Design and Fabrication of a Smart Microwave Oven

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***Abstract*—In this paper a major modification in home microwave ovens is proposed in which the food status determines the time required for reheating or even cooking the food inside the microwave instead of speculating the length of the time required to achieve the desired status. The proposed microwave called "smart microwave" features a real time temperature monitoring system, which is in charge of monitoring the food inside the microwave using some infrared sensors. It also features a PID (proportional integral derivative) controller that uses the measured temperature as the processed value which is basically the feedback that goes to the processing unit of the controller to assure that the food follows the temperature profile of the set point defined by the user. The smart microwave oven also features an electromagnetic band gap structure in order to make sure that the radiation inside the microwave cavity does not compromise the accuracy of the temperature readings caused by its parasitic effects. The fabrication process of the prototype for the proposed design is also reported in this paper. The proposed smart microwave changes the nature of this device that has always been used only for reheating the food ever since it was introduced to the market as a fast cooking appliance than can take any recipe and accomplish it in no time.**

Keywords— Microwave; Engineering; Sensors; interference;

I. INTRODUCTION

A microwave oven is considered to be one of the most important home appliances nowadays. Its concept is based on heating food using microwaves that are radio waves operating at around a 2500 MHz frequency range. Microwaves with very high power is being radiated inside the metallic chambers where the food is placed to be heated. As most of the molecules of the different foods have a polarity of a certain amount, especially in the case of water which is a very polar molecule, the microwave deals with them like dipoles, constantly attracting and repelling opposite poles. This constant process of attraction and repulsion results in the shaking of the food molecules. This vibration in the molecules, results in kinetic energy through out the food molecules, which in return heats up the food. Since the frequency and power are both high, it results in a rapid shake up of food molecules, which in return heats up the food fast, making the microwave oven an expedited way of reheating the food. Although microwaves are very well established systems for reheating food, but it must be noted that this marvelous appliancet has much more potential to it that can be of use to cooking as well. The key element that is missing in this appliance is the control over the temperature of the food inside the cavity to make sure that we are not exceeding the set point required for any particular recipe. From this missing key design element, we are planning to create smart microwave ovens.

Our approach will involve adding a temperature feedback and a proportional integral derivative (PID) controller. This addition would make sure that our processed value is always following the set point given by the user's input for a particular food that is being cooked. This project is about the design and fabrication of a smart microwave oven capable of measuring the food temperature and accordingly adjusting the time. This would be achieved through the addition of a certain number of sensors.

As a starting point, extensive literature review was completed as a part of the detailed theoretical investigation that was done on the existing microwave devices that are currently available within the Kuwait market (what is the need of mentioning Kuwait market, it can be any market since the microwaves are imported). Through this investigation, possible ways were then identified in order to achieve and develop techniques that can be used to measure the food temperature such as what.

Additionally, the concept of microwave heating is further explored, followed by the understanding of the functionality and features of a magnetron. A project problem analysis is then presented with different temperature measuring sensors analyzed, including thermocouples, RTD what is RTD, bimetallic devices, thermometers, change-of-state sensors, infrared sensors and silicon diode sensors. Appropriate solution analysis was then presented with emphasis on the black body spectrum and infrared-based detectors for temperature measurements. As a result, a detailed research study on microwave ovens was thereby covered in this project.

A. *Project aims and objectives*

As mentioned before, the aim of this project is to design (redundancy) a smart microwave oven that would be capable of measuring food temperature and accordingly setting the necessary heating time. This is achieved through certain number of modifications and developments that would be done on the conventional microwave oven that would involve the addition of new sensors.

II. METHODOLOGY

The project objectives determine the course methodology, and it is thus developed using a case study approach. The research was based on a detailed theoretical investigation on the existing microwave ovens within the market in Kuwait and through it identifying the possible solutions in which the microwave oven can be modified and developed to measure the food temperature. This approach includes the following steps:

- Looking into the project proposal thoroughly and understanding the objectives of the project.
- Conducting research about the fundamentals of microwave heating and possibly reviewing the latest publications and patents to realize the ongoing challenges in this field.
- A detailed literature review/ motivation document with a convincing argument about the need of having such a system with a feedback for food's temperature. (the first three steps can me summarized by the literature review)
- Preparing a block diagram of the solution with a feasibility study for the blocks to be implemented within the boundaries of the project.
- Looking into the technical requirements and possibly prepare a Bill of Materials (BoM) () what is the need?.
- Prepare and develop a procedure to test, validate and present the final working prototype.
- Constantly refining the methodology based on new findings and outcomes during the course of the project.

