVB-T2

Modulation type	**Rotation angle [°]**	**Usage**	**Normalization factor [-]**
BPSK	-	L1 part of symbol P2	$f_q = z_q$
DBPSK	-	P1 symbol	$f_q = z_q$
QPSK	29,0	Data	$f_q = z_q / \sqrt{2}$
16-QAM	16,8	Data	$f_q = z_q / \sqrt{10}$
64-QAM	8,6	Data	$f_q = z_q / \sqrt{42}$
256-QAM	atan(1/16)	Data	$f_q = z_q / \sqrt{170}$

(4) Frame builder

The base function of a frame builder is to assemble individual cells to final frames that are ready for OFDM generation. The DVB-T2 format uses different types of frames. The base frame is the T2 frame that include: P1 (signaling information), P2 (L1 and L2 part – extended signaling information), and data symbols. The number of P2 and data symbols is variable and depends on parameters as a guard interval (prevention against inter-symbol interference), and mode of DVB-T2 (1K up to 32K).

The number of T2 frames included in the so called super frame is also variable and information about the number is included in the P2 symbol. The maximum value of the super-frame is 63,75 s (included 255 of T2 frames). The length of the T2 frame is 250 ms.

(5) OFDM generation

The output from the frame builder is input for the OFDM generation module. The OFDM module add pilot carriers (or pilots) in frequency domain. The function of pilots is compensation of distortions in the transmission channel within the receiver.

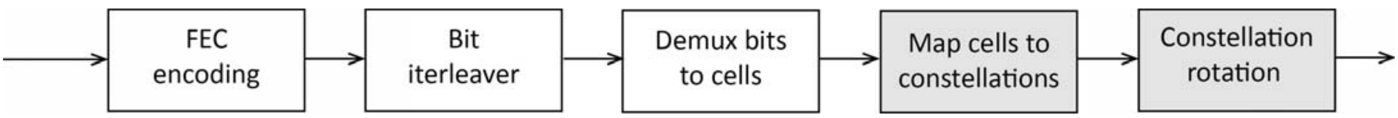

Fig. 2. Bit Interleaved Coding & Modulation.

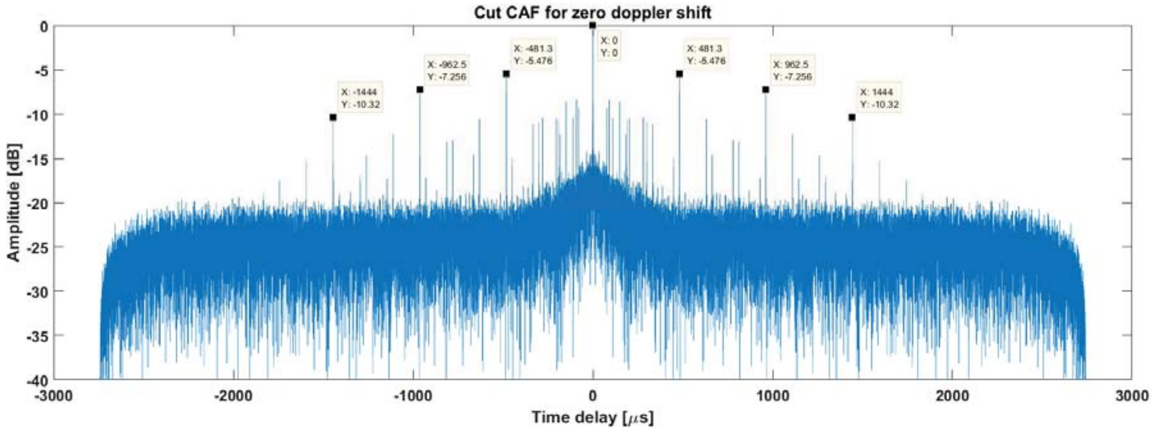

Fig. 3. Cut in ambiguity function in $f_d = 0\ [Hz]$.

In the DVB-T2 signal exist five different types of pilots:

- Scattered pilots
- Continual pilots
- Edge pilots
- P2 pilots
- Frame-closing pilots

The detailed information about pilots is described in norm [20].

III. Analysis of Cross Ambiguity Function of DVB-T2 Signal

The DVB-T2 signal is developed in the Matlab environment [21]. The input parameters of the DVB-T2 signal are: FFT size 4K, modulation of data 16QAM, guard interval 19/256, number of symbol 6 (1xP1, 4xP2, 1xData), pilot pattern (PP) 4, number of used carriers 3409, bandwidth 8 MHz. The four symbols of P2 are defined by norm [20].

The data symbol is generated randomly and does not include any real MPEG-2 stream data. The ambiguity function is computed formula (1). The ambiguity function has a maximum in time delay $\tau = 0\ [s]$ and Doppler shift $f_d = 0\ [Hz]$. The parameters of the CA function are maximum of the Doppler shift $F_{\max} = 500\ [Hz]$ in interval $\langle -F_{\max}\ ; F_{\max} \rangle$, maximum of time delay $\tau_{\max} = 2742\ [\mu s]$ in interval $\langle -\tau_{\max}\ ; \tau_{\max} \rangle$, sampling frequency $f_s = 64/7\ [MHz]$, number of samples $N = 50143\ [-]$, resolution in Doppler shift $dF = 1\ [Hz]$, resolution in time delay $d\tau = 0{,}109\ [\mu s]$.

