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MEASUREMENT THE OCCUPIED BANDWIDTH OF THE EMISSION USING SDR PLATFORM HACKRF ONE

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Abstract— *Occupied bandwidth of emission is measured by $\beta/2$-method or method X dB using spectrum analyzer or measuring receiver and subsequent computer processing. For measurement simplification it is necessary to find the spectrum level of X dB, which corresponds to occupied bandwidth. The article examines the possibility of solution problem using SDR platform HackRF One on example emission of digital television.*

Index Terms—Occupied bandwidth; emission; spectrum; SDR platform.

I. INTRODUCTION

Monitoring procedures for emissions were developed on the basis of national and international normative documents, for example [1], [2], but normative documents do not provide enough information on parameters measurement of the modern digital radio technologies particularly terrestrial digital television.

According to Rec. ITU-R SM.328 and Rec. ITU-R SM.443-4 occupied bandwidth is measured by direct method at monitoring station and can be estimated from the X dB bandwidth. When using $\beta/2$ -method the difference between spectrum reference level and the noise level should be 30 dB. Also according to State standard 30318-95 emission bandwidth is measured at the level X = -30 dB from reference level.

Experimental studies of the spectrums of digital television, the results of which are provided by The Ukrainian State Centre of Radio Frequencies (UCRF) as well as measurements conducted by the authors, show that the level of noise -30 dB in Kyiv is achievable only under certain conditions. The difference in 30 dB is obtained during the measurement in a separate points at a distance of about 2 km from the transmitter.

It is obvious that a reliable estimate of occupied bandwidth in urban conditions by $\beta/2$ -method can be obtained in the measurement process within direct visibility from the transmitting antenna to the receiving point at short distances. But in case of known spectrum level which corresponds to occupied bandwidth the emission measurement can be conducted by the method of X dB in conditions of greater noise level at greater distances.

Experimental studies were conducted in Kyiv using a spectrum analyzer R&S U3772 Advantest at SPAN = 10 MHz and RBW = 10 kHz and RBW = 3 kHz. The authors due to the lack of such class apparatus turned attention to Software Defined Radio (SDR) platform HackRF One.

II. MEASUREMENTS AND PROCESSING

Software Defined Radio platform HackRF One [3] is characterized by:

– the frequency range from 10 MHz to 6 GHz;

– sampling frequency for $20\cdot10^6$ samples per second;

– I / Q demodulator with dual 8 bit ADC;

– software controlled gain paths.

Accuracy characteristics of platform were checked by measuring output level of the signal generator R&S SMJ Vector Signal Generator using the spectrum analyzer Rohde & Schwarz FSH8 and HackRF One in a frequency range up to 1000 MHz, Fig. 1.

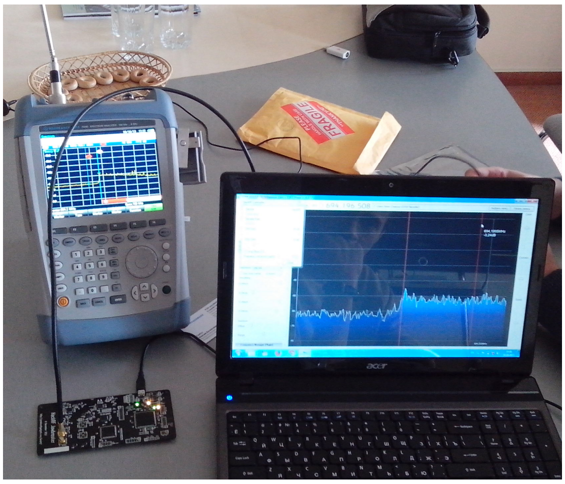

Fig. 1. Testing accuracy characteristics of a transceiver HackRF One

Maximum measurement error of the generator output signal does not exceed level 1.5 dB. The average value of error is 0.98 dB. According to the European standard [4] maximum uncertainty in the measurement out-of-band emission at frequencies up to 2.2 GHz is $\pm 2{,}5$ dB at 95 % confidence level. Measurement error platform HackRF One of 1–1.5 dB can be considered acceptable.

During measurement of digital television emission the output signal of platform is recorded in the file. Emission spectrums are obtained using FFT in computer.

Noisy spectrums need subsequent processing for properly determination the reference zero level in automatic mode. Noisy spectrums corresponds to FFT with large number of points. Here the number of points is equal to 32768, that in SPAN = 10 MHz corresponds to resolution 305 Hz.

The data in the sample at each frequency includes averaged over 10 spectra measurements for each place of acceptance, Fig. 2.

