Microwave Subsurface Imaging of Living Tissues[1]

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The microwave 2D images of the subsurface structure of living tissues (of the human thorax) have been obtained using a near-field small-aperture antenna as a probe. The microwave reflection at the frequency 1110 MHz has been measured by 2D scanning over the body surface by a registering device, stored in a computer and used to produce an image, where subsurface dielectric inhomogeneities are clearly seen.

1. Introduction

There are well-known methods of subsurface radiometry, which use the frequency dependence of the microwave skin-depth in media to retrieve the subsurface temperature by multi-frequency measurements of thermal radio emission. Recently we have proposed a new method of subsurface temperature diagnostics based on the dependence of the effective depth of thermal emission formation on the size of electrically small contact antenna [1]. In various possible applications, including medical, it is important to develop a method of subsurface structure diagnostics of media. Now we propose to use the same near-field antenna as in [1] for measurements of 2D image of reflectivity of human body that is related to the effective subsurface impedance and, hence, to the subsurface dielectric inhomogeneities structure.

2. Method of active microwave subsurface sounding

A method of subsurface imaging of living tissues has been worked out. It is based on 2-D microwave reflectivity scanning using a small-aperture near-field contact antenna with the size of 1 cm as a probe (the same antenna was used in our near-field radiometry measurements [1]). This antenna consisted of two in-phase dipoles connected to a symmetric strip line operating as a matching resonator. The scheme of measurements is shown in Fig.1.

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As the probe moves along the tissue surface, the equivalent impedance has variations related to subsurface inhomogeneities. These variations lead to variations of the antenna reflection coefficient, which can be measured. Visualization of obtained 2-D distribution of the reflection coefficient makes an image of subsurface inhomogeneities.

At first, the spectrum of the reflection coefficient for various subsurface structures under the surface of a human body has been studied. In Fig.2 one can see that different subsurface structures of living tissues have different response in the reflection. This fact makes it possible to use the reflection measurements for the microwave subsurface sounding. From results shown in Fig.2 one can conclude that the most suitable frequencies for the MW imaging can be chosen from the frequency range 1100-1140 MHz where the reflection difference for various tissues is more pronounced. It is reasonable to make measurements at near-zero values of the reflection coefficient for some place inside an area of measurements because it improves the accuracy and makes a high level of the image contrast. The frequency f_0 = 1110 MHz has been used for scanning in our measurements of living tissues.

3.Results and discussion

In Figs.3-4 results of MW imaging of the human thorax are shown. It is possible to see that details of the subsurface structure of living tissues are clearly seen. In particular, one can see two ribs and inhomogeneities of the adjacent tissue structure for the cases of adult and young men. These results show possibilities of MW subsurface imaging of living tissues.

There are also problems that should be solved. First of all, it is necessary to build the automatic scanning system. It is not easy task because the antenna properties are very sensible to small variations of inclination at the application. May be, antenna arrays can be used in this diagnostics. Second, it is very interesting to retrieve the subsurface distribution of dielectric parameters. The effective depth of this active sounding is comparable to the antenna size; hence it allows developing methods of subsurface dielectric structure sounding using the dependence of reflectivity on antenna size. There is also the possibility of multi-frequency analysis. These approaches are inevitable related to the solution of very complicated electrodynamics problems.

The measurements method used in this paper is very similar with that in [2], where a microwave near-field system for the subsurface sounding of thin dielectric samples has been built. In [2] we also had a lower space resolution as compared to the surface imaging in near-field scanning microscopy at microwave frequencies [3-4]. The high resolution in this kind of microscopy is achieved by decreasing of the probe size because the resolution is determined by this size. However, the increasing of resolution leads simultaneously to decreasing of the sounding depth because it is also about the probe size. Thus, a large penetration depth, as an important advantage of microwave range, is lost in microwave microscopy. In our subsurface microwave imaging we use larger antennas to achieve the necessary penetration depth (that is also comparable to the antenna size) but, of course, at the cost of resolution decrease. There is a difference between the approach used in this paper and methodic of [2]. We use here the wideband antenna (the band width ~ 150 MHz) instead of narrow-banded antenna (15 MHz) in [2]. The wide frequency range made it possible to optimize the wavelength selection in the approach presented here.

