SIMULATION OF DIELECTRIC PROPERTIES OF HUMAN TOOTH AND TOOTH REPLCEMENT AT GHZ FREQUENCY

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Abstract

This article deals with a research proposal of microwave testing biomaterials used in dentistry. We started to realize the schemes and optimization of measurement methods in software simulation tool COMSOL Multiphysics. This simulation tool allows quick and precise analysis of materials. For basic simulation was chosen rectangular waveguide WR – 90 at microwave frequency in X - band (8 GHz – 12 GHz).

1 Principles of microwave methods

The microwave methods (from 3 GHz to 300 GHz) of measurements for materials characterization are divided in two types, resonant and non-resonant. Resonant methods give more accurate knowledge of dielectric properties over a limited frequency range or a single frequency, while the non - resonant methods give a general knowledge of electromagnetic properties over a frequency range. The non- resonant methods are widely used to characterize different kinds of materials over a broad frequency band, [1].

However, they require a less sample preparation compared to resonant methods. Due to its simplicity, the non-resonant waveguide transmission/reflection method is presently the most widely used broadband measurement technique; it is also applied for measuring the dielectric constant of high and low lossy materials. To resonant methods belong the resonator method and the resonator - perturbation method. To non-resonant methods belong the reflection methods and the transmission/reflection methods, [2], [3].

2 Methods for investigation of tooth and tooth replacement properties

We are focused in our research on three areas:

1) the dielectric properties of biological material - tooth and biocompatible materials (to monitor degradation changes into human body),

2) the propagation of electromagnetic wave through heterogeneous structure - created from biological material and biocompatible material,

3) possibilities of in vivo and in vitro investigation of biocompatible material integrity on it is surface and in it is volume by using microwave nondestructive methods.

3 Numerical simulation and result

Firstly the filled rectangular waveguide X - 90 (2.29cm x 1.02 cm) was simulated with the Comsol Multiphysics modeling software. The waveguide was filled with air between the source of microwave signal (TE_{10}) and sample – tooth. The simulation was realized by isothermal conditions and electromagnetic waves were planar. The sample – tooth is situated at the end of waveguide. End of waveguide is terminated with short – circuit. The electromagnetic power loss density (Fig. 1) is parameter of dielectric properties of biological tissue. It has big influence on interaction with tissue. Simulation of this dependence was realized on human tooth (ε_r = 8.1885, γ = 2.0867 *S/m*) and tooth replacement – titanium (ε_r = 1, γ = 7.407x10^5 *S/m*) at frequency range from 8 GHz to 12 GHz.

In this case, electromagnetic wave is excited from the source and it is passed through the dielectric sample. The end of the waveguide is reflected by short – circuit. In both cases, EM wave is completely reflected. The wave is attenuated by the transition in dielectric sample – tooth, in contrast to metal – titanium.

Properties of the reflected wave can be determined by scattering parameter S_{11} (Fig. 2). It is possible from S_{11} parameter to calculate the dielectric properties of investigated sample and to follow their changes in bioactive environment.

