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J. M. DE BELL, JR

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ULTRA-HIGH FREQUENCY HEATING APPARATUS

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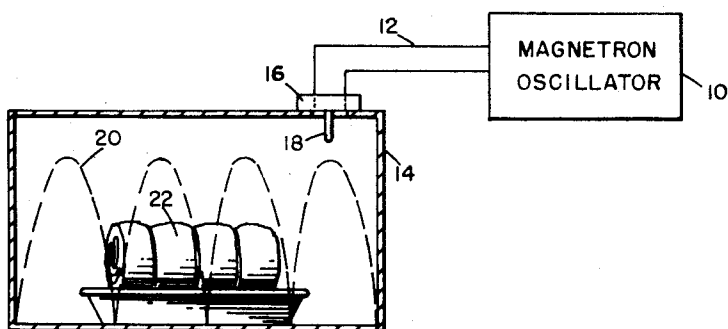


Fig. 1

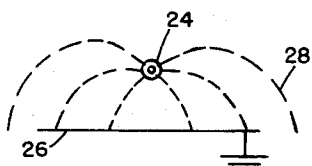


Fig. 2a

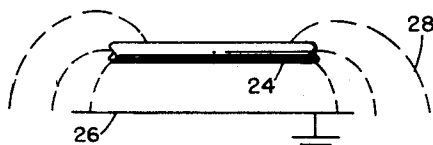


Fig. 2b

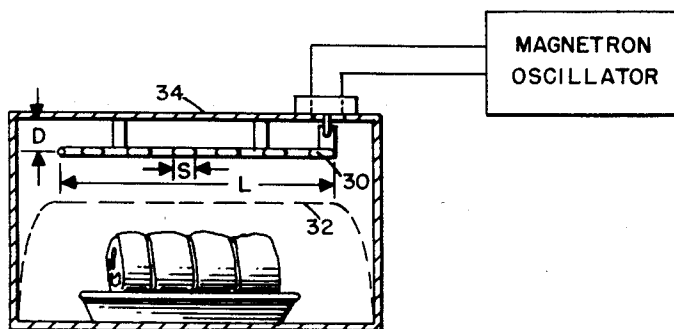


Fig. 3a

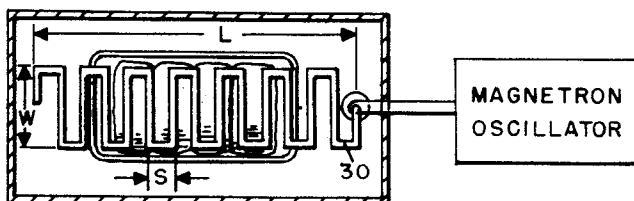


Fig. 3b

INVENTOR.
JOHN MILTON DE BELL, JR.

BY *Early + Early*

ATTORNEYS

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ULTRA-HIGH FREQUENCY HEATING APPARATUS

John Milton de Bell, Jr., Passaic, N.J., assignor to Allen B. du Mont Laboratories, Inc., Clifton, N.J., a corporation of Delaware

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11 Claims. (Cl. 219—10.55)

This invention relates to electronic heating with ultra-high frequency energy and particularly to microwave radiation apparatus for providing uniform heating.

Normally, ultra-high frequency electromagnetic energy coupled into a microwave cavity establishes a resonant multimode field intensity pattern in the cavity similar to standing waves, exhibiting regions of high and low intensities. The energy is generally inserted directly from the open end of a waveguide or by a coaxial transmission line and short exciting probe. Lossy dielectric material such as food, or certain plastics placed in the oven are heated according to their position in relation to the resonance pattern, resulting in uneven application of heat. Heretofore, one method for providing more even distribution was to utilize a fan with rotating blades within the enclosure. The blades act as reflectors which stir the resonant pattern, shifting the standing wave minima, thus promoting uniformity of heating. In another method, the item to be heated is rotated on a turntable to achieve the same result. Frequency variations may also be utilized to spread energy. A further method employs multiple feed probes which excite complex combinations of modes to produce the desired distribution. The mechanical rotation, spatial requirements, and necessity for multiple or variable inputs involved in these methods, result in objectionable complexities.

