United States Patent [19]

Crapuchettes

[11] **3,727,098**

[45] **Apr. 10, 1973**

[54] **MAGNETRON FILTER BOX**

[75] Inventor: **Paul Wythe Crapuchettes**, Woodside, Calif.

[73] Assignee: **Litton Systems, Inc.**, San Carlos, Calif.

[22] Filed: **July 22, 1971**

[21] Appl. No.: **165,113**

[52] **U.S. Cl.** **315/39.51**, 333/69, 315/39.53, 315/75, 331/86

[51] **Int. Cl.** **H01j 25/50**

[58] **Field of Search** 315/39.51, 39.53, 315/85; 333/79; 331/86, 184, 185

[56] **References Cited**

UNITED STATES PATENTS

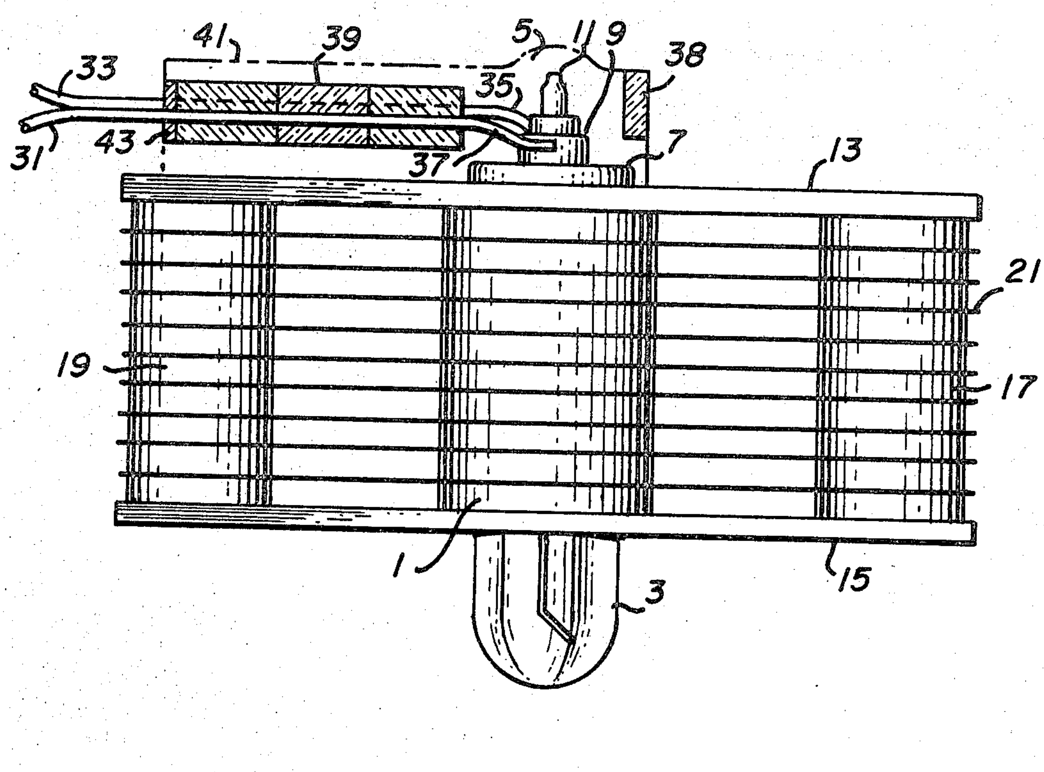
3,531,613	9/1970	Domenichini	333/79 X
3,551,858	12/1970	Cielo	333/79
3,020,447	2/1962	Schall et al.	315/39.51 X
3,543,082	11/1970	Boehm	315/39.53
3,551,735	12/1970	Staats	315/39.53
3,458,753	7/1969	Staats	315/39.53

Primary Examiner—Herman Karl Saalbach
Assistant Examiner—Saxfield Chatmon, Jr.
Attorney—Ronald M. Goldman et al.

[57] **ABSTRACT**

A magnetron filter box of novel construction serves to dissipate and filter out spurious signals appearing at the filament terminals of a magnetron. The filter box includes: two (or more) elongated electrical conductors spaced and insulated from one another which are provided with adjacent end portions of each adapted for connection to a respective one of the filament terminals of the magnetron which provide a current carrying path to the filament; microwave dissipative material of a predetermined volume is placed about and surrounds the electrical conductors minimally all along a portion of the lengths; and a metal container of predetermined dimension and volume encloses the microwave dissipative material and underlying conductors and is adapted to enclose additionally the stem or terminal end of the magnetron either with or without the metal pole piece as part of the container combination. The relative geometry between the dissipative material and the metal enclosure is such as to form a microwave cavity of a low-Q factor, suitably less than 100, and adjacent portions of the metal enclosure and the dissipative material is such as to define by analogy a transmission line with a "lossy" characteristic impedance, suitably less than 50 ohms.