A. Planning phase

A detailed research has been done about the different fundamentals of heating and the historical development of microwave systems. The magnetron is considered to be the main component of any microwave systems which is in charge of producing the necessary waves used for reheating and cooking the food (adding a reference would be better). The key feature of microwave systems is their speed in heating up food, which became a necessity to every home and restaurant due to the lack of time ?. The different types of sensors such as pyro-electric, thermopile and (InfraRed ?) IR sensors were studied and compared in order to choose the optimum type for the new microwave design. After studying a number of microwave ovens and completing our research (references), it was deduced that a modification can be applied to a microwave oven in order to enhance its performance and improve the efficiency. This can be achieved through the replacement of the microwave oven timer with a PID temperature control. As a result, improving the microwave oven performance, save time and reduce cost can be achieved. (I think in IEEE we can't start with abbreviation) PID controllers can be used in several applications. In this project, we use (I don't see the need of using the past tense) it with a built in solid state relay which is responsible for connecting and disconnecting the power to the microwave oven. PID is a cheap controller and that is of great use.

III. The EBG (what is EBG) Structure

Periodic structures have been a matter of great interest due to the merit of introducing pass bands and stop bands [6-9] or [6] and [9]. These bands are identified and the level of the propagation and the attenuation is determined by dispersion analysis of the periodic structure. Finite Element method has been successfully applied for dispersion analysis of arbitrary shaped three dimensional periodic structures both in pass band and stop band over a desired range of the frequencies [6].

In this paper an electromagnetic band gap structure is proposed that introduces a stop band at (industrial, scientific and medical ??) ISM frequencies between 2.4 GHz and 2.5 GHz in which the commercial generator class microwave devices operate. The opening of this EBG structure allows the IR emissions to pass freely to be delivered to a thermopile that is attached to the wall of the cavity.

IV. Design

A. The unit cells

The first and the most important step to design a periodic structure is designing the unit cell as the characteristics of the whole structure is represented by the unit cell and pass band and the stop band can be both predicted just by analysis of that cell I didn't understand this sentence. The unit cell of the proposed EBG structure is a 3 mm metallic cylinder with the diameter of 10 mm. An iris is loaded inside the cylinder with a thickness of 1 mm and inner diameter of 7 mm. The iris is located exactly in the middle of the main metallic cylinder the way that the unit cell is symmetric with reference to the central plane. Table.1 shows the unit cell dimensions. (A suggestion add an image about the unit cell is possible)Table 1: dimensions of Unit Cell

Unit Cell	**Dimensions**		
	Main Cylinder inner diameter	***Iris inner diameter***	***Thickness of the iris in the middle of the cell***
	10 mm	7 mm	1 mm

The unit cell was analyzed by Eigen analysis method of *Bostani-Webb [6], [7] and [8]* after several iterations to find the right dimensions. The Block diagram is presented in the results Section. Figure 1 shows the proposed structure with three unit cells and also the mesh model of the structure that has been used for finite element S-parameter analysis of the structure.