It is therefore the principal object of the present invention to provide an improved ultra-high frequency heating and cooking apparatus.

It is another object of the invention to provide a novel device for producing a smooth uniform heating pattern in a radio frequency oven, without requiring the use of moving parts or multiple inputs.

A further object of the invention is to provide a microwave cavity oven of simplified design, utilizing a novel radiating structure for evenly distributing high frequency electromagnetic energy within the oven.

According to the present invention, a source of microwave energy such as a magnetron oscillator is coupled into the interior of a multi-mode resonant cavity oven formed by a hollow orthorhombic metal container, or six-sided rectangular box. A coaxial connection is made between an external transmission line and an internal transmission and radiation structure which acts to propagate and scatter the energy within the enclosure. The structure is preferably in the form of a planar grillwork of rectangular bends positioned adjacent to one surface of the oven and in effect places a parallel wire-and-ground plane pair of conductors in the cavity, which equalize and evenly distribute the normal resonant electric field standing wave pattern, resulting in uniform heating rates.

The detailed description and accompanying drawings which follow consider the device in one particular configuration. It is to be understood that this represents but one embodiment, chosen for the purposes of explanation and illustration and is not to be construed as defining the limits of the invention. The oven may also have cylin-

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drical, spherical, or other configurations. The grill structure may be utilized in various shapes, dimensions, and positions without falling outside the scope of this invention. Other forms of the device may include planar figures such as spirals or triangular zigzags for use in conjunction with flat oven surfaces, or similar curved figures for use with correspondingly curved surfaces. Either a waveguide or coaxial transmission line may be employed with corresponding proper coupling modifications.

Fig. 1 shows the normal standing wave distribution in an enclosure having probe coupling of microwave energy, as in prior art heating apparatus;

Figs. 2a and 2b show end and side views, respectively, of the power flow distribution between a single discrete wire conductor element in relation to a ground plane;

Fig. 3a demonstrates the resultant uniform curve of energy distribution effectuated by the present invention and shows the position of the device with respect to the enclosure; and

Fig. 3b presents a plan view of the grillwork radiating device of the instant invention in relation to the oven, showing the rectangular zigzag structure.

Referring to Fig. 1 which illustrates a prior art configuration and resultant short-coming, microwave energy emanates from a generator source such as a magnetron oscillator 10 and is propagated along a transmission line or waveguide 12 which feeds into a multi-mode resonant cavity oven 14, through a coaxial coupling connection 16, and short exciting probe 18, or directly through the open end of a waveguide, developing the normal standing wave pattern of field intensity 20 characteristic of prior art heating apparatus. The probe 18 is generally a short section of conductor extending a fraction of a wavelength perpendicularly into the oven, through an aperture in a wall. Frequency and dimensions of the enclosure determine the number and type of electromagnetic modes of the wave pattern. The standing waves exhibit points of maximum and minimum voltage, which result in non-uniform heating and cooking of objects such as 22. The areas of the material under minimum voltage points have little applied energy to absorb and will not become heated.

Heat is generated within the material 22 by molecular friction and agitation produced internally by the ultra-high frequency energy. Food items and certain plastic materials may be classified as lossy dielectrics having resistive components which absorb the microwave energy rapidly. Under load conditions, with objects in the oven, the energy is absorbed in the resistive losses of the non-metallic materials.

Other low moisture dielectrics transmit the energy and respond more slowly. When an object is not present in the oven, the metallic walls act as lossless reflectors and do not absorb or attenuate the energy, which then travels back out of the cavity through the coaxial connector and transmission line, toward the source. Proper remote dissipative termination for the magnetron and transmission lines provide for absorption of reflected energy under no load conditions.

