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System to Control the RF Receiver Noise Parameters of the Radiolocation Pre-Search Station P18 Laura

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Abstract. The article presents a measuring system that allows the noise parameters of the receiver of a radiolocation station to be controlled. The existing solutions of the radiolocation pre-search station P18 Laura control unit have been adapted to the system.
Keywords: noise source, receiver noise ratio

1. INTRODUCTION

Measurements of the noise sensitivity of a radiolocation station receiver are based on the determination of the noise factor F_n.

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In general, the noise factor of a receiver shows how many times the noise power P_{sz} of the actual receiver is greater than the noise power P_{szid} of an ideal receiver, whose noise is determined only by the power of the thermal noise of its systems:

$$F_n = \frac{P_{sz}}{P_{szid}} \tag{1}$$

The methods of determining the noise sensitivity by measuring the noise factor are valid for the power of the noise generated at the input of the receiver at matching loads. The power of the heat noise at the matching load of the receiver is $P_{szid} = kTB$, so:

$$F_n = \frac{P_{sz}}{kTB} \tag{2}$$

where:

k – Boltzmann constant, equal to $1.38 \cdot 10^{-23}$ J/°K;
T – standard temperature 290 °K;
B – bandwidth of the receiver.

Measurements of the RF receiver noise sensitivity are based on determining how many times the ratio of signal power P_{swe} to the noise power at the receiver input P_{szwe} is greater than the ratio of the signal power P_{swy} to the output noise power P_{swy}. The most common is the representation of the logarithmic scale noise factor, expressed in dB (4).

$$F_n[dB] = 10 \log \left(\frac{P_{swe} / P_{szwe}}{P_{swy} / P_{szwy}} \right) \tag{3}$$

Depending on the amplification and noise level of the reception channel, appropriate measurement methods are selected. One of them is the twice-power method. It consists in determining the equivalent noise power P_{sz} by comparing the output signal resulting from the operation of the receiver's internal noise with the output signal resulting from the operation of a calibrated noise source (usually in the form of a noise diode) connected to the input of the receiver. The signal power of the calibrated source P_s should be such that the output power of the linear part of the receiver doubles in comparison with the power resulting from the receiver's own noise exclusively.

In this case, the signal strength of the source to be calibrated is equivalent to the receiver's own noise power. The following is, therefore, adopted for the method:

$$F_n = \frac{P_{sz}}{kTB} = 0.02 \cdot R_s \cdot I \tag{4}$$

where:

R_s – impedance of the noise generator equal to 75 Ω;

I – direct current of the noise generator noise diode [mA].

At the output of the receiver, the ratio of the noise voltage is measured instead of the power which is related to the ratio of the voltage dependence:

$$\frac{U_{sz+s}}{U_{sz}} = \frac{\sqrt{R_s P_{sz+s}}}{\sqrt{R_s P_{sz}}} \tag{5}$$

Assuming the loads are equal, we get:

$$\frac{U_{sz+s}}{U_{sz}} = \frac{\sqrt{P_{sz+s}}}{\sqrt{P_{sz}}} \tag{6}$$

where:

U_{sz} – the noise voltage of the actual receiver at the detector output;

U_{sz+s} – the total noise voltage of the actual receiver and the calibrated noise source at the detector output;

P_{sz+s} – the total noise power of the actual receiver and the calibrated noise source at the detector output.

When measuring the noise factor using the twice-power method, the power ratio measured with the spectrum analyser is 2, while the voltage ratio measured with an oscilloscope is $\sqrt{2}$.

Another method of determining the noise sensitivity of the receiver is the so-called *Y*-factor method. In this case, a noise source with an appropriate ENR (Excess Noise Ratio) level is used. A typical ENR noise source (e.g. HP346A / B) operates across a very wide band (e.g. 10 MHz to 18 GHz) and has a specific noise level over the entire frequency range. For the HP346B, it is approx. 15 dBm. In order to obtain the required noise power, it is necessary to supply the noise source with 28 VDC. By switching the power supply voltage of the noise source on and off, the change in power density of the receiver's output noise is measured using a spectrum analyser, or the noise voltage using an oscilloscope. The noise factor determines the relation:

$$NF = 10 \log \left[\frac{10^{(ENR/10)}}{10^{(Y/10)}} - 1 \right] \tag{7}$$

ENR is the noise source parameter. The *Y* factor value is defined as the difference between the noise output power density when the noise source is on and off.

