UDC 681.518, 533.9.15, 533.924

O. V. SHEFER,
candidate of sciences (technical), associate professor, Associate Professor of automation and electric drive Department
(Poltava National technical Yuri Kondratyuk University)

The prospects and peculiarities of plasma with hollow cathode using for satellite telecommunications noise stability increase

Розглянуті переваги та особливості застосування штучно створеного плазмового середовища з метою компенсації зовнішньої плазмової оболонки для підвищення завадостійкості супутникових телекомунікацій. Встановлено загальну закономірність впливу ефекту в плазмі порожнистого катода на створення завадостійкого середовища, що залежить від умов використання енергії швидких електронів під час їх коливального руху, позитивних іонів, швидких нейтральних частинок, метастабільних атомів та фотонів.

Рассмотрены преимущества и особенности применения искусственно созданной плазменной среды с целью компенсации внешней плазменной оболочки для повышения помехоустойчивости спутниковых телекоммуникаций. Установлена закономерность влияния эффекта в плазме полого катода на создание помехоустойчивой среды, которая зависит от условий использования энергии быстрых электронов при их колебательном движении, положительных ионов, быстрых нейтральных частиц, метастабильных атомов и фотонов.

The set of the problem.

The ascent phase of the spacecraft (SC) to the orbit designed for the SC lifting above the Earth's surface and it's dispersal to the necessary velocity.

With the use of the grounds and the satellites systems of the wireless communication, the problem of the information exchange between mobile objects is solves. This problem looks particularly acute during the SC insertion to the orbit, since there are such extreme conditions as the flight path, the aerodynamic resistance of the external gas environment, the solar and the geomagnetic activity and other factors, that significantly affect to the quality of communication with the spacecraft.

In the conditions of atmospheric entry of SC at the hypersonic speeds, through the aerodynamic resistance of external gas environment, their cover heats up. Such SC's include: the piloted space objects, space landers, space probes, warheads of intercontinental rockets, capsules with tests, and also objects which can or have to burn down, for instance, satellites which have fulfilled the resource and so forth.

As a result of heating, the huge number of heat, which leads to formation of plasma around flight vehicles is allocated. Plasma completely absorbs radar radiation. As a consequence, a frequency selective fading environment, impervious to signals of the systems of satellite telecommunications forms.

This environment completely blocks the radio signals therefore the SC isn't able to perform telemetric communication with its stations within several minutes. This period is the most dangerous from the reliability's and safety's point of view for the SC flight.

The problem in the military aspect is not less urgent: radar signals of hypersonic heads of rockets homing and fighting blocks of intercontinental ballistic are blocked and that can lead to the unforeseen consequences.

The problem of ensuring stable radio communication with the SC is quite acute

The review of recent researches and publications.

In the beginning of XXI century, leading space countries has made the mutual international standard CCSDS for the radio line transmission of specific SC information creation [1]. With the purpose of preventing loss of communication and telemetry with the SC, several approaches were proposed [2]. For instance, antennas with thermal protection, the design of which own a decreased sensitivity of its radio transparency for the interaction with the ionized gas of aerodynamic heating. Or the using of long hot-resistant antennas, which are represented like the tape of the plasma sheath. In [3] the creation of the devices for the passage of radio waves through the plasma is represented, but such devices require substantial amounts of energy. In [4] use of a special external screen with a metal ring, located in the dense plasma behind the shock wave and the creation of electric field in the vicinity of slit antenna to compensate the influence of the external ionized gas for the radio signal passage were proposed. At the same time, available sources don't provide the information about the deterioration of aerodynamics and other negative factors.

The formulation of an objective of the study. The purpose of the task is to create a noise immunity environment on the basis of artificially created energy efficient compact plasma device in the middle of the SC for the radio transparent medium creation.

The main material.

The latest technologies have changed the ideology of noise immunity radio communication systems construction, have made the application of sophisticated tools that improve and lower the cost of the supporting functions of communication, and simultaneously open up almost unlimited possibilities of satellite telecommunications of SC possible.

In recent years, the progress in the study of unbalanced plasma states has noticed. Quasi-neutral gas – is plasma, which contains both charged and neutral particles. Whereas these parts are moving, the plasma has the property to conduct electric current.

For the necessary plasma creation, the studies of the physical processes that lead to the creation of plasma environment with new properties, which meet the requirements of navigation technology are required [5].This is possible in a gas discharge, where the plasma state and its properties are formed by a huge number of complex phenomena, depending on the applied electricity, pressure, gas type, electrode material and geometry of the discharge gap. Discharge plasma is formed just in the areas of positive poles and negative radiation discharge that glow.

