

Nov. 30, 1948.

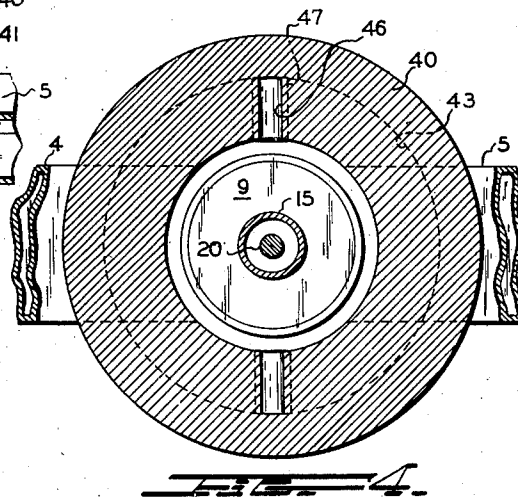
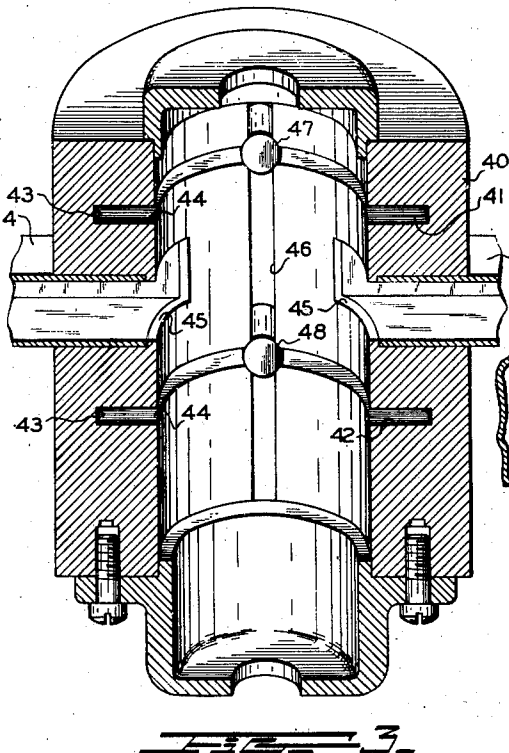
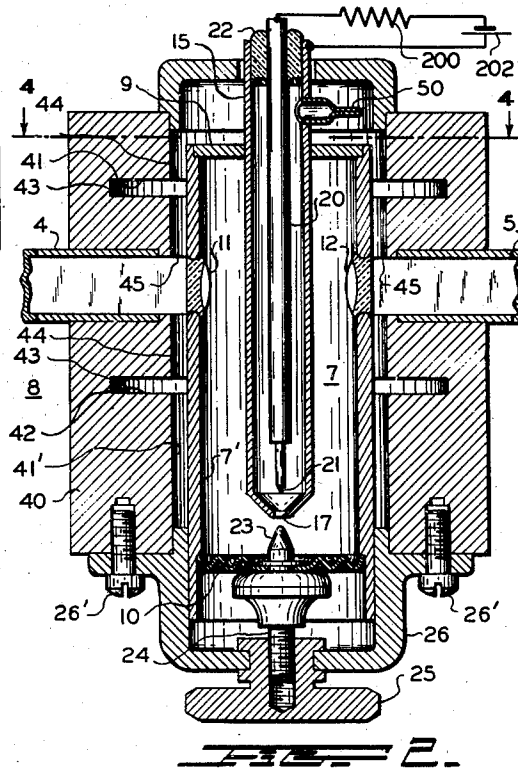
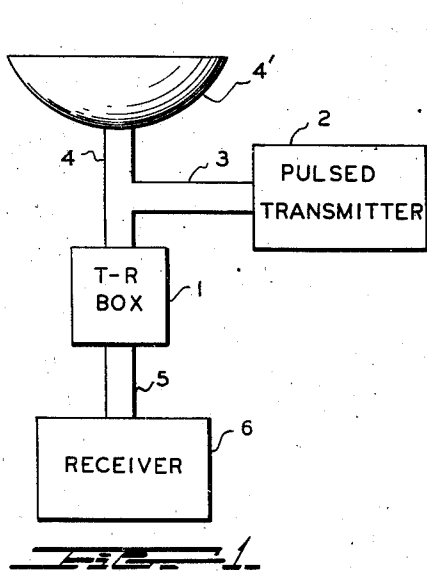
W. L. BARROW ET AL