14 Claims, 11 Drawing Figures



PATENTED APR 10 1973

3,727,098

SHEET 1 OF 3

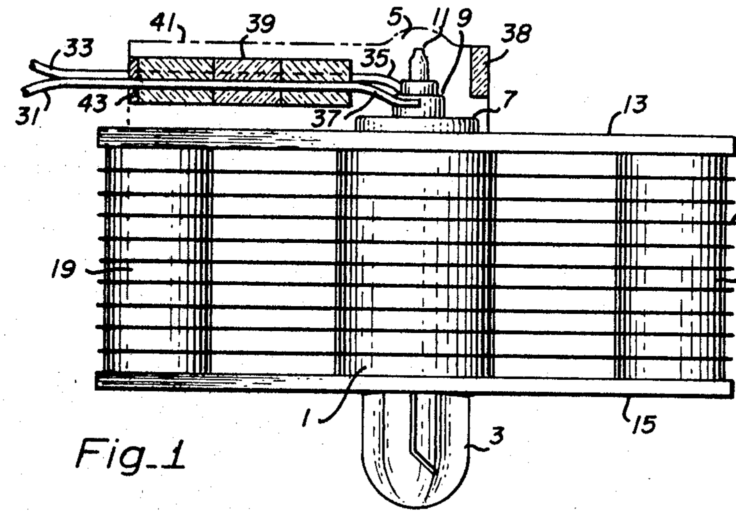


Fig_1

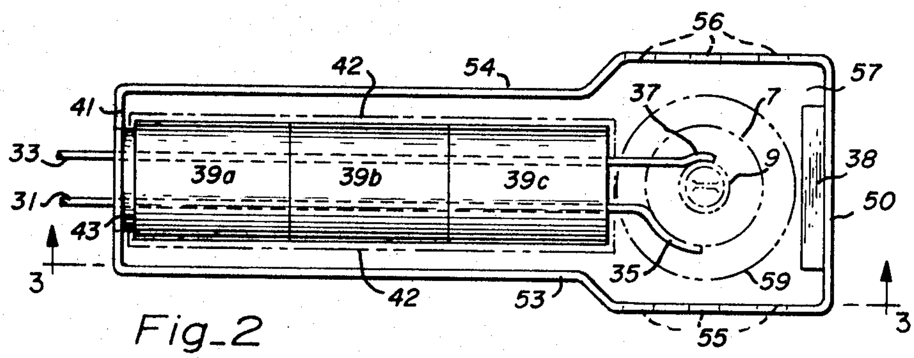


Fig_2

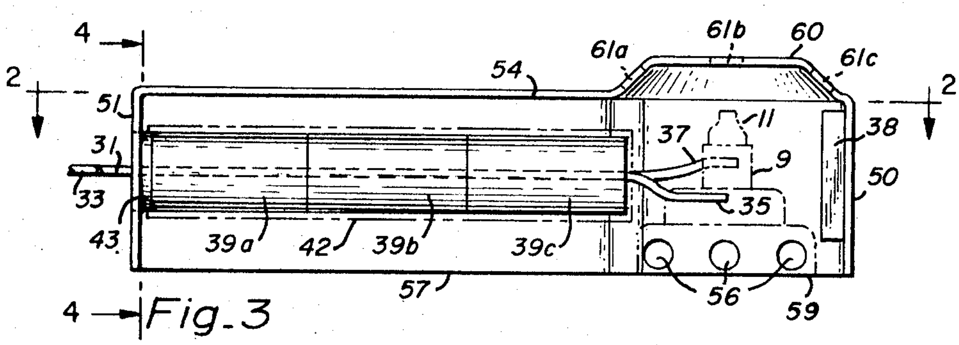


Fig_3

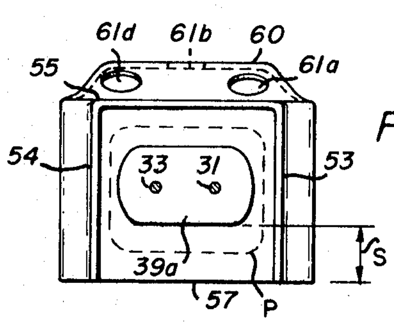


Fig_4

INVENTOR.
PAUL W. CRAPUCHETTES
BY Ronald M. Goldman

ATTORNEY

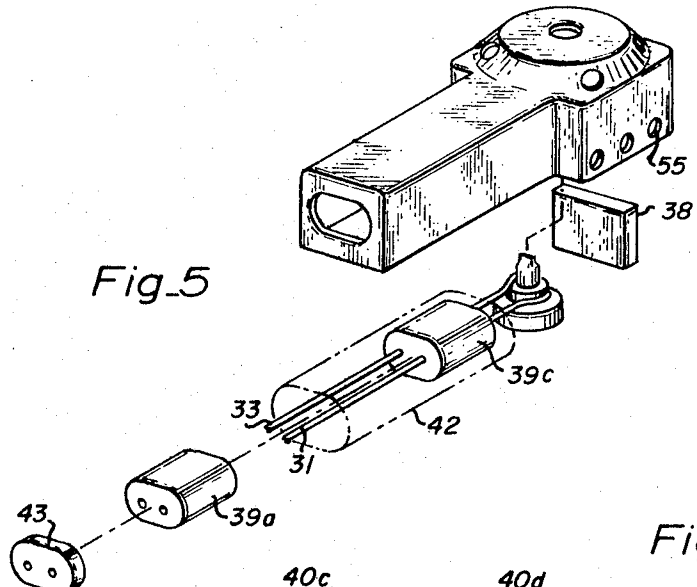


Fig_5

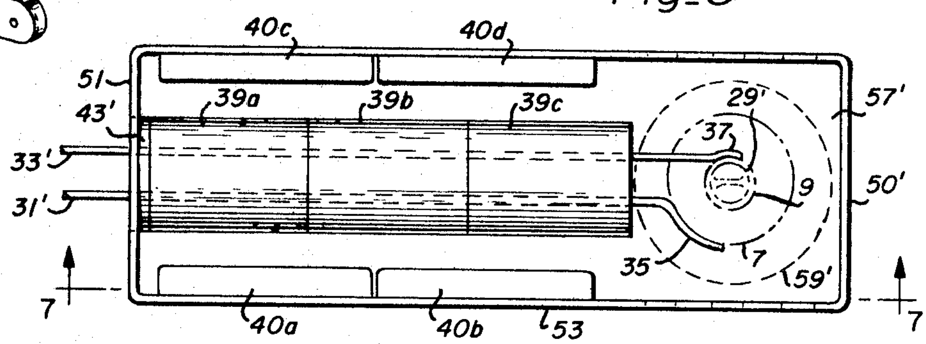


Fig_6

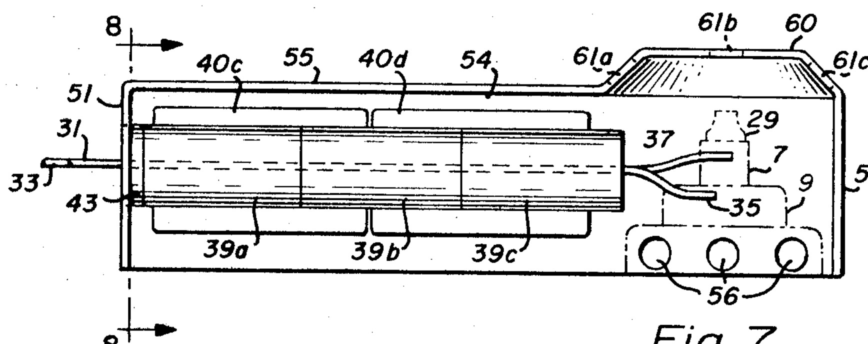


Fig_7

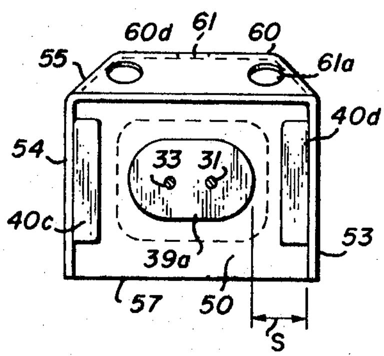


Fig_8

INVENTOR.
PAUL W. CRAPUCHETTES
BY Ronald M. Goldman
ATTORNEY

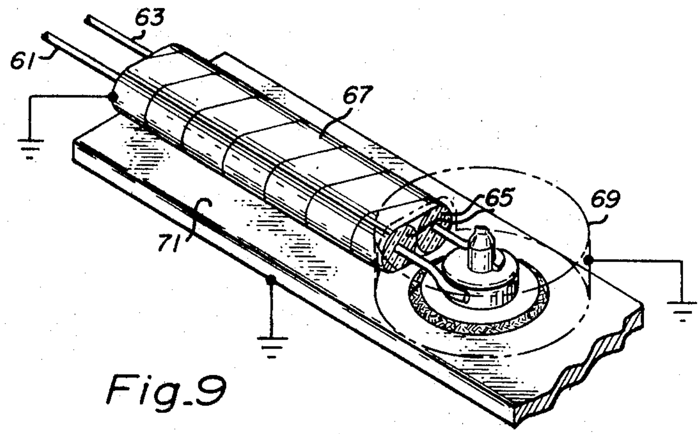


Fig. 9

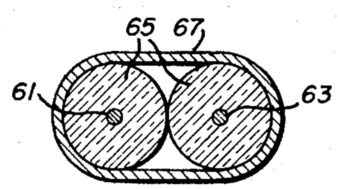


Fig. 10a

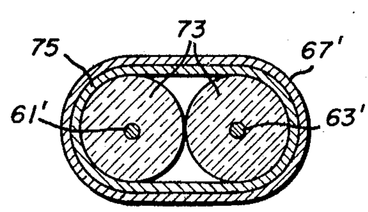


Fig. 10b

INVENTOR.
PAUL W. CRAPUCHETTES
BY Ronald M. Goldman
ATTORNEY

MAGNETRON FILTER BOX

BACKGROUND OF THE INVENTION

This invention relates to a magnetron filter box and, more particularly, to a dissipative filter which is adapted to be used in conjunction with the filament leads of a magnetron.

