12th IMEKO TC4 International Symposium
Electrical Measurements and Instrumentation
September 25-27, 2002, Zagreb, Croatia

DIGITAL MEASUREMENT OF NOISE PARAMETERS OF COMMUNICATION RECEIVER

Karol Korcz[1)], Beata Pałczynska[1)], Ludwik Spiralski[1), 2)]

[1)] Gdynia Maritime University, Department of Marine Radio Electronics, Poland
e-mail: korcz@wsm.gdynia.pl, palbeata@wsm.gdynia.pl
[2)] Technical University of Gdańsk, Department of Measuring Instrumentation, Poland
e-mail: kapsz@pg.gda.pl

Abstract – The digital system for the measurement of noise parameters of the communication receiver has been presented. The advantages of the presented digital method in comparison with these recommended by the norms analog methods have been given. The assesment of the digital measurement accuracy of the noise parameters has been run.

Keywords: virtual instruments, noise measurements, communication receiver

1. INTRODUCTION

Communication receiving equipment, in respect to the noise, is usually described with the help of the noise factor F and its sensitivity E_s. These parameters depend on the mean noise power of the receiving equipment.

In the case when the dominant part of the output unwanted run of the receiver is its own noise there is a strict connection between the noise factor F and the sensitivity E_s. If these parameters are stated in the same frequency conditions, at the same value of the signal source (antenna) resistance R_s, the signal source (antenna) temperature T and for the assumed value of the ratio n_o of the signal to the noise this connection may be expressed by the following equation:

$$E_s = (A\Delta fF)^{\frac{1}{2}} \quad (1)$$

where: Δf is the energy passband of the receiver depending on the signal modulation and $A=R_sTn_o$ [V^2/Hz] is a constant (for standard values: R_s= 50 Ω,. T_0 = 290K and n_o = 20 dB, $A = 3{,}2\cdot10^{-17}$ V^2/Hz)

In the recommended digital method of the measurement of the receiver noise parameters as an input signal source the standard noise generator has been used (Fig. 1). This solution, because of the same character of the runs of the standard generator and the internal noise of the receiver, for the measurement of the noise factor F, the measuring energy passband is not needed. For the calculation of the receiver sensitivity values E_s, in accordance with equation (1), the noise factor F and the noise passband Δf should be measured.

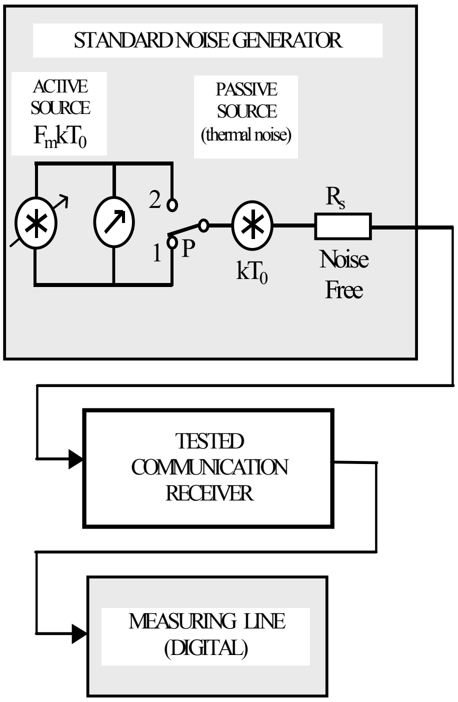

Fig. 1. Meter circuit for digital determination of noise parameters of receiver

The numerical values of both parameters can be measured by the farther described virtual instrument.

2. MEASUREMENT OF NOISE PARAMETERS OF COMMUNICATION RECEIVER

The measurement of the noise factor F is made in two stages (Fig. 1). In the first step (the switch P in position 1) the receiver output noise power is read off while the active source of the standard noise generator is turned off. Then, the power measured at the output of the tested receiver is equal to the sum of the thermal noise power of the signal source and of the receiver internal noise power. Whereas, in the second step (the switch P in position 2), such a level of noise from the active source of the standard generator is entered to cause the output power of the tested receiver to increase twice.