2,454,761

ULTRA HIGH FREQUENCY DEVICE

Filed Nov. 20, 1942

3 Sheets-Sheet 1



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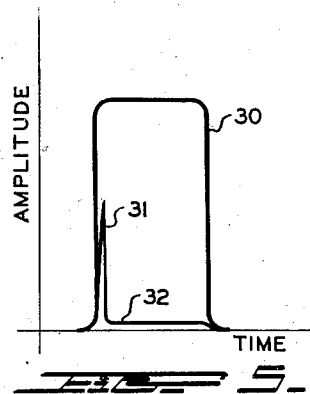
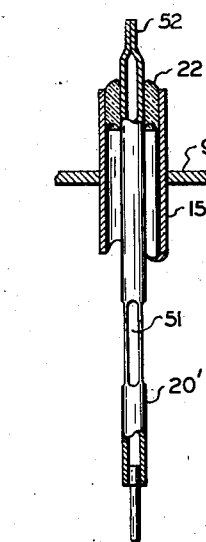
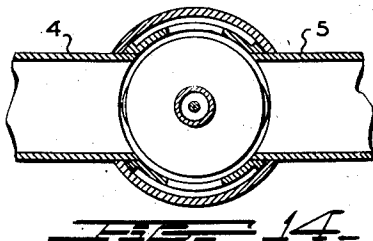
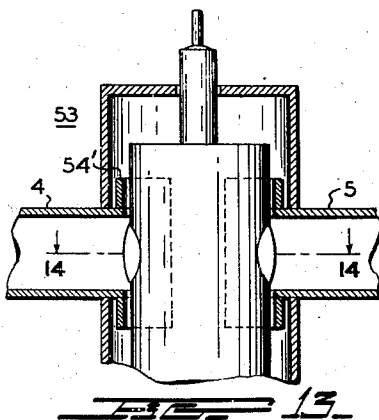
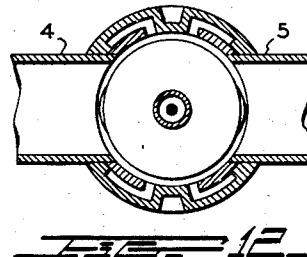
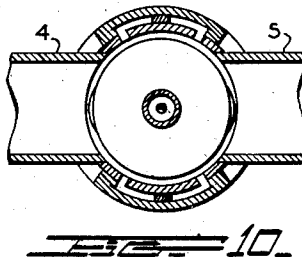
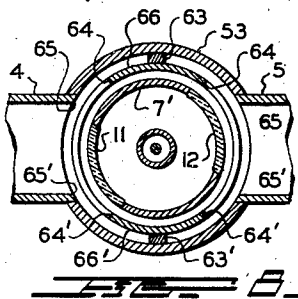
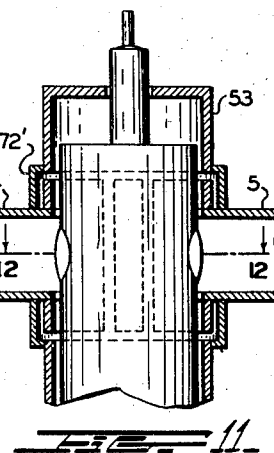
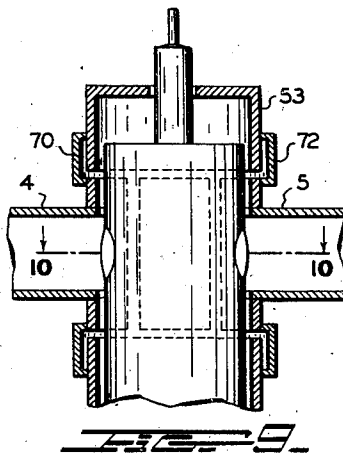
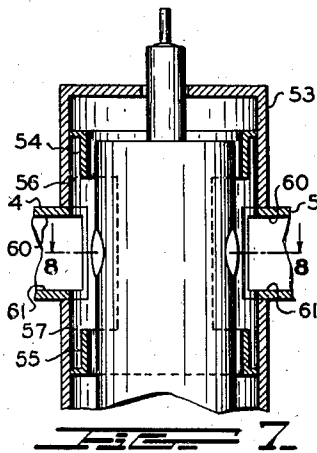
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3 Sheets-Sheet 2



