The Influence of Air-Water Interface Boundary Conditions on Thermal Radio Emission at 2, 5 and 8 mm

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The influence of air turbulence and oil films presence on thermal radio emission of water at millimeter wavelengths has been investigated. This paper continues our radiometry investigations of water thermal regime dynamics due to air turbulence by measured dynamics of radiobrightness using the measurements method which have been worked out in laboratory conditions [2] and investigations of thermal emission of water in the presence of oil films [3]. The investigation of water near-surface thermal regime by one-wavelength radiobrightness dynamics are especially interesting because temperature gradients in thin subsurface layer and evaporation from water surface determine the heat exchange between ocean and atmosphere. The strong dependence of the radiobrightness on the oil film thickness, which is due the interference of the thermal radio emission retroreflected at the interface, can be used to determine this parameter from radiometric data.

Measurements have been carried out in the open air using the equipment which included the water pool with sizes 2, 1.5, and 0.2 m, three radiometers at wavelengths 0.23, 0.5 and 0.8 cm with horn nadir-looking antennas at 1 m above the water surface. The radiometers sensitivity was about 0.1 K. The diameter of the beam footprints on the water surface was about 10 cm.

So, firstly, the radiobrightness dynamics due the water cooling by air turbulence has been measured. For this purpose, the initial homogeneous temperature distribution in the water was obtained by means of mixing and this distribution was unchanged in the absence of air turbulence during a few minutes interval. On the basis of the solution of corresponding inverse problem [1], all the details of temperature profile dynamics in the water and of the heat flux dynamics through air-water interface have been retrieved. In Fig.1 it is possible to see the radiobrightness dynamics related with atmosphere air turbulence variations (after mixing of water to make the homogeneous initial distribution of the temperature) at wavelength 0.5 cm (solid line) and at 0.2 cm (dashed line) as well as retrieved dependencies of surface temperature T_0 (by radiobrightness T_b at 0.5 cm - solid line, by radiobrightness at 0.2 cm - dashed line) and the temperature at depth level z = - 0.1 cm (solid line - by $T_b(0.5)$ and dashed line - by $T_b(0.2)$).

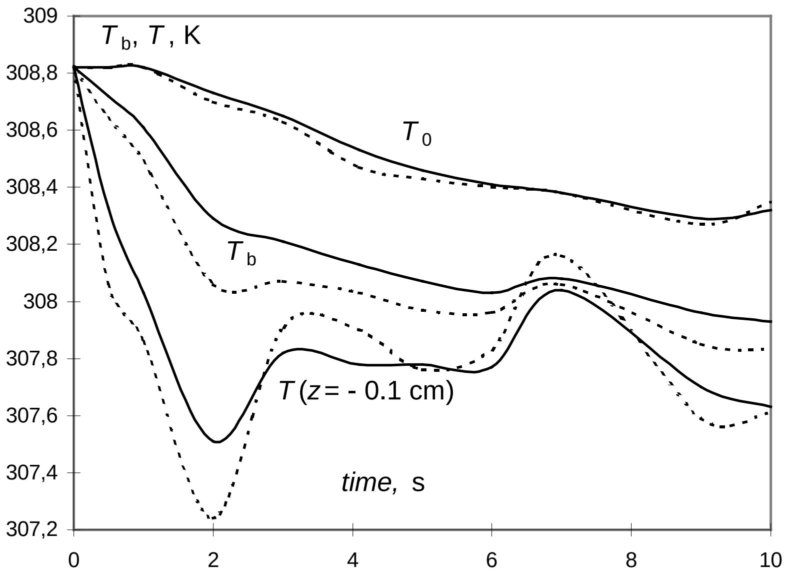

Fig1. Measurements of radiobrightness dynamics at 0.229 and 0.5 cm and retrieved temperature

In Fig.2-4 the radiobrightness dynamics and corresponding retrieval of temperature and heat flux is given at more long time interval.

