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# Application and Generation of Microwave Technique through Dielectric Heating

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## ABSTRACT

This paper presents an overview of microwave heating technology and a survey of its application in dielectric heating. It depends on radio wave frequency, at moderate frequency & small time delay b/w permanent dipole and electric field the heat can be generated. Due to this technology, the efficient low cost microwave power source has progressed not only to permit the economic feasibility of the microwave oven, but also a growing myriad of other commercial and industrial application. Mostly, these are used in the food industries for cooking and tempering of meat. Limitations associated with hazard perception and interference is recognized as effective research area in this field. For resolving these problems, cooperation between different parties, including the wireless communication industries and the power application industries is required.

**Keywords:** *Microwave, Dielectric heating, Radio wave*

## 1. INTRODUCTION

Microwave, is one of radio wave, and the radio wave is one of an electromagnetic wave since the electromagnetic wave is spread by the interaction of electric field and the magnetic field it can also be spread in a Vacuum. An electromagnetic wave has two components frequency and wavelength [1]. Wavelength is about the length of the top to top of the wave, frequency is the number of waves that appear in a second. The velocity of the electromagnetic wave in free space, such as vacuum and air, is constantly 300,000 km per second, regardless of frequency, wave length equals to this divided by frequency. As shown in Figure 1, the electromagnetic wave is called differently depends on frequency. It is used in various applications according to their characteristics [2]-[6].

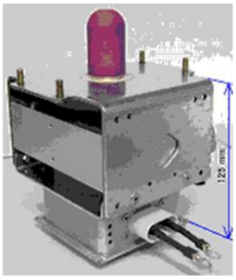

Fig 1: 2450MHz band magnetron (output 2kw water-cooled type).

Light is also a kind of electromagnetic wave. The electromagnetic wave that is less than 3000 GHz is classified as a radio wave. The radio waves with 300 MHz to 300 GHz frequency (wavelength of 1m to 1mm) are referred to as the microwaves [7].

Microwave has been applied to communication, radio, telescope for astronomy, radar surveillance system, and also to GPS positioning system known as a car navigation system. Heating is another application of Microwave.

## 4. THE FREQUENCY USED FOR MICROWAVE HEATING DEVICE

We now present an overview of frequency which is used for the heating device. ITU (International-Telecommunication Union) would assign the available frequencies of radio wave that depends on use. These frequency ranges are standardized by the laws of each country. Microwave has a frequency of 300 MHz to 300 GHz (wavelength of 1m to 1mm), are allocated by the ITU for medical, industrial, scientific use etc. and these are briefly described in Table 1.

ISM frequency in some countries is 433.92 MHz, for the first region (Europe). ISM frequency is 915 MHz for the second region (North and South America) allocated as per standards [8]. ISM frequencies that can be used World Wide is the ISM frequency of 2450 MHz or higher.

However, strict laws are associated to regulate radio waves leakage for avoiding interference, which may lead to telecommunication failure. While, the radio laws not regulate the limits of leakage for the ISM frequency band of 2450 MHz. Therefore, microwave devices that use this frequency band (called ISM equipment) better be designed to meet the safety limits. However, the devices which use radio frequencies rather ISM frequency, need a large-scale counter measurement for Radio leakage to accomplish the Radio Law regulations, such as in radio wave shields for the installation room, or for the whole building [9]-[10]. This is why various industries heating equipment is using ISM frequency, including a microwave oven at home. In ISM frequency bands, one of the frequently used is 2450 MHz. This is not because as it can be used in any country but it can also be used for microwave oscillator tube as shown in Figure 1.

