Non-Destructive Evaluation of Dielectric Structural Materials by Holographic Subsurface Radar

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The existing methods of non-destructive testing of structural and building materials or components have a number of disadvantages. X-ray devices, for example, require two-way approach to the observed detail. This is complicated sometimes and more often even impossible. X-ray devices are widely used in medicine, for hand-luggage control in airports and in technological processes where two-way approach to the object to be examined has no problems as a rule. Ultrasonic equipment has proved to be ineffective in media containing a great number of micro cracks and heterogeneities. Its main application is the examination of relatively homogeneous media with few defects and inclusions, for example, metal details of relatively large dimensions.

From this point of view, the microwave devices are the most promising as they make possible the use of reflective sounding, i.e., transmission and reception of electromagnetic waves is performed from one side of the sounded surface. It enables to examine walls, ceilings and decorative elements and so on in ready-for-service buildings. Thus, it is possible to control the quality of their construction and repair. When using a specially designed antenna, the proposed method also makes it possible to examine corners between walls. This is hardly possible otherwise. Another advantage of radar sounding is a relatively large wavelength λ in the used microwave band, at which there is no reflection from minor natural heterogeneities of media under investigation, for example, by cracks and small (compared to λ) technological hollows in bricks and other construction materials. By choosing wavelength of emitted signal, it is possible to carry out preliminary selection of heterogeneities in surveyed object in view of features of a task.

However, taking into account that water possesses a very high permittivity of 80, cracks filled with moisture have high contrast. This effect can be used in practice. While constructing and reconstructing, concrete structures or their parts, which are under the level of the construction site ground, have to be sealed to prevent water intrusion. This type of structures includes underground garages, automobile parking places, underground pedestrian crossings, and etc. This problem becomes especially actual in spring and autumn when the soil water level is high.

The recent disastrous loss of Space Shuttle Columbia has aroused the great demand in new methods and devices for non-destructive testing and evaluation of the Space Shuttle Thermal Protection System heat protection tiles, as well as the external fuel tank insulating foam. Various approaches have been suggested for determining the integrity of the tiles and foam. However last flight Space Shuttle Discovery has shown that the difficulties with diagnostics of heat protection system are not overcome till now.

The radar under consideration was originally designed for producing non-destructive microwave images of construction details, buried land mines, and etc. The preliminary investigations indicated that its high resolution and sensitivity to cracks or voids, and variations in the subsurface moisture content of materials under inspection could be useful in providing early warning of hidden, incipient problems in the Shuttle protection systems.

This holographic radar method differs from traditional surface-penetrating radar (which typically uses impulse signals) in the simplicity of equipment design and the considerably smaller aperture of scanning antennae. These innovations allow improvement in the spatial resolution of surface-penetrating radar images. It is noteworthy that the effective detection depth of this method is less than that of traditional impulse radars. Nevertheless, for many applications, the holographic radar will provide sufficient detection depth. A good example is the space shuttle heat protection system, which has tile thickness in the range of 4.3–10 centimeters. Another extremely important advantage of this holographic radar technology is the possibility that it can image, without reverberation, dielectric materials that lie above a metal surface as in case heat protection cover. Such materials cannot effectively be inspected non-destructively with traditional time-domain impulse radar technology.

Some experiments concerning surveying of construction details and foam above metal plate will be presented in full paper.