The shape of the ambiguity function includes a lot of different maxima caused by parameters of the DVB-T2 signal, specially a pilots and guard interval.

In Fig. 3 is shown a cut in ambiguity function for $f_d = 0\ [Hz]$. The maxima visible on right side of the symmetric graph are caused by repetition of symbol P2. The position of the first maximum is $481{,}25\ [\mu s]$. The FFT length 4K correspond to 4 symbols P2 (viz. Table 51 of DVB-T2 standard) [20]. The time value corresponds to the sum of time duration of P2 symbol ($448\ [\mu s]$) and guard interval defined by formula $(19/256)\cdot 448\ [\mu s] = 33{,}25\ [\mu s]$. The next maxima are in positions $962{,}5\ \mu s$ and $1443{,}75\ [\mu s]$ that correspond to $k \cdot 481{,}25\ [\mu s]$, $k \in \langle 1, P2-1 \rangle$, $P2$ is number of symbols. The positions of peaks are shown in Fig.3. The influence of the ambiguity function is strong with the number of symbols and with the kind of symbols that are included in T2 frame. T2 frame can include different combinations of P1, P2 and data symbols. Different symbols use different parameters of guard interval or FFT size (1k – 32 k). In the case that symbols parameters are same, then in the ambiguity function, maxima emerge.

In Fig. 4 the main peak of second P2 symbol with highlighted secondary peaks is shown. The secondary peaks have always the same spacing $149{,}3[\mu s]$. The value of $149{,}3[\mu s]$ is derived by the formula $f = 1/149{,}3 \approx 6697{,}924[Hz]$. The initialization of an input parameter for the P2 symbol is FFT 4K. For this length, the spacing between individual carriers correspond to 2232 Hz. This value equates to the with DVB-T2 standard shown in Table 66 [20]. The ration between $6697{,}924/2232$ is approximately 3. This number corresponds to the period of the pilot carriers of the symbol P2 (P2 pilots). The secondary peaks for other P2 symbols are shown in Tab. II. The analysis of the ambiguity function in the Doppler domain will be done in future.

TABLE II. Delay of Secondary Peaks of P2 Symbols

	Delay of secondary peaks [µs]						
1st	-448	-298,7	-149,3	0	149,3	298,7	448
2nd (Fig. 5)	not defined	182,7	332	481,3	630,6	780	929,3
3rd	514,6	663,8	813,2	962,5	1111,8	1261,3	1410,6
4th	not defined	1145,1	1294,5	1443,8	1593,1	1742,5	not defined

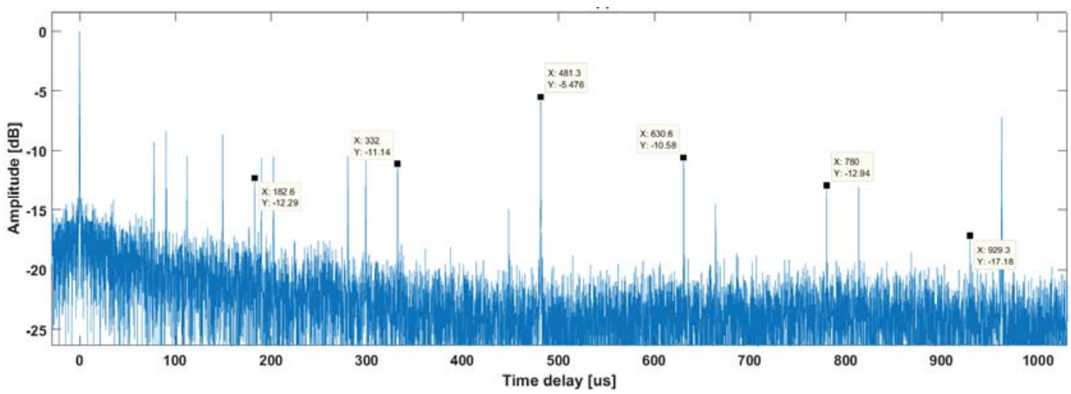

Fig. 4. The detail of P2 symbol with secondary peaks.

IV. Conclusions

The paper presents analysis of DVB-T2 signal from the point of view of its use in a PCL system. The paper is part of extensive research in new PCL signal processing. In the paper is briefly described format of DVB-T2 signal, properties of DVB-T signal and input parameters that influence target detection capabilities in PCL radar. It was shown, that variable parameters of DVB-T2 signal caused multiple peaks (maxima) in output of the ambiguity function and can caused false detection of target or lost target detection capability of PCL.

The future research will focus on detailed analysis of DVB-T2 parameters and their combinations (as combinations of different type of data packets, different settings of guard interval, pilot patterns, type of modulations etc.) and afterwards, elimination of DVB-T2 signal influence on cross ambiguity function. For this analysis, a DVB-T2 generator will be developed as of part of DVB-T2 system that corresponds to maxima in the CA function.

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