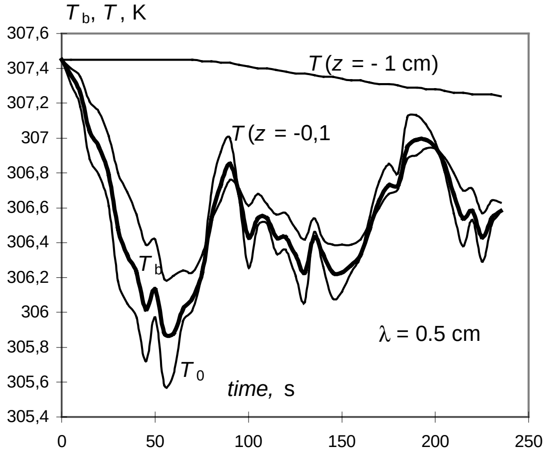

Fig.2. Radiobrightness at 0.5 cm and retrieved temperature at various depths

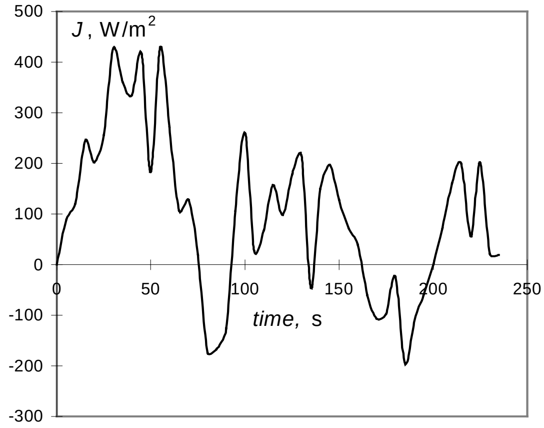

Fig.3. Retrieved heat flux dynamics through air-water interface

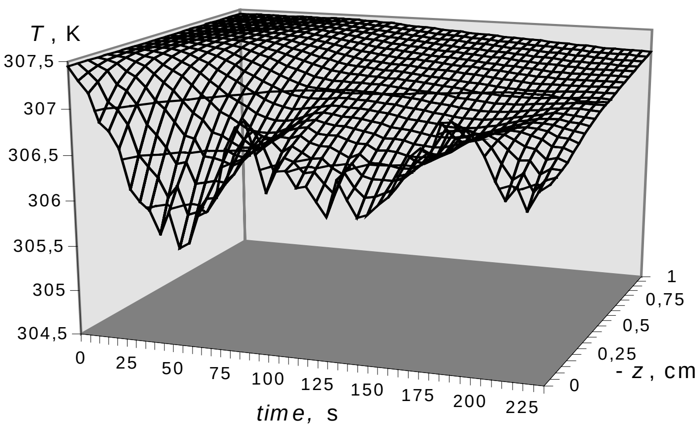

Fig.4. Retrieved temperature profile dynamics due natural air turmulence

Second, the dependence of radiobrightness on oil thickness at both wavelength has been measured. Many authors (see, e.g. [4-6]) have developed theories of thermal radio emission and experimentally investigated oil films on water surface. It has been found that the strong dependence of the radiobrightness on the oil film thickness in such two-layered medium, which is due the interference of the thermal radio emission retroreflected at the interface, can be used to determine this parameter from radiometric data. In principle, measurements at one wavelength are sufficient for film-thickness determination, but it is more reasonable to use two or three wavelengths, because the dependence on film thickness is periodic, so that the interpretation of the results becomes ambiguous in a certain stage. Of course, it is possible to choose a sufficiently large wavelength to ensure that the ambiguity domain besides outside the range of potential film thickness, but this would reduce accuracy in the measurements of thin films. Therefore, it is reasonable to make measurements at two wavelengths, using a long-wave channel to avoid ambiguity, and a short-wave channel to estimate exactly the oil-film thickness.

Experience shows, however, that, as a rule, the observed radiobrightness do not fall on the curve calculated for pure oil [4-6]. The reason of such deviation is the fact that in natural conditions the pure oil includes the water and forms oil-water emulsion. Investigations show that this effect is absent only in fresh spills. To take into account humidity, which radically changes the permittivity of oil films, the well-known Clausius-Mosotti equation is in use. This equation has been checked experimentally in laboratory conditions [5], and used in interpretation of real experiments. To determine both thickness and water content in oil-water film it is necessary to use two-frequency measurements.

In reality, there are other factors, which influence the radio emission of oil films, for example, in [6] the authors considered the influence of film-thickness variations within the limits of the antenna pattern spot. It was found that the interference flattened with the increase of film-thickness variations, but this effect is strong enough only if the variations are about 30% of the average film thickness.

The experimental results, presented in this paper, show the influence of the new effect which leads to practical disappearance of periodical dependence of thermal radio emission on the oil thickness related with the interference. For the pure oil film on the water surface measurements results appeared in excellent agreement with the theory (see results in Fig.5).

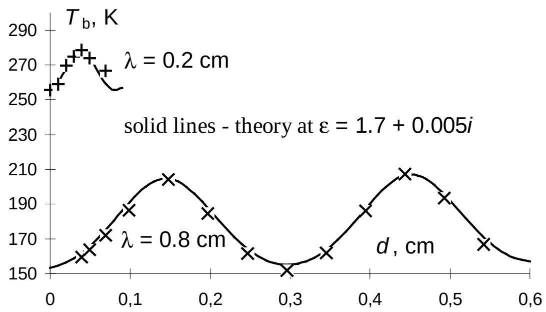

Fig.5. Measurements in pure oil films on water surface

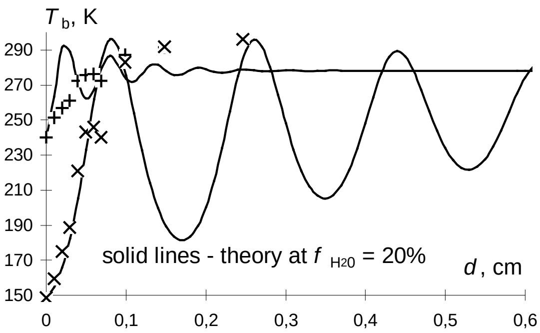

Fig.6. Measurements in oil-water emulsion films

Next, measurements have been carried out after the first summer rainfall. The results are given in Fig.6. In that case the radiobrightness dependence changes drastically - there was practically no interference features at both wavelength, and this dependence was unaccountable from the point of view of mixing theory at all possible values of water content. It is also impossible to explain observed radiobrightness dependencies on the basis of thickness variations in the pattern footprints. It should be mentioned, that the obvious interference features were not seen during our above mentioned helicopter radiometer measurements (at wavelengths 0.8 and 3 cm) of oil spills on lakes in Siberia [3], and this fact enforced us to make the present investigations. Also, the temperature dependence of oil films radio emission has been measured.

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