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Critical analysis of the work „Experiment to create a radio communication channel in the marine environment“

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The article „Experiment to create a radio communication channel in the marine environment“ (authors: A.K. Tomilin, A.F. Lukin, A.N. Gulkov) published in Journal „Technical Physics Letters“ (2021, vol. 47, Issue 11) is analyzed from the standpoint of classical physics. The organization of the experiment in the mentioned publication, interpretation of its results, and theory underlying the work are criticized. The proposed material is a methodological commentary and is intended to form consistent approaches to be used in studying and interpreting further works on creation of radio communication channels.

Keywords: Radio communication in the marine environment, electromagnetic waves, methodological notes

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To describe all the known processes of electromagnetic waves propagation in free space and their interaction with the material media, in most practical cases it is sufficient to use as a theoretical base the classical macroscopic electrodynamics [1] resting upon the Maxwell's equations and simplest material equations describing the media by such parameters as dielectric and magnetic permeability and conductivity. The electromagnetic waves propagation in free space is associated with mutual generation of electric and magnetic fields whose strengths are expressed by two of four Maxwell's equations. The varying electric field generates such a magnetic field that is able to again generate the varying electric field able in its turn to generate the magnetic field. In this case, the vectors' properties themselves and vector algebra rules lead us to understanding that the wave propagation direction, magnetic field vector and electric field vector form a triplet of mutually perpendicular vectors. Representing this fact in other form, we can see that an electromagnetic wave creates the electric and magnetic field excitations across the propagation direction, i.e., the electromagnetic wave belongs to strictly transverse waves in the scope of the Standard Model.

Nevertheless, some authors continue publishing experimental studies [2–10] (see also review [11] and monograph [12]) that interpret obtained results as a consequence of excitation of longitudinal electromagnetic waves. Longitudinal waves by themselves are not something extraordinary in the electrodynamics. Here the classical case [13] of Langmuir waves in plasma may be taken as an example. However, it is evident that not longitudinal electromagnetic waves are considered here but the charge density oscillations. In the up-to-date electromagnetic theory, the concept of longitudinal waves is represented by material equations for the media with spatial dispersion [14,15]; the general theory of waves in electromagnetic elastic media is also being developed [16]. Notice also that here are considered just elastic waves but not electromagnetic ones. The spatial dispersion of the medium often causes a rather exotic, at the first glance, behavior of electromagnetic waves, but nevertheless all this is well consistent with the up-to-date theory [17].

Regardless of all the achievements of the modern theory of electromagnetism and radio waves, the above-mentioned papers insistently use the alternative interpretation and approach to the conducted experiments. Although the alternative consideration itself is a useful physical/mathematical exercise, nevertheless it should be applied in research work only when the capabilities of the Standard Model are exhausted, and the experimentally revealed contradiction cannot be resolved within its scope. Criticisms against works [2–10] may be found in such publications as [18,19] that comprehensively explain both the results and mistakes of the published works. Therefore, publication of a new paper [20] explaining the experimental results by longitudinal electromagnetic waves makes it necessary to repeat the criticism of this alternative approach to the experimental results interpretation.

In setting the problem, this paper points to the drawbacks of up-to-date hydroacoustic devices and to essential attenuation of high-frequency electromagnetic waves in seawater. What is especially noticed is that the use of ultralow frequencies is restricted by the necessity of applying large-size antennas and by insufficiently high data transmission speed.

The approach used by the authors of [20] is based on the theory referred to as „*generalized electrodynamics*“ that takes into account „*both the vortex and potential electromagnetic processes*“. At the same time, the authors insist that „... *a potential magnetic field component* *describable by the scalar induction function has been revealed experimentally*".

The authors assert that transverse electromagnetic waves arise „*as a result of vortex processes*" while „*potential processes*" generate longitudinal electromagnetic waves.

Based on their own theory, the authors assembled a receiving/transmitting setup. Since the transmitting and „*receiving station are of the same design*", it is possible to conclude that the authors took two radio stations „Shturman-882M" and connected to both of them (transmitter and receiver) a solenoid-like antenna with a spherical terminal on one end and earthing on the other. The transmitter, receiver and antennas were insulated against seawater. In the experiment, the transmitting station was fully submerged into the marine environment to the depth of 4 m. In some time after installing the transmitter under water, the above-water receiver received a signal from the transmitter; after that, the receiver was submerged into the marine environment to the depth of 6 m using an „*anchored buoy*" and installed approximately equidistantly from the sea bottom and surface. The receiver recorded the signal with a digital voice recorder mounted in a sealed compartment. After that, the buoy was being towed away from the transmitting station during 34 min, the modulating signal at the receiver being maintained at the level of about -87 dB.