According to research [6], the radiation of the plasma negative glow intensity causes higher emission of the plasma's positive column from 3 to 4 times (Fig. 1).

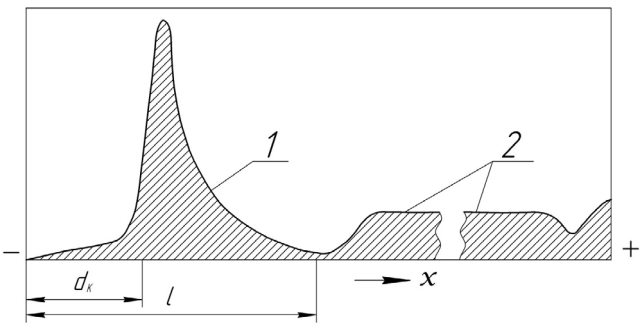

Fig. 1. The intensity distribution of discharge plasma radiation, that glow, with flat parallel gap:
1 – emission of negative plasma;
2 – plasma's positive column radiation

Based on studies [6] it can be concluded that as a result of the low average energy and a sufficiently high concentration of slow electrons *N*e a major role in the researched function *f(ε)* is played by the interaction of electrons. As a consequence, the electrons in the researched function *f(ε)* in the energy range 0 – 6 eV, have maxwell distribution.

Classic plasma of negative radiation is the plasma that generated in the discharge gap glow, which consists of a hollow cathode and anode in the form of a flat disk or rod.

The cathode, which geometry has a cavity with a negative curvature, is called a hollow cathode. The most common hollow cathode is shown in the form of tubes of round, rectangular, or two parallel plates that have common electrical contact.

Discharge, that glows with hollow cathode is significantly different from the discharge with flat parallel electrodes of electric and optical characteristics, and also outwardly. Researches of plasma with negative radiation in the hollow cathode are thoroughly conducted in [7, 8].

On appearance, discharge, which glows with the hollow cathode, represents the short discharge in the case when the anode is at distance from the hollow cathode, which does not exceed thickness of the dark faraday space, if there is sufficient gas pressure.

Steady discharge of a single emission region is a negative emission, which symmetrically located in the middle of the hollow cathode.

The cathode fall in the discharge with the hollow cathode is steeper, since the high falling. The dark crooks space has a smaller length. This leads to the fact that the electric field is larger. In such electric field, the electrons and ions acquire a huge number of kinetic energy which spends in a negative glow on the ionization and excitation of neutral atoms. Also, gas's neutral particles are excited by the atoms and ions of cathodic material action.

According to [7], in the spectrum of plasma's negative glow radiation, in the hollow cathode the large number of spark lines fits in. The highest intensity of plasma luminescence focuses on its axis, while in plasma with the negative emission flat cathode, the most intensive glow is located on the border with the dark crossover space.

Under the influence of positive ions that fall on the cathode with high energy and fast neutral atoms, which are created in the process of ions charge, on the cathode surface there is a greater secondary electron emission. The intensive radiation from the plasma negative glow is also makes a significant contribution to secondary electron emission.

The effect of the hollow cathode discharge [8] is explains by the oscillatory motions of the electrons, which penetrate plasma between two opposite dark crooks spaces.

A stream of fast electrons from one dark crooks space reaches through the double glow plasma, to the same, but contrary space. Then stops, turns back to his fields and returns to the first crooks space (Fig. 2).

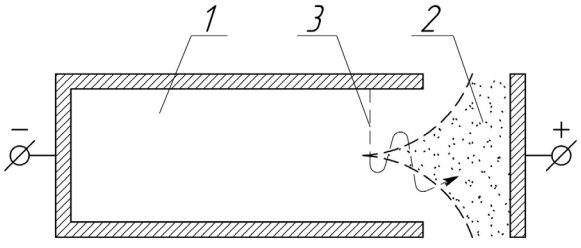

Fig. 2. The hollow cathode discharge:
1 – dark cathode space;
2 – plasma; 3 – trajectory of the electron,
which performs the oscillatory motions in the middle
of the cathode's cavity

The consequence of such repeated reciprocating movements of the electrons is to increase their ionizing and

exciting abilities, which lead to the current density increasing, the length of the dark crooks space reduction and the strength of the electric field increasing, as a result the conditions for the secondary current amplification are created.

Since the required power of the current has achieved by the drop of smaller cathode potential, primary development of intensive ionization processes and excitation in the plasma of the hollow cathode are created.

