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WHAT DID THE DISCOVERY OF DYNAMIC CHAOS BENEFIT TO SCIENCE AND TECHNOLOGY?

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The paper considers practical aspects of the use of dynamic chaos. Examples of devices using chaotic signals are presented. The main focus of the work is on the system of information transmission using wideband and ultra-wideband chaotic signals. The authors show possibilities of transmitting information to wireless sensor networks for various purposes using mentioned chaotic signals. The prospects of applying dynamic chaos in practical applications in the near future are considered.

Keywords: dynamic chaos, chaos generators, ultra-wideband chaotic signals, masking device.

Introduction

It is barely more than 50 years since the dynamic chaos was discovered. The starting point for researchers, who devoted their scientific lives to its study, is the publication of E. Lorentz [1] in the journal "Journal of The Atmospheric Sciences" in 1963. For a long time this article did not attract the interest of specialists until mathematicians paid attention to a curious phenomenon of non-periodic, noise-like behavior of a determinate dynamic system. Since then a large-scale advance of ideas of dynamic chaos begins in various fields of science and technology, followed by huge number of publications in scientific journals. Chaos begins to be observed (and consequently studied) in chemical, biological, mechanical, optical, medical and other systems. One of the most fertile fields for research is radiophysics, where simple structures of auto-oscillating system make it possible not only to develop their mathematical models and perform simulation, but actually reproduce them at low-frequency mock-ups and study their behavior using the measuring facility of that time. The process of active research of dynamic chaos lasted until the 90s of the last century. By the time its theoretical basis was basically formed, the cause of the chaos and the basic laws of its development in various oscillating systems became clear. The researchers were confronted with the question of possibilities of practical application of dynamic chaos. Many teams of scientists, having only recently studied this amazing phenomenon, tried to offer their perspective of using ideas of dynamic chaos in science and technology. However, the path has proven to be thorny and so far only a few groups of researchers in the world continue to search for interesting and useful to society applications of chaos.

One of the most famous teams, successfully solving the problem, is a group of scientists led by Professor A.S. Dmitriev at V.A. Kotelnikov Institute of Radio Engineering and Electronics of Russian Academy of Sciences (Moscow) [2-4]. On the other hand, current trends of scientific and technological development, especially in the field of radio engineering, begin to actively enhance the application of the stored database in the study of dynamic chaos to use in the national economy. Chaos is no longer exotica, and for example, chaos generators, as sources of chaotic oscillations become really required in a variety of devices. Chaotic signals are often intrinsically wideband or ultra wideband signals begin to steadily appear in international standards regulating the development and use of new radio and electronic devices.

The objective of this paper is to review some works on use of dynamic chaos in practical applications. The review is not complete and does not include the interesting results of respected

researchers in other countries and regions, but it is associated with the retrospective of works of Professor A.S. Dmitriev's research group.

The authors were directly involved in the development of submitted applications, in particular in dealing with a problem of making sources of chaotic signals for them.

1. Early examples of using chaotic signals

Early applications of chaotic signals are associated with the name of Prof. V.Ya. Kislov and his scientific school at IRE RAS. To pay tribute to this great scientist, it should be noted that he and his disciples began to study the chaos as far back as the 60s of the last century. However, after gaining early interesting results, reporting on this topic was prohibited until the early 80s. Thus, for almost 15 years the scientific community was not able neither to get acquainted with the research results of the collaborators of the above-noted school of thought and, accordingly, nor to refer to them [5, 6]. Today it is recognized that applied research of dynamic chaos of V.Ya. Kislov and his followers made an enormous contribution not only to the study of chaos, but also turbocharged the search for its application in practice.

Perhaps, the first property of chaotic signals that came under the practising scholars' notice was associated with characteristic of them relatively wideband continuous power spectra in different frequency bands, very similar to the spectra of noise and noise-like signals. But unlike the latter ones, chaotic signals made it possible to control the spectral characteristics and, besides, to obtain by orders of magnitude greater spectral density power of output signals as compared to noise signals. Fig.1 shows some examples of power spectra of output signals from different chaos generators. The specified property predetermined the early applications of chaotic signals related to radio countermeasures and radio camouflage [7, 8].