Then, the value of the noise factor F_m is directly read off from the indication of the level of the standard noise generator and is equal to the values of the noise factor of the tested receiver F_{Rx}.

The measuring method of the receiver energy passband Δf consists in determining the output noise power density $G_n(f)$, then determining the maximum value of this density $G_n(f)_{max}$, and finally calculating the energy band Δf from the equation [1, 2]:

$$\Delta f = \frac{\int_0^\infty G_n(f)df}{G_n(f)_{max}} \quad (2)$$

Determining the energy passband can be realized with the use of the meter circuit showed in Fig. 1.

The research results obtained by the authors, experimentally confirmed, explicitly indicate that it is possible to determine the receiver energy passband by the measurement of the only internal noise of the receiving equipment without using the standard noise generator.

3. DIGITAL MEASURING INSTRUMENT

Measurements are realized by the measuring system using the digital signal processing in the „on-line" mode. The measuring analog signal is preliminarily conditioned (amplified and filtered) and processed by the a/d converter in the hardware part of the measuring instrument, with the use of the National Instruments (NI) components.

The matching of the signal level to an a/d converter input of a measuring card is realized by an input amplifier. Its amplification is set by a software into 1, 2, 5, 10, 20, 50 and 100. It allows obtaining at the output the range of changes in the measuring voltage noise signal +/- 5V. In order to attain possible optimum measuring resolution of the run and the maximum rate of the useable signal to noise (which was assumed as a convertor a/d quantization error), the maximum possible value of the amplification is chosen which doesn't cause exceeding this range yet. The elliptical low-pass filters (8th order) with a cut-off frequency 25 kHz, also setting by the software, fulfil the function of an antialiasing filters.

Digital processing and the analysis of the sampled signal are made by the virtual instruments working in the LabVIEW software environment [3].

The digital measuring data are software (computer) processed where step by step the receiver noise parameters are determined. First the receiver noise factor F (Fig. 2) and the receiver energy passband Δf (Fig. 3) are determined and then the receiver sensitivity is calculated from (1) [2]. The symbol Δt used in the algorithms in Fig. 2 and Fig. 3 is the sampling period.

