

Encrypted by noise

If the behavior of macroscopic objects is determined by quantum laws, then their past is indefinite

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One of the best visualizations of thermal noise is ripples on an untuned TV screen. But even from this "ripple" it is sometimes possible to mold something reasonable.

Photo

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As [quantum computers](#) cease to be a purely theoretical construct and acquire the features of a real (even if not yet realized) technical device, the question of [quantum cryptography](#) is also transferred from the theoretical sphere to the practical one. Existing and quite successfully operating to this day cryptographic schemes with the advent of the first sufficiently efficient quantum computers will immediately reveal their vulnerability.

Imagine that you decide to rob a bank, but when you break into it, you find out that just a week ago, all the police stations in the district received a mysterious package with a videotape. By viewing such a video cassette now, everyone will be able to see all the details of the raid, but only on the condition that no one in any section has opened his package and looked at his cassette.

This metaphor was proposed by the American physicist Terry Bollinger ([Terry Bollinger](#)), trying to visualize the essence of the entangled states of quantum mechanics, on which, in fact, the entire technology of quantum encryption is built. If the states of two physical systems are "mixed up" with each other, then a change in one (in this case, the cracker, or "you") will immediately lead to a change in the other (videotape). It may even appear that this change is traveling backwards in time, passing through that moment in the past when a single quantum system splits into two connected parts. It seems that there can be no classical analogue to such a phenomenon. The more interesting are attempts to make a classical cryptographic mechanism with the properties of a quantum one.

Mistakes that cannot be avoided

Neither technology nor science can exist without measurements, and often their results determine the fate of one or another physical theory. At the same time, the accuracy of any measurement is finite, and this is not always reduced only to the limited capabilities of measuring instruments. In [quantum mechanics](#), measurements play a very special, one might even say decisive, role: if the accuracy of measuring the speed with which a taxi driver skips an intersection is determined solely by his speedometer or the radar at the guard, then the uncertainty in measuring the speed with which a proton in a collider crashes into a target, obeys the well-known [Heisenberg formula](#).



By mounting a telescope with an 8-inch mirror on the windowsill of his office, physicist Joshua Bienfang can receive photons sent from the top floor of the Standards Institute office building and decipher the information they carry. Encryption is carried out by methods of quantum cryptography.

Photo

Gail Porter/NIST

In physics there is a concept of "natural limits of measurement", but its content depends on the circumstances. [Meter standard](#) held by the Bureau International des Poids et Mesures ([Bureau International des Poids et Mesures](#)), changes its length depending on the temperature and humidity of the air surrounding it, and its different edges - after all, it is a three-dimensional body - cannot have exactly the same size.

What determines the accuracy in determining such fundamentally macroscopic quantities as the current strength or the electrical resistance of a conductor? Is it only from the "quality" of measuring instruments - a voltmeter or an ammeter? Also, it turns out, no - the concept of "natural measurement limits" extends to electrical circuits. Back in 1928, employees of the famous Bell Labs ([Belllabs](#)) Harry Nyquist ([Harry Nyquist](#), 1889–1976) and John B. Johnson (1887–1970) discovered the thermal noise effect ([thermal noise](#)).

Experimentally, the effect of the stochastic appearance of a potential difference at the ends of a conductor in the absence of current sources was discovered by Johnson. And Nyquist gave

him a theoretical explanation. If the conductor is not cooled to ultra-low temperatures, the electrons, colliding with metal atoms vibrating at the nodes of the crystal lattice, also participate in chaotic thermal motion. Order emerges randomly from chaos. According to the Nyquist-Johnson formula, voltage fluctuations are determined by the resistance of the corresponding section of the circuit and its temperature.

It is this formula that determines the "natural measurement limits" of the voltage in the conductor, since thermal noise is present in any electronic device. In a household TV, for example, the power of such noise is estimated in tenths of a picowatt (about 10^{-13} W), and it is simply impossible to notice them. But if we are talking about low-current signals - for example, in the logic circuits of a computer - then the thermal noise factor can be a very significant obstacle to normal operation. And then the engineers develop various heat dissipation schemes to reduce the noise level.

What are we buzzing about?

The probabilistic nature of noise in a sense brings it closer to quantum phenomena. American physicist of Hungarian origin, computer scientist at Texas A&M University ([Texas A&M University](#)) at College Station and Editor-in-Chief [Fluctuation and Noise Letters](#) Laszlo Kish ([Laszlo Kish](#)) found a way to encode, using noise in communication channels, the signal transmitted over these channels. At the same time, according to Kish, this cryptographic method, being entirely classical, will give results very close to the methods of quantum cryptography.

Laszlo Kish's idea is to use the Nyquist-Johnson effect to transmit encrypted messages. In this case, the communication line can be absolutely any, including a regular telephone line. Suppose this line connects two subscribers, who, according to the tradition established in cryptography, are usually called Alice and Bob. Each of them has two resistors, one with a large resistance, the other with a small one. Both Alice and Bob can randomly connect these resistors of their own to the transmission line, changing its impedance. Even if it's a simple conductor from Alice to Bob, they can connect one resistor terminal to the conductor and the

other to ground. In a word, specific implementations here can be different - the main thing is that the total resistance changes noticeably.