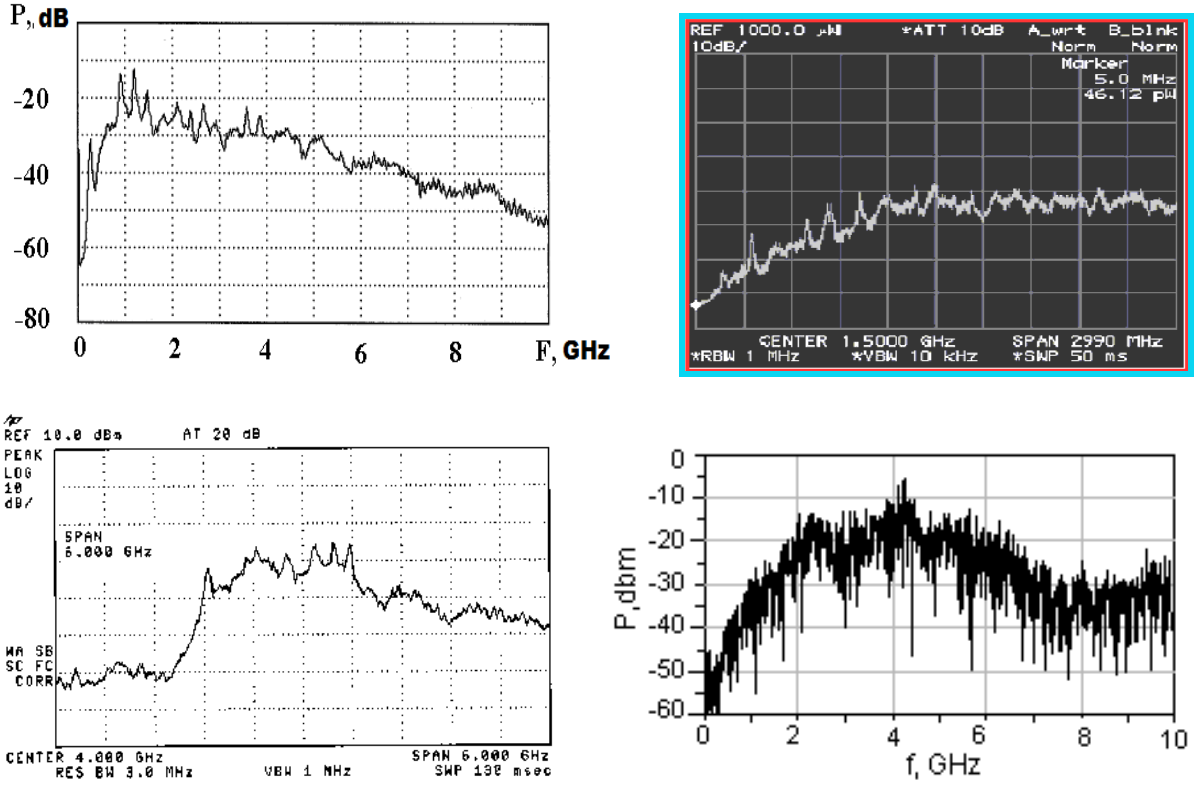
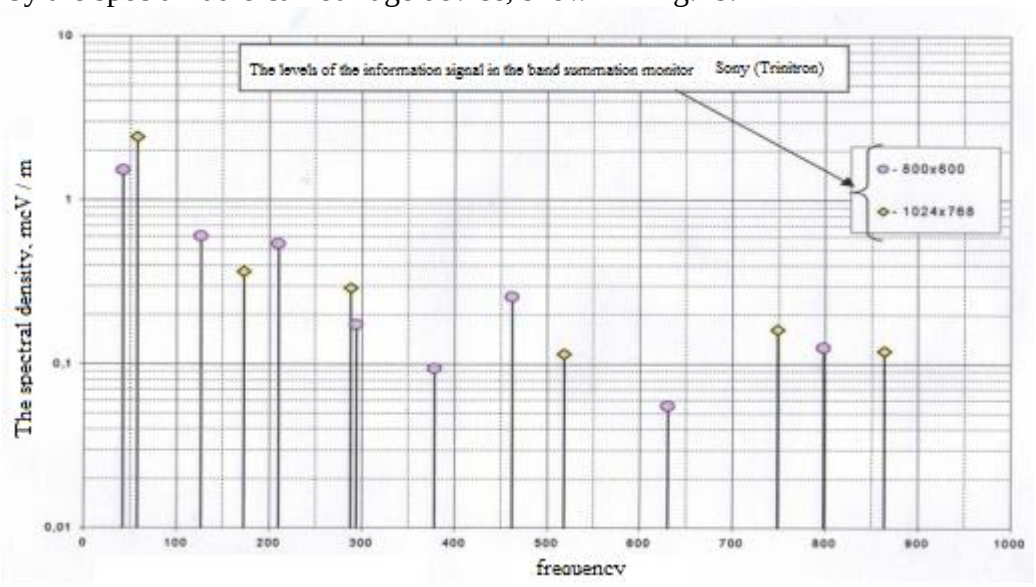


