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APPLICATION OF THE NANOSECOND PULSES

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In operation two usages of short impulses are considered: a radiolocation and physical chemistry. The features of the characteristics of units of an impulse locator are reduced. Its high noise immunity is marked. The examples of application of power electromagnetic impulses for an exposure of water, water solutions, foundry mixtures and melts of metals are reduced. The considerable changes of properties of substances after an exposure are marked.

Conditionally it is possible to select two major usages of nanosecond electromagnetic impulses (NEMP) – radiolocation and radiation physical chemistry. The application NEMP in a radiolocation has a number of features. Let's consider basic units of a radar.

The generator should have given parameters. A pulse length τ should be selected outgoing from sort of the found out purposes. Reflected from the purpose the long l impulses have minimum duration $\tau_p = l/c$ (c – the speed of light). The actual reflected impulse is longer in 2…3 times. Usage short (0,1 ns) impulses for the meter purposes therefore is not meaningful. For detection of the wide class of planes it is enough to take τ the order 2…3 ns. On the same reasons it is not necessary to set the rigid requirements of duration of front τ_f of impulse. The acceptable requirement is equality of front and back fronts. The generated impulse should not have sites with zero by derivative on time, as these sites are not radiated by an antenna. The pulse amplitude U is determined by the power characteristics of a locator.

The pulse-recurrence frequency f depends on the purpose speed and its mobility. Generally it appears, that for different types of generators the product of amplitude and pulse-recurrence frequency is equal $10^7 \ldots 10^8$. Probably, it is defined by the power characteristics of modern electron devices. At usage of a stroboscopic method processing it is necessary to select frequency more.

The parameter jitter determines the shift of a leading edge concerning a trigger pulse. It is possible not to take account a jitter if in the processing device to take synchronization from emitted impulse.

The best generators are the generators Belkin-Schulgenko [1] in author's opinion. One of them has the following characteristics. A pulse length 0,5 ns, $U = 8$ kV, $\tau_f < 0{,}2$ ns, $f = 0{,}1...1$ kHz, overall dimensions $290 \times 90 \times 40$ mm. The parameters of other generators are reduced in operation [2].

The receiving-transmitting antennas of a locator can be combined or separate. The emitted in space impulse has a number of features in comparison with a radio pulse in any case. Explicitly this problem is surveyed in operation [3]. The form of emitted impulse is proportional to derivative of a current in an emitter. At a unipolar current space impulse is two-polar and its form depends on a radiation direction. The zone of a zero field will be derivated in the middle of impulse for directions far from a normal to an emitter. The amplitude diagram has not side lobes. Its width is inversely proportional to sizes of an antenna. The usage of effective antenna lattices (as at harmonic signals) is impossible as the impulses are not completely added in all directions.

As the main parameter of antennas it is better to use a through spatially-temporary pulse response by receiving and transmitting of antennas $g(t,\theta,\varphi)$, which is defined by a relation

$$S_{\text{out}}(t) = \int_0^t \mathrm{S}_{\text{in}}(t)\, g(t-x)\, dx\,, \qquad (1)$$

where $S_{\text{in}}(t)$ – input signal on a transmitting antenna, $S_{\text{out}}(t)$ – output signal on a receiving antenna, which are defined for all angles θ and φ. The knowledge $g(t)$ saves of necessity of development receiving-transmitting antennas with the rigid characteristics.

The best antennas, which are manufactured by the author, have the following characteristics in the terms of sine-wave antennas. The four logarithmic helical antennas joint in a ring of the Mobius with sizes $1000 \times 1000 \times 80$ mm has $K < 2$ in a range 40 … 1200 MHz. The TEM-horn with resistive load on the ends with an aperture 250×480 mm and flare angle 30° has $K < 2$ in the range 100…1200 MHz. The ferrite antenna is fulfilled as one closed wire loop (a cable central core) on a rod $70 \times 30 \times 4$ mm, located on a metal substrate 120×60 mm. A closed loop and cable braid are joined to a substrate by the different sides of a rod. The antenna has uniform $K < 3$ in the range 200…2000 MHz. This antenna provides the impulse by 1 ns duration on reception with the same form, as well as on a transmitter output.

