ABOUT USAGE POSSIBILITY OF PRINCIPLES OF EXCITATIONS TRANSMISSION BY NERVE FIBERS FOR TELECOMMUNICATIONS

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Annotation: *Analysis of physiological properties of the nerve fibers, associated with their specialized function – excitation transmission, is done. Possibility in principle of the same principles' usage in the communication channels is established. It is shown that characteristics of nerve fibers as communication channels are comparable to characteristics of existing wire transmission media of information in telecommunications. Prospectivity of research of excitations transmission principles as the basis for implementation of communication channels is established.*

Keywords: *nerve fibers, medullated (myelinic) nerve fiber, communication channel, conductor, propagation velocity.*

Keywords classification of ACM: *B.4.1 Data Communications Devices, B.4.2 Input/Output Devices, B.4.3 Interconnections (Subsystems), H.1.2 User/Machine Systems*

«Seldom do more than a few of nature's secrets give way at one time.
It will be all too easy for our somewhat artificial prosperity to collapse overnight
when it is realized that the use of a few exciting words like
information, entropy, redundancy, do not solve all our problems»

Claude E. Shannon

Introduction

Throughout last several decades of rapid development of science and technics it is still actual the problem of research and usage of human potential for the purpose of understanding and adopting the mechanisms realized and successfully functioned in human throughout millennia. However not all is so simple: the human body represents the whole galaxy which is not explored yet even a half. As for researches about physiological features of the person from the telecommunications point of view – results of such researches were not found in the open press.

The article subject is to fill in this gap and represents logic continuation of researches associated with process of information perception and processing by the person and information technology. These researches are carried out by the authors group of the information-communication technologies' department representing professor Gayvoronska scientific school. Some results of these researches have been presented to the ITHEA International Scientific Society at the III International conference "Natural Information Technologies" where authors' report about possibility of information technology usage for satisfaction of the human basic natural needs has been noted as the best. Positive in all respects results of these researches have strengthened authors group in expediency of their further development. This article is devoted to the research of principles of excitations transmission by human nerve fibers in order to define possibility of these principles usage as a prototype for implementation of similarly functioning telecommunication systems.

At the comparison of the basic physiological properties of nerve and muscular tissues according to [Georgieva, 1981] it is defined that excitability and liability of nerve fiber is higher and the refractory period is shorter than of the muscular tissue. This is caused by the higher level of metabolic processes in the nerve. That is velocity of excitation propagation and impulse transfer by nerve fibers excels velocity of other conductors of the human body – muscular tissues. This is especially important at the research of nerve fibers as communication channels. Therefore nerve fibers at the process of excitation propagation are the object of the research.

Physiological properties of the nerve fibers

As it is known, the nerve is the complex formation consisting of great number of nerve fibers – axons (nerve-cell processes), involved in the common connective tissue membrane, bearing excitation to the central nervous system or from it to the periphery. Depending on histological features of constitution, nerve fibers are distinguished between medullated (myelinic) and nonmyelinated.

The myelinic fiber (Figure 1) consists of an axis cylinder coated by myelinic and neurilemma. A surface of the axis cylinder is presented by plasma membrane. The cylinder contains axoplasm.

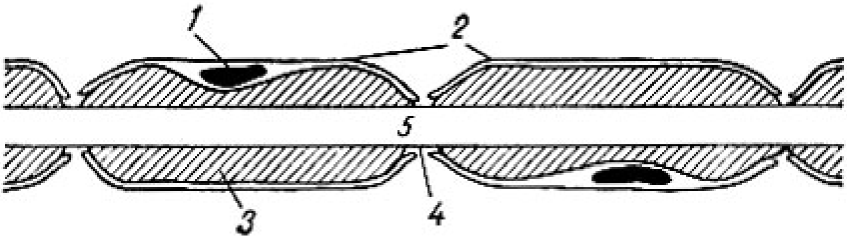

Figure 1. Structure of the myelinated nerve fiber (schema).
1 – nucleus of neurilemma lash; 2 – neurilemma; 3 – myeline; 4 – Ranvier's constriction; 5 – axoplasm

Excitation transmission is specialized function of nerve fibers. A possibility of nerve fibers to propagate excitation in the form of nervous impulses is determined by their constitution reminding a construction of electrical cable: axons playing the role of conductor for the transmission of electromagnetic signals bearing the information, axon's myelin sheath, representing membrane of lemmocyte coiled on the axon in some layers, is functioning as isolating shell of the cable. Lipoprotein myelin, possessing dielectric properties, is major component of myelin sheath. The myelin sheath coats the fiber not uninterruptedly along all its length, but forms similarity of the sectionalizing joint, tightly strung on the axon like on the bolt of e.g. electrical cable. There are only small electrically bare fields between the next myelin joints. Current can easily stream through them from the axon to the outside medium and back. In this way current stimulates membrane and invokes generation of action potential only in the bare fields of the axon which has received the name of Ranvier's constrictions. The length of interconstrictions sectors depends on diameter of the fiber and ranges from $0,2\cdot10^{-3}$ m (0,2 mm) to $1\cdot10^{-3}$-$2\cdot10^{-3}$ m (1-2 mm). Thus nervous impulse propagates through the myelinated fiber by hops – from one Ranvier's constriction to the following.