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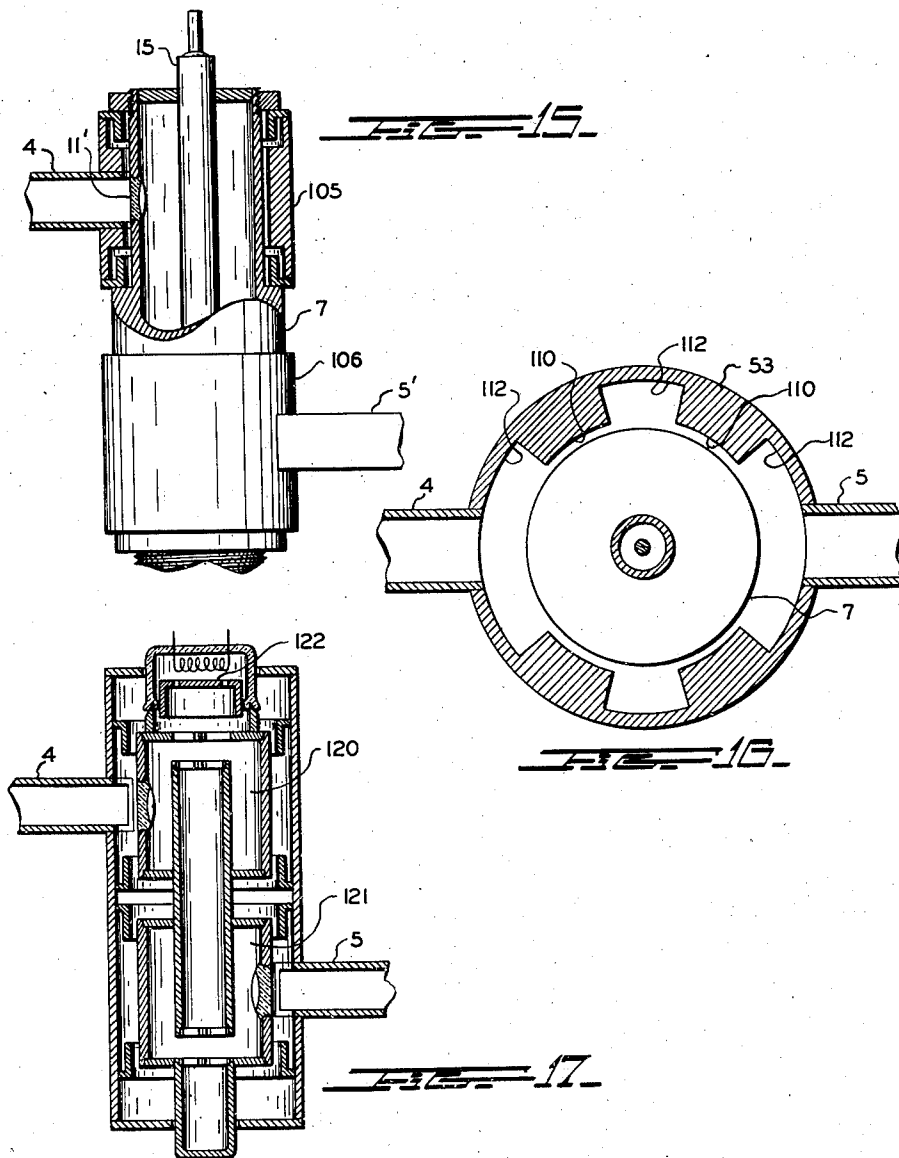
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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,454,761

ULTRA HIGH FREQUENCY DEVICE

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Application November 20, 1942, Serial No. 466,530

27 Claims. (Cl. 315—39)

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This invention relates, generally, to ultra high frequency transmission, and, more particularly, to a type of gas-discharge resonant tube useful in stopping the flow, through a wave guide or other conductor, of ultra high frequency energy above a predetermined adjustable maximum amplitude and in allowing energy below that amplitude to flow substantially unattenuated, and also to apparatus for conveniently and removably mounting such tubes and other apparatus in a wave guide circuit.

Such devices have been found useful in ultra high frequency pulse radiating and receiving systems. In many such systems, space and weight considerations demand that a single device serve both as a transmitting and receiving antenna. The device of the present invention makes it possible for high energy transmitter pulses to be introduced into a wave guide also utilized by the receiver, in such a manner that the receiver is not paralyzed or permanently damaged by the high energy of the transmitted pulses.

In common parlance, this gas discharge device has come to be known as a "T-R box," an abbreviation for the term "transmission-reception box," and will be referred to in the following specification as such.

The T-R boxes of the prior art have been provided with a gas-enclosing metallic resonant casing or enclosure having glass or other ceramic walls or windows through which the radio frequency energy enters or leaves the box. The enclosure also contains discharge electrodes which are adapted to provide a gas discharge within the enclosure in response to high intensity received energy, to destroy the resonant condition of the enclosure and thereby to block the passage of such energy through the device. In such devices it is a practical necessity to form the glass or ceramic windows within the casing walls before fully enclosing the casing, as by soldering, brazing or welding the metal-to-metal joints.

In previous devices of this type the forming of the metal joints was extremely difficult, since particular pains had to be taken to prevent damage to the glass or ceramic windows. This is especially the case, since prior art T-R boxes have been designed for operation with electrical resonance of the fundamental or dominant resonant mode, for which the operating frequency is the lowest permissible for resonance to occur. In such T-R boxes, there is only one point of voltage maximum, at which the windows should

be placed. This feature restricts the physical shape and dimensions of the casing and the location of the windows, so that the above-discussed disadvantages in the electrical and mechanical design and manufacture are present.

