Title : The optimization heating of microwave oven by studying 3D microwave pattern

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Field : Physics and Astronomy

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Abstract

Electromagnetic wave generated in a microwave oven is generally in the form of a standing wave. When an object is put into the operating oven, it will interrupt and alter the wave pattern. This is due to the fact that part of the microwave energy is absorbed as it passes through the object, resulting in the modification of wave pattern which in turn depending on the kind of an object. This work thus attempted to find way to readjust the microwave pattern that has been changed from its original state. To meet this goal, experiments were set up and were divided into two parts. In the first part, we studied the wave pattern of generated microwave in the oven. This was achieved by measuring the temperature difference of heated water in the oven, thus enabling the calculation of power being absorbed by the water. This led to the estimation of microwave power distribution at various locations in the oven, giving a microwave pattern in three-dimensional graphic presentation. The results showed that water positioned close to the wave generating source (magnetron) gave the highest temperature as compared to other locations, indicating the corresponding largest wave power. Furthermore, a contour of power distribution in three dimensions could also be obtained. In the second part of this work, a modification was made on the microwave oven by drilling a hole at the back of oven wall and a movable solid metal rod of 10 cm in diameter inserted. Using a Samsung microwave oven, model ME711K and capacity 800 Watts, it was found that the rod position at 2 cm from the wall gave the maximum power absorption of 490.45 Watts for heating 400 gram of water, which was 23.55% increasing, as compared with the unmodified oven. This result agrees well with a corresponding better quality of three-dimensional wave pattern model.

Keywords : microwave, magnetron, standing wave, 3D-microwave pattern, heat power

Introduction

In a microwave oven, the wave is generated from a source called a magnetron by converting electrical energy into a wave. Once, the wave is released, it travels and reflects in a random manner within the oven as a standing wave. When an object is put into the operating oven, it will interrupt and alter the wave pattern. This is due to the fact that part of the microwave energy is absorbed as it passes through the object, resulting in the modification of wave pattern which in turn depending on the kind of an object.

This work thus attempted to optimize the heating of microwave oven by finding way to readjust the microwave pattern that has been changed from its original state. To meet this goal, experiments were set up and divided into two parts. In the first part, we studied the wave pattern of generated microwave in the oven. This was achieved by measuring the temperature difference of heated water in the oven, thus enabling the calculation of power being absorbed by the water, based on the following equation:

$$P = \frac{mc\Delta T}{t} = 2\pi V f \varepsilon_0 \varepsilon_r{}' \varepsilon_r{}'' E^2$$

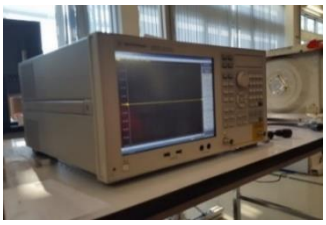
Whereas P is the microwave power absorbed by material, m is material mass, c is material specific heat capacity, ΔT is material temperature different of after and before be heated by microwave, t = material heating time, V= material volume, f is microwave frequency, $\varepsilon_0 = 8.85 \times 10^{-12} F/m$ is vacuum permittivity, $\varepsilon_r{}'$ and $\varepsilon_r{}''$ are the real part and imaginary part of material relative permittivity, and E is microwave electric field strength, this led to the estimation of microwave power distribution at various locations in the oven, thus giving a microwave pattern in three-dimensional graphic presentation.

In the second part of this work, a modification was made on the microwave oven by drilling a hole at the back of oven wall and a movable solid metal rod inserted. The purpose was to find the position of the solid metal rod that the water can absorb the maximum amount of microwave. Under this condition, the three-dimension wave pattern can be created and the wave quality can be compared with that of the unmodified oven condition.

Methodology

The experiments were divided into 2 parts as follows,

Part 1: Study of wave pattern generated in the microwave oven



1.1 Optimum wave frequency for maximum wave retaining

A network analyzer was used to generate microwave at various continuous frequencies in an empty chamber condition. The purpose of this test was to determine the optimum microwave frequency that gave the minimum back scattering of the wave and hence maximum retaining of the wave energy.

1.2 Effect of an object on generated electric field or bead pull experiment

Experiments were performed similar to Part 1.1 but with an object (plasticine) being put at various locations in the microwave oven. An optimum wave frequency was then determined for each location which could be related to an electric field generated in the oven.

1.3 Absorption of microwave by water

The temperature of water in a container at various locations in the microwave oven was measured after 1 min heating using a fiber-optic measuring device. Ten grams of water and 800 Watts of power were used in the experiments.

Part 2: Modification of microwave oven

2.1 A slight modification was made on the microwave oven by drilling a 10-cm-diameter hole at its back panel through which a movable metal rod was inserted.