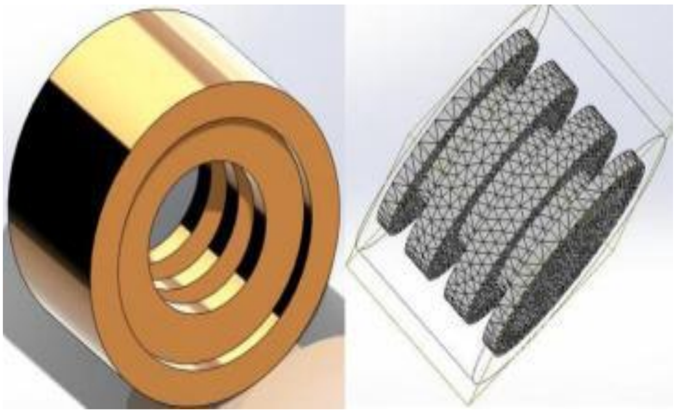

Figure 1 The proposed structure and the mesh model of the structure

B. The overall structure

As it is seen figure 1, due to the limited space on the wall of the microwave cavity, as only three unit cells could fit the designated place, another deterministic (what is FE) FE analysis was conducted by an s-parameter solver of commercial software and effectiveness of the whole structure in attenuating the radiation was confirmed. The structure was fabricated and tested on a microwave oven and the temperature was satisfactory read by the IR sensor any numerical result?

V. Results

As it is mentioned in the previous section, the unit cell of the periodic structure was analyzed using the *Bostani-Webb* method [1-3] to find the location of the pass band and the stop band. Using this method, we could make sure that the microwave operating frequency of 2.45 GHz falls into the stop band. Figure 2 shows the propagation constant of the periodic structure in which we can see the level of the propagation in the pass band and the level of the attenuation in the stop band (you need to add a and b). The periodic structure described in the previous sections was analyzed using the full wave 3D high frequency finite element simulation software, HFWorks (any reference). The structure was discretized into a finite element mesh and the analysis was conducted with the S-parameter solver. The meshed structure, shown in Figure 3, is the complement (or air-filled negative) of the periodic structure. (This approach to the simulation model is based upon analysis is in the Gigahertz frequency range and the skin effect depth of aluminum in the range of micron-level) I didn't understand this sentence

Therefore, a perfect electric conductor boundary condition is applied, and meshing of the metallic part is avoided.

For the frequency sweep, the fast sweep option was used, where one frequency point was defined as an expansion point. Figure with bad quality (snipping tool is good).

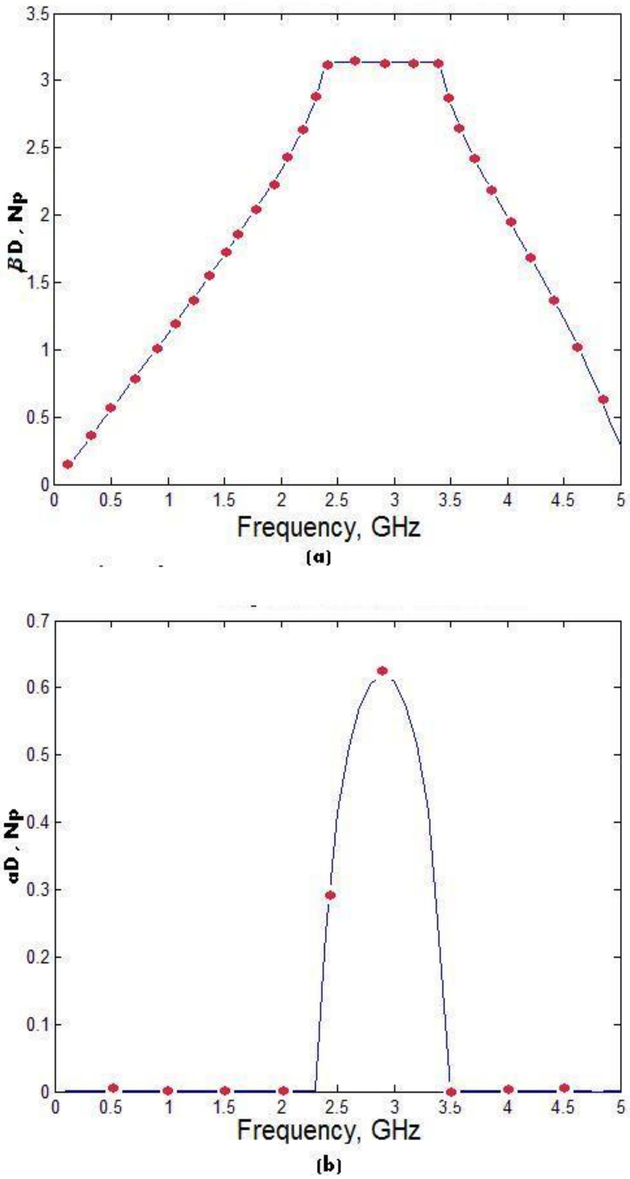

Figure 2 The propagation constant of the proposed structure in the pass band (a) and the attenuation in stop band (b)

A full size matrix is solved for the expansion frequency, while for the other frequency points; only solution of a reduced order model is required. As the focus of these analyses was the single 2.45 GHz frequency and preferably a limited band, the fast sweep can be considered as an efficient option to expedite the simulation.