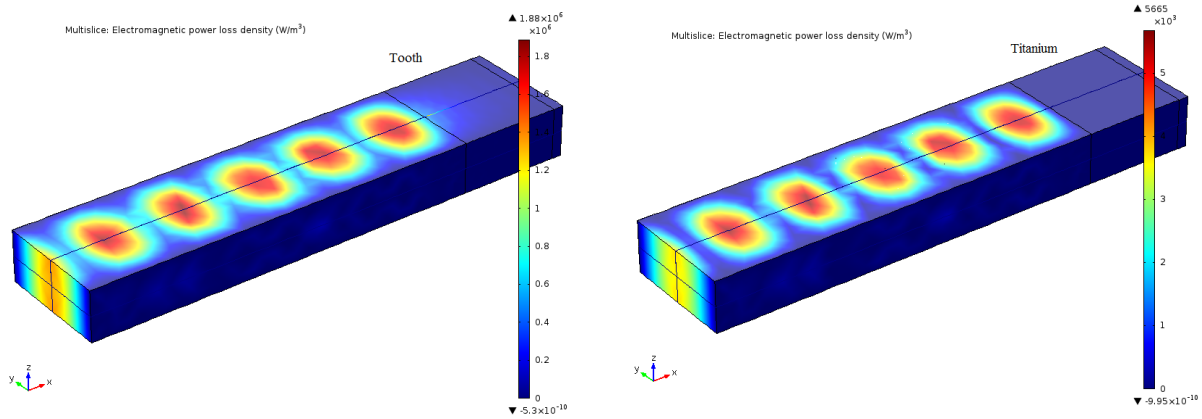

Fig. 1: Rectangular waveguide WR – 90 filled with air and with dielectric material: tooth (left side) and titanium as replacement (right side) at 12 GHz (electromagnetic power loss density)

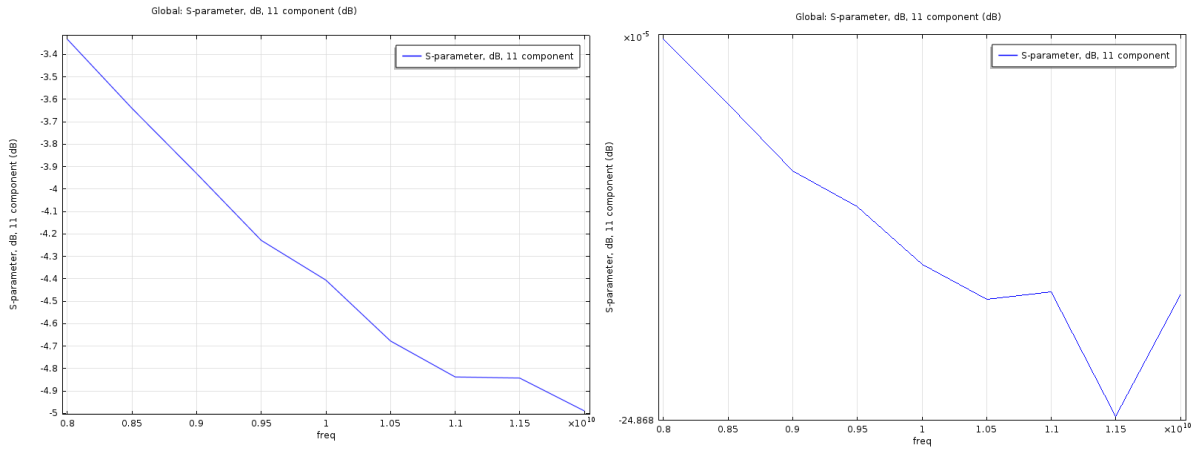

Fig. 2: S_{11} parameter: for short-circuited waveguide filled with tooth (left side) and titanium (right side) at 8 - 12 GHz

The values of scattering parameter inhibition/absorption (vertical axis) compared tooth titanium can be stated: EM wave is significantly attenuated transitions through the lossy dielectric material - tooth and on other side, EM wave passes through titanium through conductor almost with no losses.

4 Conclusion

This paper is a research proposal of microwave testing to specify dielectric properties (and in general, to search defects and non - homogeneities) of biomaterials used in dentistry (designed to use high frequency). It is based on EM simulation setup consists of waveguide method and a human tooth. The analysis resides in observation/evaluation of EM energy absorption. Due to the absorptions of EM energy, different peaks are appeared in the S - parameters. This analysis shows that the GHz frequencies can be used to detect the composition material.

Our next aim is to create 3D tooth model and to analyze the properties of various biocompatibility materials in detail and to compare the properties of materials after interaction between tooth tissues and using biomaterial. Further research work is required to obtain data about the position, dimension and heterogeneity presence of denture by using high frequency electromagnetic method. Monitoring dielectric properties of tooth and implant, especially in the microwave frequency range and exploring new possibilities of application new materials elements are very important to improve quality of biomaterials and level of treatment.

Acknowledgement

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