Also, the gas discharge between the electrodes tends to evaporate some of the material of these electrodes, so that a film of this metal, or other material formed by interaction of the metal vapor and the gas, is deposited on the glass or other ceramic walls. This film continues to build up with the continued use of the T-R box, and harmfully affects the entrance or egress of radio frequency energy from the box while also causing serious power losses. Eventually this film renders the T-R box unusable and makes replacement necessary.

In prior art systems, it has been the practice to solder or otherwise permanently seal the T-R box directly into its connecting wave guides or other high frequency energy conductors, in order to prevent loss of energy at the joints. However, the finite life of these devices due to the causes just described makes the permanent installation of the device in the conducting system impracticable.

According to the present invention, these prior art defects are substantially overcome. An improved type of T-R box is provided in which resonance occurs at a higher mode of resonance than the fundamental modes, so that more points of voltage maximum are obtained, whereby the glass or ceramic windows may be spaced from the metal joints whereby the required soldering, brazing or welding of these metal joints will have little effect upon the windows, and a greater flexibility in electrical and mechanical design and manufacture may be obtained. Furthermore, the discharge electrodes are so located as to reduce and delay formation of the harmful film on the windows, thus providing longer life and lower losses. In addition, an improved form of holder for such devices is provided, adapted to removably support such T-R boxes or other similar devices, with a minimum of energy loss and impedance mismatch at the improved joints forming a part of the holder.

It is therefore a principal object of the present invention to provide improved form of T-R box having a rugged type of construction such that damage is unlikely even under rough military, naval or other service conditions.

It is another object of the present invention to provide an improved construction of T-R boxes or other similar devices in which neces-

sary glass-metal seals are relatively removed from soldered, brazed or welded metal joints, whereby the construction of the device is improved and its manufacture is facilitated.

It is still another object of the present invention to provide an improved form of T-R box adapted to be plugged into a wave guide or other high frequency energy conductor system, and to be easily removable therefrom.

It is yet another object of the present invention to provide an improved T-R box operating at a higher mode of resonance whereby advantages in electrical and mechanical design and manufacture are obtained.

It is a further object of the present invention to provide a socket or holder means in a wave guide or high frequency energy conductor system for removably supporting a T-R box or other ultra high frequency device, without permitting energy to leak through the joints therein into space or to bypass the device, and to provide minimum impedance discontinuity at the joints.

A still further object of the present invention is to provide improved impedance matching means at joints presented to the flow of high frequency energy, whereby impedance discontinuities to the energy leakage are avoided.

Other objects and advantages will become apparent from the specification taken in connection with the accompanying drawings, wherein the invention is embodied in concrete form.

In the drawings,

Fig. 1 is a schematic block diagram, showing a system in which a T-R box according to the present system may be used.

Fig. 2 is a longitudinal cross-sectional view of a preferred form of the T-R box of the present invention.

Fig. 3 is a perspective cross-sectional view of a T-R box or other wave guide accessory holder according to the present invention.

Fig. 4 is a fragmentary cross-section view taken along the lines 4—4 of Fig. 2.

Fig. 5 is an explanatory graph.

Fig. 6 is a fragmentary longitudinal cross-section view of an alternate form of a portion of Fig. 2.

Fig. 7 is a partial cross-section view of another form of the invention.

Fig. 8 is a cross-sectional view taken along the lines 8—8 of Fig. 7 with the structure 7' rotated slightly.

Fig. 9 is a cross-sectional view of an alternate form of the device of Fig. 7.

Fig. 10 is a fragmentary cross-sectional view taken along the line 10—10 of Fig. 9.

Fig. 11 is a fragmentary cross-sectional view of another modification of the device of Fig. 7.

Fig. 12 is a fragmentary cross-sectional view taken along the line 12—12 of Fig. 11.

Fig. 13 is a fragmentary cross-sectional view of a further modification of the invention.

Fig. 14 is a fragmentary cross-sectional view taken along the line 14—14 of Fig. 13.

Fig. 15 is a partial longitudinal cross-sectional view of still another form of the invention.

Fig. 16 is a plan cross-sectional view of yet another form of the invention.

Fig. 17 is a longitudinal sectional view of another form of high frequency device cooperating with the holder of the present invention.

Similar characters of reference are used in all of the above figures to indicate corresponding parts.