Microwave vacuum tubes have heretofore been used as generators of microwave frequency energy, microwave sources or, as variously termed, microwave oscillators, and as such are found in common use in many electronic systems. One such microwave tube is the magnetron. The magnetron is, essentially, a self-contained device in that the elements which cooperate to generate the microwave frequency energy are internal of the envelope. Terminals for connection of various electrical circuitry, including filament terminals, which permit current to be applied to the magnetron filaments, a cathode terminal, an anode terminal, and an output terminal or window are provided outside the tube envelope. Very simply explained, when the appropriate sources of filament current are applied to the filament terminals and an appropriate source of high electrical voltage is applied between the anode and cathode terminals, the microwave frequency energy is generated internally within the tube and this energy is delivered at the magnetron output window.

In magnetrons, as with all utilitarian devices, there is always some degree of imperfection, however slight, which requires correction, compensation, minimization, or adjustment. In particular, the magnetron by design provides the predetermined microwave frequency at the designed power level. However, there are in fact other frequencies generated in varying degrees in varying levels, usually substantially less than the predominating output signal, such as harmonics of the fundamental frequency, and these signals may be termed "spurious." Included in this definition of spurious signals are any portions of the fundamental frequency which leak out through other than the output window. These spurious signals in practice have either been so small as to be disregarded or were reduced to acceptable levels by conventional electrical filters, electrical devices which filter out or eliminate, ideally, the undesired spurious signals. In recent years, however, the magnetron has found a prime commercial application as the source of microwave energy used in microwave cooking appliances or ovens. And it is in connection with this appliance that the magnetron and spurious signals is next considered as background of my invention.

The microwave oven provides the means by which one can cook or heat food by exposure to microwave radiation. In this manner food is heated or cooked very, very rapidly in comparison to cooking with conventional ovens and such a decrease in cooking time is an advantage and represents a significant convenience for many people.

As with all technically sophisticated appliances, however, special care is given to the design and maintenance of the appliance in order to maintain its utilitarian values while avoiding abuse. While microwave radiation is of utility in cooking food, it is not to be exposed to humans or interfere with other electronic equipment in any significant degree.

The magnetron is inclined in the oven and in operation generates the microwave energy which is fed into the cooking chamber of the oven for the purpose of "cooking" food. The magnetron and its associated power supplies are installed, typically, at the top of the oven, or in any space within the sheet metal work above or behind or to the side of the actual metal walled cooking cavity, but accessible from the rear or sides of the enclosure and large removable metal panels which enclose the oven rear. The metal panels and walls prevent radiation leakage from these areas. A door closes the cooking chamber during operation of the magnetron.

Any leakage of radiation, either from around the edges of the door closing the cooking cavity or from the back panel of the oven housing in which the magnetron and associated power supplies are physically enclosed, is to be avoided.

A first consideration must be made regarding leakage of microwave energy. The Federal Communications Commission, another Government agency, prescribes and allocates the frequencies which may be used for various purposes and has assigned the frequency of 2,450 MHz for microwave cooking. By regulation, the FCC requires the radiating unit to be of such a construction that intensity of radiation leakage at frequencies outside of a 70 percent bandwidth of the assigned frequency range of 2,400 to 2,500 MHz must be less than 25 microvolts per meter measured at a distance of **1000** feet per **500** watts of output. The purpose of this limit is to prevent signals from the microwave oven from interfering with other forms of radio communications and television.

A second consideration regarding the degree of radiation is made. Initially, such radiation leakage as was permissible and harmless to humans was originally determined to be on the order of 10 milliwatts per square centimeter at a distance of 2 inches. This represents a level of radiation comparable to that normally emanating from the sun on a clear spring day. When one considers that the magnetron delivers into the oven cavity some 500 to 1,000 watts of microwave energy, such leakage represents a rather small portion. Oven designs and equipment then available met this standard and were thus considered safe. However, recently the heretofore permissive radiation limits were re-examined, particularly having in mind the increasing number of electronic appliances being introduced into the home by the consumer and to the possibly cumulative effects of harmless doses of radiation from each. Thus, to provide additional protection the levels of permissible radiation were reduced even further as an attempt to account in some way for the unknown amounts of radiation that the consumer may be exposed from an unknown quantity of additional appliances, each of which by themselves are harmless. Accordingly, by Government regulation, the permissible radiation leakage whether from the door seal area of the microwave oven or from the back area of the microwave oven has been reduced (by a factor of 10) to 1 milliwatt per square centimeter, at a distance of 2 inches, levels which are barely detectable with instruments and of such a small magnitude as has been said to be equivalent to the normal levels of radiation from moonlight. These radiation standards are met by close attention to manufacturing tolerances and more sturdy and expensive sheet metal work.

By comparing regulations of the two agencies one determines essentially that of the two, the restrictions on spurious "out-of-band" radiation promulgated by the FCC to prevent interference with radio and television reception stations is more restrictive by some 60 db than the permissive radiation levels announced by the other Government agency. However, the permissible limits of radiation of the latter are more strict in a different sense, they include leakage at the assigned frequency of 2,450 MHz or "in-band" radiation.

One type of magnetron widely used in microwave ovens is the L-5001 or variations thereof, manufactured by Litton Industries, Electron Tube Division, San Carlos, Cal., which are perhaps better illustrated in U.S. Pat. Nos. D-215,298, D-208,861, D-218,169, and D-212,758.

The filament terminals on the magnetron, as previously noted, physically appear as bands of conductive material on a stemlike projection at one end of the magnetron. The stem is actually divided into electrically insulated parts separated by aluminum oxide, an insulating material, with the tip of the stem comprising a "pinched-off" copper tube. This stem end of the tube was inserted within or surrounded by a large metal or large shielding enclosure referred to as the choke box or magnetron filter box, and this latter unit was added during assembly of the magnetron into the equipment. Such an element appears in two of the cited patents. Typically, one end of this enclosure was formed of a metal screen material or a perforated metal sheet so that air could be introduced into that region. The openings in the enclosure are, however, of such dimension as to prevent the passage of any spurious signals above a predetermined intensity from the vicinity of the cathode stem. The power supply leads including the high voltage cathode supply and the two leads through which filament current was coupled to the filament terminals of the magnetron extended from the outside of the enclosure through an opening to the magnetron stem.

The filter box typically included wire inductors and capacitors. The inductors were placed in series with the respective filament leads and the capacitors were placed between a filament lead and electrical ground to form a "low pass" filter. Such a filter prevented beyond permissible limits any high frequency signals which might leak from the cathode to the filament terminals from traveling along the electrical leads to the outside of the oven enclosure, and the capacitors served to short circuit to ground as much high frequency energy as was possible. In addition, or as an alternative construction, beads of "lossy" or dissipative microwave material such as ferrites were included in such a filter box to positively absorb and dissipate any microwave energy in that vicinity.