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TABLE 1
FREQUENCY RANGE FOR MICROWAVE APPLICATIONS

| Name of Electromagnetic Wave | Frequency Range (Hz) | Wavelength Range (m) | Source | Application |
|---|---|---|---|---|
| Gamma rays | 5×10ˆ20 - 3×10ˆ19 | 6×10ˆ-15 – 1×10ˆ-10 | Decay of radioactive nuclei, fusion and fission of atomic nuclei etc | Gives information about the structure of nuclei. |
| X-rays | 3×10ˆ19 – 1×10ˆ16 | 1×10ˆ-10 – 3×10ˆ-8 | Sudden retardation of high energy electrons | X-rays therapy, industrial, Radiography ,crystallography. |
| Ultraviolet rays | 1×10ˆ16 – 8×10ˆ14 | 3×10ˆ-8 – 4×10ˆ-7 | Excitation of atoms and vacuum spark. | Structure of molecules and of external atomic electron shells. |
| Visible light | 8×10ˆ14 – 4×10ˆ14 | 4×10ˆ-7 – 8×10ˆ-7 | Excitation of atoms spark and arc flames | Structure of molecules and of external atomic electron shells |
| Infrared rays | 4×10ˆ14 – 1×10ˆ13 | 8×10ˆ-7 – 3×10ˆ-5 | Excitation of atoms and molecules. | Gives the informations about the structure of molecules and of external atomic electron shells |
| Heat radiations | 1×10ˆ13 – 3×10ˆ9 | 3×10ˆ-5 – 1×10-1 | Hot bodies | - |
| Radio waves | 3×10ˆ9 – 3×10ˆ4 | 1×10ˆ-1 – 10ˆ4 | Oscillating Circuits. | Radio communication television. |
| Electron waves | 60 - 50 | 5×10ˆ6 – 6×10ˆ6 | Weak radiations from A.C circuits. | Lighting. |

This is also because of not much costly magnetron (with output: 300W to 10KW) which is lightweight, compact and permanent magnet is also attached [11].

You may experience that you could not have seen the broadcasting TV channel when it is raining hard. The most efficient frequency of the microwave absorption of water is said to be around 18GHz. The frequency of the microwave oven is 2.45GHz. And the Frequency of BS broadcasting TV is around 12GHz.You can probably understand the reason for not being able to see the BS broadcasting TV in hard rain by now it is that BS airwaves have been absorbed by the rain. Mostly, the BS airwaves power is weak; therefore rain will not be heated. Rain water is heated due to the absorption of power of BS airwaves [12]. Different ISM frequency bands for microwave are shown in Table 2.

TABLE 2: ISM FREQUENCY OF MICROWAVE BAND

| Center Frequency (Mhz) | Frequency Range (Mhz) | Remarks |
|---|---|---|
| 433.920 (*1) | 433.05 - 434.79 | (*1) for part of first region |
| 915.000 | 902 -928 | First region |
| 2450 | 2400 -2500 | (*2) for part of second region |
| 5800 | 5725 -5875 | Second region |
| 24125 | 24000 - 24250 | - |
| 61250 | 61000 - 61500 | - |
| 122500 | 122000 - 123000 | - |

## 3. THE PRINCIPLE OF MICROWAVE HEATING

In this study, we described about the microwave power absorbed by the dielectric, the principle of microwave heating, dielectric properties of the dielectric and the depth of microwave penetration into the dielectric.

As per IEC (International Electro-technical Commission) describes, microwave heating is to heat dielectric materials commonly by their molecular motion and ionic conduction by EM waves of 300 MHz to 300 GHz. The principle of microwave heating is much easy and it is difficult to explain, but in this paper, it is explained in detail.

For the vibration of the microwave field, such as, permanent electric dipole in the dielectric material follows the oscillation of the microwave field slightly later, i.e., to the change of microwave field, therefore permanent electric

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dipole changes with phase lag, this phase delay results in the change in resistance of microwave field. After that, the permanent electric dipole is heated by this resistance. Hence, the permanent electric dipoles are vibrated, resisting and generates heat due to this [13].

The following are explanations with the figures. The principle of microwave heating described in Figure 2. It shows the structure of water molecules that are discussed. Water consists of two hydrogen atoms and an oxygen atom. It doesn't have an electric charge as a whole; an oxygen atom is bounding with two hydrogen atoms at an angle of $104.5^0$. Those atoms take a little charge of each minus (-) and plus (+) to form a dipole.