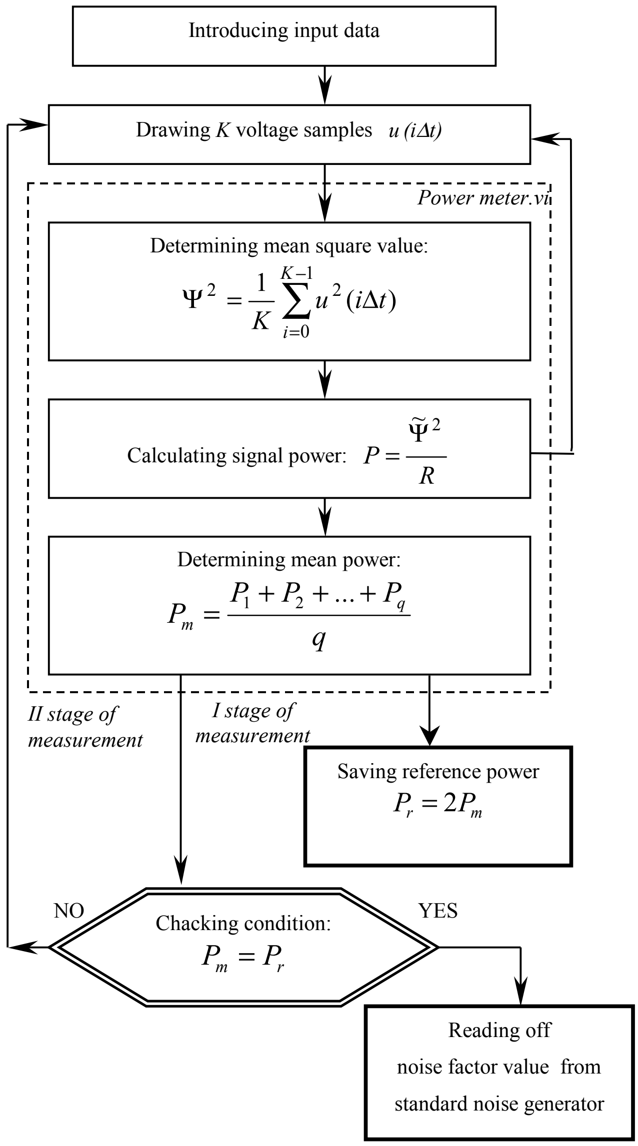

Fig. 2. Algorithm determining noise factor

At the input of the virtual instruments the following data are entered:

- Δt – sampling period,
- K – number of samples in the set,
- q – averages number.

The relative standard error of estimating the mean square value Ψ^2, calculated in the virtual instrument for the noise factor F measuring (Fig. 2), for the Gaussion white noise at a zero mean value, may be expressed by the equation:

$$\frac{e}{\Psi^2} \cong \sqrt{\frac{2}{K}}, \quad (3)$$

and for K=1024 samples, it approximately equals 4,4%.

The spectrum analysis resolution in the algorithm determining receiver energy passband (Fig. 3) is described by the equation $df = \frac{q}{N\Delta t} = \frac{1}{K\Delta t}$, where $N=2^P$ is the whole samples number. For the sampling frequency 20 kHz (sampling period Δt=50 μs), the samples number K=1024 and the averages number q=1000, it is equal df=19,5 Hz. The length of the samples sequence $G_n(k)$ is K/2=512 samples. The relative standard error of estimating power density depends on an averages number. For the Gaussion white noise this error is equal [1]:

$$\frac{e}{G_n(k)} \cong \frac{1}{\sqrt{q}} = \sqrt{\frac{T_s}{N\Delta t}} = \sqrt{\frac{K}{N}} \quad , \qquad (4)$$

for example, for 1000 averages it doesn't exceed 3,2 % (T_s – is duration time of the analysed time signal segment).

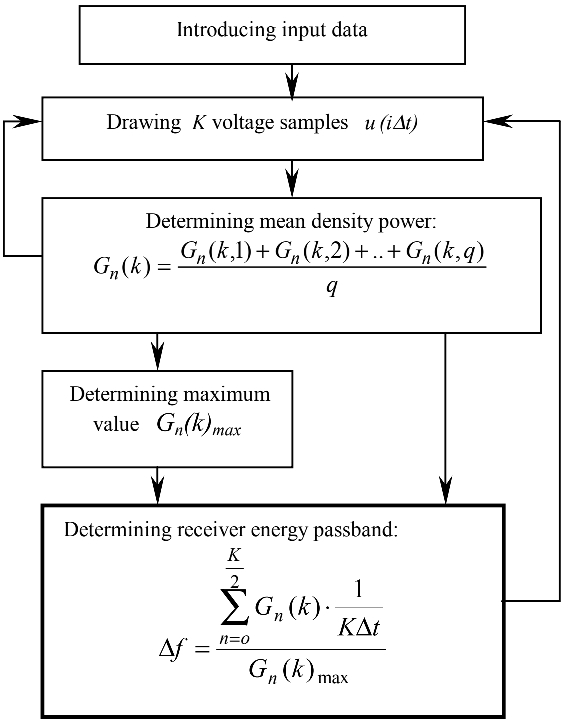

Fig. 3. Algorithm determining receiver energy passband

As a result of this error occurrence the succeeding power density measurements may be different from a real value more than *e*, because the equation (4) described only the value of the relative standard deviation of so determined estimator of the power density.

The fluctuations of the measuring results may be decreased by increasing the signal, that is to say the averages number of the power density.