Nonmyelinated nerve fibers have no myelin sheath; they are coated only by lemmocytes. There is 15 nanometers (150 ampere) cleft filled with intercellular fluid between lemmocytes and the axial cylinder. According to such features of the constitution, the superficial membrane of the axial cylinder is intercommunicated with medium, surrounding nerve fiber (intercellular fluid).

Excitation propagates through the nerve fibers at the expense of the small circular currents arising inside the fiber and surrounding it fluid (Figure 2). Nowadays this thesis of German physiologist Herman has received theoretical and experimental verification. The current propagates from plus to minus between excited and unexcited sectors of nerve fibers in the axoplasm and surrounding fluid. That leads to initiation of so-called small or circular currents. Circular currents when leaving nerve fiber consistently excite its sectors (1, 2 and etc). Irritant action of circular currents weakens in process of moving off from the excitation locus (sectors 3 and 4) and they start being incapable to invoke excitation. Thus, in case of consecutive spread of excitation through the each sector of nerve, fiber nervous impulses are being transmitted with decay at the expense of continuously running wave.

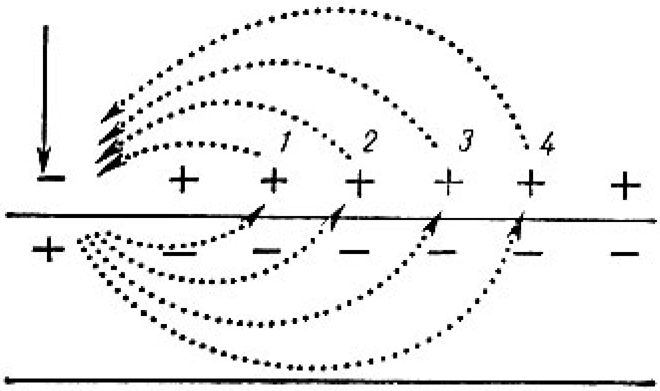

Figure 2. Schema of the excitation propagation through the nerve fiber at the expense of small circular currents. Vertical arrow marks place of irritation's infliction. Circular arrows show moving direction of electric current in the fiber and surrounding fluid

Because of histological features of medullated nerve fibers' constitution, in particular due to presence of the myelin sheath having high resistivity, electric currents can enter into specified fibers and leave them only in the field of Ranvier's constriction (Figure 3).

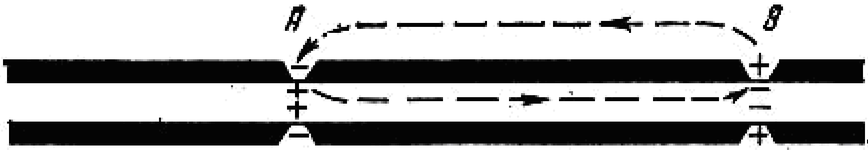

Figure 3. Saltation mode of excitation propagation in medullated nerve fiber from constriction to constriction. Arrows show direction of the current arising between excited (A) and next resting (B) constriction

At the irritation's infliction there is a depolarization in the field of the nearest Ranvier's constriction – A. The next Ranvier's constriction – B is in polarization state. There is difference of potentials between constrictions. It leads to appearance of circular currents (see Figure 2). Ion current runs from plus to minus in the axoplasm and surrounding medium. Yield of circular currents in constriction B leads to its depolarization and firing. Then subsequent Ranvier's constrictions become excited at the expense of circular currents. Thus, in the medullated nerve fibers, excitation is transmitting by hop (saltation) – from one Ranvier's constriction to another.

Saltation is more economic transmission mode, than excitation propagation through the nonmyelinated nerve fibers. Excitation propagates through the medullated nerve fibers without decay, thus propagation velocity of excitation through them is much higher, than through the nonmyelinated fibers. That leads to the conclusion that in case of organization of communication channels it is expedient to use principles of impulses transfer just by myelinic fibers.

Excitation is being transmitted only by one nerve fiber (isolated transmission of excitation is provided by myelin sheath in medullated nerve fibers and by high resistivity of fluid surrounding nerves in nonmyelinated fibers) without propagation on the next fibers. It causes realization of strictly coordinated reflex activity in the organism. From the point of view of fiber as communication channel this fact satisfies natural demand of address delivery of the information. The nerve trunk consists of great number of nerve fibers. That leads to analogy with organization of group communication channels, bundles of lines in telecommunication networks, as well correlates with features of realization of fiber-optical communication channels.

