Study of the Shape of a Microwave Chamber for Heating a Dielectric Object

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Abstract. Currently, microwave energy is actively used in various industrial spheres for heating dielectric materials. In order to ensure uniform heating, it is necessary to obtain a uniform distribution of absorbed power in the volume of a dielectric. In this paper, we consider two models of a microwave chamber for heating a dielectric object – a rectangular chamber and a cylindrical chamber. Computer simulation was performed in the FEKO software for several cases: using two and four radiation sources and using two different dielectrics, with parameters corresponding to water and wheat. The results show that a cylindrical chamber provides a more uniform distribution of absorbed power in the inner volume, and therefore, allows to obtain a more uniform heating of the dielectric object inside it, than a rectangular chamber. One possible variant of implementation of a chamber for microwave heating of a dielectric object may be a rotating cylindrical chamber. Its application will allow obtaining uniform heating with a smaller number of emitters due to the choice of the optimal cylinder rotation speed.

1. Introduction
Currently, microwave energy is actively used in various industries: in the drying and evaporation processes of highly pure substances, for the heat treatment of building materials, in the thawing of frozen soils, in the fabrication of rubber products, such as automobile tires, in drying and disinsection of grain, in textile industry and in other spheres. The use of microwave heating for processing of various dielectric materials is described in [1-15]. In the food industry, heating objects in an electromagnetic field allows to intensify heat transfer processes, ensure microbiological safety and increase the nutritional value of raw materials. Based on international agreements, the frequencies in the range of 895-915 MHz and 2350-2450 MHz are used for microwave devices [9]. Various areas of application of microwave energy for processing materials are combined by the need to ensure uniform heating of the entire processed material.

2. Problem statement and method of solution
In order to ensure uniform heating of the dielectric material, it is necessary to obtain a uniform distribution of absorbed power in the dielectric volume. The distribution of the electromagnetic field inside the microwave chamber directly depends on its shape and location of the irradiators. In this paper, in order to choose the most optimal design, we consider two models of microwave chambers, the implementation of which is the simplest and, accordingly, practically expedient.
The first model is shown in Fig. 1. It is a rectangular chamber. A dielectric object of the same shape is located inside the chamber at some distance from the walls. Waveguide-slot antennas with dimensions of 43x86 mm are used as sources of electromagnetic field. The waveguides are located directly close to the walls of the chamber. Microwave radiation gets into the chamber through slots cut in the wide wall of the waveguide. Fig. 1a) shows a model of a rectangular chamber with two radiation sources. Fig. 1, b) illustrates the model with four sources. Both models were built in FEKO program.

![Figure 1. Model of a rectangular microwave chamber: a) 2 radiation sources; b) 4 radiation sources](image1)

The second model is shown in Fig. 2. It is a cylindrical chamber filled with a dielectric material of the same shape. Waveguide-slot antennas are used as radiation sources, similar to the previous case. Fig. 2a) shows a model of a cylindrical chamber with two waveguides, and Fig. 2b) – same model with four waveguides.

The simultaneous use of several irradiators located on the opposite walls of the chamber is due to the need to ensure uniform heating of the dielectric material inside the chamber.

The dimensions of the model are chosen in such a way that the volume of the heated dielectric material is the same for both rectangular and cylindrical shapes of the microwave chamber used.

![Figure 2. Model of a cylindrical microwave chamber: a) 2 radiation sources; b) 4 radiation sources](image2)

Computer simulation in the FEKO program was used to calculate the distribution of the electromagnetic field and specific absorbed power in the dielectric volume. To solve the problem, the method of moments embedded in the program was used. To reduce computational requirements, the solution to the problem was performed in two stages, based on decomposition. At the first stage, a solution to the antenna problem of the field distribution in the aperture was obtained, that is, the currents were calculated on a rectangular area corresponding to the radiating wall of the waveguide. At
the second stage, using a rectangular platform with the already known current distribution as the source of the electromagnetic field, the distribution of absorbed power in the chamber volume was calculated.

