Damping of Thermal Emission Interference in Oil-Water Emulsions[1]

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Abstract - It was discovered from measurements of thermal radio emission of oil films on the water surface at wavelengths 0.23 and 0.8 cm that the quasi-periodical dependence of the brightness temperature on the film depth is disappeared after the first rain. The effect can be related with the phase decorrelation of thermal emission because of scattering on water droplets or on random dielectric heterogeneities in the oil-water emulsion.

Introduction

Many authors (see, e.g. [1-6]) 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 [1,3,5]. 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:

$$\frac{\varepsilon_{\text{ь}} - 1}{\varepsilon_{\text{ь}} + 2} = \frac{\varepsilon_0 - 1}{\varepsilon_0 + 2}(1 - f_{H_2O}) + \frac{\varepsilon_w - 1}{\varepsilon_w + 2} f_{H_2O} \qquad (1)$$

where ε_m, ε_0, ε_w are permittivities of the mixture (oil-water emulsion), oil, and water, respectively, f_{H2O} is the relative volume content of water in mixture. Equation (1) has been checked experimentally in laboratory conditions [1], and used in interpretation of real experiments [3,5]. To determine both thickness and water content in oil-water film it is necessary to use two-frequency measurements [3,5].

In reality, there are other factors, which influence the radio emission of oil films, for example, in [2] the authors considered the influence of film-thickness variations within the

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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.

Experiment

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, two radiometers at wavelengths 0.23 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.

Firstly, the dependence of radiobrightness on oil thickness at both wavelength has been measured for the pure oil film on the water surface. In Fig.1, it is possible to see measurements results, which are in excellent agreement with the theory at given value of real part of the permittivity (the value imagery part, which is too small to influence on results, is chosen 0.05).

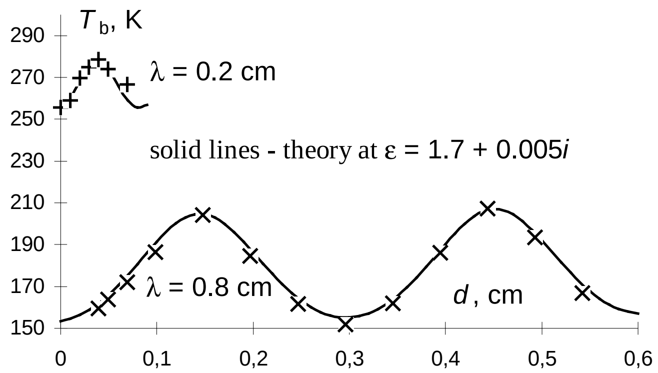

Fig.1. Measurements in pure oil films on water surface.

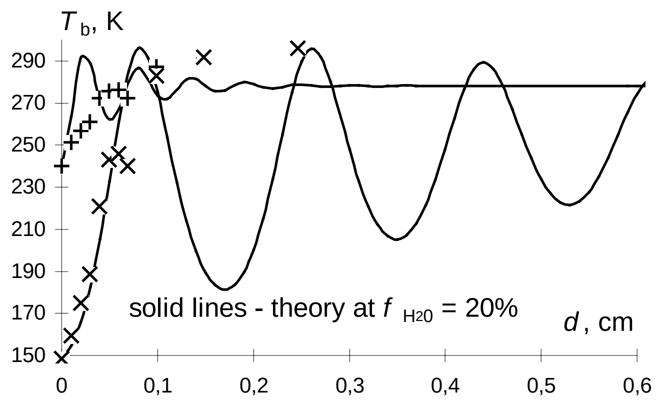

Fig.2. Measurements in oil-water emulsion films.

Next measurements have been carried out after the first summer rainfall. The results are given in Fig.2. One can see that the radiobrightness dependence changes drastically - there is practically no interference features at both wavelength, and this dependence is unaccountable from the point of view of mixing theory, which lead to the expression (1), 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. So, it is obvious that the new effect has been discovered. It is possible to suppose that the origin of this effect consist in the influence of the emission scattering on water droplets into oil-water emulsion medium or on random dielectric heterogeneities. These processes lead to decrease of coherent part of emission, and, hence, smooth the interference of direct and reflected from interface emission. The theory of the thermal radio emission of the two-layered medium with random dielectric heterogeneities is very complicated and there are only few attempts in this directions (see, for example, [7]).

It should be mentioned, that the obvious interference features were not seen during our helicopter radiometer measurements (at wavelengths 0.8 and 3 cm) of oil spills on lakes in Siberia [3,5], and this fact enforced us to make the present investigations.

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