UDC 621.396.13

THE PRINCIPLE OF NONLINEARITY IN THE NOISE CONDITION UNDER THE INFLUENCE OF THE SUPERHIGH FREQUENCY BROADBAND AND HARMONIC SIGNALS

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A method for increasing the sensitivity of a nonlinear radar to nonlinear elements possessing small overall properties is considered; a method for determining the optimum frequency for the detection and investigation of NEs in the region of its optimum frequencies. An algorithm for using the UWB signal for NLR was developed. A structural diagram of the NLR has been developed, which applies this algorithm.

Of all the variety of possible methods of searching for objects, nonlinear radar occupies one of the most important places and has been actively developing since the 70s of the last century. Nonlinear radar (NLR) allows detecting nonlinear elements (NEs), not only in the active mode (during signal transmission), but also in the passive mode (accumulation mode) and also in the off state.

A significant difference between the NLR and the classical one with the active response is the direct conversion of the probing signal incident on the object to the energy of the higher harmonics. In this connection, the model of radar detection in conditions of nonlinear location can be classified as an observation with a semi-active response, which is connected with the lack of energy consumption by the object from a special power source. Its peculiarities are the very small value of the coefficient of nonlinear transformation ($\xi N << 1$) and the dependence on the frequency and power of the sounding signal of the locator [1].

At present, the sensitivity of NLR plays a huge role. The leads (NEs), as well as the conductors of the embedded device's printed circuit board, function as an antenna for broadcasting the re-emitted signal. Due to the reduction of the overall dimensions of the NE, the operating frequency of the antenna is increased. The rapid development of micro- and nanoelectronics poses the task of improving the sensitivity of NLR to embedded devices with small dimensions.

It is possible to improve the sensitivity of traditional radar in several ways:
- increase the frequency of sounding;
- apply a complex signal as a probing signal;
- reduce the duration of the pulses of the probing signal;
- increase the power of the sounding signal.

In traditional radar, the use of complex signals allows us to resolve the contradiction between the energy potential and sensitivity [2]. In nonlinear radar, the application of complex signals has a slightly different character [3]: the use of complex signals leads to a deterioration in the sensitivity and accuracy of the range measurement. Therefore, a method using ultra-wideband signals and optimizing the frequency of the sounding signal is of interest.

As shown in the source [4], different NEs have different optimum frequencies for detection. An example is shown in Table 1. The power of the re-emitted signal depends on the frequency of the probing signal and, of course, on the NE itself, its dimensions or the dimensions that make up its p-n elements. In this case, the power of the generated higher harmonics in the re-emitted signal becomes larger when the wavelength of the sounding signal corresponds to the linear dimensions of the NE [4].

Table 1. – Results of practical measurement of the level of the second harmonic of nonlinear objects at the level of the probing signal +10 dBm

Object\F	960 MHz	3600 MHz	7200 MHz	10400 MHz
КТ315	-114 dBm	-81 dBm	-83 dBm	-108 dBm
SIM card (two different)	-90/-88 dBm	-68/74 dBm	-78/-88 dBm	-105 / noise -118 dBm (NE defined)
Led	-105 dBm	-88 dBm	-88 dBm	-103 dBm
КД522	-82 dBm	-69 dBm	-65 dBm	-96 dBm
Processor MSP430F149	-108 dBm	-85 dBm	-90 dBm	-97 dBm
2А606 diode	-65 dBm	-60 dBm	-53 dBm	-55 dBm

To determine the optimal frequency of NE detection, it is proposed to use ultra-wideband (UWB) signal as a sounding. Using it determines the optimum frequency for NEs and conducts further analysis of the nonlinearity at the optimum frequency. For this purpose, the following algorithm for detecting NEs has been developed.

First, the NLR evaluates the noise level in the received frequency range and determines the trigger threshold to prevent false positives. At the next step, the NE is irradiated by the UWB signal with the band fmin - fmax. The re-emitted signal is received by an NRL receiver with a bandwidth of 2fmin - 2fmax. The spectrum of the received signal is analyzed. As a result of the analysis, it is determined whether harmonic components are present in a given band with an amplitude level above the established threshold, which is determined in the previous step. In the positive case, the search for harmonic components with the maximum value of the amplitude is conducted. In the negative case, it is concluded that there is no negative effect. If the NE is present and the harmonic component of 2Famax with the maximum amplitude in the re-emitted signal is determined, then the UWB signal radiation ceases, and the harmonic superhigh frequency signal transmitter is turned on instead. The frequency of the generated superhigh frequency signal is Famax. Finally, a standard method is used to determine the type of semiconductor (false or real) - analysis of the levels of the second and third harmonics of the re-emitted signal [1]. A flowchart of the algorithm is shown in Figure 1.