Figure 3 shows the electric field distribution in the periodic structure for frequency of 2.45 GHz. As illustrated, since the 2.45 GHz frequency is in the stopband of this periodic structure, the field cannot go through the cylinder and is stopped.

Consequently, the power is reflected back into the tunnel. Figure 4 shows the electric field distribution for the same structure but for the 300 GHz frequency. As this result shows, the field can easily pass through the cylinder as this frequency is in the passband of the structure.

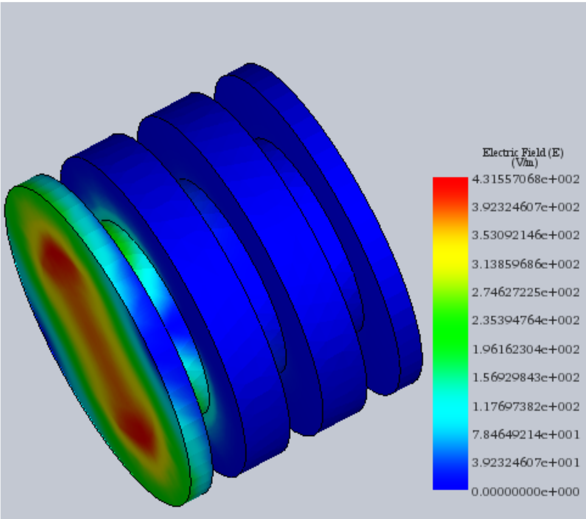

Figure 3 change the title The corresponding Electric field at 2.45 GHz

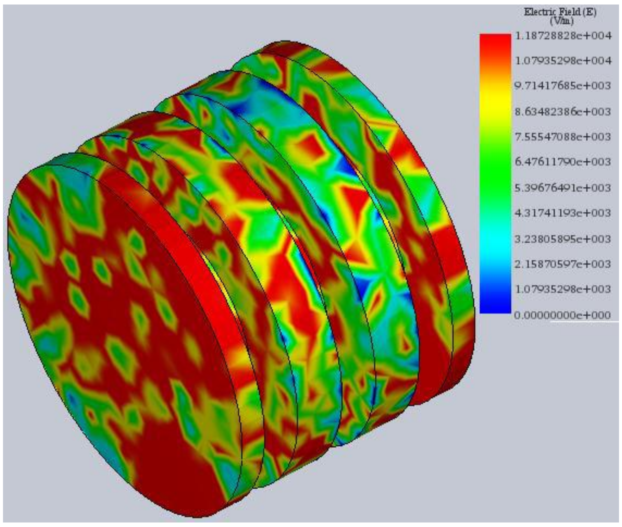

Figure 4 change the titleThe corresponding Electric field at 300 GHz

A. Implementation Phase

The team whichb team has developed the Arduino code for the newly designed microwave oven in order to achieve the desired goal of temperature dependability instead of time I think you need to elaborate more about this is your contribution besides the designing of the cell unit. A BOM has been prepared for the required components to be used in the implementation phase as shown in Table 2. Many sensors have been tested in order to choose the most appropriate ones to be used in the final microwave oven design. Arduino mega with port 2560 has been used in this project. The code was tested and simulated on the Arduino Compiler C, while the circuit was simulated using PROTEUS software. After mounting the sensors to the rooftop of the microwave oven and completing the rest of the circuitry, it was then possible to set temperature provided by the user and accordingly adjusting the necessary time automatically. Therefore, the desired goals are successfully achieved.

