UDC 621.396

USE OF ULTRA-WIDEBAND SIGNALS IN NONLINEAR RADAR

ALIAKSANDR PRONIN, MIKHAIL IVANOU
Polotsk State University, Belarus

The analysis is given of the ways to improve the sensitivity of nonlinear radar to eavesdropping devices having small dimensions and having in its composition nonlinear objects. We investigated the method to increase the sensitivity by using, as the probe signal ultra-wideband pulses together with the harmonic signal of microwave frequency, which could result in intermodulation effect, through which run the identification nonlinear objects among the plurality of reflectors, which do not apply to non-linear objects.

Introduction: from the variety of possible methods of searching objects, the nonlinear radar is one of the most important ones and has been actively developing since the 70-ies of the last century. The nonlinear radar (NRL) detects nonlinear objects (NO), not only in the active mode (transmission signal), but also in the passive (accumulation operation) one and being turned off.

Currently sensitivity plays an important role in NRL. Conclusions transistors diodes and other nonlinear elements, as well as the conductors of the PCB laying device serve as an antenna to broadcast a re-emitted signal on the air. The rapid development of micro- and nano-electronics sets the task of improving the sensitivity of the NRL to mortgages devices having small dimensions, such as GSM bug N9 Nero Apple 40x30x10mm size [1]. The sensitivity of a conventional radar is improved in several ways: to increase the sensing frequency of use sophisticated signal as a probe, to reduce the duration of a probing signal pulse, increase the power of the probe signal. Increasing the operating frequency of NRL causes complication of the radar receiver path and leads to deterioration of the penetrating power of the radio signal.

The traditional use of complex radar signals allows to resolve the contradiction between energy potential and sensitivity [2]. The use of complex nonlinear radar signal has a different character [3]: the use of complex signals leads to the deterioration of the sensitivity and accuracy of the range measurement.

Of interest is the use of ultra-wideband signals for probing nonlinear objects. Midget duration of such signals provides a high level of resolution (up to mm units).

The goal: to explore the sensitization method using ultra-wideband pulse as a probing signal together with the ultra-high frequency harmonic signal

Objectives: to increase sensitivity of the mortgage nonlinear radar devices having small dimensions and having in its composition nonlinear objects.

It is proposed to use the effect of intermodulation as the foundation of such a method [4]. At the same time NO should be irradiated with a powerful harmonic signal E_0 (t) and ultra-wideband pulses Er (t). Reradiated signal from the NO is determined by (1):

$$E_r(t) = E_0(t) + g\left[E_0(t)\right], \tag{1}$$

where g (x) – the form of nonlinearity.

When the powerful high-frequency harmonic E_1 (t) signal, given by the expression (2), rescattered signal from the NO will be determined by the expression (3):

$$E_1(t) = A\sin(\omega t + \phi), \tag{2}$$

$$\begin{aligned} E_r(t) &= E_0(t) + E_1(t) + g\left[E_0(t) + E_1(t)\right] = \\ &= E_0(t) + A\sin(\omega t + \phi) + g\left[E_0(t) + A\sin(\omega t + \phi)\right]. \end{aligned} \tag{3}$$

To analyze the efficiency of this method, the simulation scheme «Matlab» program (Fig. 1) is synthesized. In the simulation, the case of the presence of eavesdropping devices in an environment that does not have shielding and absorbing properties of radio waves is considered.

Ultra-wideband pulses formed «Pulse Generator» blocks and «Digital Filter Design». The harmonic signal is generated by «Sine Wave» block. With the help of these two signals combiner is formed and sent to the NO «Fcn», the current-voltage characteristic of which is given by a polynomial of the third degree. Blocks

«AWGN Channel» simulate communication channel with noise. The simulation results are presented in the form of spectrograms of the control points scheme: «Spectrum Analyser», «Spectrum Analyser1», «Spectrum Analyser2».