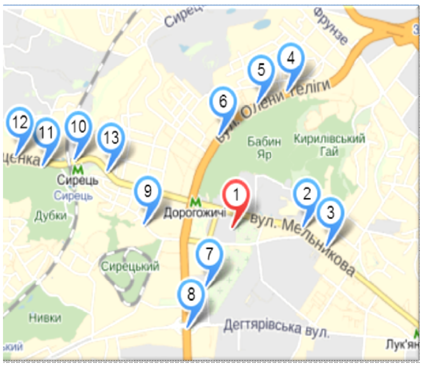

Fig. 2. Measuring points of the emission in the vicinity of the television tower in Kyiv

Example of emission spectrum of digital television at a frequency 554 MHz using HackRF One is shown in Fig. 3. The spectrum is characterized by noisy due to the large number of points in the sample.

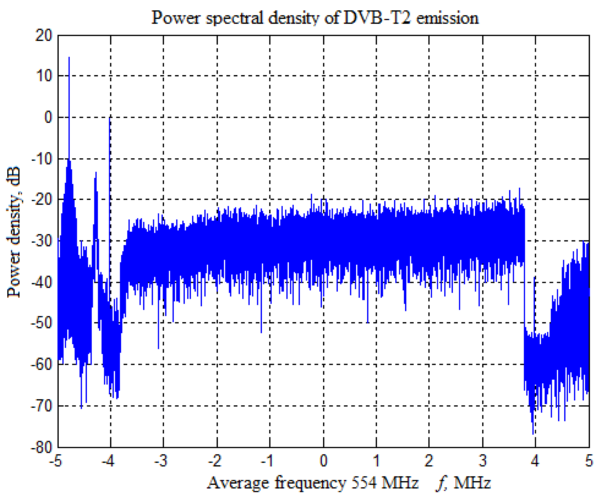

Fig. 3. Example of spectrum using HackRF One with resolution 305 Hz

Matlab environment offers a number of tools to smooth the sample, including the method of rolling averaging, Savitzky-Golay filter, local regression weighted and with robustness or without them.

Method of rolling averaging gives arithmetic mean values of points in a moving sequence.

Local regression weights were proposed by W. Clevelan and in MATLAB are represented by algorithms LOWESS and LOESS. LOWESS is a local linear model with smoothing weight [4], which is given by

$$w_i = \left(1 - \left|\frac{x - x_i}{d(x)}\right|^3\right)^3, \qquad (1)$$

where x is value at a point which is smoothed; x_i is value in the ith point of the set of local regression; $d(x)$ is the distance from the point x to the most remote point of set.

From (1) follows that the greatest weight has the farthest point of set. The algorithm LOWESS searches parameters α and β locally linear model $y = \alpha + \beta x + \varepsilon$, and the algorithm LOESS uses locally quadratic model.

If reductions are in the sample the smoothing error increases. Therefore at using robust algorithms LOWESS and LOESS the influence of a few offsets is compensated with robust weight, which is calculated after the parameters of the local regression.

Spectrum smoothing can also be carried out using the Savitzky-Golay filter (SG filter) [5], in which to each sequence of $2m + 1$ points corresponds by method of least squares the polynomial $l < 2m + 1$ degree. The derivative with order $p < l$ of sequence in the middle point is found using the polynomial. Moving polynomial approximation is obtained by convolution of input data with digital filter size $2m + 1$. Conditions for obtaining convolution coefficients is odd number points in sequence.

Algorithm of occupied bandwidth determining firstly set the spectrum boundary. In the absence of obstacles, as experience shows, the borders of frequency spectrum can be taken as ± 4 MHz from the center frequency. In this case, on the spectrum boundary the signal level is at least -30 dB from level, taken as reference. However, often there are cases of action closely spaced obstacles. Therefore, the boundary of the spectrum lies in the range of values ± 3,85 MHz.

For all smoothing methods the spectrum noisiness and shape depends on the number of points in the local sequence as example in Fig. 4. More importantly at this changing occupied bandwidth value.

Table 1 includes the results of spectrum smoothing on average frequency 554 MHz. Without processing the occupied bandwidth is BW = 7,402 MHz. After smoothing occupied bandwidth must be approximately equal to initial value.

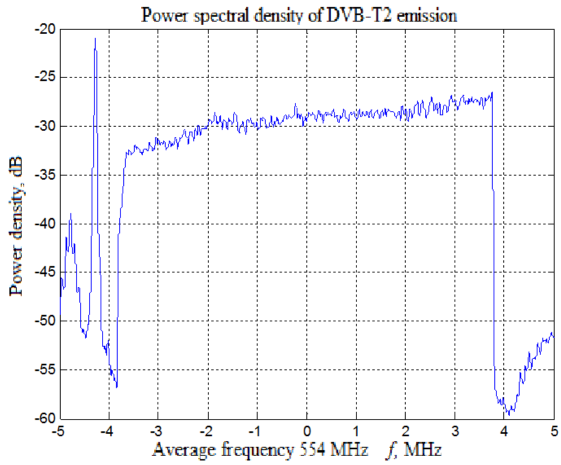

Fig. 4. Spectrum smoothing using LOWESS algorithm with a set of 201 points

TABLE 1

Occupied bandwidth of emission on 554 MHz using smoothing algorithm

Algorithm	Number of points in a moving set	*BW*, MHz
1	2	3
Rolling averaging	151 101 201	7,396 7,391 7,376
LOWESS	151 101 201	7,398 7,394 7,387
LOESS	51 101 201	7,400 7,400 7,398
Robust LO-WESS	51 101 201	7,396 7,380 7,380
Robust LOESS	51 101 201	7,398 7,397 7,395
SG filter Order – 2	51 101 201	7,400 7,400 7,397
SG filter Order – 3	51 101 201	7,400 7,400 7,397
SG filter Order – 4	51 101 201	7,401 7,401 7,401
SG filter Order – 5	51 101 201	7,401 7,401 7,401