The receiver NEMP is one of the most problem devices of a radar. It is coupled to necessity of an amplification of very short and feeble pulse signals. The receiver should have a range of magnified frequencies $f_{\text{rec}} = (2...3)/\tau$ and small figure of noise. The amplifiers with a working bar from 10 MHz up to 10 GHz are known, but their amplification factor is 2. Usage of several parallel amplifiers with overlapped ranges also is the difficult task. The possible variant of the receiver build-up can be the usage of resonance narrow-band amplifiers at the main and multiple harmonics of a pulse signal. The receiver worked effectively for the amplification of 8 impulses pack by 7 ns duration in one of the system for ice width measurement. The receiver had 7 operating frequencies multiplied to 21,5 MHz. The shortcoming of such way of an amplification is the periodic control of an amplification value coefficient and its phase, that is necessary for precise assembly of impulse. Such control can be carried out on a special test signal taking off the transmitter output through a divider. Generally the absence of good receivers NEMP constrains a build-up of effective radars.

First of all the processing device should contain an analog-to digitizer for input of a signal in a computer. Build-up of the analog-to-digital converter is the difficult technical task because of a small pulse length. The difficulties are decreased if to use a stroboscopic principle of conversion. However it needs a major repetition frequency of emitted impulses.

In the processing device the main advantage of the short impulse locator (its heightened noise stability) can be implemented. It is known, that the most effective interference is the locator signal. Above it was mentioned that the signal form radiated and reflected from the purpose depends on the radiation direction and purpose characteristics. On principle this information misses and can not be obtained on the server of interferences. Besides the reception of a short pulse signal and its repetition is a very difficult technical task.

The usage of processing correlation method in a locator also considerably boosts locator noise stability, as the pulse signal is unknown on the interference server.

There is the radar mockup with the following parameters. A pulse length is 0,5 ns, amplitude $U = 8$ kV, $f = 1$ kHz, stroboscopic converter and amplifier is on the basis of the oscillograph C1-122/4 (equivalent band – 0…18 GHz, minimum input voltage – 5 mV, maximum – 1 V), 10 bit analog-digital converters. On the mockup there were obtained the signals reflected from a number of the next purposes: a slice 20×20 cm, pipe $\varnothing 15$ cm, $l = 2$ m, sphere $\varnothing 30$ cm, located apart 10…20 m.

A new field of NEMP usage is radiation physical chemistry.

The first outcomes were obtained by the author in operation [4], more complete – in [2]. The researches have begun from an exposure of water. It was used the single- and twice distilled water, that provided recurrence of the results.

The water was irradiated in glass vessels with different emitters. The horn and spiral emitters were used. The time of an exposure was from 100 up to 2000 s. There were metered a specific electroresistance ρ, dielectric factor ε and hydrogen metric pH. The following results were obtained. During an exposure up to 1200 s it was observed the decrease of ρ to 15…20 %, growth of ε to 10…12 %, increase of pH to 0,1…0,15. Further the change of properties is essentially decelerated. The irradiated water saves its modified properties in darkness up to 10…15 day.

The radiolysis of water under radiation operation is selected as the model for the description of happening processes. His essence consists in the next. After dissociation of a water molecule on components H^+ and OH^-, last radical breaks up to a mobile electron e^- and OH. The electron is hydrated and the cluster from water molecules is appeared around it. It explains the decrease of ρ and increase of ε. Further the hydrated electron e_{aq} enters into chemical reactions with the water, radicals H^+ and OH^-, therefore it's appeared H, H_2, H_2O_2. The neutralizing H explains the increases of a metric pH.

If the other substances are dissolved in the water electron e_{aq} enters with them in chemical reactions, because it is very active chemical particle with a potential $\varphi = -2{,}77$ V. It can be used for the water clearing from heavy metals, such as Fe, Cu, Zn etc. For example, the contents of Fe is decreased in 3…4 times after an exposure.

In foundry production for manufacture of the forms the compositions are widely used on the basis of a liquid glass. These compositions have restricted period of 1…2 days robustness. The exposure of these compositions by NEMP has magnified period of their robustness till 2 years. The foundry forms manufactured from the irradiated compositions, have major strength in cold and hot statuses in 1,5…2 times.

The considerable influence renders an exposure by NEMP on corrosion stability of steels. Two types steels were taken for experimental researches: wide application – 08КП (СТ.3) and special application 38ХН3МФА. The plotting of a protective film was carried out on the following technique. The sample was located in electrolyte solution and one of the outputs of NEMP generator was joined to it. The add electrode was immersed in the same solution, was joined to the second output of generator. The salt of a sulfuric acids, NaCl and specially fitted solutions were used as solutions.