Laszlo Kish.

Photo

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In accordance with Nyquist's law, as the resistance changes, the spectrum of thermal noise in the entire circuit will also change. If Alice connects one of her resistors and then listens to the noise, she will know how Bob's resistors change. If Bob, for example, inserts a large resistance instead of a dash, and a small one instead of a dot, then Alice will easily turn the noise in the circuit into a regular Morse code.

The trouble is that the insidious Eve, having connected with her resistor, will be able to measure the same noise and get the same Morse code. And here Alice has her own trump card: by accidentally changing the resistance at her end of the circuit with the help of her two resistors, she will make jumps in the change in thermal noise chaotic and meaningless. Without knowing how Alice's resistance changed, Eve will not be able to know what message Bob was transmitting to her. And even then, this is only if Eve knows for sure that someone is transmitting something here. If she connects to the line just to check, then she will not hear anything, except for the usual "rustle". And Bob and Alice will be immediately

warned: someone is listening to their correspondence, because the noise spectrum has become "wrong"!

An unusual look at the usual noise

The noise factor, when viewed from an unexpected angle, was already showing its usefulness. Known, in particular, is the history of the discovery [of relic radiation](#) by Robert Wilson ([Robert W. Wilson](#)) and Arno Penzias ([Arno A. Penzias](#)). The radio astronomers Penzias and Wilson, who all worked in the same Bell Labs, studied in 1964 the radio emission of one of the stellar objects in [constellation Cassiopeia](#). Having minimized all possible sources of interference (including thermal ones), they could not get rid of the abnormally large background noise that prevented the study of objects of interest to them.

Around the same time, Penzias' colleague MIT radio astronomer Bernard Burke ([Bernard F Burke](#)) ended up at a lecture by Robert Dicke ([Robert Dicke](#), 1916–1997), cosmologist at Princeton University ([Princeton University](#)), about the theory of [the Big Bang](#) and [the hot universe](#). Dicke mentioned there one of the consequences of the theory: some of the photons emitted during the Big Bang or shortly after continue to fly in empty space without interacting with matter. The average density of matter in the Universe is so low that these relic photons still carry information about the first moments of its life. However, due to the fact that since then its dimensions have greatly increased, the temperature of the radiation has dropped dramatically - the same thing happened to it that happens to freon in the evaporator of the refrigerator, when the compressor pumps out its vapors from there.

It was from Burke that Penzias learned the contents of Dicke's lecture, and it was then that it occurred to him that the noise that had been so disturbing to him and Wilson was perhaps something more significant. After making the necessary measurements together with Wilson, he was convinced that the background radiation that had been so annoying to them was actually the cooled radiation of the Big Bang. As a result, Penzias and Wilson in 1978 became Nobel laureates in physics for "the discovery of the cosmic microwave background radiation." This radiation is now called relic and is considered as one of the most convincing confirmations of the correctness of the hot model of the Universe.

The encryption method proposed by Laszlo Kish aroused great interest, also because it infringes on the monopoly of quantum cryptography and on the adequacy of the assertions that only quantum cryptography can reliably protect commercial and military secrets. Recall that the method of quantum cryptography involves the transmission of information using single photons of different polarizations. A potential spy, when measuring the characteristics of a photon, inevitably changes these characteristics due to the peculiarities of the quantum measurement procedure. And this means that the fact of eavesdropping can be quite easily established.

What are the successes in implementing Laszlo Kish's idea? A device has already been made that can send secret messages along a wire 2000 km long. Note that the Kish method allows the use of conventional communication lines, while quantum cryptography usually involves the use of much more expensive fiber optic lines. Currently, experimental quantum cryptography devices operate at distances not exceeding several hundred kilometers.



The technical implementation of the Kish method is quite simple, but the discussion about its reliability is not yet over.

Photo

Fluctuation and Noise Exploitation Laboratory/Department of Electrical Engineering, Texas A&M University

Laszlo Kish himself estimates the cost of a future installation at only a few hundred dollars. Talking about Laszlo Kish's idea, magazine [New Scientist](#) in one of the latest issues, he also cites the opinion of experts. [Bruce Schneier](#), founder of network security firm BT

Counterpane, says Kish's device "should be taken seriously" and says he was struck by the simplicity of the idea when he first heard about it. Another expert is Weston Tew, a physicist at the National Institute of Standards and Technology in Gaithersburg ([National Institute of Standards and Technology](#)) - believes that the implementation of the method at large distances may encounter problems. And Janos Bergu ([Janos Bergou](#)), theoretical physicist at Hunter College of the City University of New York ([Hunter College of the City University of New York](#)) even makes some suggestions about these problems: if the wire itself has a noticeable resistance, then the fluctuations should be somewhat higher at the end of the wire where the larger resistor is chosen. A potential spy can take advantage of this circumstance.

Approximately the same is said by Terry Bollinger, already quoted above. Quantum laws, in the form in which they manifest themselves in the reduction of a wave packet or some other unraveling of an entangled state, imply the possibility of "correcting" the past, while no one knows about it. Classical physics forbids this in principle. Isn't Kish's cryptographic construction just the invention of a new, even stronger lock on the doors of a bank that is planned to be raided? The question is still open.

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