3. Discussion of results

The distribution of the specific absorbed power in the microwave chamber with the dielectric object inside was simulated in this work. Calculations were performed for two dielectrics with parameters corresponding to water ($\varepsilon = 81$, $\tan \delta = 0.1$) and wheat ($\varepsilon = 4$, $\tan \delta = 0.1$). The electrophysical parameters of dielectrics did not change, since the calculation was carried out at a single frequency, which was taken equal to 2.45 GHz.

Fig. 3 and Fig. 4 show the distribution of the specific absorbed power in the cross section of a rectangular chamber. Fig. 3 illustrates the case when water was used as the dielectric filling of the chamber. Fig. 4 refers to using wheat as a dielectric. Fig. 3a) and Fig. 4a) show the power distribution when using two radiation sources, and Fig. 3b) and Fig. 4, b) are given for the case of using four sources.

Figure 3. Distribution of the specific absorbed power in the cross section of a rectangular chamber filled with water: a) 2 radiation sources; b) 4 radiation sources

Figure 4. Distribution of the specific absorbed power in the cross section of a rectangular chamber filled with wheat: a) 2 radiation sources; b) 4 radiation sources

Fig. 5 and Fig. 6 show the distribution of the specific absorbed power in the cross section of a cylindrical chamber. Fig. 5 illustrates the case when water was used as the dielectric filling of the chamber. Fig. 6 refers to using wheat as a dielectric. Fig. 5a) and Fig. 6a) show the power distribution when using two radiation sources, and Fig. 5b) and Fig. 6, b) are given for the case of using four sources.

The results confirm the theoretical assumption that when using four sources, the resulting distribution of power absorbed in the volume of a dielectric material is much more uniform than when using only two sources. In addition, it is seen that a cylindrical microwave chamber provides a more uniform distribution of absorbed power inside it than a rectangular one, and therefore, it ensures uniform heating of the dielectric.
Figure 5. Distribution of the specific absorbed power in the cross section of a cylindrical chamber filled with water: a) 2 radiation sources; b) 4 radiation sources

Figure 6. Distribution of the specific absorbed power in the cross section of a cylindrical chamber filled with wheat: a) 2 radiation sources; b) 4 radiation sources

It should be noted that the use of several sources of radiation at the same time may be difficult due to material or technical reasons. Therefore, one of the possible variants of implementation of a chamber for microwave heating can be a rotating cylindrical chamber.

The simplified design of such a chamber, modeled in the FEKO program, is shown in Fig. 7a). A cylindrical chamber rotates around a metal rod that extends through the center of the cylinder along its axis. Fig. 7b) shows the distribution of the specific absorbed power in the cross section of a chamber filled with wheat.
Figure 7. A model of a cylindrical microwave chamber with four radiation sources and the distribution of the specific absorbed power in the cross section of a cylindrical chamber.

This design allows to get more uniform heating due to reflections from a metal rod in the center of the chamber. Besides, choosing the optimal speed of cylinder’s rotation around its longitudinal axis, it is possible to ensure uniform heating using fewer emitting antennas (up to one).

4. Conclusion
In this paper, we consider two models of a microwave chamber for heating a dielectric object – a rectangular chamber and a cylindrical chamber. Computer simulation was performed in the FEKO software for several cases: using two and four radiation sources and using two different dielectrics, with parameters corresponding to water and wheat. The results show that a cylindrical chamber provides a more uniform distribution of absorbed power in the inner volume, and therefore, allows to obtain a more uniform heating of the dielectric object inside it, than a rectangular chamber.

One possible variant of implementation of a chamber for microwave heating of a dielectric object may be a rotating cylindrical chamber. Its application will allow obtaining uniform heating with a smaller number of emitting antennas due to the choice of the optimal cylinder rotation speed.

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Acknowledgments
The research was carried out under the project “Creation of high-tech production of hardware and software systems for processing agricultural raw materials based on microwave radiation” (Agreement with the Ministry of Education and Science of the Russian Federation № 075-11-2019-083 of 20.12.2019, SFU Agreement № 18 of 20.09.2019, number of work in SFU № XD/19-25-RT).