Ii was obtained, that after an exposure in a solution $ZnSO_4$ the speed of corrosion of the steel samples 08КП has decreased twice. The current of anode dissolution has decreased in 3 times after an exposure the same samples in a solution $NaOH + Na_2CO_3 + SiO_2$. The similar results were obtained for the samples from steel 38ХН3МФА. It points that the main protective factor is the protective film, instead of the steel type. The origin of an effective protective film is coupled with the activation of a solution and changes of surface properties of a defended hardware product.

A method of change of petroleum properties after their NEMP exposure can find wide application. The influence of an exposure to a contents of sulfur in benzine from naphtha and gaseous condensate was researched. It was obtained, that the contents of sulfur in petrol in 2…3 times are less after an exposure, than at absence of an exposure. The increase of octan number on 3…5 unites is also marked for petrols from the irradiated raw material.

The NEMP exposure are rendered the considerable changes on melting metals. Their exposure was carried out by the following way. Inside the melting metal, which was in heat resisting conductive vessel, the feed antenna – tube are located. The feed antenna was isolated from a melt by the quartz. One of outputs of the generator was joined to a feed antenna, and the second one with the vessel. The mass of irradiated metal varied from 5 up to 3000 kg, time of an exposure – from 10 up to 60 min. There were irradiated aluminum АК7 and АК5М and zinc ЦА4 AND ЦА4М3 alloys.

It was obtained, that the fluidity of an alloy АК5М is magnified by 60 % in hot form after the exposure. It was marked the increase of a tensile strength, increase of a relative elongation, change of the form of grains on more compact in the hardened samples after an exposure. For an alloy ЦА4 after an exposure the decrease of a specific electrical resistance was obtained.

In some experiences at an exposure of water solutions of salts and metal melts the cases transmutation of chemical units are captured. The transitions are remarked $Zn \leftrightarrow Cu$.

An aqueous solution of $CuSO_4$ and $ZnSO_4$ was irradiated in a glass beaker 90 mm in diameter and 120 mm in height. A horn radiator with the opening 60×60 mm and 90 mm in height was dipped into this solution. The horn walls were coated with a water-resistant varnish. The concentrations of metal ions (mg/L) before and after irradiation for 100-800 s are listed in Table 1.

Table 1.

pH = 7	Initial	100 s	400 s	800 s
Cu^{2+}	0,16	0,18	0,18	0,18
Zn^{2+}	0,03	—	—	—

The experiment was carried out at 20°C so that the evaporation of the solution did not take place. The uncommonness of this result is that the copper concentration increases, while the zinc concentration vanishes.

In the next experiment, an aqueous solution of the same salts at a decreased pH value was irradiated for 16 min. The same radiation source was used. The solution was stirred by means of a magnetic stirrer. The results of this experiment are summarized in Table 2.

Table 2.

	pH	Cu^{2+}, mg/L	Zn^{2+}, mg/L
Initial	3,32	4,8	3,0
Radiated	3,35	4,6	3,2
Error	0,01	0,01	0,05

Comparison of the data in Tables 1 and 2 shows that the direction of the process depends on pH.

The transmutation $Fe \rightarrow Mn \rightarrow Cr$ are remarked in metal melts.

The explained above results display that the NEMP exposure has very wide usages.

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ПРИМЕНЕНИЕ НАНОСЕКУНДНЫХ ИМПУЛЬСОВ

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Рассматривается использование коротких импульсов в радиолокации и в физической химии. Получены особенности характеристик составных частей импульсного локатора. Отмечена его высокая шумоустойчивость. Приведены примеры применения мощных электромагнитных импульсов для облучения воды, водных растворов, расплавленных смесей и сплавов металлов. Отмечены существенные изменения свойств веществ после облучения.

ЗАСТОСУВАННЯ НАНОСЕКУНДНИХ ІМПУЛЬСІВ

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Розглянуто застосування коротких імпульсів у радіолокації та у фізичній хімії. Отримано особливості характеристик складових частин імпульсного локатора. Наведено приклади застосування потужних електромагнітних імпульсів для опромінення води, водних розчинів, розплавлених сумішей та сплавів металів. Відзначено суттєві зміни властивостей речовин після опромінення.