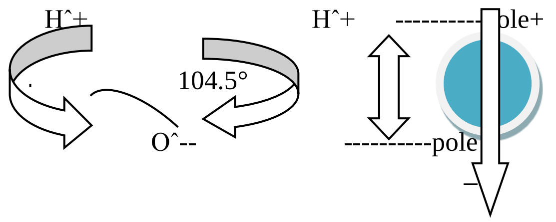
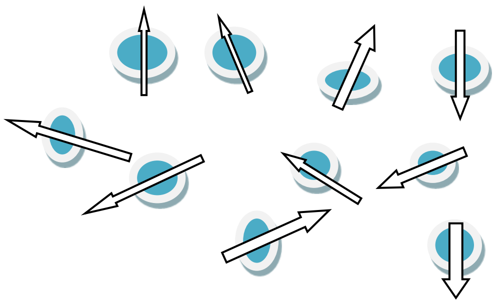
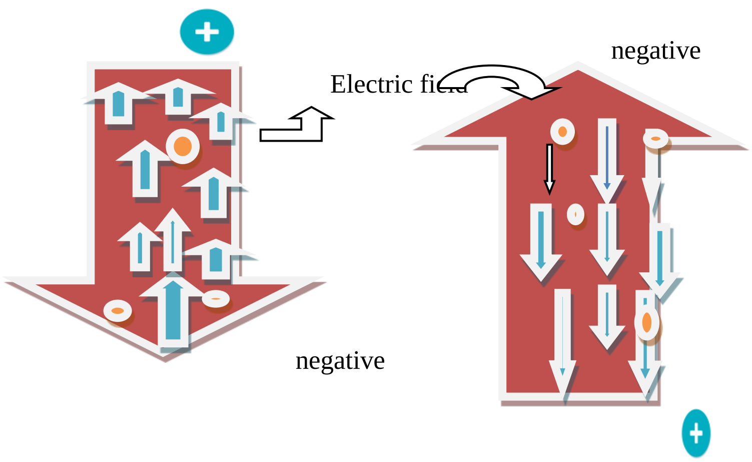



Fig 2: The structure of water molecules (left) and image of permanent dipole (right)