Referring now to Fig. 1, there is shown a block

diagram of an illustrative system using a T-R box, shown as a pulse-type object location system. High energy pulses from a pulsed transmitter 2 are fed by means of a wave guide 3 or other high frequency energy conductor into the wave guide 4, and thereby to a reflector or other antenna arrangement 4'. Wave guide 4 forms a T-joint with guide 3, and is also connected to the T-R box 1, whose other end is connected to a wave guide 5 leading to a receiver 6. T-R box 1 is so designed that when a pulse is emitted by transmitter 2, the T-R box is made non-conducting, as will be described, so that substantially all the energy of the transmitted pulse is rejected by the T-R box 1 and substantially none is introduced into the receiver 6. This transmitted pulse is emitted by antenna 4', and, in the illustrative system used, may be reflected by any object within the radiation pattern of the antenna 4'. Depending upon the size of the object and the distance between the system and the object, the transmitted pulse is reflected and returns to the antenna 4' somewhat attenuated and after a time delay corresponding to the distance between antenna 4' and the reflecting object. The energy of this received pulse is considerably smaller than the transmitted energy. T-R box 1 is accordingly made conducting to this lesser energy, so that this received pulse is transmitted directly through the T-R box 1 substantially unattenuated, to be received and utilized by the pulse receiver 6. Pulse transmitter 2 is designed so that its admittance to the received pulse is low, so that little of the reflected pulse energy is absorbed by transmitter 2. T-R box 1 thus serves to protect the receiver from high energy intensities. It will be clear that many uses exist for such T-R boxes other than the illustration just given.

As seen in Fig. 2, the T-R box 1 consists, in a preferred form, mainly of a resonant chamber or resonator 7. The two wave guides 4 and 5 fixedly terminate in an external holder or socket 8, and which removably supports resonator 7. The resonant chamber 7 itself is preferably made cylindrical, its cylindrical wall 7' being of some such alloy as the commercially well-known alloy Kovar, and has its external and internal surfaces plated with material of high electrical conductivity, such as silver or copper. In the form of the invention shown in Fig. 2, the resonator 7 is closed at one end with a rigid wall 9 and at its opposite end by a flexible diaphragm 10.

Reentrant from a central aperture in end wall 9 is a tube 15 which extends into the resonator 7 nearly to end wall 10. The internal end of tube 15 is conical, and has a small hole 17 centrally positioned at the apex thereof. Coaxially positioned within tube 15 is a conducting rod 20, which terminates in a conical point 21 just inside of hole 17. Rod 20 is positioned with respect to and electrically insulated from tube 15 by a metal-to-glass seal 22. Centrally fastened in a central aperture in the diaphragm 10 is a conical bluntly-pointed conductor 23, which reaches to within a short distance of the hole 17. Rod 23 is extended through the diaphragm 10 and threaded outside of the diaphragm 10, as at 24, to be axially adjustably moved by rotation of a nut 25 which is fixed axially relative to the outer cylindrical wall 7' of resonator 7 by means of end bracket 26 fixed to wall 7', whereby the operating point of the T-R box may be adjusted, as will be seen. Bracket 26 also serves as a mounting device for the T-R box. A pair of openings 11 and 12 are made in the

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cylindrical wall 7' of resonator 7 for the purpose of permitting high frequency energy to enter and to leave the resonant chamber 7. In order to permit the evacuation of the chamber 7 and to enclose a gas therein, openings 11 and 12 are supplied with suitable windows, such as formed by glass or other ceramic seals.

Resonant chamber 7 is dimensioned to be resonant at the operating frequency. A mode of resonance is employed corresponding closely to that of a coaxial line short-circuited at each end and having an open space in the center conductor across which some capacitance is connected. In such a structure, resonance may occur at the lowest mode, in which the effective capacitance combines with the effective inductance of the line of length less than one-quarter-wavelength. The over-all length of the cavity may be varied, depending on the capacitance, to provide resonance at a given fixed frequency. This length may not, however, exceed a value equal to one-half of the free-space wavelength, and there can be only one place along the length of the cavity at which the voltage is a maximum. This lowest mode is that of prior art T-R boxes.

If, now, at the same operating frequency, the T-R box length only is made greater, a second length will be reached at which resonance again takes place. This second length would be one-half-wavelength greater than that for the first case just described. The voltage distribution would now have two maxima along the length of the device. Similarly, if the length is still further increased, a third length, then a fourth, and so on, will be found for which resonance again occurs, in which the voltage distribution has respectively three, four, and so on, maxima. Generally, the new lengths for resonance will be equal to an integral number of half-wavelengths plus the length of the resonator for the lowest resonance condition. All modes, except the original lowest one are called "higher resonant modes." In the T-R box of the invention, we make use of the higher modes, rather than the original lowest mode of prior art devices of this type. Particularly, the second or third resonant mode is preferred, although the fourth or other not-too-high mode may be practically useful.