While such constructions proved acceptable in the past, costs must be reduced and the recent reduction in level of permissible radiation leakage requires reevaluation of design and manufacturing procedures. Thus, although the level of radiation from this particular element of the oven, the magnetron, is still below the acceptable limits, the measurements taken cover leakage from all sources within the oven. Even with all such sources considered, the normal level of spurious radiation in present ovens is below the FCC limits. Conservative design principles require the manufacturer to provide an oven with components which have leakage, if at all, substantially below the 25 microvolt per meter level prescribed by the FCC so that considering the vagaries of normal mass production manufacturing techniques, all ovens built should comply with the radiation standards, regardless of the degree of perfection of assembly by personnel on any given day and in this way waste or scrap in the manufacturing process is eliminated.

Spurious signal radiations from stem area of the magnetron can be of many possible types. By design the operating frequency of magnetrons for microwave heating applications is nominally 2,450 MHz. Energy of this frequency is transmitted out the output window of the magnetron into the oven cavity. However, under certain circumstances it is possible to couple some of this energy to the filament leads internal of the tube such as by capacitance coupling between the anode and filament, which also serves as the cathode, inuring due to asymmetries in the anode. From the filament the microwave energy passes through the terminal on the stem and appears on the power supply leads, unless there filtered out or dissipated.

A second source of spurious signals are subharmonics. These are microwave signals of some submultiple of the fundamental frequency of 2,450 MHz which are inherently generated in the tube but in very, very low levels. A prime objection to such subharmonic signals is that they may fall within the television frequencies and thus could potentially interfere with normal television reception during operation of the magnetron.

A third form of spurious signal derives from the multiplicity of resonant modes of the multi-segment anode found within the magnetron tube. If the anode has N resonators there will be N resonant modes of the first order, second order, etc. Since the normal mode of operation, called "π" mode, has been optimized for impedance all other signals are comparatively lower. Since these other resonant modes will always be outside of the allotted frequency range band allotted fro microwave cooking and heating, care must be exercised to assure that energy produced and radiated is less than the permissible level.

A fourth form of spurious signal derives from an electronic interaction between the impedances associated with the normal "π" mode and unintended systematic impedances. Generally such signals, if generated, are within 2,415 and 2,485 MHz where their magnitude can exceed 25 μv/meter, as described above.

OBJECTS OF THE INVENTION

Accordingly, it is an object of this invention to provide an improved magnetron filter box.

It is another object of the invention to provide a magnetron filter box which has improved results and which is relatively inexpensive to manufacture.

It is a further object of this invention to provide a filter box which eliminates or dissipates spurious microwave frequency signals that may appear at the filament terminals of a magnetron.

And it is a still further object of the invention to provide magnetrons with integral filters for use in microwave ovens that reduce further any potential leakage from the microwave oven.

BRIEF SUMMARY OF THE INVENTION

In accordance with my invention, at least two elongated electrical conductors are spaced from one another and have adjacent end portions adapted for connection to filament terminals of a magnetron and form a portion of the electrical path by which filament current is supplied to such magnetron. Microwave dissipative material is located along the length and substantially surrounds the two conductors. In addition, a microwave cavity comprising metal walls surrounds and contains within the loss material and underlying conductor portion, the conductor ends and the magnetron filament terminals. In accordance with the invention an opening is provided in this metal cavity into which a magnetron stem portion containing the filament and high voltage terminals can be inserted for connection to the respective end portions of said electrical conductors and a passage is provided in a remote end portion of the cavity to permit suitable connections to be made with said conductors.

Further, in accordance with the invention, the microwave cavity is of a low Q factor, suitably less than 100. In accordance with said low Q factor, the ratio of the volume defined by the microwave cavity to the volume of the loss material is a number of fraction greater than 1 and lesser, approximately, than 20.

In accordance with an additional aspect of the invention the outer cavity walls and the elongated conductive wires and attached loss material are considered analogous to a coaxial transmission line and the geometry of such line is defined to have a characteristic impedance Z_0 preferably less than 50 ohms.

In accordance with a still further aspect of the invention one wall of the microwave cavity may comprise the flat pole piece section of the magnetron.

The foregoing and other objects and advantages of the invention together with the elements comprising the invention, including equivalents and substitutions for the elements thereof, become apparent to one of ordinary skill in the art from a consideration of the following detailed description taken together with the figures of the drawings in which:

DESCRIPTION OF DRAWINGS

FIG. 1 illustrates schematically a filter box of the invention in place on a magnetron;

FIG. 2 illustrates a top view of a preferred embodiment of the invention with the upper container wall removed;

FIG. 3 illustrates a side view of the embodiment of FIG. 1 with the side container wall removed;

FIG. 4 illustrates an end view of the preferred embodiment illustrated in FIGS. 2 and 3;

FIG. 5 illustrates in an exploded view the relationship of the elements in the preferred embodiment and their method of assembly; and

FIG. 6 illustrates a top view of another embodiment of the invention with the upper container wall removed;

FIG. 7 and 8 illustrate side and end views of the embodiment of FIG. 6;

FIG. 9 illustrates still another embodiment of the invention;

FIG. 10*a* represents in cross section the conductors and loss material of FIG. 9; and

FIG. 10*b* represents a modified form of the conductors and loss material suitable for the embodiment of FIG. 9.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 illustrates, symbolically, the elements of my invention in a magnetron filter box and its relationship to a magnetron, symbolically illustrated, used in microwave oven. The magnetron is of the type L-5260A sold by Litton Industries, Electron Tube Division, illustrated in greater detail in U.S. Pat. No. D-212,758 and U.S. Pat. No. 3,493,810. The magnetron includes a body portion 1, typically a hollow copper cylinder, containing therewithin in a vacuum the elements of the magnetron that are necessary for the generation of microwave energy including cathode, anode, filament, and magnetic pole piece extensions, which details are not illustrated or otherwise explained since they form no part of the instant invention and are available elsewhere in the prior art. At one end of the magnetron body is an output terminal of window 3 which is the exit for the microwave energy generated within body 1. At the other end is a stem portion 5. Stem 5 extends from the body 1 and includes spaced metal portions or terminals 7 and 9 which internally complete a circuit to the magnetron filament winding. The terminals are insulated from one another by a vacuum tight aluminum oxide insulating material or spacer. Both stem 5 and window 3 protrude through openings provided in pole pieces 13 and 15. The pole pieces are of a flat rectangular shape and consist of ferromagnetic material, typically annealed iron, and function as part of the magnetic circuit necessary to the operation of the magnetron. A first permanent magnet 17 is located between and at one end of pole pieces 13 and 15, and a like second permanent magnet 19 is located at the left end and between the same pole pieces. Both magnet 17 and magnet 19 have their North Poles facing pole piece 13. The magnets provide the magnetic flux which is carried through the magnetic path formed by the pole pieces and by means of magnetic material connected at the front and back ends of magnetron body 1, and internal pole pieces (not illustrated) present the magnetic flux internally of the tube where such forms a necessary ingredient to the generation of microwave energy. The horizontal lines 21 are symbolic of the metal, suitably aluminum, cooling fins which are stacked in between the pole pieces in a heat conducting relationship with the body 1. The cooling fins contain suitable openings to permit them to be fitted over the magnetron body 1 and magnets 17 and 19. Obviously in the variation of the magnetron illustrated in U.S. Pat. No. D-218,169 the cooling fins would be arranged vertically and radially outward from body portion 1.