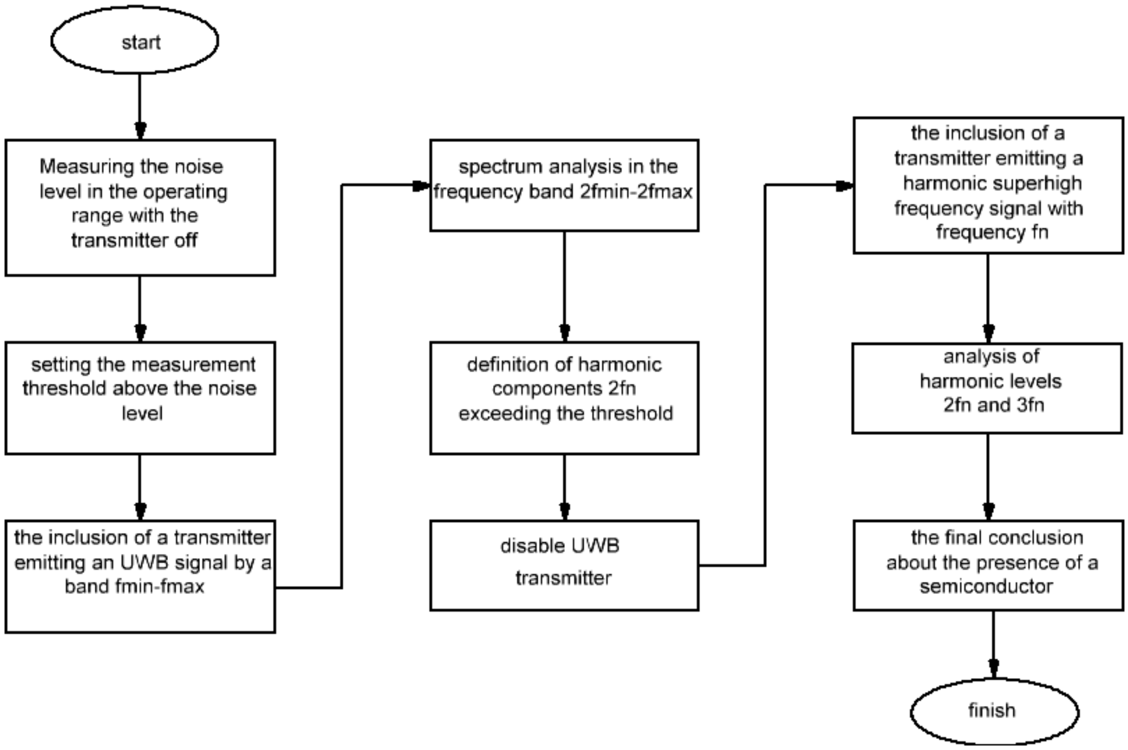

Fig. 1. Block diagram of the algorithm for detecting NEs

According to the above-described NE detection algorithm, the structural scheme of NLR was synthesized with the determination of the optimal frequency for detecting NEs (Figure 1).

In the structural scheme, the antenna switch commutes the UWB antenna to the UWB transmitter or to the programmable superhigh frequency transmitter. The UWB signal is generated by the UWB transmitter unit. The programmable superhigh frequency transmitter generates a harmonic superhigh frequency signal at a predetermined frequency upon the command of the microcontroller. The re-emitted signal is received by the UWB receiver, sent through the matching device to the unit performing the fast Fourier transform (FFT) and, accordingly, in the harmonic detection device with the maximum amplitude where the frequency component with the maximum amplitude is determined. The results of the analysis are transferred to the microcontroller, which sets the operating mode and sends the results of the operation of the NRL to the input / output device that a PC can serve.

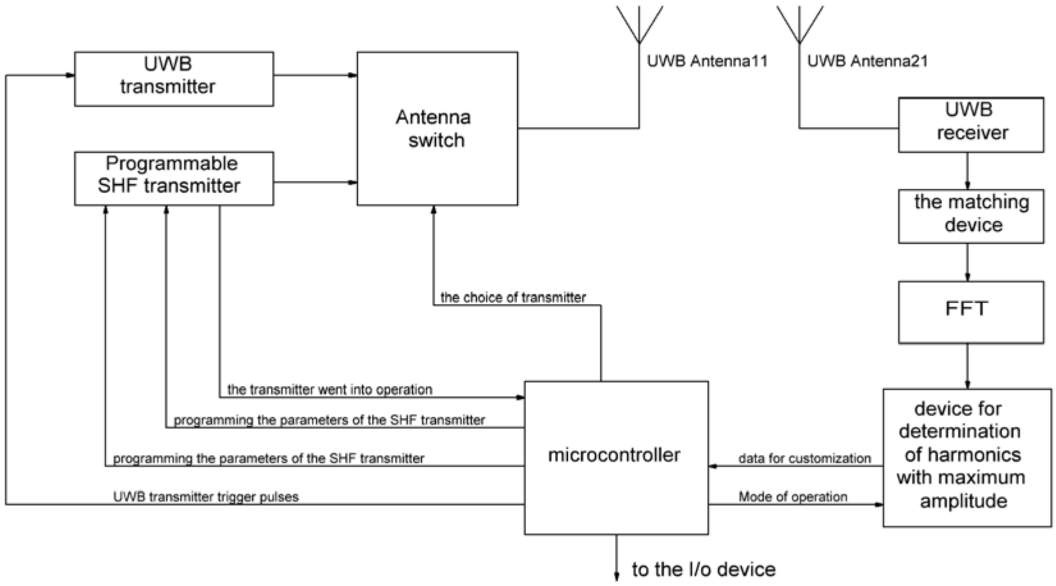

Fig. 2. Block diagram of the NLR

Thus, the use of UWB signals leads to:

- the possibility of investigating NEs in the region of its optimal frequencies;
- increasing the sensitivity of NLR to NE with small dimensions;
- decrease in sounding power.

The combination of detection methods leads to an increase in the accuracy of identification of semiconductor compounds and the detection of false semiconductors.

The presented algorithm for detecting NEs and the structural diagram of NRL are the foundation for further research and practical tests.

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