The experiment provided data which were represented by the authors as a plot of dependence of the decrease in the modulating signal power and background noise versus the experiment duration.

Generally, the task in that study was stated correctly, the modern techniques and problems of the under-water radio communication were listed consistently. However, it should be noticed that the use of ultralow and extremely low frequencies for the under-water communication does not need large-size structures, since waves of this scale are being fixed not with antennas but by magnetometric methods [21].

Since in the study a theoretical model [22] is used, we have to analyze it, too. The theory is of the heuristic character. In its scope, the scalar function of the magnetic field strength is postulated as

$$H^* = \frac{1}{\mu_0}\mathrm{div}\mathbf{A}. \quad (1)$$

This equation should be interpreted as follows: all the point sources of the vector field potential form the „*scalar magnetic field strength*". For the readers not familiar with vector analysis, let us notice that one of the divergence operator properties is that its application to a closed vector function gives a zero result. In essence, the author of [22] postulates that, since H^* is not zero, in nature there exist certain sources of the field vector potential. The experiments do not confirm this property (and indeed cannot confirm because of the vector potential nature).

Now notice that the authors of the paper under consideration use the engineers' slang quite freely, e.g., they refer to the antenna in the form of an earthed solenoid with a spherical terminal at the other end as to „*Tesla coil*". Actually, the Tesla coil is a resonance transformer [23]. This means that such a slang term could have been applied to that device if the signal had passed from the transmitter to the coil through the transformer coupling. However, the schematic circuit presented in the considered paper shows that the signal was transferred to the antenna through a wire.

To analyze the description of the experiment itself, we should turn to work [24]. Chapter 5 of this work considers a dipole in the vicinity of the flat ground surface, while para. 30 considers the problem of radio waves transference from the source installed deep in soil to either the receiver installed on the ground surface or to that installed also deep in soil. Keeping in mind that soil is a solid medium with high dielectric permeability and high dispersion coefficient, this model may be applied to the discussed experiment on creating a communication channel in the marine environment. The author shows that if the radio signal wavelength is comparable with the depth the emitting dipole is submerged to, then the electromagnetic radiation first comes from the depth to the surface, namely, into the more permeable medium, propagates through it, and is caught by the receiver inside the soil. Evidently, this is consistent with the least-action principle. One can easily see that depths of 4 and 6 m are close to the radio wave lengths of 10 m (27.4 MHz) in air and ~ 1 m in seawater. Finally notice that the signal attenuation was determined by the authors of the experiment based on the signal level recorded with a digital (!) voice recorder, i.e., not the electromagnetic radiation intensity but just the voice-recorder signal value was measured. Thus, it is not clear which with the signal power was compared: either with the power of the transferred sound, or with the transmitter radiation power (these powers are evidently different). Hence, the data presented in that paper cannot be interpreted as the electromagnetic wave attenuation in the marine environment.

This paper shows that on the one hand the experimental results of [20] are interpreted inconsistently with the classical electrodynamics, and on the other hand the theory applied is of the heuristic character, does not comply with known experimental data and does not involve previously proved laws.

To the opinion of the author of this analysis, the authors of the analyzed study have been captured by the purely positivistic approach in which the experiment is the only source of true knowledge on the process. In other words, the experimentalists took a device similar to the patented one [25] and got sure that it „*realy works*"; based on this, they came to the conclusion that the device generates longitudinal electromagnetic waves or, as they cautiously wrote, „*... it is possible to assume that radio signals are transmitted in the seawater with longitudinal (electrically scalar) waves*". However, nature dictates that any device operates according to physical laws independently of the idea assigned to the device. On the other hand, the authors did not take into account the dialectics of the experimental procedure itself, namely, they did their best to protect the instruments against seawater but absolutely missed the fact that the emitted wave length is comparable with the experimental medium depth. This resulted in a wrong conclusion about wave propagation in strictly aqueous environment.

Conflict of interests

The author declares that they have no conflict of interests.

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