4. Conclusion

It is possible to conclude from the results of our study that the MW living tissues imaging has a good prospect, and it is much less harmful in comparison with the X-ray diagnostics. This method can be used also for the subsurface imaging of other dielectric media.

References

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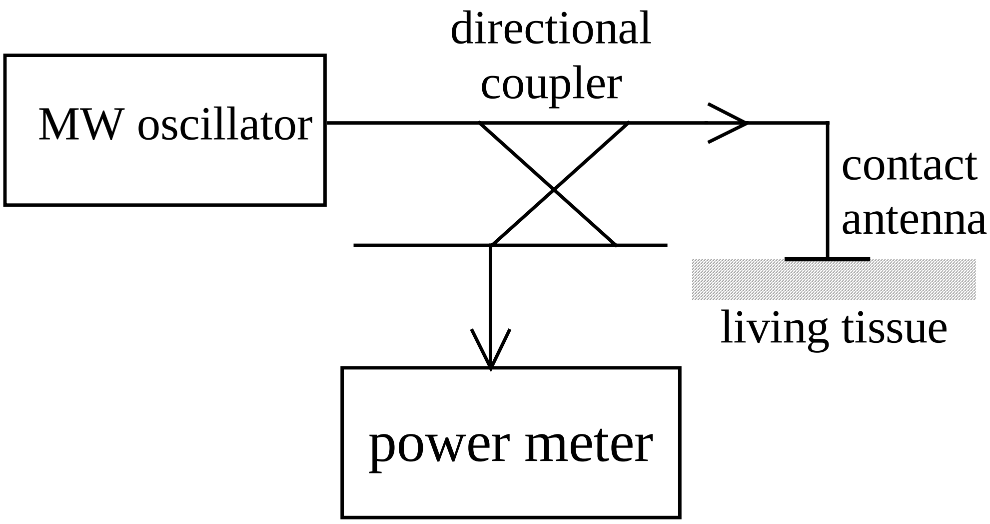

Fig.1. Measurements scheme.

