Study of dielectric properties of human skin in millimeter wave range and its correlation with physiological condition

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INTRODUCTION

Modern imaging techniques such as magnetic resonance and ultra-sound have been responsible for significant advances in medical science. In recent years the interaction of electromagnetic signals with the human body has been studied intensely for health and safety applications as well as diagnostic and therapeutic purposes. However, the field of dielectric spectroscopy of biological materials at high microwave frequencies (above 20GHz) is relatively unexplored but would seem to offer several important benefits to the real-time monitoring of human health. In this work the dielectric properties of human tissues, specifically skin and blood, in the millimetre wave band (30-300GHz) we studied. Such research would contribute towards our understanding of the electromagnetic properties of both normal healthy tissues and tissues exhibiting various abnormalities in this band. This, in turn, would enable the development of fast and non-invasive methods of monitoring human health. Such methods would be safe and offer a real-time monitoring of dynamic life processes. We propose to study the interaction between electromagnetic radiation in the millimetre wave (MMW) band and the human body in vivo. The main parameter of interest which is indicative of the response of the human body is the *complex dielectric permittivity*. It is a macroscopic quantity which is a function of frequency, dielectric polarisation and relaxation phenomena. MMW are strongly absorbed by human tissues and therefore only penetrate the skin. Experimental studies of human skin in vivo will be used to develop a model of the dielectric properties of skin and to study of mechanisms of dielectric relaxation and polarisation of human skin in MMW band. The data will be used to search for correlations between dielectric properties in MMW band and physiological conditions of human body.

MATERIALS AND METHODS

Materials: we have studied human organism by investigation of complex dielectric permittivity of living human skin in vivo using reflection coefficient of electromagnetic wave only [1] and of a single sample of excised human skin fixed in formaldehyde at body temperature [2].

Methods. The reason for usage of MMW for bioelectromagnetic study are follow. Skin is tissue with high water content. In this case: 1. The sensitivity to the content of water and other dipole liquids in different media increases with frequency (e. g., a free space absorption of MMW in water a > 40 1/cm is much greater than that in all monitored host materials; as wavelength decreases, the absorption in water increases more rapidly than the absorption in these host materials). 2. MMW practically are not sensitive to conducting impurities in liquids. 3. MMW allow one to realize non-destructive, real-time, in-flow measurement of the dielectric properties of media. These properties are closely related to the chemical composition of substances under test.

Investigation of correlation of dielectric properties of skin in millimeter (MM) frequency range and its physiological parameters demand own methods for investigations. We have elaborated and realized the original methods for measurements of dielectric parameters for materials, media and tissue. In detail, quasi optical methods of measurements in non-reflected beam waveguides. This method allows: a) to eliminate errors because of reflections in experimental setups; b) to work with the samples much more smaller as with the usual quasi-optical methods allow, i.e. with the cross-section area about some wavelengths; c) in comparison with the usual methods, that use metal waveguides, in our method it is not needed to make the cross-section area of the samples exactly suitable to the cross-section area of waveguides; d) because of in our method experimental setups are open, then there is no problem to place the samples under investigation in every place of the setup, e) there is no problem to realize influence of external factors like temperature, electrical and magnetic fields, light, mechanical pressure. The main original method proposed to human skin is non-destructive (non-invasive) method for determination of complex dielectric permittivity with the use of measurements of minimal reflection coefficient and the frequency, in which this coefficient is obtained. The reflection is connected with the special dielectric with known parameters. This method is much more easy and much more accurate then usual non invasive methods, that use measurements of the module and phase of reflection coefficient. The reason for this high accuracy is the next: the accuracy of frequency measurements is much more higher then one for the measurements for reflected wave [1].

RESULTS

This method was realized in frequency range 28—150 Ghz and at frequency about 10 GHz. The next measurements were carried out. Dielectric properties of glucose solutions with concentrations of W from 5 to 0.25% wt. are measured in the frequency range 30–93 GHz and at 10 GHz. Dielectric properties of blood (using one drop) are investigated *in vivo* at frequencies of 42 and 66 GHz. The measurements have shown that the method developed in this project can be used for the real-time determination of the glucose content in blood without strips used in optical invasive glucometer after oral glucose tolerance test (OGTT).

Dielectric properties of skin in vivo in the frequency range from 30 to 80 GHz and excised human skin fixed in formaldehyde in frequency range from 90 up to 100Ghz are determined. The experimental results have been used to determine the parameters of a Cole-Cole function which gives the best fit to the measured data. The measured skin data has also been used to calculate power deposition in skin exposed to millimetre wave radiation. This work concludes that a skin surface temperature rise of only 0.20C results from a thirty second exposure to signals of $100 W/m^2$.

CONCLUSIONS

It is shown that our results allow, to create a non-invasive measurement method for skin water content for different strata of skin, and in principle, for the glucose content in blood determination, at least after OGTT and some parameter of human organism.

REFERENCES

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