A pair of elongated electrical conductors or wires 31 and 33 are illustrated spaced from one another above pole piece 13. Electrical conductors 31 and 33 include respective end portions 35 and 37 located proximate one another and connected, respectively, to filament terminals 7 and 9. These conductors extend through passages in and support three bodies of a dissipative or loss material 39. The passages, not clearly illustrated in this figure, permit the loss material to be mounted so that it surrounds all portions of each conductor and at the same time serves to maintain the predetermined spacing between conductors 31 and 33.

Dashed line 41 represents the walls of a compact metal container which encloses the ferrite material and a portion of the wires 31 and 33 including the end portions 35 and 37 thereof. The container covers, also, and encloses the stem end 5 of the magnetron. In this illustration one wall of the metal container 41 is effectively formed by the flat surface of pole piece 13. The relationship between the metal can or cover and the dissipative material will be discussed hereinafter in greater detail. Loss material in addition to 39 is included in the metal cover. An additional slab of microwave loss material 40 is attached to an end wall of the container.

An insulator 43 is inserted in a passage in an end wall of the container. The insulator contains two passages spaced from one another through which wires 31 and 33 extend, and the insulator serves to prevent the wires from contacting the metal walls of container 41. It is apparent that the particular conductors 31 and 33 need not be made so long as to extend beyond the confines of container 41 but instead may be terminated at a socket fixed at the end wall. However in such an instance the extension of electrical circuitry would require the inclusion of a plug fitted to be received with such a socket so as to permit an extension of the electrical path through the containers beyond the walls of container 41 to the appropriate source of filament current. The foregoing description provides background to the more exact description of the preferred embodiment. As can be seen the magnetron filter box is formed in a small and convenient package suitably mounted integral with the magnetron. In connection with the remaining figures, it is noted that when an element is assigned a numeral in a preceding figure that same numeral is thereafter used, for convenience of the reader, in subsequent figures where the same element appears.

The top view of the preferred embodiment of the magnetron filter box is illustrated in FIG. 2 with a top wall or side removed in order to provide better illustration of the contents. A container or box which forms a microwave cavity is of an elongated narrow construction and is formed of metal, suitably aluminum or stainless steel. This includes a pair of end walls 50 and 51, a front wall 53, a back wall 54, a bottom wall 57 and a top wall (removed 55 in FIG. 3). End wall 51 includes a passage in which is mounted an insulator, 43 in FIG. 1. Wall 53 includes passages therethrough proximate the bottom 57 indicated as 55 in the figure and back wall 54 includes openings 56 therethrough adjacent bottom wall 57. Openings 55 and 56 form air passages for cooling purposes and are generally smaller in dimension or diameter than 1/6th of the wavelength of a fundamental microwave frequency of 2,450 megacycles. A first elongated electrical conductor 31, illustrated in part by dashed lines, includes a bent end portion 35. A second elongated electrical conductor 33, illustrated in part by dashed lines, is mounted spaced from and generally parallel with the first conductor 31. Conductor 33 includes a front end portion 37 proximate end portion 35 of conductor 31. Suitably, conductors 31 and 33 used are Teflon insulated, as made by Gore Industries, to eliminate corona. End portions 35 and 37 are bent so as to engage or contact satisfactorily the filament terminals of the magnetron stem, represented by the dashed lines 9 and 7. In this embodiment conductors 31 and 33 are of such a length as to extend through wall 51 and the insulator 43, mounted in wall 51, so that they are maintained spaced at that end and insulated from electrical contact with the metal container walls. Beads 39*a*, 39*b* and 39*c*, of microwave dissipative or loss material, suitably ferrite, are mounted on conductors 31 and 33 along the straight elongated portion thereof within the metal container. Each of the ferrite beads is a standard material, usually grade 9 or 11, and has an elliptical cylindrical geometry and the consistency of a solid sintered pressed powder body. Each of the beads has two spaced passages therethrough through which conductors 31 and 33 extend. In this way the conductors 31 and 33 support the ferrite beads and, in turn, the ferrite beads assist to maintain the conductors spaced apart. In addition, it is seen that the ferrite material surrounds conductors 31 and 33 along a major portion of the length thereof up to the front end portions 35 and 37.

A sheath 42 of heat shrinkable tubing, suitably irradiated polyvinyl tubing, such as that sold by Raychem Company, which may include additional loss material, covers the beads 39*a*, 39*b* and 39*c*. To permit a clear illustration of the beads the cover tubing is represented solely by dashed lines.

In addition, a standard size slab of ferrite microwave loss material 38 is attached to end wall 50, suitably with epoxy.

Bottom wall 57, represented by a dashed line in FIG. 3, of the filter box in the preferred embodiment is in fact a portion of the flat iron pole piece of the magnetron, such as illustrated in FIG. 1. An opening 59 represents the opening in the pole piece through which the magnetron stem containing the filament terminals and cathode terminals extends. The side walls 50, 51, 53 and 54, are simply joined to the metal pole piece in a manner which eliminates any gaps or cracks therebetween. This is suitably accomplished by welding or by electrically conductive epoxy material. The magnetron pole piece thus serves to provide an electrically conductive body or wall to the metal container with an opening adapted to receive the end of the magnetron. However, it is apparent that in an obvious variation of this embodiment of the invention, a metal wall can be provided to close the bottom of the container before the box is placed atop the magnetron pole piece. Of course, a suitable opening or passage such as 59 would be formed at the location in the figure to permit the insertion therethrough of the magnetron stem. In such a construction the bottom wall is fastened to the magnetron pole piece and the pole piece serves only to support the filter and eliminates its function as an electrically conductive boundary.

FIG. 3 illustrates the filter box from one side facing wall 53 but with side wall 53 and attached ferrite removed, the embodiment of FIG. 2. End wall 50, insulator 43, installed in the passage through side wall 51, electrical conductors 31 and 33, in part illustrated by dashed lines, and the respective front end portions 35 and 37 thereof, are presented. In this figure the conductors are also shown extending through the ferrite beads **39***a*, **39***b* and **39***c*, and the ferrite beads are enclosed in tubing **42**. In addition, ferrite slab **38** is shown attached to the end wall **50**, and air openings **56** are visible in back wall **54**. Bottom wall **57** in this view is represented by dashed lines since in the preferred embodiment the electrically conductive wall is formed by a portion of the surface of the pole piece of the magnetron and in the alternative construction, discussed in connection with FIG. **2**, may be a separate metal wall. The stem portion of the magnetron is represented by the dashed lines and includes a pinch off tube and filament terminals **7** and **9** shown extending through the opening **59** in this bottom wall. The top wall **55** of the container includes a raised portion, bulge, or dome **60** at the end of the container adjacent end wall **50** and over the opening **59**. This raised portion forms a dome over the end of the stem of the magnetron and serves to maintain a proper insulating space between the metal parts and the end of the magnetron stem while otherwise permitting a smaller dimension or height to the container elsewhere than at this location, thus reducing cavity Q.