Similar data were obtained for emissions on average frequencies 514 MGz, 538 MHz, 634 MHz, 650 MHz, 698 MHz, 818 MHz. Better results give the use Savitsky-Golay filter with polynomial degree 3-4 and LOESS algorithm with a locally quadratic model.

Recommendation ITU-R SM.1541 notes that reference level of spectrum can be found in two ways: to determine the maximum power level or the average value of "shelf" range. The shape of the signal digital television DVB-T2 corresponds to both methods of determining the reference level, Table 2.

TABLE 2

Determining reference level

Algorithm	Number of points	Reference level	
		By the maximum value, dB	By the average value, dB
1	2	3	4
554 MHz			
LOESS	51	-24.8	-29,6
	101	-25.8	-29,6
	201	-26.5	-29,6
	301	-26.8	-29,6
SG filter Order – 3	51	-25.0	-29.6
	101	-25.8	-29.6
	201	-26.5	-29.6
	301	-26.8	-29.6
SG filter Order – 4	51	-24.1	-29.6
	101	-25.5	-29.6
	201	-26.2	-29.6
	301	-26.6	-29.6
SG filter Order – 5	51	-24.1	-29.6
	101	-25.5	-29.6
	201	-26.2	-29.6
	301	-26.6	-29.6
634 MHz			
LOESS	51	-31,8	-35,8
	101	-32,6	-35,8
	201	-33,3	-35,8
	301	-33,5	-35,8
SG filter Order – 3	51	-31.9	-35,8
	101	-32.7	-35,8
	201	-33.2	-35,8
	301	-33.2	-35,8
SG filter Order – 4	51	-31,284	-35,8
	101	-32,3	-35,8
	201	-33,1	-35,8
	301	-33,331	-35,774
SG filter Order – 5	51	-31.284	-35,774
	101	-32.347	-35,774
	201	-33.118	-35,775
	301	-33,331	-35,774

From Table 2 follows that reference level defined by average value of "shelf" does not depend on the number of point in a moving set. Reference level by the maximum value becomes stable at two hundred points in the set at total 32768 points in the sample. Better results are obtained for SG filter order 4–5.

Processing procedure simplified at using determination of reference level by maximum value.

Algorithm for the occupied bandwidth, in which the frequency range gradually narrows on each side before reaching the border, outside each of which is 0.5 % of the total power spectrum can not be directly used in order to find the appropriate X level.

The borders of occupied bandwidth emissions of digital television standards DVB-T, DVB-T2, which correspond to definite X levels of spectrum, sometimes are not on the slopes but on the "shelf" of the spectrum. The spectrum "shelf" is characterized by low steepness that reduces the accuracy of the X dB method. Besides level on the slopes of the spectrum, corresponding to 0.5 % of the power is different.

It was proposed to determine occupied bandwidth of digital television emission using the modified method of X dB, which is as follows:

– for ease of measurement the spectrum bandwidth at level -10 dB from the reference level is deternined;

– occupied bandwidth equals to the difference of spectrum bandwidth at -10 dB and amendment, which must be defined for different apparatus adjustments.

III. Conclusion

Software Defined Radio platform HackRF One can be used for radio engineering measurements in particular for a justification the spectrum level which correspond to occupied bandwidth of digital television emission.

X dB method is simpler in comparison with $\beta/2$ - method. At this emission parameter control can be carried out on a large distances from transmitter antenna.

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Л. В. Сібрук, О. А. Басанський. Вимірювання займаної ширини смуги частот радіовипромінювання за допомогою SDR платформи HackRF One

Розглянуто визначення займаної ширини смуги частот радіовипромінювання цифрового телебачення за допомогою SDR платформи HackRF One. На відміну від аналізаторів спектра або вимірювальних приймачів ця платформа є доступною для широкого кола користувачів.

Ключові слова: займана ширина смуги частот; радіовипромінювання; SDR платформа**.**

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Л. В. Сибрук, А. А. Басанский. Измерение занимаемой ширины полосы частот радиоизлучения при помощи SDR платформы HackRF One

Рассмотрено определение занимаемой ширины полосы частот радиоизлучения цифрового телевидения при помощи SDR платформы HackRF One. В отличие от анализаторов спектра и измерительных приемников платформа доступна широкому кругу пользователей.

Ключевые слова: занимаемая ширина полосы частот; радиоизлучение; SDR платформа.

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