The noise source provides the noise level at two “noise temperatures”: hot source $T = T_H$ with the supply voltage, and cold source $T = 290^0$K for DC power off. By definition, the ENR for this type of noise source is:

$$ENR = \frac{T_H - 290}{290} \tag{8}$$

The ratio of noise power at the output of the receiver to the “cold source”, $T_n = 290^0$K, and then with “hot source”, $T = T_H$, is:

$$Y = \frac{\left(\frac{T_H + T_n}{290}\right)}{\left(1 + \frac{T_n}{290}\right)} \tag{9}$$

Assuming the noise level at:

$$F = \frac{T_n}{290} + 1 \tag{10}$$

then the sought Y factor s is determined by the relationship:

$$Y = \frac{ENR}{F} + 1 \tag{11}$$

As in the twice-power method, the receiver must operate in the linear range with an impedance-matched load to obtain correct measurement results.

2. MEASUREMENT SYSTEM DIAGRAMS

One of the tasks of the control system is proper tracking the receiver's noise sensitivity by measuring the noise amplitude level using the built-in oscilloscope unit. The noise generator is controlled by a processor based on ARM architecture, which is connected via an Ethernet interface from the oscilloscope unit. In addition to the tasks associated with controlling the noise generator, the processor manages a semiconductor switch that allows us to connect the signal generator to the receiver input when measuring signal sensitivity. The processor turns off the power supply to the signal and noise generators when a trigger signal from the station transmitter is detected. In this way, no self-emitted interference signals are transmitted to the radiolocation pre-search station receiver, and both generators are protected from damage. The switch (Fig. 1) is based on the MASW936 system, whose internal structure is based on controlled PIN diodes.

A positive control voltage applied to inputs 7 and 14 causes them to block, which ensures adequate attenuation of the signals (input 7 – about 40 dB, input 14 – about 15 dB).

If a negative control voltage is applied to input 7, it will be disconnected and transmitted to output 2, to which the SMA output connectors are connected.

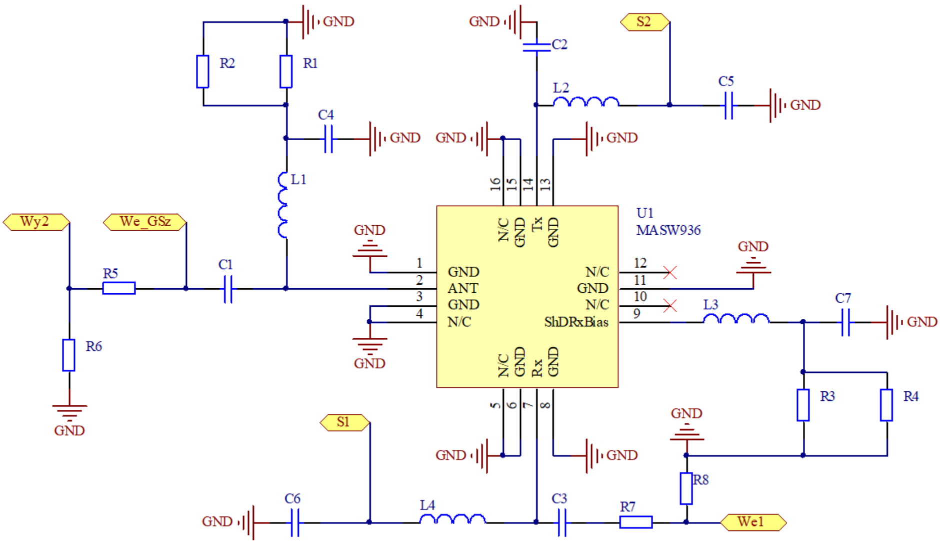

Fig. 1. Switch circuit schematic

The noise generator (Fig. 2) is built with the use of a D_{Sz} NS103 noise diode controlled by a resistor voltage divider from an adjustable current stabiliser of a U1 LP2951 diode. The adjustment of this current and the selection of ATa÷ATc output attenuator resistors during system calibration allow the proper noise level to be obtained, which is fed to the output connector.