The dome portion **60** of top wall **55** includes several holes or passages therethrough, such as **61***a*, **61***b* and **61***c*, visible in this figure. These openings are generally less than 1/10th of the wavelength of the fundamental microwave frequency of 2,450 MHz so as to preclude any leakage of microwave frequency therethrough and at the same time permitting a passage for air to cool the magnetron stem.

In the structure of the preferred embodiment the top wall **55** and bottom wall **57** are enlarged at the right hand ends in FIGS. **2** and **3**, primarily to make the container large enough in volume at that end to receive the stem of the magnetron and allow sufficient clearance therebetween so as to provide appropriate high voltage insulation and prevent corona or high voltage breakdown therebetween. At the left hand end of these walls the width of the wall is significantly more narrow so as to provide a slender appearance, preferably with a slight spacing between the end walls and the ferrite beads. Overall the top view of the top and bottom walls is seen to resemble in shape paddles with handles. As a result, the front and back walls, **53** and **54**, are bent in shape so as to conform to edge of the top and bottom walls. End front wall **50** is rectangular in shape but of a larger area than the other end wall **51**.

The end view of FIG. **4** illustrates the filter box with end wall **51** and insulator **43** removed. Viewing the filter box from that end, electrical conductors **31** and **33** are visible and extend through passages in ferrite bead **39***a*. For clarity, sheath tubing **42** and ferrite slab **38** illustrated in FIGS. **2** and **3** is omitted. Top wall **55** is seen to include the dome portion **60** and in this view an additional hole, **61***d*, is visible, in addition to the holes **61***a* and **61***b* visible from the view of FIG. **3**.

The metal walls of the container form essentially a closed microwave cavity in which any microwave energy is confined. By design, the microwave cavity in the filter box of the invention is of a low Q, Q representing the quality factor of the cavity, and thus is considerably smaller in size than the shielding cavities of the prior art constructions. The ferrite material installed within the cavity occupies a predetermined volume, represented by V_t. In turn, the volume of the cavity is of a predetermined volume, represented as V_c. In order to obtain a low Q cavity on the order of one-hundred or less, the relationship or ratio between V_c and V_t or V_c/V_t is such as to be a number, including any fraction thereof, approximately less than 20 and at least slightly greater than the number 1 (one).

A second factor used to determine the relative geometry and actual dimension of the metal container and ferrite of the preferred embodiment, FIGS. **2** through **4**, is best illustrated in connection with FIG. **4**. Considering the narrow length of the metal container (apart from that over the stem of the magnetron) as analogous to a transmission line in which the electrical conductors **31** and **33** and the surrounding ferrite are considered as the center conductor thereof, an approximate characteristic impedance Z_o can be assigned. In the preferred embodiment of the invention this characteristic impedance is as low as feasible, preferably less than 50 ohms. An approximation in obtaining such impedance is that there is a mean perimeter such as represented by the dashed lines P in FIG. **4**. This means perimeter is the average between the perimeter of the ferrite material and the perimeter of the inner surface of the metal container. In addition, a mean or average spacing S between the ferrite material and inner surface of the walls of the metal container is defined, disregarding the end ferrite slab **38** which is not a part of the cross-section. Accordingly, the impedance characteristic Z_o is approximated as 377 ($S\ P$). It is noted that in the instance where the metal container is formed such as to directly contact the enclosed ferrite material, then S reduces to approximately 0 and the perimeters of the ferrite, the container, and the mean perimeter P approach a common value for which there is no limiting impedance Z_o. The addition of ferrite such as **38** at the end wall **50** reduces further Q_L or quality factor of the entire enclosed cavity.

In an actual construction of this embodiment of the invention the following dimensions for the container were chosen and are presented here by way of an example. At its widest end top and bottom walls **55** and **57** of the filter box are 1½ inches wide; at their narrow end these walls are ⅞ inch wide. In addition, the transition between wide to narrow width occurs at a location 1½ inches from either end, and the length of the top and side walls is 3 inch overall. The height of the front and back walls is ¾ of an inch.

By contrast to the invention, one prior art construction had a filter box 1¾ inches deep by 4 inches in width and 5 inches in length. Such prior art filter box contained four 1 inch balun coils and two filter capacitors. In addition to requiring many difficult assembly operations, the costs were high and the results were barely equivalent to that obtained in the filter box of the invention. In another prior art construction the filter box was 1½ inches deep by 4 inches in length and 3 inches in width, and incorporated therewithin inductive components. Not only is this of a larger size and of a relatively more expensive cost of manufacture, but the results were poorer by some 20 db's, which increased the possibility of television interference and required the power supply enclosure to be very tight. Broadly speaking, other prior art constructions appear comparable in operation theoretically; however in each it is difficult to assemble the box to the tube in a manner which allows no leakage. In the preferred embodiment of the invention only one such connection is required, that from the tube to the magnet plate. In the design of the invention the filter box is welded permanently to the magnet plate to form a permanent reliable leak-free enclosure that can be supplied as an integral part of the magnetron structure. This eliminates any possibility of assembly error.

A calculation of Z_0 as defined above in this practical construction is given. Bead **39** cross-section is 5/16″ × 9/16″ so that its perimeter, P_f, is [5/16 π + (⅝ − 5/16) × 2] which reduces to 1,605 inches. The height of the box is ¾ inches and its width is ⅞ of an inch so its perimeter, P_b, is [¾ + ⅞ + ¾ + ⅞] or 3.25 inches. The mean perimeter, P, is approximately equal to ½ the sum of P_f and P_b = ½ (1.605 + 3.250) = ½ (4.855) = 2.428 inches. To determine, S, the mean spacing as heretofore defined, the outer diameter of the ferrite bead **39** is the effective working surface, since, the dielectric constant, for the bead is 13.5. Thus S = ¾ inch the height of the box less the height of the bead, 5/16 multiplied by ½ = 0.219 inches. Thus, $Z_o = 377 \times 0.219/2.428 = 34.0$ ohms. Note that if in determining, S, the width of the box and the width of the ferrite bead were used to determine the average spacing a value of Z_o, as defined, is obtained of 24 ohms.

To determine the quality factor Q_L in this practical construction as herein defined and taught, the volume, V_{tf}, of the enclosed ferrite material is first determined and equals the sum of volumes of the three ferrites **39***a*, **39***b*, and **39***c* plus ferrite **38**: $V_{tf} = (9/16 + 9/16 + 9/16 + 1)\,A$, where $A = (5/16)\,(1 + \pi/4) = 0.175$ thus V_t = 0.470 cubic inches. The volume of the container, V_c, is according to the exemplary dimensions previously given: $V_c = [(1½ \times 1½ \times ¾) + (1½ \times ⅞ \times ¾)] = 2.657$ cubic inches.

$$Q_L \approx V_{c}/V_t \approx 2.657/0.470 \approx 5.6$$

The measured attenuation for this unit was −60 dbm and the measured attenuation for the FCC limit on the same scale was −54 dbm.