Windows 11 and 12 are preferably positioned along the length of the device at a place where the voltage is maximum when wave guides are employed, in order more easily to transfer maximum power from the wave guide into the T-R box, and vice versa. Of course, other locations may also be employed.

At the shorter wavelengths of operation of the device, which may be of the order of 15 cm. and even much less, it is difficult to construct a resonator chamber for the T-R box as short as a half-wavelength, since end walls 9 and 10 must be spot-welded or soldered in place and in so doing, damage might occur to the windows 11 and 12, as by heat conduction. Furthermore, in such a resonator, a gaseous discharge between tube 15 and rod 23, as will be described, causes evaporation of metal from these electrodes, which tends to obscure the windows 11 and 12 and thereby lessen the effectiveness and life of the device. Therefore, a longer resonator is preferably used, and the resonator of the present invention is preferably chosen to be of such length as to provide a higher mode of resonance, in which case windows 11 and 12 are placed at a voltage maximum of the field within chamber 7, which will be substantially a quarter-wavelength from the end wall 9. In

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this manner, the harmful effects discussed above may be avoided without substantially increasing the size or amount of material required for the device, and a more efficient coupling of chamber 7 to wave guides 4 and 5 is obtained. If desired, or if practicable, any integral number of half-wavelengths may be added to either end of the resonator, to provide still higher modes of resonance.

Resonators of the present type have been found capable of several modes of oscillation, which may occur at neighboring frequencies. Such multiple modes of oscillation are undesirable, since they tend to permit undesired passage of energy through the resonator. These multiple modes may be avoided by a proper choice of the diameters of the resonator case 7' and of the tube 15. The diameter of the windows 11 and 12 partially determines the value of the Q of the resonator when loaded, which, for a particular frequency of excitation, determines the amplitude of the electromagnetic field that can be built up inside of resonator 7. The resonator 7 may be evacuated and filled with gas through tube 15 from a T-connected pipe 50, which may be pinched off and sealed after the chosen gas is introduced into the chamber.

Fig. 6 shows an alternate means for performing this function. Here the electrode 20' corresponding to electrode 20 is made hollow and has holes 51 communicating to the interior of chamber 7. The chamber 7 is pumped out through tube 20', the chosen gas inserted, and the tube 20' is then sealed off by pinching its outer end and sealing it, as at 52.

In practice, a unidirectional voltage of the order of 1000 volts, derived, for example, from battery 202, is placed between the "keep-alive" electrode 20 and its surrounding tube 15, in series with a current limiting resistor 200, so that, if resonant chamber 7 is filled with an ionizable inert gas, such as nitrogen or water vapor at a pressure of about 6 or 7 mm. of mercury, a continuous low-current discharge occurs between the tip 21 and the rim of the hole 17, providing a source of ions. Some of the ions formed by this discharge migrate through the hole 17, so that a low concentration of ionized gas molecules is maintained in the space between the rim of hole 17 and the blunted point of rod 23, to permit the main high-current discharge to be initiated more readily between these electrodes. If an ultra-high frequency high-energy pulse, such as ideally represented at 30 in Fig. 5, is introduced through one window, such as window 11, of the resonator 7, an electromagnetic field will correspondingly be built up inside of the resonator 7. As a definite, if short, time is required for the ion concentration to build up, in response to the voltage between electrodes 17 and 23, to a point where it may cause a discharge to occur, the chamber 7 remains in a resonant condition for a very short length of time, and, as shown by the curve at 31 in Fig. 5, a small finite amount of energy is transmitted into the resonator 7 and out through window 12 for a very short period of time. After a period of time, short compared to the duration of the pulse, has elapsed following the initial steep wave front of the exciting pulse 30, the ion concentration builds up to the point where a discharge occurs between the edge of hole 17 and electrode 23. The chamber 7 then becomes instantly non-resonant and detuned, so that the amount of energy transmitted through the resonator and out of window 12 falls

to a very low level, as shown by the portion 32 of the curve 31 of Fig. 5. In this way, the high intensity pulse 30 is substantially blocked by the T-R box.

When the main pulse is over, this high-current discharge between 17 and 23 ceases, the T-R box becomes tuned again, so as to be capable of passing energy from the low energy reflected pulse to the receiver 6.

The gap between electrodes 15 and 23 is preferably placed as far as possible from windows 11, 12, so as to prevent any metal sputtered from electrodes 15 and 23 during the interval when the discharges occur, from condensing on windows 11, 12, thus preventing aging of the device by increasing the attenuation of these windows.

The breakdown point of chamber 7 and hence the point of demarcation between the pulses transmitted and blocked thereby may be adjusted by means of knob 25.