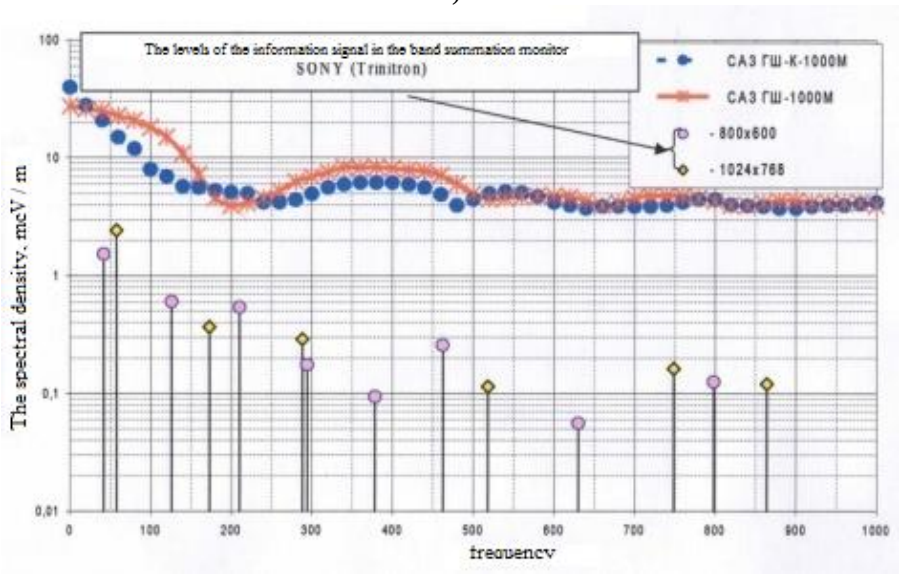
Fig. 1. Examples of power spectra of the output signals of different chaos generators.

As an example, in Fig.2a, a power spectrum of the signal emitted by the personal computer monitor is shown, and in Fig.2c, there is the same spectrum with the spectrum of the masking signal generated by the special radio camouflage device, shown in Fig.2b.



a)

b)

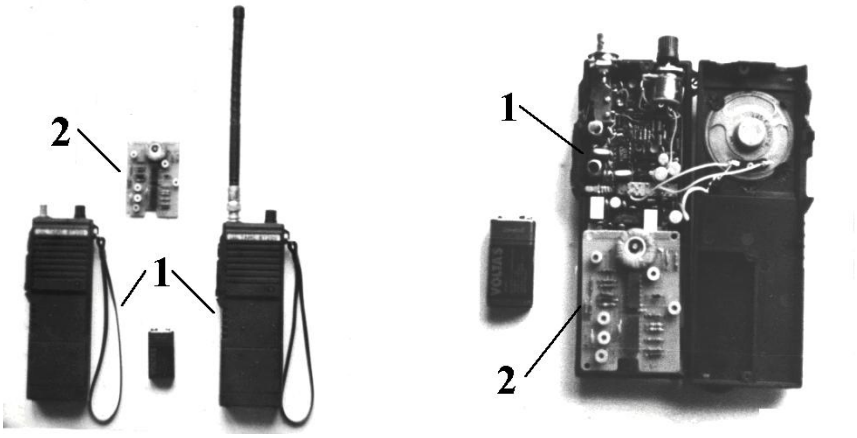


c)