2.2 Experiments were performed to study the optimum rod position that gives the maximum absorption of microwave. The studied conditions were 700 grams of water, 800 Watts of microwave power, 1 min heating time and rod position at 0-4 cm from the wall with 0.5 cm increments.

2.3 Repeat the experiment 1.3 in the modified microwave oven using the optimum rod position obtained from experiment 2.2

Results

It was found from experiment 1.1 and 1.2 that the object inside oven decreased the optimum frequency and alter the wave pattern of the empty oven.

Analysis of data from experiment 1.3 allowed the creation of three-dimensional wave pattern in the microwave oven, as shown in Figure 1. The results showed that water positioned close to the magnetron gave the highest temperature as compared to other locations, indicating the corresponding largest wave power.

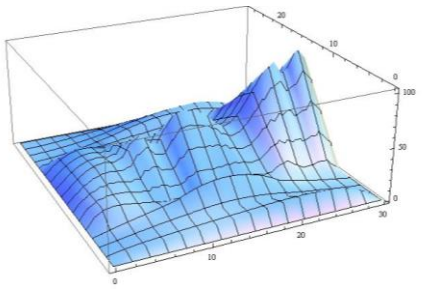


Figure 1 : Three dimensional microwave pattern in the oven

This information was further analyzed to suggest a method for compensating the standing wave being lost in an empty oven (without an object). This was done by oven modification as explained earlier in the experimental part. It was found that the rod position at distance 2 cm from the wall gave the maximum wave absorption of 490.45 Watts by water, as shown in Table 1.

Table 1 : Power being absorbed by the water at the different position of the solid metal rod

The position of the solid metal rod (cm)	Power being absorbed by the water (watt)	The position of the solid metal rod (cm)	Power being absorbed by the water (watt)
0	470.95	2.5	470.95
0.5	451.44	3	451.44
1	434.72	3.5	434.72
1.5	323.25	4	323.25
2	490.45		

The efficiency of a microwave oven in heating an object has increased after being modified, as observed from the increase of absorbed power from 398.49 Watts (no modification) to 490.45 Watts, an increase of 23.55% (see Figure 2).

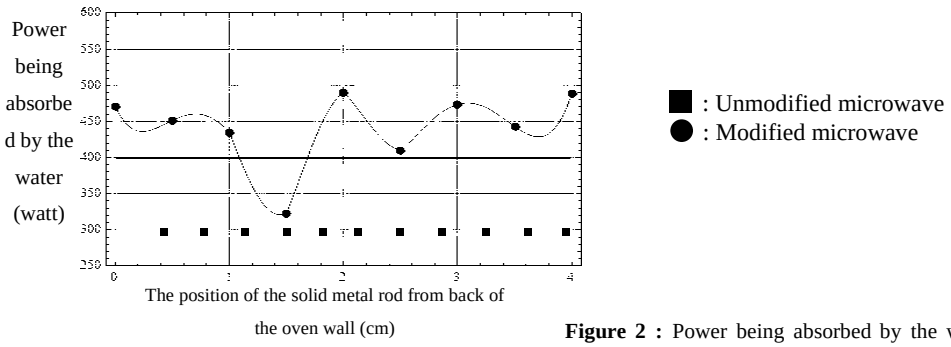


Figure 2 : Power being absorbed by the water in unmodified microwave and modified microwave

The increase of power absorbed in the modified oven corresponded to the improved quality of the three-dimension wave pattern, as shown in the Figure 3 and Figure 4.

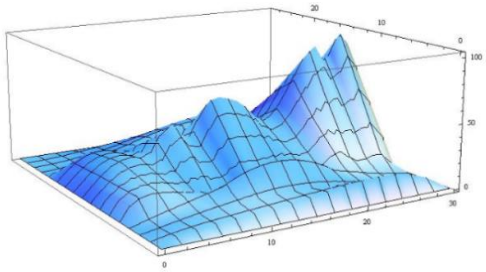


Figure 3 : Three dimensional microwave pattern in the unmodified oven

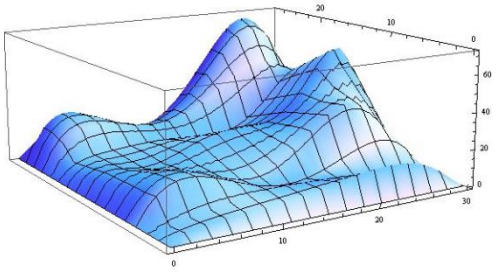


Figure 4 : Three dimensional microwave pattern in the modified oven

Conclusion

A slight modification of a microwave by inserting a movable metal rod through the back wall was able to compensate the lost pattern of standing wave. This was observed from the ability of water to absorbed more power with maximum absorption occurring at a distance of 2 cm of the inserted rod from the wall of the oven. This corresponds to a 23.55% increase in the absorption efficiency, in accord with the increased quality of the three-dimensional wave pattern.

Acknowledgements

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