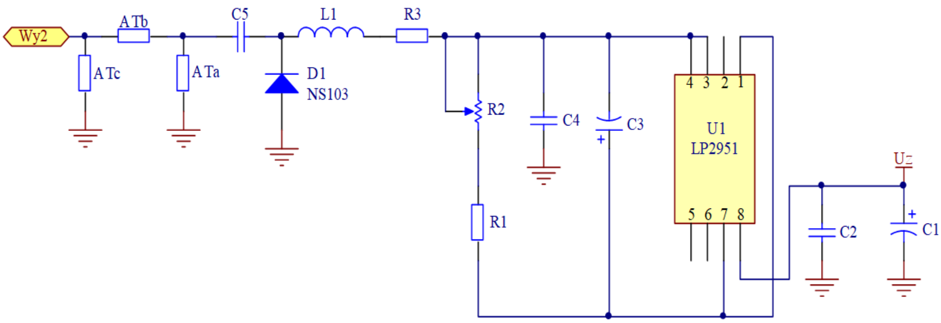

Fig. 2. Noise generator system scheme

The switch and noise generator circuits are mounted on a printed circuit board, which is placed in a shielded box to minimise external interference for the noise generator operation. The view of the switch and noise generator set is shown in Fig.3.

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Fig. 3. Switch and noise generator set view

The use of a noise generator allows the radio station operator to assess the noise sensitivity of the receiver. The correctness of the measurement results depends on the calibration of the noise generator. This calibration is performed by adjusting the current of the noise diode, selecting the attenuation of the noise generator output attenuator, and comparing the obtained output noise level of the receiver with that of the HP346B reference source. If both signals are equal, the ENR of the noise generator is assumed to be comparable to the ENR of the source, which is approx. 15dBm. By applying the abovementioned dependencies and appropriate procedures, software has been developed which uses the presented methods to measure the receiver noise sensitivity, based on the measurement of the amplitude level of the output signal with the noise generator off and on.

3. SOFTWARE

On the basis of the presented dependencies, control unit software was developed and implemented, which uses the twice-power and *Y* factor methods to measure the noise sensitivity of the receiver unit. The assessment of noise sensitivity is based on the measurement of the amplitude level of the output signal with the noise generator switched off and on. The control unit software also manages the operation of the oscilloscope unit and the noise generator system.

The application is compatible with a MIO-2263 computer running the Windows 7 operating system. This OS was chosen due to its hardware optimisation and standardisation of the MIO computer family. In addition to the 32-bit version of the operating system, the necessary drivers have been installed to support computer peripheral circuits. The specialised software has been written in C++ in a modular way, using the concurrent programming technique. To develop a graphical user interface that simultaneously integrates the whole software, an integrated development environment (IDE) was used to support the process of designing, developing and implementing applications.

The control block software consists of the following modules:

- main process application – responsible for the operation of the user interface, control, configuration and communication with the systems of noise and signal generators;
- signal acquisition set application – responsible for controlling and setting up an appropriate acquisition set configuration and performing the task of transmitting recorded signals.

The main task of the developed software is:

- management and diagnostics of the oscilloscope unit and the noise generator system;
- digital processing and visualisation of recorded data;
- control of external sets, which allows the noise and signal sensitivity of the reception channel to be checked.

The operation of the software can be presented on the basis of the application controlling the noise sensitivity of the reception channel. In order to carry out such an inspection, it is necessary to:

1. Launch the "*Noise Generator*" function. The noise generator is switched on or off by pressing the "*G.Sz.*" button. The  icon indicates that the generator is switched on, while  indicates that it is switched off.
2. Launch the measurement of the receiver's noise value by means of the "*Noise Factor Measurement*" icon located at the bottom of the control panel.

Figure 4 shows an example of a noise factor measurement with the noise generator off (a) and on (b). Figure 4 (c) shows the software control panel. The noise sensitivity measurement procedure is then carried out automatically and the calculated noise factor value is displayed on the screen.