In the present invention the ordinary feed probe is modified and a coupling connection is made to a much longer conductor within the enclosure, situated parallel and close to one surface. The conductor acts as an internal antenna or transmission line of the wire-above-ground type, with the adjacent oven wall acting as the ground. The exact theory of operation of this type of transmission is not yet completely developed, and results have been largely determined experimentally. However, a general discussion of the wire-and-ground plane technique as applied to transmission of microwaves may be found in a series of articles appearing in "Proceedings of the I.R.E.," December 1952, the first of which is entitled

"Microstrip—A New Transmission Technique for the Kilomegacycle Range," by D. D. Greig and H. F. Englemann. The basic principle concerns the propagation of electromagnetic waves through a dielectric medium utilizing a single conductor supported above a ground plane, in place of more familiar waveguide or coaxial structures. Such a configuration is equivalent to a parallel wire system, having a pair of conductors, for the image of the conductor in the ground plane produces the required symmetry. The ground plane in effect acts as the second conductor.

Figs. 2a and 2b show, in two different transverse planes, a single discrete straight wire element 24 above and parallel to ground 26. A power flow distribution pattern 28 is produced which radiates out from the conductor in all directions, to ground. As applied to the present invention, the ground plane 26 represents the adjacent surface of the oven, the parallel wire conductor 24 represents a small segment of the entire radiation structure, and air is the dielectric.

Fig. 3a shows one view of the transmission and radiation device 30, of the present invention, extending into the cavity adjacent and parallel to one surface for a length L, much longer than that of known exciting probes. It was discovered that by insertion of this device the attainment of a uniformly distributed energy pattern 32 was made possible. The outer shell of the coaxial transmission line connector or coupling was affixed to the oven wall exterior as a common ground and the center conductor joined to the instant device through an aperture in the wall surface. Where waveguide transmission is employed, the end of the radiator structure may be inserted into the open end of the waveguide as a probe to provide direct coupling. The waveguide structure is affixed to the oven surface.

The device is placed parallel and immediately adjacent to one wall of the oven for its full length, separated from the surface by insulated spacers 34 at a constant distance D. The optimum radiating structure was found to be one formed by conductive wire rod material made into a continuous longitudinal planar grillwork having a series of lateral rectangular zigzag shaped loops or bends, as shown in Fig. 3b, sometimes known as a fret design in the field of fine arts. The dimensions of the radiator are dependent upon frequency and desired size of the oven enclosure. In the instant arrangement, the lateral bend width W was designed to be approximately one wavelength, or five inches at a fixed frequency of about 2400 megacycles, and longitudinal dimension S about one-quarter wavelength, or close to one inch at the same frequency, for best results. The overall length L varies with the oven dimension. For maximum coverage the length of the radiator structure should occupy substantially the entire dimension of the longest side of the oven. The device is placed centrally along the longitudinal center line of the wall parallel and next to the surface and separated by the fixed distance D. Both longitudinal and lateral axes of the grillwork are parallel and in immediate proximity to the particular wall. The lateral dimension W of the rectangular bend, equivalent to one wavelength, is preferably located along the width or smallest dimension of the oven.

When the conductor of Fig. 2 is formed into the series of rectangular bends of the radiator structure of Fig. 3, the energy is propagated along each section and the power flow radiation pattern is scattered randomly in various diverse directions, equivalent to having excitation from a multiplicity of sources. Thus the formation of standing waves is not permitted and a composite uniform distribution, equalized rate of heating and greater efficiency result. The concentration of energy normally confined to the area between the straight conductor and ground is dispersed by the convolutions of the instant radiator and spread throughout the volume of the container by the six lossless metal surfaces which serve as reflectors. The

immediately adjacent wall acting as a ground plane, produces an image of the conductor and causes the primary reflections of the concentrated energy. The walls also act to confine the radiation within the oven cavity with all the energy being absorbed at an equal rate by the lossy material, resulting in uniform heating.

The strength of the radiation is dependent upon the spatial relation between the conductor and the ground plane, with a stronger field and reflections occurring when the distance is small. Greater spacing will result in excessive losses through the air medium. Thus, movement of the radiator toward or away from the oven wall it is adjacent to, provides different field intensities, reflections, and heating rates. The optimum location and size of the radiator are a function of frequency and oven dimensions. Conversely, changes in frequency or in oven or radiator dimensions will affect radiation strength.