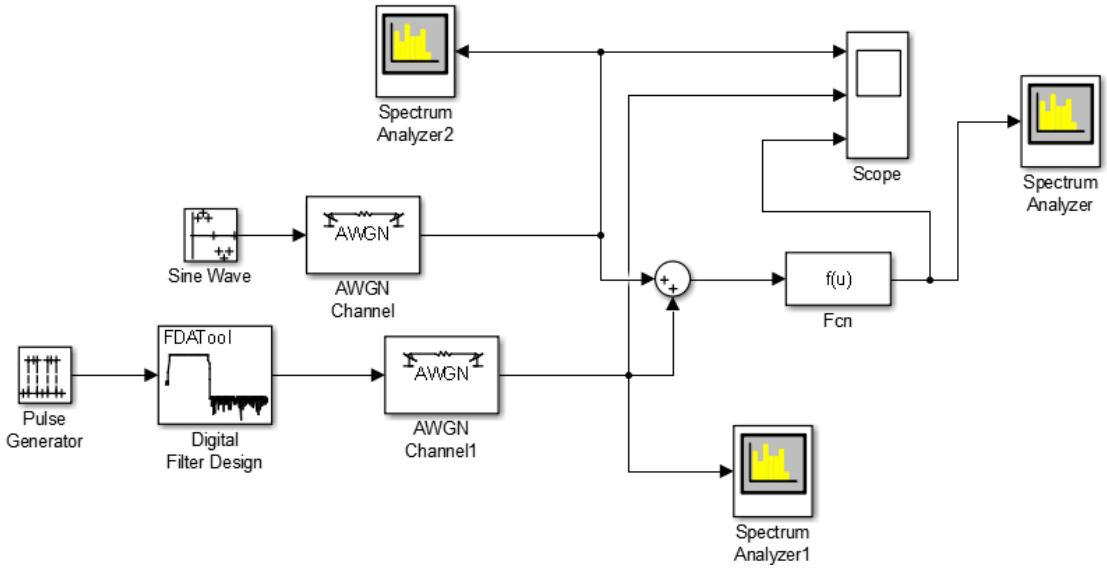
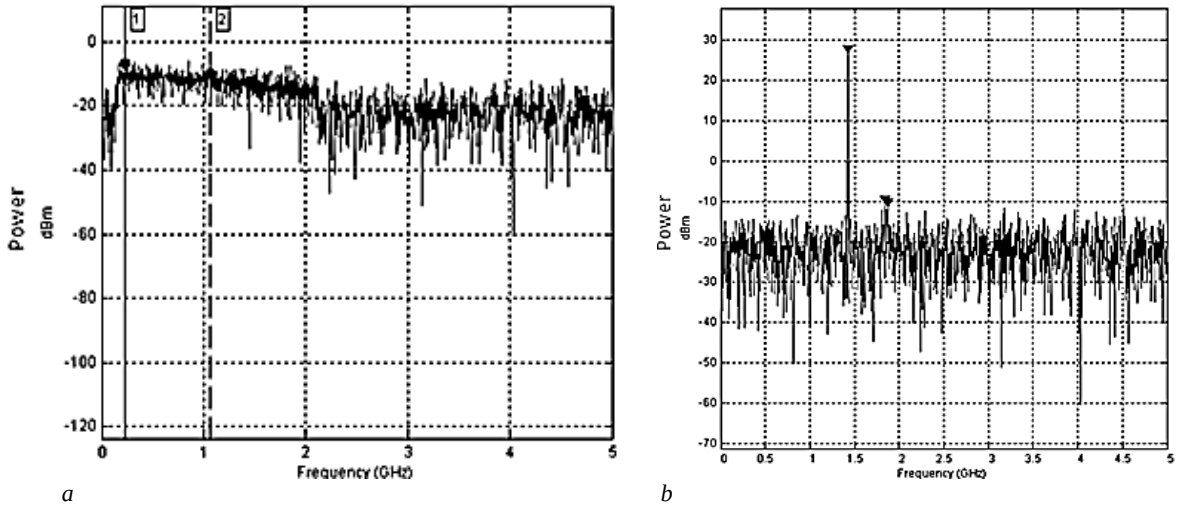