Fig. 2. Radio camouflage of the signal emitted by the monitor (a, c), (b) – a masking device

2. Information transmission using dynamic chaos

So far, one of the most interesting, and perhaps the most promising practical applications of dynamic chaos are the information transmission systems. Chaotic signals are not only wideband in nature, but also have a very important from the practical point of view property of synchronization and self-synchronization of oscillations. It is this property that radically differs chaotic signals from noise ones and it is that, which forced the researchers to look for its use alternatives. Discovered at the turn of the 90s the phenomenon of synchronous chaotic response [9], induced a lot of proposals on the organization of secure information transmission using chaos [3]. For several reasons, most of them remained on paper, but the scheme “with nonlinear overlaying of some information to the chaotic signal” [3] was experimentally tested [10-11], and even developed in the form of a special device for secure communication within the radiofrequency band. Figure 3 shows a photograph of the pilot transmit-receiver device with a built-in module for "nonlinear overlaying of a speech signal to a chaotic one."



a) b)

Fig. 3. The pilot radiofrequency band transmitter-receiver device using chaotic signals:
a) the exterior view of the transceiver (1); b) a chaotic module (2) built in the transceiver

Another property of chaotic signals barred the further development and progress of covert communication systems using chaos. It was their sensitivity to disturbing factors, in particular, to noises in a communication channel. Always present in practice, noises disturb synchronization of chaotic signals and consequently, lead to misrepresentation of communicated information, i.e., that one acquired at the receiving end. Perhaps this line of practical application of chaos would have ended, but for a new surge of interest to widedband signals in communication systems.

Congestion of currently used frequency bands, on the one hand, and the consumers' desire to transmit large amounts of information at higher speeds, on the other hand, have led scientists and researchers to the idea of "frequency reuse." To implement this idea sources of wideband and ultra-wideband signals are required for using them as carrier signals. Then they again remembered chaotic signal sources, wideband by nature. Prof. A.S. Dmitriev and his colleagues proposed the concept of creating "direct chaotic communication systems" in which a wideband chaotic signal is formed directly within the microwave band and is then used as a carrier signal for information transmission [3]. The development of this concept led to a number of communication devices with a maximum transfer speed of up to 500 Mbit/s. Photos of some of them are shown in Fig.4.

a) b) c)

Fig.4. Examples of communication devices based on chaotic signals.
a) one of the earliest transceivers using chaotic signals; b) the "Pervatsch"robot;
c) a universal ultra-wideband transceiver for wireless sensor networks.

3. Wireless ultra wideband sensor networks based on chaotic signals

As has already been noted, by its fiftieth anniversary, dynamic chaos was no longer interpreted as an exotic phenomenon. Recently released international standards IEEE 802.15.6 and 802.15.4a may serve to confirm it. They regulate the design and building of wireless sensor networks for monitoring various systems, including a human body. As the main UWB carrier signal of sensor networks a chaotic signal is used [12]. Such official recognition of dynamic chaos makes this sphere of its application a priority in the coming years. Fig.5 shows currently under development examples of monitoring systems, using chaos.

a) b) c)

Fig.5. Examples of monitoring systems using chaos:
a) universal teaching and research complex of a wireless sensor network; b) wireless monitoring (structural strength of) a building; c) body wireless sensor network for monitoring the state of a human body.

CONCLUSION

Judging by the way things are going in solving the problem of application of dynamical chaos, we can assume that mankind is on the verge of wide use of chaos for practical purposes. This paper presents only those lines of research in which the authors have participated.

At the same time, the search for the possible applications of chaotic signals in other fields of science and technology is going on. In conclusion, the question: "50 years – is it long or not?" – can be answered by the phrase from one of poems: "50 years – it is only the beginning!"

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