Title

MECHANISM OF DIELECTRIC PROPERTIES OF HUMAN SKIN IN MILLIMETRE WAVE BAND

Research Aims 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.

Research Proposal

The principle that the dielectric properties of biological tissues depend on their physiological conditions has already been proven for many bands of the electromagnetic spectrum. It is hypothesised here that there exists a correlation between the dielectric properties of biological tissues in the MMW band and their physiological conditions. The main goal of this project is to prove this hypothesis for living human tissues.

Complex dielectric permittivity is a macroscopic parameter which is indicative of the average bulk dielectric polarisation and relaxation characteristics of the dielectric in question. Dielectric polarisation and relaxation phenomena depend on chemical composition, structure, chemical bonding and external influences; they also vary in each frequency band and hence the dielectric properties vary accordingly. In the MMW band these processes are associated with reorientation of the fastest dipoles and the slowest atomic groups.

MMW are strongly attenuated in human tissue and are almost completely absorbed by the human skin; there being negligible power which penetrates to deeper lying tissues. Thus the most appropriate tissue to study in the MMW band is the skin. The skin is a heterogeneous tissue, composed of many layers and a measure of its permittivity gives the average characteristics for this complex media. However, by changing the frequency of the measurement it is possible to study the different layers of skin such as the stratus cornelious, derma and hypoderma. Skin is a very complex organ containing water (free and bound) and blood etc in which many physiological and biochemical processes take place continuously. All these processes depend on the physiological condition of the human subject. Some of these processes are connected with blood perfusion of the skin, which is one of the most general characteristics for the physiological condition of the skin. Thus the condition of skin tissue is connected with the general condition of the human subject. Since the dielectric properties of skin are dependent on its composition and structure, one can gain an insight into the physiological condition of the human body by a study of the dielectric properties of its skin. In order to understand the dielectric properties of skin one must consider the dielectric polarisation phenomena of skin and its constituent structures and chemicals.

Working plan.

Task 1. Theoretical and experimental investigation of dielectric properties of "blood imitators" with different sugar, cholesterol, haemoglobin contents. Task to be conducted at FIRE RAS Russia. Start month is 1, duration is 7 months.

Task 2. Experimental and theoretical investigation of dielectric properties of different parts of human skin and skin of different persons. Task to be conducted at FIRE RAS (Russia) and Cranfield University (UK). Start month: 8, duration: 5 months.

Task 3. Experimental and theoretical investigation into the dynamics of the dielectric properties of human skin of different persons under the influences of pressure, temperature and illumination. Task to be conducted at FIRE RAS (Russia). Start month: 13, duration: 5 months.

Task 4. Experimental and theoretical investigation into the mechanisms of dielectric polarisation and relaxation of human skin in MMW band. Task to be conducted at FIRE RAS (Russia). Start month: 18, duration: 5 months.

Task 5. Search for correlation between dielectric properties of human skin and physiological parameters of human organism. Task to be conducted at FIRE RAS (Russia) and Cranfield University (UK). Start month: 13, duration: 10 months.

Task 6. Conclusion. Preparation of journal paper to be undertaken by both partners. Start month: 23, duration: 2 months.

Visits:
Dr C. Alabaster will make two visits to FIRE RAS (Russia) for a 10 day period each (one visit per year).
Prof V. Meriakri and Dr S. von Gratowski will make a single visit to Cranfield University, Shrivenham (UK) of 10 days duration.

Resources Required – *Other participants*

List of participants from Russian side:

1. Prof. Dr. Meriakri Vjacheslav Vjacheslavovich, Head of Laboratory
2. Dr. Parkhomenko Mikhail Pavlovich - senior reseacher,
3. Dr. Chigriai Evgenii Evgen'evich – leading reseacher,
4. Dr. von Gratowski Svetlana Vjacheslavovna – scientific researcher,
5. Dr. Nikitin Ivan Petrovich – senior reseacher,
6. Akatjeva Viktoria Vjacheslavovna – engineer,
7. Kalenov Dmitriy Sergeevich - technician,
8. Akatjeva Milana Georgievna - technician,
9. Fedoseev Nikolay Aleksandrovich – senior electronic engineer

In recent years, the Russian partners have intensively studied the interaction between electromagnetic radiation in the MMW band with the human body. Participants #1, 2, 3 and 5

have worked as experimental researchers on the development of experimental methods and set ups, participant #9 has worked as an electronics engineer and participant #4 as a theoretical researcher. Participants #6, 7 and 8 have supported the other participants. Their work has achieved considerable advances in this field which have included the development of very simple and original methods for the measurements of the dielectric properties which have previously been applied in the investigation of human tissues in the MMW band. Their methods would be used in the project proposed here and are suitable for the determination of complex dielectric permittivity for high losses media like water, blood and skin. The combined expertise of this team would be required for the proposed project. The previous work of this team is testament to their proven track record in this field.

List of participants from UK side:

1. Dr Clive Alabaster, lecturer.

Participants – *PhD students* (max 1000 characters, including spaces)

None from Cranfield University (UK)
Two masters students (Russia)

Contact
Over the last 5 years, the UK and Russian partners have been in regular email contact concerning their common interest in measurement methods of the permittivity of human skin in vivo in the MMW band, new goals and challenges in this research area and current publications on this subject. We have often debated the possibility of a joint bilateral collaborative research project in this field.

Policy on Animals: Not applicable

Benefits to Individuals/Institutions
We hope this project will result in a strong partnership between the individuals and their institutions in order to promote further research work in this field. Each will benefit from the experimental methods developed by the others. Successful completion of this project would result in the publication of a journal paper and also be advantageous in the winning of future research grants and contracts in this field, both of which would enhance the reputations of those involved.

Benefits to UK
1. Access to the expertise of the Russian team and their experimental methods in the measurement of complex permittivity in the MMW band. Similar experimental methods could be applied for alternative applications such as the monitoring of the structural health of composite materials and structures.
2. This work may lead to the development of new diagnostic methods for various medical conditions/skin abnormalities.

Benefits to Oversees Country

1. The investigation into the effects of radiating the human body with MMW radiation in bands to which it is not naturally exposed due to the filtering of these bands by Earth's atmosphere.
2. This work may lead to the development of new diagnostic methods for various medical conditions/skin abnormalities.
3. Access to the MMW vector network analyser in use at Cranfield University.