The T-R box just described is adapted to be removably held within a holder fastened permanently to the remainder of the system, in order to permit ready replacement upon deterioration or damage. In the past, great difficulty has been experienced in providing removable devices for connection in an ultra high frequency system such as the present system, since the necessary joints required to provide removability introduce undesirable and harmful impedance discontinuities and also permit leakage of energy outside the system and around the removable device, which may be a T-R box as in the present illustration, or any other type of high frequency device similarly insertable in the system.

According to the present invention, these former difficulties are overcome by the provision of special features in such a holder for a removable device, which minimize the effects noted above. A mounting is provided in which the coupling between T-R box and wave guides takes place without surface-to-surface contacts playing any part in the electrical operation, thus removing entirely any variations, irregularities or losses associated with such contacts. In the present illustration, the T-R box described above, or any other similar device, is adapted to be removably held within a holder or socket arrangement 8, as by means of suitable fastening members 26 holding bracket 26 firmly but removably against the thick wall 40 of holder 8. Wall 40 is made of highly conductive material with its inner conducting surface 41' of slightly greater diameter than the outside diameter of resonator 7, and is substantially of the same length as that of resonator 7.

Wave guides 4 and 5 are rigidly positioned in wall 40 and extend therethrough to form openings directly opposite windows 11 and 12. Above and below wave guides 4 and 5, at a distance of substantially one-quarter-wavelength of the operating frequency, are placed annular grooves 41 and 42 extending radially for a distance of a quarter-wavelength of the operating frequency. These grooves 41 and 42 and the space between resonator 7 and cylindrical wall 40 form a filter and impedance matching system, to prevent high frequency energy from leaking from the interior of wave guides 4 and 5 out of the top or the bottom of the socket or holder 8, and to minimize the impedance discontinuities at the joint between the holder 8 and the T-R box.

To explain the operation of this portion of the device, grooves 41 and 42 may be considered to

constitute quarter-wave sections of a two-conductor transmission line, short-circuited at their remote ends, such as at 43, by the conductive material of wall 40. As is well known, such a short-circuit quarter-wave transmission line presents a very high impedance at its open end, as at 44. In the apparatus of Fig. 2, this high impedance is effectively in series with the unknown impedance which is characteristic of the space between holder 8 and resonator 7. The series connection of such a high impedance with an unknown impedance necessarily yields a resultant very high impedance. The quarter-wave transmission line formed by the concentrically disposed inner wall 41' of holder 8 and the outer wall 7' of the T-R box transforms this resultant high impedance into a very low impedance at point 45. Accordingly, the gap at 45 presents an extremely low impedance to the flow of energy through wave guide 4 into the T-R box. By virtue of this condition, the physically necessary discontinuity at this point has little effect upon the system, and little or no energy leaks outwardly from the joint, at least in the longitudinal or axial direction of the T-R box. Even though the dimensions herein referred to are not held to exactly, a substantial blocking of the egress of energy will result.

It will be clear that the explanation offered for slot 41 and wave guide 4 applies equally well to the remaining slots and wave guides.

As seen more clearly in Fig. 3, means are provided to prevent whatever high frequency energy is propagated longitudinally from the joint from travelling around annular grooves 41, 42, which are similar to wave guides extending around and bypassing the resonator 7, and thereby out from guide 5. Substantially 90° displaced from the wave guides 4 and 5, and a quarter-wave from the edges of the guides, is placed a vertical slot 46 which has a depth of a quarter-wavelength. The crossover points between annular grooves 41 and 42 and vertical slot 46 are blocked to high frequency energy by means of conducting pins 47 and 48, or by other conducting means, so that there can be no communication of energy between the annular grooves 41, 42 and the slots 46. Also, pins 47, 48 prevent the flow of energy through grooves 41, 42. Slot 46 then acts in a manner similar to that of the grooves 41 and 42, to prevent energy from bypassing the resonator 7. If the circumferential distance between adjacent edges of wave guides 4, 5 is substantially greater than a half-wavelength, a pair of slots, placed a quarter-wavelength respectively from wave guides 4 and 5, may be used in place of the single slot 46.

In order to more easily construct the holder and to conserve material, it is not necessary that the filter grooves 41 and 42 be formed in a solid block of metal 40 as shown in Figs. 2 and 3. They may also be made by simply fastening the filter structure to a thin wall tube 53 forming the outside of holder 8, as in Fig. 7. In Fig. 7, annular quarter-wave deep sections 54 and 55 are provided on opposite sides of the wave guides 4 and 5, and inside of wall 53, the open ends 56, 57 of the sections 54, 55 being located a quarter-wave distance from the upper and lower conducting surfaces 60, 61 of the guides 4 and 5. These sections 54, 55 operate in exactly the same manner as explained in Fig. 2 to prevent axial leakage and to provide minimum impedance at the joint.