On the basis of it in the discharge with the hollow cathode, the smaller tension of burning, than abnormal cathodic fall of potential has is observed (Fig. 3.).

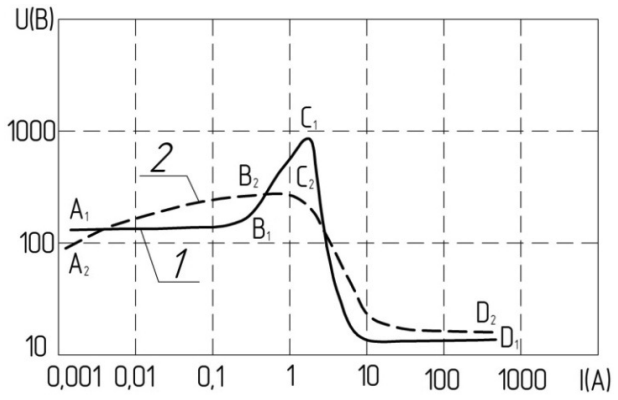

Fig. 3. Volt-ampere characteristics of the discharge that smolders, with flat (1) and hollow (2) cathodes

According to [9] for the creation of plasma with hollow cathode efficiency, oscillating motion of electrons is not as important as merge of negative radiations. In this case the part of the metastable atoms, ions and photons, which comes from plasma with negative radiation to the cathode, will considerably increase.

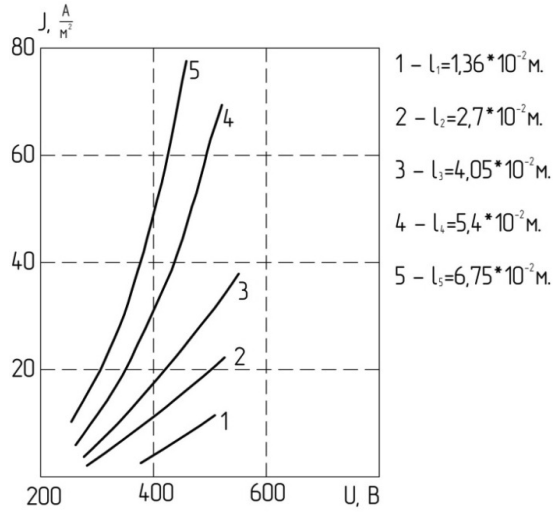

Fig. 4. Volt-ampere characteristics of the discharge with the hollow cathode of varying length in neon at P = 26,6 PA

In [10] it is shown that efficiency of the discharge with the hollow cathode is caused by exclusively significant influence of ultra-violet radiation from plasma with negative radiation which creates intensive γ - processes on the cathode.

Obviously, for this purpose the conditions of discharge with a relatively high pressure suit better, when electrons unable to keep the direction of movement to perform oscillations through a large number of collisions.

On the contrary, in sources [11], claim that the photoeffect in discharge with the hollow cathode has no essential value.

According to [12] authors come to a conclusion about efficiency of the discharge with the hollow cathode on the basis of the course and type of volt-ampere characteristics of the discharge in various gases, and with different length of the hollow cathode of a cylindrical form.

Volt-ampere dependences (fig. 4) are experimentally established and testify about the following:

1) Curves $\gamma=f(U)$ lie over the corresponding curve for the discharge, that glows, with the flat cathode;

2) Raising of a curve $\gamma=f(U)$ with growth of U pass much more steeper, than on condition of the discharge that glows, with the flat cathode;

3) With increase of pressure, volt-ampere characteristics show small influence of oscillating motion of electrons;

4) In case of small lengths of the hollow cathode not only current, but also current density – are functions of the hollow cathode's surface;

5) Optimum conditions of efficiency arise in that case when in plasma with negative radiation quanta of recombinational radiation are formed and greatly used on the cathode.

It is offered to utilize these properties of plasma using for satellite telecommunications noise stability increase.

In close proximity from the SC's antenna, plasma with negative radiation which pushes away the ionized external stream of plasma (ions and electrons) is generated, thereby creates radio transparent environment. It occurs without interventions into the external construction of SC, and depends on geometry of plasma's generator, pressure and gas type.

Generated noiseproof environment is not able to exist during a long period of time, whereas an external plasma membrane is not stationary regarding to SC due to hyper velocity. External plasma except electrons has positively charged ions which can be attracted to artificially created plasma. Therefore artificially created plasma is generated every few milliseconds – pulsewise. This interval is sufficient to ensure the telemetry from the SC.