Comparison of impulses propagation's features by nerve fibers and by communication channels

Completed analysis leads to the conclusion about the possibility in principle to develop communication channels with information transfer principles similar to excitation transmission by medullated nerve fibers. However, realization of such systems should be preceded by serious research of experts in field of physics, biology and telecommunications in order to receive necessary theoretical justification and its experimental verification. Thus, there is a natural question about expediency of carrying out of such laborious researches. For now there is only one convincing argument in favour of the telecommunication systems' organization on the basis of excitation propagation's principles of myelinic nerve fibers. It is absence of decay. For sure, this is essential advantage. However, it is not true to interpret this factor as exhaustive.

In order to formulate hypothesis about usage possibility of excitations transmission's principles of human nerve fibers as a prototype for realization of similarly functioning telecommunication systems, it is necessary to estimate velocity of impulses propagation by nerve fibers and to compare this value with velocity of impulses propagation by conductors of telecommunication communication channels.

At present time at designing of telecommunication systems and networks following types of communication channels are used: wire (aluminum, copper and fiber-optic); wire and wireless radio channels of terrestrial and satellite communication; wireless laser (including infrared). As the myelinic fiber in principle can be considered only as the prototype of the wire/cable communication channel, the analysis of characteristics of wireless and radio channels, as well as their subsequent comparison with the nerve fibers, is not necessary. Conductors, in the capacity of which we examine the nerve fibers, of existing telecommunications are quartz glass for fibers of optical cables and copper (thin copper) or aluminum core for electrical cables.

Most of people suppose that information propagates with the speed of light in the fiber-optic cables. For its definition in vacuum value of $3 \cdot 10^8$ m/s is usually used, however, in spite of the fact that optical fiber is carrying out transmission of light impulses, actual data transfer speed is much more low (approximately for 31 percent below the speed of light in vacuum). According to [Yirka, 2013] propagation velocity of light in quartz glass, of which fibers of optical cables are made, is $0{,}69 \cdot c$, where c –value of the speed of light in vacuum.

According to [Baziev, 2011] propagation velocity of current by the copper conductor (radius $1{,}115 \cdot 10^{-3}$ m) is $2{,}423 \cdot 10^8$ m/s, by the thin copper conductor (radius $2{,}5 \cdot 10^{-4}$ m) – $3{,}89 \cdot 10^8$ m/s, by the aluminum conductor (radius $0{,}85 \cdot 10^{-3}$ m) – $2{,}52 \cdot 10^8$ m/s.

According to [Georgieva, 1981] propagation velocity of excitation by the nerve fiber with diameter $12 \cdot 10^{-6}$-$22 \cdot 10^{-6}$ m is 70-120 m/s, while by nerve fiber with diameter $8 \cdot 10^{-6}$-$12 \cdot 10^{-6}$ m – 40-70 m/s. That is, the more diameter of the fiber, the higher propagation velocity of excitation in it. So, there are grounds to suspect that, if to enlarge diameter of nerve fiber to the value at least corresponding to the dimensions of existing metal conductors (i.e. to enlarge diameter of the fiber a minimum in 1000 times), it will possible to receive transfer velocity of excitation by nerve fibers, at least, comparable to those in the modern telecommunication systems. Moreover, nerve fiber can reproduce up to 2500 impulses per second. In view of the fact that e.g. realization of quadrature amplitude modulation 4096-QAM allows transmission of 12 bits per one change of a symbol (impulse value), it is possible to receive acceptable for practice bandwidth velocity in communication channels organized by analogy to the nerve fibers. Especially at the organization of systems, similar to the nerve trunks, consisting of big number of fibers, in order to transfer information in determined direction.

Conclusion

Impulses propagation is the specialized function of the nerve fibers. This is determined by their constitution, reminding construction of the electrical cable, and leads to the conclusion about expediency to research principles of impulses transfer by nerves as basis for realization of communication channels. This hypothesis is authenticated by given in the article, and comparable to conductors of existing telecommunications, characteristics of excitation's propagation velocity of the nerve fibers and reproduction velocity of impulses. Besides it, myelinic fiber conducts impulse in saltation mode through Ranvier's constrictions without decay, what is very important. This mechanism allows spending less energy at the transmission, therefore realization of the described in the article methods in technics could open up new horizons of its development as a whole, and perspective directions in telecommunications in particular.

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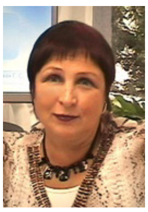

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