The exploded view of the filter box illustrated in FIG. **5** illustrates one method of assembly of the filter box of FIGS. **2–4**. The insulation coated electrical conductors **31** and **33** are relatively rigid and their end portions **35** and **37** may be first formed to the desired shape. The ferrite beads **39***a*, **39***b*, and **39***c* are thereupon slipped over the insulated conductors. Additionally, the ferrite slab **38** is cemented in place to the end wall of the can or metal container. The heat shrinkable tubing is placed over the ferrite beads and shrunk in place to form a good fit. Thereupon the ends of the wires **35** and **37** are attached to the ends of the magnetron, suitably by soldering, to form a firm electrical path and mechanical joint therewith. Next the can is moved down and the wires **31** and **33** slipped into the passage in the can and the can is then placed over the entire assembly and in abutment with the pole piece, not illustrated, of the magnetron. Subsequently, insulator **43** is slipped over the ends of electrical leads **31** and **33** and pushed into position within the opening in the can. Subsequently the can is welded to the pole piece of the magnetron to form a complete unit.

In operation a suitable source of filament current is supplied to electrical leads **31** and **33** and the latter conductors carry this current to the filament terminals of the magnetron. Should any microwave frequency energy be coupled from the cathode terminal into the stem area it is ideally absorbed by the ferrite material **39***a* through **39***c* and **38**. The ferrite material thus serves to eliminate any high frequency energy which couples from the cathode to the filament leads **31** and **33**. In addition, the entire combination of metal cavity and ferrite material constructed according to the preceding teachings present a load to both the fundamental, to any harmonics of the fundamental, and to any subharmonics of the fundamental energy. This essentially loads down the tube and inasmuch as the characteristic impedance Z_o of the unit considered as a transmission line is low, suitably below 50 ohms, any possibility of propagating beyond the filter box any so-called fast modes is eliminated.

Another embodiment of the invention is illustrated in FIGS. **6**, **7** and **8** showing the magnetron filter box from various views. For convenience, elements in FIGS. **6**, **7**, and **8**, which find a corresponding element in the preceding embodiment of the invention of FIGS. **2** through **5**, are similarly identified with a corresponding numeral which is primed. Moreover, since each of those elements has been discussed in connection with the preceding preferred embodiment of the invention and have the same function and purpose, it would appear redundant to repeat in detail that description which is already in the reader's understanding. For description of those elements reference should be made to the preceding description. For conciseness, therefore, the description of structure following is, in essence, a description of features different from that found in the preferred embodiment with some comparison between the two.

In this embodiment it is first noted that the container walls are essentially rectangular in shape. Accordingly, that portion of the metal container surrounding the ferrite beads, **39***a*′ through **39***c*′, is spaced from those beads by a slightly larger distance and in this forms a basic transmission line, analogously, of a lossy characteristic impedance Z_o slightly larger than that of the embodiment of FIGS. **2–4**. In addition, slabs of ferrite material, **40***a*, **40***b*, **40***c* and **40***d*, are installed within the metal container and provide additional loss material. Ferrite slabs **40***a* and **40***b* are cemented or epoxied to front walls **53**′, and ferrite slabs **40***c* and **40***d* are cemented or epoxied to back wall **54**′. While it is possible to obtain the same volume of ferrite within the container by simply increasing the dimensions of ferrite beads **39***a*′, **39***b*′ and **39***c*′, to do so would result in a design that requires ferrite beads of a nonstandard size and hence of a substantially more expensive per unit volume cost. It is noted that the size and geometry of ferrite slabs **40***a* through **40***d* are such as is commercially available as standard items. An additional advantage of locating these standard ferrite elements **39**′ along the walls of the metal container accrues: any heat built up in the loss material through dissipation of microwave energy is conducted through the metal wall on which they are attached and this heat is thereafter dissipated in the air atmosphere surrounding the metal can. In other respects the design mode of operation and application of the filter box of the embodiments of FIGS. 6, 7 and 8 is the same as that in the preceding embodiments.

In an actual construction of the embodiment of the invention of FIGS. 6 through 8 the following dimensions were chosen and are given by way of an example. The width of the box is 1½ inches wide. The length overall is 3 inches and the height is ¾ of an inch. The results obtained with this embodiment are comparable with that of the preferred embodiment although numerically a larger number of elements are required and the overall volume of the box is larger with this construction. The ferrite pieces **40***a*, **40***b*, **40***c* and **40***d* located on the walls **53** and **54'** are approximately 5/16 inches in thickness while the dimensions of ferrite beads **39** are the same as in the preceding example. Thus, although the wall separation is actually greater than in the preceding example, and is 1½ inches in width, the distance or spacing is the same. Thus 1.5" − 2 (5/16) = ⅞ of an inch. Hence the calculation of effective impedance, $Z_o \approx 377\ (S/P) = 33.51$ ohms.

The Q_L in this example is determined as in the preceding case: V_t = volume of **7** ferrite beads = 0.740 cubic inches. $V_c = 3'' \times 1½'' \times ¾'' = 3.37$ cubic inches. Thus $Q_L = V_c/V_t = 3.37/0.740 = 4.6$. The measured value of attenuation was −59 dbm.

The embodiment of FIG. **9** represents a special case wherein the mean or average spacing S is approximately equal to 0 and the mean perimeter length P is substantially the same as the inner perimeter of the metal cavity. This embodiment includes the two spaced electrical conductors **61** and **63** which are insulated from one another and are adapted to be connected to a suitable supply of filament current and high voltage. The conductors are first surrounded or packed with a lossy dielectric material such as Eccosorb CRS or FDS, illustrated as element **65**. In turn, the lossy dielectric is covered by a metal wrapping **67** which may be in the form of a metal tape. In addition, a metal container **69** is fitted over the ends of conductors **61** and **63** and in electrical contact with the metal tape **67**. Metal container **69** forms a dome which covers the stem section of the magnetron and serves a shielding function. As illustrated the magnetron filter box is mounted on a section of the pole piece **71** of the magnetron, the pole piece serving as one of the electrically conductive walls of the filter box in the cavity otherwise formed by the domelike member **69**. In turn, this wall effectively has a passage through which the magnetron stem portion is inserted and introduced within the filter box. FIG. **10a** shows in cross-section a portion of the filter box which includes the conductors **61** and **63**, the packing **65** of electrically lossy dielectric material, and the underlying layer of metal tape **67**. A modification of the foregoing is illustrated in FIG. **10***b* in which conductors **61'** and **63'** are first ensleeved by a dielectric material **73**, and this material is in turn covered by a heat shrinkable tube consisting of lossy material such as ferrite powder **75**. In turn, the entire assembly is covered with a conductive member **67'** which suitably may comprise a metal tape. As illustrated in FIG. **6** the pole piece **71**, metal tape **67** and metal dome member **69** are all placed in electrical contact and are grounded.

Thus, the magnetron filter boxes of the prior art included either dissipative material or reactive networks, or both, within a large shielding metal enclosure, but no attempt was made to integrate the shielding enclosure with the dissipative networks to form a compact and more efficient magnetron filter box that comprised a fewer number of lower cost parts.

By the teachings of my invention the shielding is integrated into the simple compact arrangement of the drawings with the dissipative material so as to form structure analogous both to a low Q microwave cavity and a lossy transmission line, and in this more efficiently eliminates the leakage of the fundamental frequency, leakage of subharmonics, and any fast modes which in the prior art structures were capable of circulating between the filament lines and the large cavity.