Fig. 1. Driving simulation

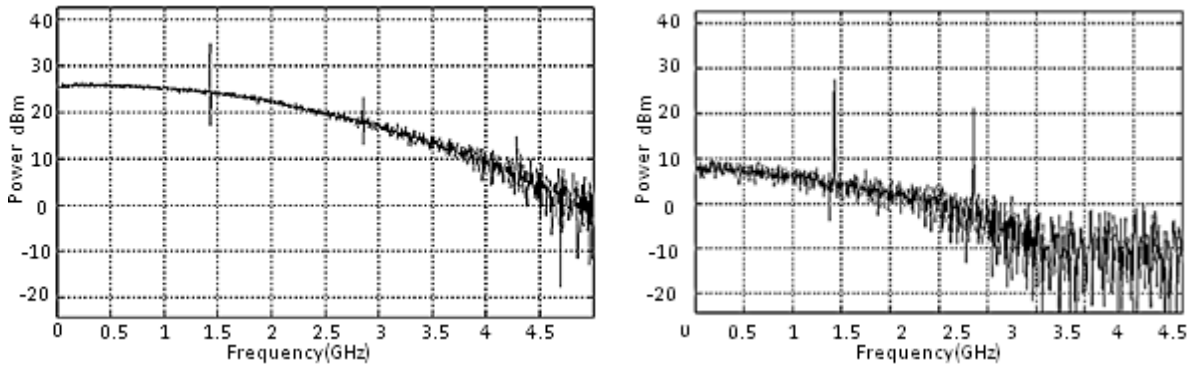
The spectrum ultra-wideband signal of the probe is shown in Figure 2, *a*. Signal to noise ratio in the simulation is set to + 20dBm. The spectrum ultra-wideband signal is limited to a band pass filter at the level of the main lobe. Pulse takes the form of the second derivative of a Gaussian pulse. The width of the spectrum in this case is on the level of 0.833GHz –3dB relative to the maximum power level, which is equal to –10 dBm. The spectrum of a harmonic signal (Fig. 2, *b*) has a single spectral component power 27 dBm in the 1.4 GHz frequency, which is higher than the maximum frequency of UWB signal spectrum at 600 MHz.



a *b*

Fig. 2. Spectrograms probing signals:
a – UWB signal spectrum, *b* – the harmonic spectrum signal

Output signals by converting NO described by a polynomial of the third degree is shown in Figure 3, *a*. As seen in the spectrogram, the reradiated signal is composed of harmonic signal emitted at the speed of 1.4 GHz 35 dBm level, twice the level of 25 dBm and three times the level of 15 dBm. In addition, there is cross modulation between the harmonic and UWB signals. And the range is similar to the amplitude-modulated signal, which serves as a carrier wave signal. When the quadratic nonlinearity (Fig. 3, *b*) is also present, and the double but not three times harmonic modulation of the radiated harmonic signal.



a *b*

Fig. 3. The spectrum of the signal after the nonlinear transformation:
a – for NO, described by a polynomial of the third degree; *b* – for the quadratic NO

Conclusion. Based on these results it is clear that irradiation as well as the harmonic signal and UWB pulses observed the effect of intermodulation. With NRL receiver tuned to a sideband of the modulated signal obtained as the result of the nonlinear transformation, NO is detected. Furthermore, the use of ultra-wideband signal can improve the sensitivity to NRL mortgage devices having dimensions of approximately a few centimeters. The programming model confirms the possibility of use in nonlinear radar the method of detecting eavesdropping devices having small dimensions and having in its composition NO. The model is the basis for practical tests in order to obtain more detailed studies.

REFERENCES

1. GSM жучок N9 [Электронный ресурс]. – Режим доступа: http://www.spytome.net/manuals/Nero-Apple.pdf. – Дата доступа: 02.04.2016.
2. Лезин, Ю.С. Оптимальные фильтры и накопители импульсных сигналов / Ю.С. Лезин. – М. : Сов. радио, 1969.
3. Горбачев, А.А. Особенности зондирования электромагнитными волнами сред с нелинейными включателями / А.А. Горбачев // Нелинейная радиолокация : сб. ст. №2. – М. : Радиотехника, 2006.
4. Дистанционная сверхширокополосная томография нелинейных радиоэлектронных элементов / В.П. Якубов [и др.] // Журнал технической физики. – 2015. – Т. 85, Вып. 2. – С. 122–125.