4. EXPERIMENTAL RESEARCH RESULTS

The presented experimental research results of the transfer characteristics and the noise factor F tested communication receiver RA1776 made by RACAL have been conducted in the marine band 8 MHz (on the receiver tuned frequency 8243 kHz) and for J3E type of modulation (receiver passband 2,7 kHz).

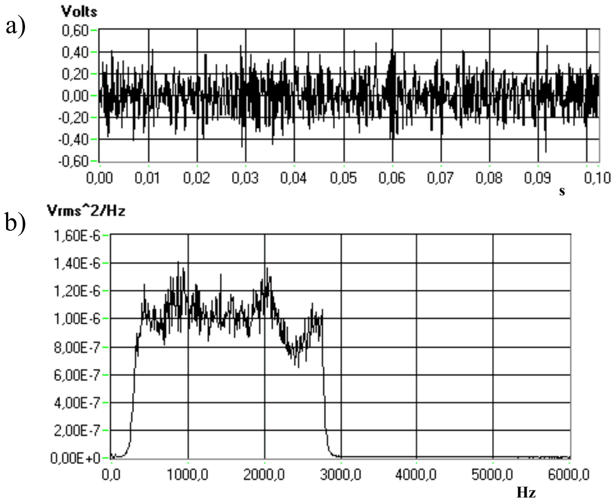

Fig. 4. Instantaneous voltage run (a) and receiver transfer characteristics (b) at the switched the noise generator and the averages number equal 100 [*virtual instrument panel*]

In Fig. 4a the noise time run at the receiver audio frequency output has been presented and in Fig. 4b – the achieved transfer characteristics of the receiver at the switched standard noise generator (switch P in Fig. 1 in position 2) and the active source level 30 dB (with reference to kT_0) and the averages number of the digital meter circuit equal 100.

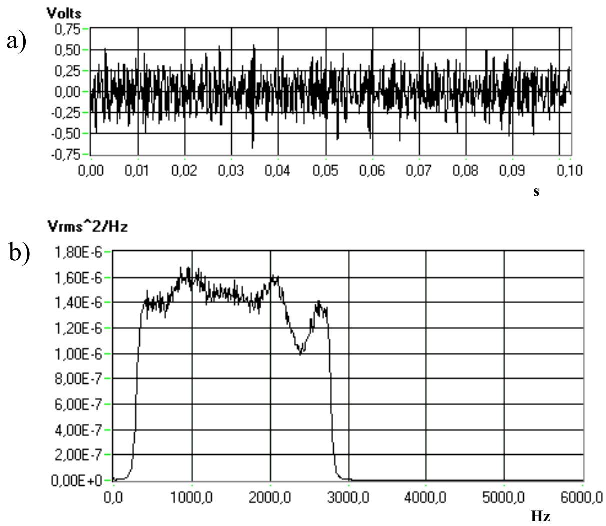

Fig. 5. Instantaneous voltage run (a) and receiver transfer characteristics (b) at the switched the noise generator and the averages number equal 1000 [*virtual instrument panel*]

The receiver transfer characteristics for the same measuring conditions as for the characteristics in Fig. 4 but at the averages number equal 1000 has been presented in Fig. 5. From the comparison of both characteristics it follows that by increasing the averages number it is possible to achieve smoothing of the transfer characteristics. It allows calculating the noise passband with more accuracy.

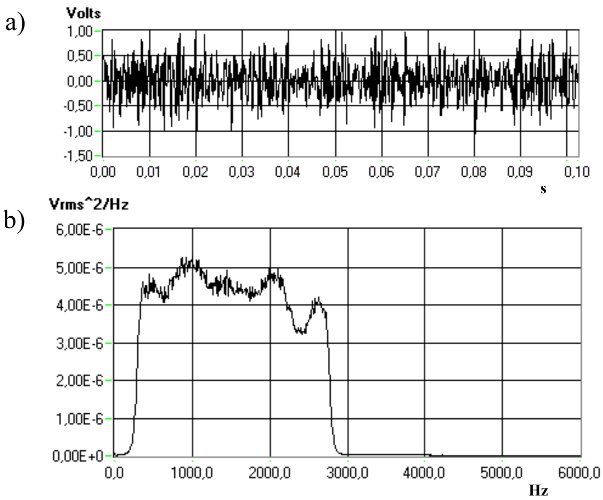

Fig. 6. Instantaneous voltage run (a) and receiver transfer characteristics (b) at the connected but switched off noise generator [*virtual instrument panel*]