(a) When there is no external electric field




(b) When there is an external electric field

Fig 3: Direction of Dipoles Influenced By External Electric Field

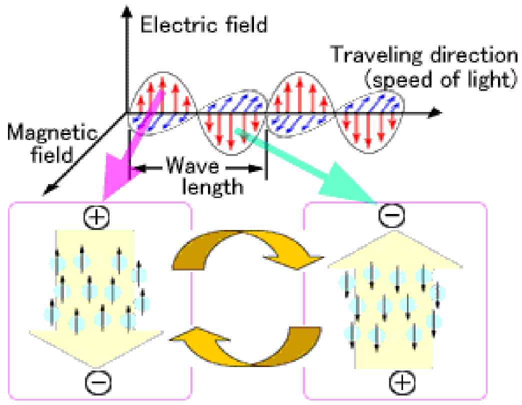



Fig 4: At too lower Frequency of radio wave

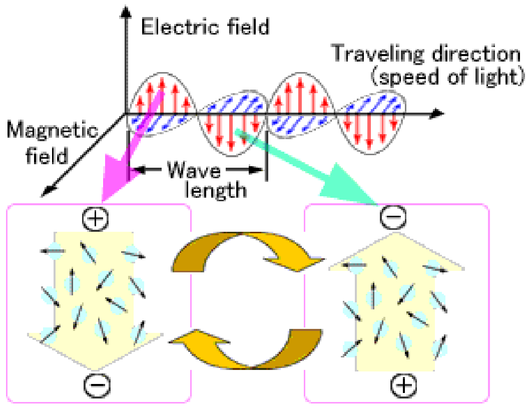



Fig 5: At too higher Frequency of radio wave

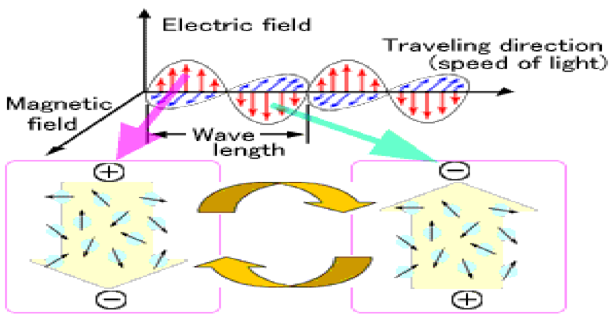



Fig 6: At too moderate frequency of radio wave

Then as shown in Figure 3, when there is no external electric field, it has set a balance. But when placed in the external electric field, a dipole will turn towards the electric field. For example, when the water is irradiated with radio waves, it means to give an electric field for alternating [14]. In case of the microwave oven, the vibration of 2450 Million times plus and minus to be replaced per second.

Figure 4 shows a case when a too much lower frequency of radio wave is irradiated to the permanent dipole of water. In this case, the permanent Dipole will immediately follow the directions of electric field. So in this case, Water doesn't generate heat [15].

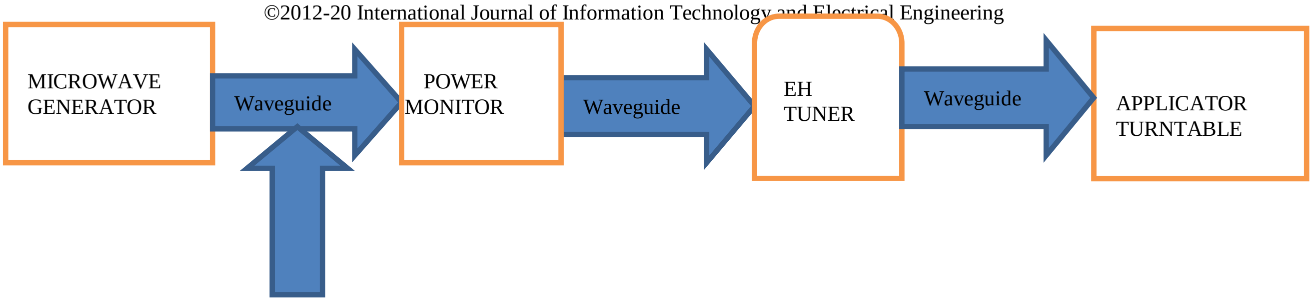



Fig 7: Block Diagram of Microwave Application Apparatus.

On the other hand, Figure 5 shows a case where a too much higher frequency of radio wave is irradiated to the permanent dipole. In this, since the electric field changes its direction too fast, dipole won't be able to follow. Then, water does not generate heat in this case also.

In contrast to these, Figure 6 shows a case where the moderate frequency of radio wave is irradiated to the permanent dipole. In this case, the permanent dipole changes a little behind the electric field. During the time delay, water is absorbing energy from moderate frequency is the microwave [4].

## 4. MICROWAVE POWER APPLICATION APPARATUS AND MICROWAVE DEVICE

Microwave power is generated by magnetron built inside. The generator (oscillator), Transferring waveguide, Isolator, power monitor, waveguide, EH Tuner, Then reaches the applicator to heat the object to be heated inside the applicator. In here, microwave that is oscillated by the Generator is called the travelling wave. On the other hand, microwave that is reflected by the applicator is called the reflector Wave and the microwave power consumed within in the applicator, is same value as reflected wave deducted by the travelling wave. Figure 7 shows the block diagram of microwave application apparatus.

## 5. CONCLUSION

Microwave is used for the heating device. Heating device basically depends on radio wave frequency, at a moderate frequency & small time delay between a permanent dipole and electric field, the heat can be generated. Due to this, heat we have used in many applications.

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