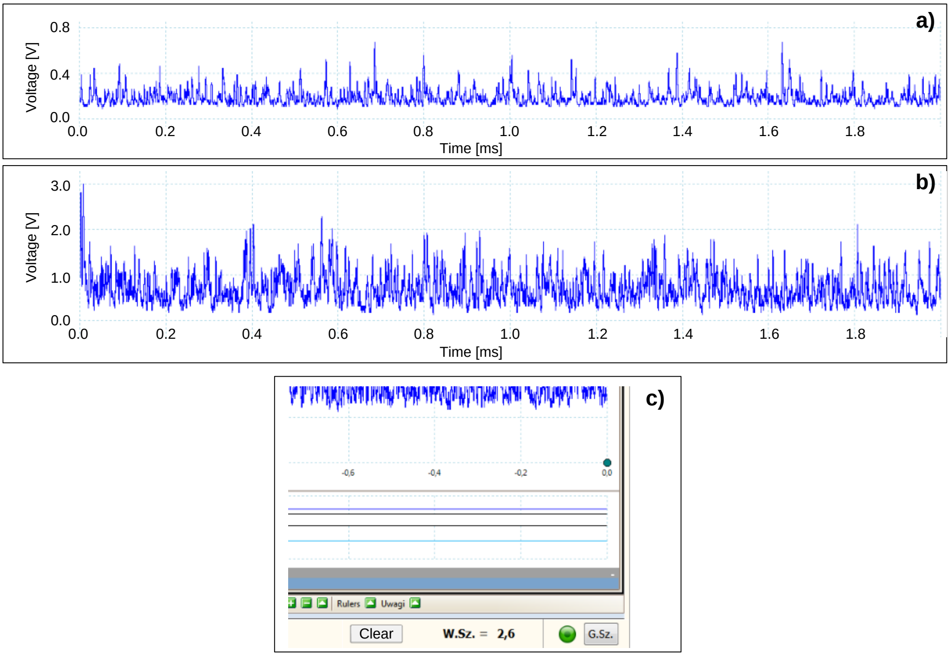

Fig. 4. Example of a noise factor measurement: a) generator switched off, b) generator switched on, c) "*Control Options*" panel with calculated noise factor

4. CONCLUSION

The paper presents a solution comprising a measuring system and noise generator developed as part of the solution, which allows to automatically control the noise parameters of the radiolocation pre-search station receiver using the twice-power method and *Y* factor method. On the basis of the research, it has been concluded that both methods give similar results and can be used interchangeably. In order to obtain correct results, it is necessary to calibrate the noise generator in an appropriate manner. The designed control system with the implemented software allows for automatic measurement of the noise sensitivity of the receiver without the need to use expensive instruments and complicated measurement methods.

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REFERENCES

[1] Żygadło Stanisław, Stanisław Grzywiński, Krzysztof Kowalik. 2017. „Automatic Control System for Transceiver of the Radar Station" (in Polish). *Problemy Mechatroniki. Uzbrojenie, lotnictwo, inżynieria bezpieczeństwa – Problems of Mechatronics. Armament, Aviation, Safety Engineering* 8 (4) : 141-150.

[2] Żygadło Stanisław, Stanisław Grzywiński, Krzysztof Achtenberg. 2016. Model generatora kontrolno-pomiarowego do kontroli wybranych parametrów stacji radiolokacyjnej. W *Materiały XX Międzynarodowej Szkoły Komputerowego Wspomagania Projektowania, Wytwarzania i Eksploatacji*, Jurata, maj 2016. Warszawa: Wydawnictwo WAT.

[3] *Radiolokacyjna stacja wstępnego poszukiwania RSWP P-18. Opis techniczny. Tom 1. Blok BPS, blok BK*. 2017.

[4] *Radiolokacyjna stacja wstępnego poszukiwania RSWP P-18. Instrukcja użytkowania. Blok BPS, blok BK*. 2017.

Układ do kontroli parametrów szumowych toru odbiorczego stacji radiolokacyjnej

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Streszczenie. W artykule przedstawiono układ pomiarowy, który pozwala na przeprowadzenie kontroli parametrów szumowych toru odbiorczego stacji radiolokacyjnej. Na potrzeby opracowanego układu zaadaptowano istniejące rozwiązania bloku kontroli RSWP P18 Laura.
Słowa kluczowe: źródło szumów, współczynnik szumów odbiornika