In the following Fig. 6a the noise time run characteristics at the receiver audio frequency output has been presented when to the input of the receiver the standard resistance for its recommended input impedance has been connected (50 Ω). On the basis of the data of this run the transfer characteristics of the receiver has been determined.

From Fig. 4-6 it results that in order to determine the transfer characteristics of the communication receiver and to calculate the values of energy passband for different types of modulation, it is necessary only to record its own noise, and then by software to determine desirable parameters.

The analogoues measurements carried out for other cmmunication receivers confirmed the obtained above results.

5. CONCLUSIONS

From the carried out by the authors research work, it results that the measuring inaccuracy of the communication receiver noise parameters (the noise factor F and the sensitivity E_s) with the use of the digital methods in comparison with the analog methods included in the standarization documents [4] is much lower.

The inaccuracy of the measurement of communication receiver noise parameters by the standard methods is affected essentially by the following factors:

- the standard signal generator, especially the range of changes and the inaccuracy of setting its level and the entered interference in the measuring system,
- the level of emitted interference by the standard generator,
- linear amplitude distortion, deviation from the nominal resistance of load and the parameters change in the function of temperature, humidity, etc. of the power meter,
- the method of the measurement of the ratio of the signal to the noise power at the receiver output n_o.

The above measuring errors are minimalised or just eliminated in the presented method of the measurement of the noise parameters of the communication receiver.

The measuring errors with the digital method (except quantization errors) result only from the algorithms of processing digital measuring data (the errors of parameters estimation) and can be usually omitted.

A/d converters should have the possible biggest number of bits so that it could be possible to take into account the frequency components which introduce slight power to the analysed time run.

It should be also noted that the presented digital method of the measurement with the use of the standard noise generator, or with the use of the internal noise of the tested receiver, is characterized by the following additional advantages [2]:

- considerably shortens the estimation time of the noise parameters and characteristics of the receiver,
- allows to modify the calculating procedure in the „off-line" mode,
- enables the measurements of the noise characteristics (i.e. in the function of frequency) using the internal noise of the tested receiver.

REFERENCES

[1] L. Hasse, L. Spiralski, „Noise in electronic elements and circuits", „Szumy elementów i układów elektronicznych", *WNT*, Warsaw, 1981,

[2] K. Korcz, B. Pałczyńska, L. Spiralski, "Digital measurement of noise and sensitivity of communication receiver", "Cyfrowy pomiar szumów i czułości użytkowej odbiornika radiokomunikacyjnego", *KKM*, Warsaw, 2001.

[3] LabView Analysis VI Reference Manual, *National Instruments*, 1994.

[4] ETSI, "Technical characteristics and methods of measurement for maritime mobile transmitters and receivers for use in the MF and HF bands", *ETS 300373*, 1997.

Authors: M.Sc. Karol Korcz[1)], Ph.D. Beata Pałczyńska[2)], Prof. Ludwik Spiralski[3)], Gdynia Maritime University, Department of Marine Radio Electronics, Morska 81-87, 81-225 Gdynia, Poland, tel: +48 (58) 6901406[1), 3)], +48 (58) 6901552[2)], fax: +48 (58) 6219938, e-mail: korcz@wsm.gdynia.pl[1)], palbeata@wsm.gdynia.pl[2)]; Technical University of Gdańsk, Department of Measuring Instrumentation, Poland, +48 (58) 347 15 04, fax +48 (58) 341 61 32, e-mail: kapsz@pg.gda.pl[3)].