Conclusions

The article considers advantages and prospects of using plasma with hollow cathode and negative radiation for the noiseproof channel of radio communication creation.

As a result of the executed researches it is established, that during achievement of effect, the discharge which glows with plasma with hollow cathode shows characteristic regularities which significantly differ from regularities of the discharge, that glows with the flat cathode.

Consider ***established*** that the effect in plasma with hollow cathode occurs when the best conditions for the use of fast electrons in their oscillating motion energy, the positive

ions created in α - processes, fast neutral particles which are formed in a processes of recharging metastable atoms and photons are created.

Believe established that the effect in the plasma with the hollow cathode occurs in cases where there are better conditions for using the energy of fast electrons in their oscillatory motions, positive ions, created in the α - processes, the fast neutral particles formed in the processes of recharge, metastable atoms and photons.

The size of a contribution of each process significantly depends on gas pressure. Efficiency of plasma with the hollow cathode is reached during the oscillating motion of electrons with small pressure, when the distance between two opposite elements on a surface of the hollow cathode is less than the length of a free run of electrons. On this condition, on border of plasma with negative radiation, dark crooks space and in the plasma, much more electrons, than in plasma with the flat cathode are formed.

At high gas pressures, that fill the working volume, a crucial role in the effectiveness of plasma is played by quanta of ultraviolet radiation and metastable atoms with negative plasma. The positive ions play a minor role, since they disappear in the processes of recombination.

Efficiency of plasma with the hollow cathode increases with increase in length of a cylindrical part of the hollow cathode. It complicates disappearance of photons and metastable atoms in processes of side diffusion. According to [12], plasma with negative radiation in the hollow cathode has very intensive processes of working gas's neutral particles excitation. As a result, it creates intensive radiation.

Creation of a system with the increased noise stability of radio signals during the passage of a frequency selective fading environment by hyper fast SC with the use of artificially created low-temperature plasma of intensive radiation, will provide the increase in security of a radio communication with an object without deterioration of the aerodynamic properties and additional costs on transformation the signals of telemetry.

REFERENCES

1. TM Space Data Link Protocol. Recommendation for Space Data System Standards, CCSDS 130.1-G-2. Green Book. Washington, D.C.: CCSDS, November 2012.
2. Teylor M. Radio communications through the plasma at the entrance of missiles in the atmosphere. [Radiosvyaz cherez plazmu pri vhode raketyi v atmosferu] // Zarubezhnaya radioelektronika. – 1968. – # 2. – S. 76 - 89.
3. Wolverton M. Piercing the Plasma: Ideas to Beat the Communications Blackout of Reentry. Scientific American.New York: Scientific American. 2009. no. 12. pp. 28–29.
4. Konyahin G. F., Melashenko A. Yu., Litvina Z. Yu. Device for the information transmission from the descent aircraft. [Ustroystvo dlya peredachi informatsii so spuskaemogo letatelnogo apparata]. Sistemi obrobki Informatsiyi – 2001. – # 5(15). – S. 201-203
5. Crymley H. M., Elemeleus K. G. – Brit J. Appl. Phys., 1965, 16, c. 281.
6. Wilhelm J., Kind W. // Beitr. Plasmaphysik v.5, p. 395,1965.
7. Hantzsche E., Popescu I., Lova I. Ann. d. Physik, 1969, 5, p. 308.
8. Moskalev B. I. Discharge with full cathode. [Razryad s polnyim katodom]. Energiya, M.: 1969. – 184 s.
9. Döpel R. Die Bedeutung des Ähnlichkeits gesetzes für die Abhängigkeit der Doppelkatoden-Glimmentladung vom Gasdruck und Katoden abstand. // Wiss. Zeitschr. Der Techn. Hochschule Ilmenau 1965. V. 11. No 1. P. 9 18.
10. Rohatgi Vijay K. Electronic and Ionic Current at the Cathode of a Hallow Cathode Discharge. Journal of Applied Physics, 32, 1173 (1961).
11. Badareu E., Popescu I., Iova I. Vorgangein den Kathoden teilen von anomalen Glimmentladungen in Helium.-Rev. Phys. Acad. RPR, 1960, v.5, N 3-4, p. 287-293.
12. Popovici C., Somesan M. On the emission spectrum of the negative glow plasma of a hollow-cathode discharge in magnetic field. // Appl. Phys. Letters. 1966. V. 8. No 5. P. 103- 105.

Рецензент С. В. Козелков, д-р техн. наук, проф., директор Навчально-наукового інституту телекомунікацій та інформатизації Державного університету телекомунікацій