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Remote Identification of Liquids in a Dielectric Container Using Millimeter Waves. 3. Angular Scanning[1]

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Abstract—The use of radiometric and quasi-optical principles enables obtaining remote thermal portraits of the studied liquids in a closed dielectric container for distances from few centimeters to several meters. Microwave angular polarization radiometric scanning was used for the first time, and allows to remotely obtaining authentic thermal portraits for liquids that are similar in their physicochemical properties. It was experimentally shown that objects that have nearly indistinguishable thermal portraits (water-alcohol solutions, diesel fuels) in case of linear scanning, reveal signatures that make it easy to identify them and also to distinguish the dielectric containers for liquids in case of angular scanning. The method of angular radiometric scanning enabled obtaining the components of transmitted, absorbed and reflected waves for the authentication of liquids based on their thermal portraits in one measurement cycle. The broadband noise electromagnetic wave generated by the illumination source carries the information about the liquid and the container. The use of angular scanning reduced the time for obtaining useful information to 14 s or 4 times compared with linear scanning. The results of the study of hazardous liquids are presented on the example of combustible liquids: refined petroleum products (solvents, diesel fuels) and aqueous-alcoholic solutions in containers with dielectric constant $\varepsilon = 2$–16. It was experimentally shown that a microwave radiometric thermal portrait carries information about the number of molecules with a weak hydrogen bond in aqueous-alcoholic solutions. The proposed method for remote identification of liquids in a closed dielectric package is safe and environmentally friendly, since the required level of the illuminating noise radiation does not exceed the value of 20 dB/kT_0.

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1. INTRODUCTION

It was shown [1–7] that the specific features of short-range radar allow solving problems that are fundamentally insoluble by means of conventional (long-range) radar and infrared technology, for instance, remote measurement of the temperature distribution of objects—thermal portrait (TP). On the basis of the TP, the parameters of these objects, including liquids, located in closed dielectric containers are determined. References [1–7] also demonstrate the principal possibility of remote detection of hazardous liquids in a dielectric container and define the criteria for their difference from safe liquids, for example, mineral waters.

It was shown [1–4, 7] that radiometric studies allow remote sensing and identification of objects at distances up to several meters. A variety of physical and chemical properties of liquids, including fuels, does not allow them to be uniquely identified using the results of measurements of only the dielectric constant and loss tangent during single measurement in one frequency range. Different liquids, including fuels, can have the same effective dielectric constant at different ratios of the constituent components.

The use of a thermal portrait of liquid fuels that are in closed dielectric containers for their identification is more illustrative and informative. Using the dependence of the spatial temperature portrait of a container with a liquid at different polarizations of the received signal allows increasing the probability of the liquid authenticating. TP for gasoline from different manufacturers obtained by linear scanning in the single

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