It is understood that the foregoing embodiments of the invention are presented as illustrative of the invention and not by way of limitation, since one skilled in the art, upon reviewing this specification, finds many equivalents and substitutions for the details of the elements illustrated and which substitutions or equivalents do not depart from the spirit and scope of the disclosed invention.

Accordingly, it is specifically understood that my invention is to be broadly construed within the spirit and scope of the appended claims.

What I claim is:

1. A combination of a magnetron and magnetron filter box comprising:

a magnetron which includes a body portion, said body portion having an elongated stemlike end, and said stemlike end containing cathode and filament terminals, a pole piece of ferrous material, said pole piece containing an opening therethrough, said body portion positioned with said stemlike end extending through said opening and projecting outward from the surface of said pole piece, and means preventing microwave energy leakage through said pole piece opening between said body portion and said pole piece;

first and second elongated electrical conductor means for carrying electrical filament current and a high cathode electrical voltage, said electrical conductor means being insulated electrically from one another and having first respective end portions adjacent one another and each connected to a respective one of the cathode and filament terminals of said microwave tube;

microwave dissipative material for dissipating microwave energy and comprising a predetermined volume, V_t, said microwave dissipative material surrounding said first and second conductor means and extending therealong a major portion of the length thereof each to a point proximate said end portions of said conductor means;

microwave cavity means defining a predetermined region of volume V_c for confining microwave energy therewithin, said cavity comprising walls of electrically conductive material and including as one wall thereof a portion of said pole piece surface, said microwave cavity including therein said electrical conductor means, said stemlike ends of said magnetron body and said microwave dissipative material;

means for providing a filament current and high voltage path to said conductor means from outside said cavity;

and wherein the volume of said cavity, V_c, and the volume of said dissipative material, V_l, define a ratio of V_c to V_l, which ratio comprises a quantity equal to or less than 20 whereby said microwave cavity is of a low Q factor electrical characteristic; and

wherein a predetermined impedance Z_o is defined as approximately equal to 377 (S P) ohms, wherein said relationship of S and P being such that said Z_o is equal to or less than 50 ohms,

where S is defined as an average spacing distance between the outer surface of said dissipative material and the inner wall surfaces of said cavity means and where P is defined as a mean perimeter length about the space between said dissipative material and said cavity walls.

2. The invention as defined in claim 1 further comprising a slab of microwave dissipative material located on a wall of said microwave cavity at a location adjacent said stemlike end of said magnetron body portion.

3. The invention as defined in claim 2 further comprising a plurality of small holes less than 1/10th λ in diameter located in at least some walls of said microwave cavity to provide a path out of and into said cavity for air.

4. An electromagnetic energy filter means comprising:

first and second elongated electrical conductor means for carrying electrical filament current and a high cathode electrical voltage, said electrical conductor means being spaced and having end portions adjacent one another for connection to the respective terminals of a microwave tube;

microwave dissipative material for dissipating microwave energy, said microwave dissipative material surrounding said first and second conductor means and extending along a predetermined length thereof up to a point proximate said end portions of said conductor means, said dissipative material further comprising a predetermined volume V_l;

microwave cavity means for confining microwave energy within a predetermined region of volume V_c, said cavity comprising walls of electrically conductive material, said cavity means including therewithin said microwave dissipative material, and said first and second conductor means, including said end portion of each said conductor means;

and wherein the ratio of cavity volume, V_c, to dissipative material volume, V_l, comprises a quantity equal to or less than 100 to define a low Q cavity;

a first opening in a first wall of said cavity means, said first opening being of sufficient size to permit positioning within said cavity means of a terminal socket end of a microwave tube for permitting connection within said cavity means between terminals on said socket and the corresponding end portions of said conductor means and to permit said microwave tube to close said first opening;

means for permitting application of filament voltage and high voltage to said conductor means from outside said cavity;

and wherein an average spacing distance is defined between the outer surface of said dissipative material and an inner surface of said cavity means which comprises a predetermined length S, and wherein a mean perimeter length, P, is defined about the space between said dissipative material and said cavity walls, and wherein a predetermined impedance, Z_o, is defined as approximately equal to the quantity 377 S/P ohms, said relationship of S and P being such that said Z_o is equal to or less than 50 ohms.

5. The invention as defined in claim 4 wherein said electrical conductor means are sufficiently spaced from said cavity walls to provide high voltage insulation therebetween.

6. The invention as defined in claim 5 wherein said ratio of V_c/V_l is equal to or less than 20.

7. The invention as defined in claim 4 wherein said cavity means comprises the metal box open along one side, and a metal pole piece of a microwave tube closes said open side to complete said metal cavity, and wherein said tube socket extends through said pole piece into said cavity.

8. The invention as defined in claim 7 further comprising a plurality of additional openings in said metal box for permitting passage of air, each of said openings having as its longest dimension a length equal to or less than the quantity 1/10 λ where λ is the wavelength of the operating frequency of the magnetron.

9. The invention as defined in claim 8 further comprising an additional quantity of microwave dissipative material located along an end wall of said cavity adjacent said first opening.

10. The invention as defined in claim 8 wherein said dissipative material further comprises a plurality of discrete portions arranged in side by side relationship, each of said portions having a passage therethrough and wherein said conductor extends through said passages for supporting said portions, and a single sheath of heat shrinkable polyvinyl tubing material extending over and covering all said portions to retain said discreet portions in said side by side relationship.

11. The combination of a magnetron and magnetron filter box comprising:

a magnetron microwave tube for generating microwave frequency energy of a wavelength λ;

said magnetron microwave tube including a tube body, microwave passage means for permitting passage of generated microwave energy from said tube body to a load, and filament and high voltage terminal means for coupling filament current and high voltage to within said tube body;

a low Q microwave cavity of a predetermined volume, V_c, covering said terminal means, said low Q microwave cavity including therewithin elongated electrical conductor means adapted for connection to an external source of filament current and high voltage for providing an electrically conductive path to said terminals, and microwave dissipative material of a predetermined volume, V_l, surrounding said conductor means along a substantial portion of the length of said conductor means for dissipating microwave energy exiting from said magnetron tube via said terminals,

and wherein the outer surface of said dissipative material and the inner surface of said microwave cavity is separated by an average spacing distance of a predetermined length, S, and wherein a mean perimeter length, P, is defined about said space between said dissipative material and the surrounding walls of said cavity; and wherein a predetermined impedance, Z_o, is defined as approximately equal to the quantity 377 (SP) ohms, said relationship of S and P being such that Z_o is equal to or less than 50 ohms, and wherein the ratio V_c/V_l is a quantity equal to or less than 100.

12. The invention as defined in claim **11** wherein said dissipative material further comprises a plurality of discreet portions arranged in side by side relationship, each of said portions having a passage therethrough and wherein said conductor extends through said passages for supporting said portions, and a single sheath of heat shrinkable polyvinyl tubing material extending over and covering all said portions to retain said discreet portions in said side by side relationship.

13. The invention as defined in claim **11** wherein said microwave cavity means includes a plurality of openings through the walls thereof to permit passage of cooling air into said cavity, each of said passages having as its longest dimension a length less than 1/10th λ.

14. The invention as defined in claim **11** wherein said ratio of V_c to V_l is approximately 20.

* * * * *