B. Bill of Materials

Table 21 bill of materials

Sr. No	Bill Of Materials		
	Item	***Description***	***Price***
1	Arduino Mega	Mega 2560 R3 Mega2560 REV3 ATmega2560-16AU	$32.44
2	Small Keypad	High Quality 3x4 12 USE Keys Keypad Module	$3.64
3	LCD	1602 5V Blue Screen	$1.70
4	Temperature Sensor	GY-906 MLX90614ESF	$5.65
5	Diodes	Diodes	$0.79/100
Total			44 $

$$\alpha + \beta = \chi. \qquad (1)$$

What is this equation?

C. Challenges

(A lot of challenges have been faced during the implementation phase of the project. One of these challenges were during the decision phase of picking the appropriatee temperature sensor and controller. As a result, it was necessary to use the latest and newest equipment to enhance the project. The Arduino mega kit has been programmed by Arduino IDE, which is based on C programming language, different libraries had to be used in order to control the LCD and keypad. It was also necessary to use a I2C protocol in order ???. As a result, making the PID controller have a high efficiency with good performance.) this part is not good.

Is there any difference between implementation and installation?

There are several challenges that have been faced during the installation process of the new proposed circuitry and during the implementation phase of the project, which are as follows:

- The electrostatic effect on the sensor inside the microwave oven, to check the effect of the waves, police siren has been installed inside the oven instead of a sensor as shown in figure 5. it has been noticed that the siren has not been affected by the waves.

- Another challenge was to obtain the right voltage to pass through the Arduino Circuit, the voltage value should be approximately 5 V, diode and other components have been used to adjust the voltage in order to overcome this challenge.
- Finding the correct and necessary Arduino Libraries how did you find them.
- Figuring out the connection mechanism between the LCD, Keypad and Arduino. (there is no need to mention those things)
- Find the the optimum of placing the food so that the sensor can read it properly. To achieve this, many tests have been conducted to determine the optimum distance between the food and the sensor. it was found that the optimum distance should be in the range from 3 to 7 cm and not exceeding 10 cm, if the distance is more than 10 cm, the sensor will not work properly.

VI. NEW MICROWAVE OVEN

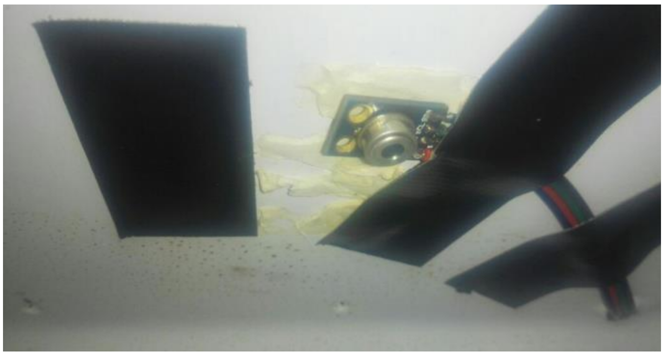

Figure5.Temperature sensor mounted inside microwave oven

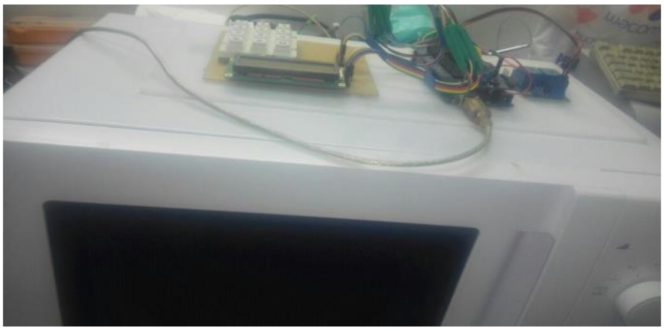

Figure 6. Modified Microwave from outside

A. Future work

The following recommendations and future scopes can be proposed for future work:

- Mobile application can be developed to control the microwave oven instead of using Keypad and LCD.
- Develop new ways for remote control of the microwave.
- Further research on mounting a camera inside the microwave oven to give a live video stream to the user to know the progress of the cooking process.
- Further researches on temperature sensors.
- Involve new technologies such as Wi-Fi and Bluetooth to operate the microwave oven.
- Measure the food calories that are inside microwave and send the data to the user.
- Develop various connectivity techniques between microwave ovens and smart devices.

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