The bend dimensions W and S, shown in Fig. 3b, have a definite relation to a fixed frequency wavelength, as previously described. A higher operating frequency having smaller wavelengths would result in smaller dimensions for the rectangular elements, while a lower frequency would result in larger sizes to provide the desired uniformity of distribution. In an oven of a particular size, a higher frequency would cause more standing waves to be developed than a lower frequency. The oven dimensions are determined by its practical application. A longer oven would necessitate a longer radiator length L, in order to sufficiently cover a larger area. Shorter lengths and other dimensions and shapes may be utilized where less efficient distribution can be tolerated.

It has been demonstrated that utilization of the transmission-radiation device of the present invention produces substantially uniform heating and cooking, eliminates the cumbersome and complex arrangements presently required, and permits simplified design of more efficient microwave ovens.

While only a single embodiment of the invention has been indicated, it will be apparent that the invention is not limited to the exact forms or use illustrated and that many variations may be made in the particular design and configurations without departing from the scope of the invention as set forth in the appended claims.

What is claimed is:

1. An internal ultra-high frequency energy radiating and transmitting device for a microwave oven, comprising: a convoluted wire conductor arranged in a planar form positioned parallel and adjacent to and electrically insulated from a surface of said oven and extending for substantially the entire length of said oven, said radiating device and said surface forming a microwave conductive path for transmitting said energy along said length and providing substantially uniform energy distribution and heating within said oven.
2. An internal microwave energy radiator structure for an ultra-high frequency oven comprising: a convoluted wire conductor formed into a planar configuration and positioned parallel and immediately adjacent to and electrically insulated from a metallic radiation reflecting and conductive surface of said oven and extending for substantially the entire length of said oven, said parallel wire and surface forming two conductors of a transmission line for transmitting said energy and providing substantially uniform microwave energy distribution and heating within said oven.
3. The radiator of claim 2 wherein said configuration is a spiral.
4. The radiator of claim 2 wherein said configuration is a triangular zigzag.
5. A microwave oven comprising: a source of microwave energy; a heating cavity; external microwave energy transmission means connecting said source with said cavity; means for transmitting and radiating said energy within said cavity including an internal radiator structure fully enclosed within said cavity, said structure com-

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prising a convoluted wire conductor formed into a planar configuration, and positioned parallel and adjacent to a surface of said cavity and extending for substantially the full length of said cavity, said surface and said radiator being electrically insulated from each other and providing a conductive path for said energy; means for coupling said energy from said external transmission means to said internal radiator structure through an aperture in said cavity; said radiator structure providing substantially uniform energy distribution and heating within said oven.

6. An internal radiator structure for a microwave oven designed to operate at a given frequency, comprising: a conductive wire rod having a planar configuration and positioned in a longitudinal relation, parallel and immediately adjacent to a surface of said oven; said configuration being a series of rectangular bends known as a fret design, each said bend having longitudinal and lateral dimensions, said lateral dimensions being substantially equal to one wavelength of said frequency.

7. The device of claim 6 wherein said longitudinal dimension of said bend is substantially equal to one quarter wavelength corresponding to said frequency.

8. A microwave oven combination comprising: a heating chamber having an energy reflecting surface; and an enclosed microwave energy radiation structure comprising a convoluted wire conductor forming a planar configuration positioned parallel and immediately adjacent to and electrically insulated from said surface and extended for substantially the entire length of said chamber, said structure being substantially the sole source of said microwave energy radiation within said chamber, said radiation being initially transmitted between said wire

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conductor and said adjacent surface and being distributed uniformly within said chamber by said convolutions and said reflecting surface.

9. An internal radiator structure for a microwave oven comprising: a wire conductor formed into a planar configuration and positioned parallel and immediately adjacent to and electrically insulated from a metallic radiation reflecting surface of said oven and extending for substantially the entire length of said oven, said configuration having the form of a grillwork comprising a longitudinally positioned continuous series of rectangular bends known as a fret design, each said bend having a longitudinal and lateral portion, said radiator structure providing substantially only microwave energy radiation within said oven, whereby distribution of said energy and heating within said oven is substantially uniform.

10. The device of claim 9 wherein the dimension of each lateral portion is substantially five inches long.

11. The device of claim 10 wherein the dimension of each longitudinal portion is substantially one inch long.

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