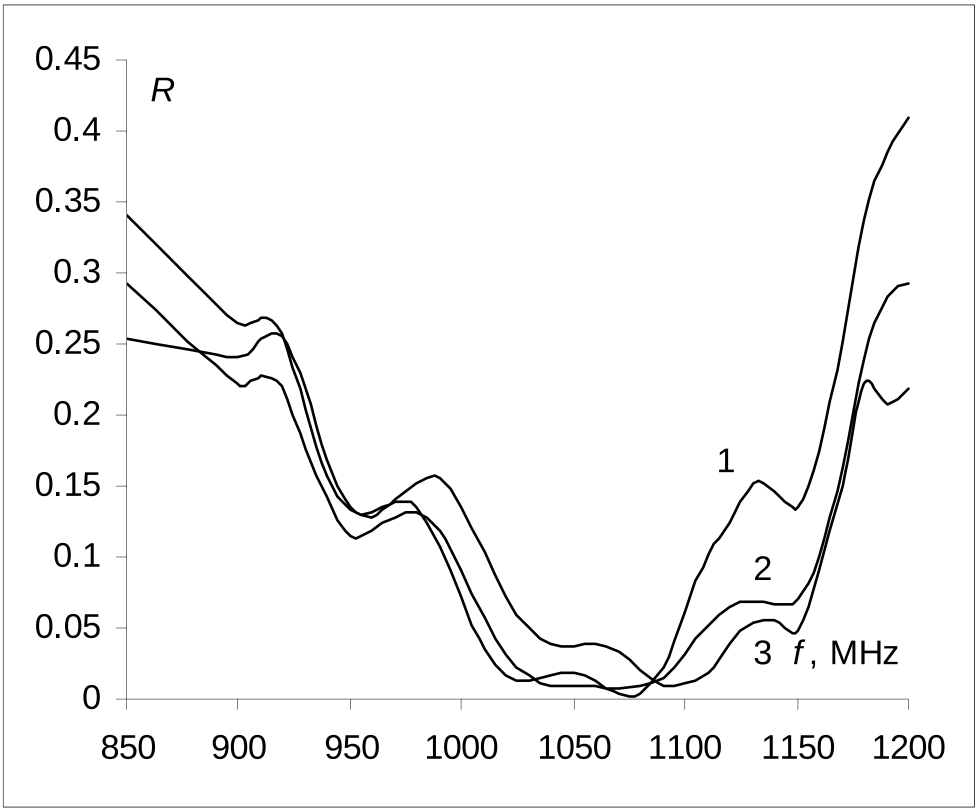

Fig.2. Reflection spectrum for living tissues. 1 – forehead, 2 – biceps, 3 – belly.

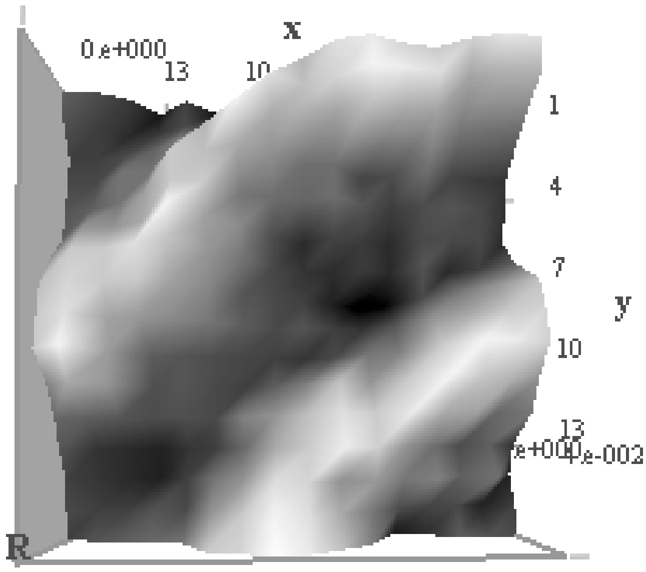

Fig.3. MW image of 8×8 cm^2 area of the human thorax of an adult men.

Pixel size is 5×5 mm^2.

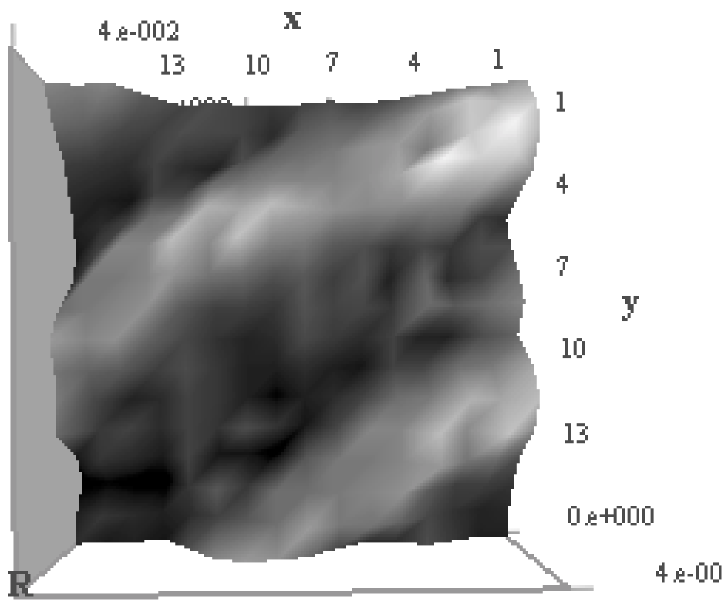

Fig.4. MW image 8×8 cm^2 area of the human thorax of a 15-year-old boy.

Captures to the figures

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Fig.3. MW image of 8×8 cm^2 area of the human thorax of an adult men. Pixel size is 5×5 mm^2.

Fig.4. MW image 8×8 cm^2 area of the human thorax of a 15-year-old boy.