As shown in Fig. 8, if the windows 11 and 12 are rotated relative to the openings of the wave guides 4 and 5, the coupling between guides 4 and 5 may

be altered, thus effectively varying the Q and the coupling of the system. As shown, an equal change in the coupling of the T-R box to the two wave guides is provided by any rotational adjustment of the T-R box. Obviously, it could be arranged to change the coupling to one guide only if desired, as by providing a variable angle between the axes of the two guides terminating in the holder, and by other means readily apparent to one skilled in the art.

As seen in Fig. 8, filter means, similar to that shown in Fig. 7 to suppress leakage of energy out of the top and bottom of holder 8, may be also placed vertically on each side of the resonator 7 in order to prevent energy from bypassing the resonator. For this purpose, in the annular space between shell 53 and the casing 7' of T-R box 1 there are placed two members 66, 66' formed as longitudinal sections of a cylinder and concentric with respect to shell 53. The leading edges of each of these members, such as 64 and 64', are spaced from the edges 65, 65' of the wave guides 4 and 5 by substantially a quarter-wavelength. Connecting members 66, 66' with shell 53 are members 63, 63' which are chosen to have such a width that the members 66, 66' provide a quarter-wavelength short-circuited line sections in a manner similar to that shown in Fig. 3. It will be clear that these devices will perform in the same manner as those of Fig. 3 to prevent bypassing of the T-R box 1 by the high frequency energy flowing between wave guides 4 and 5. Members 66, 66' may be formed integrally with flanges 54, 55 of Fig. 7, whereby members 63, 63' prevent bypassing of T-R box 7 through the sections 54, 55.

Figs. 9, 11 and 13 show several modifications of the arrangement of Fig. 7, all operating upon the same general principle. Thus, in Fig. 9, the quarter-wave short-circuited line section 72 is formed outside of shell 53 and communicates with the interior thereof by annular slot 70. As before, section 72 is separated from wave guide 4 by substantially a quarter-wavelength. In Fig. 11, section 72' is shown folded downward instead of upward, but otherwise similar to that of Fig. 9. Fig. 13 is similar to Fig. 7, merely reversing the direction in which the short-circuited quarter-wave section 54' extends. It will be clear that each of these modifications will operate in the same manner as Fig. 7 and Fig. 2 to prevent axial leakage of high frequency energy and to maintain a minimum impedance at the joint between the holder 8 and T-R box 1. Obstructions equivalent in function to pins 48 of Fig. 3 may also be used in these figures.

Figs. 10, 12 and 14 show modifications of Fig. 8, corresponding to their respective figures, 9, 11 and 13. In each of these cases again the intermediate external leakage impedance is connected in series with a short-circuited quarter-wave line section and the resultant series impedance is transformed at the opening of the wave guide to a very low impedance to provide minimum impedance at the joint and to prevent energy leakage. These figures are otherwise self-explanatory.

If desired, the windows 11, 12 of Figs. 1 and 7 need not be oppositely located, but may be placed at any suitable orientation or location relative to each other, as pointed out above. In Fig. 15, wave guide 4 is shown fastened into a rotatable filter structure 105 opposite window 11', while wave guide 5' is shown positioned in a filter structure 106 opposite a window laterally, and if desired also angularly, displaced from window 11'. Filter structures 105 and 106 are shown similar to the

type described in Fig. 9, but may be of any suitable type. Filter structures 105 and 106 may be made individually rotatable with respect to chamber 7 so that wave guides 4 and 5' may be disposed at any desired angle. The construction of this modification has the advantage of separating laterally the filter structures of the two wave guides and windows, and thus decreasing the likelihood of transfer of energy from one guide to the other through the holder without passage through the resonator of the T-R box.

A further means for preventing energy from bypassing the resonator 7 is shown in Fig. 16, which describes the application of a type of filter structure first shown in a coaxial-line type of ultra high frequency filter in copending application Serial No. 417,229, entitled "A high frequency tube structure," filed October 31, 1941, in the name of William W. Hansen. External holder wall 53, into which wave guides 4 and 5 are inserted opposite windows 11, 12 in T-R box 7, expands in thickness at alternate quarter-wave intervals around the circumference to form approximately quarter-wave long conducting members 110 with slightly greater inner diameter than T-R box 7 with similar unexpanded members 112. In designing the filter, the lengths of sections 110 and 112 are selected by experiment if necessary, to provide an impedance inversion from section to section by means of the usual quarter-wave transmission-line action such that a very low effective impedance is caused to appear between the wave guide 4 or 5 and the oppositely disposed T-R box 7 or other device.

In the illustration shown in Fig. 16, the impedance appearing, for example, between guide 4 and T-R box 7 will be transformed by the first adjoining quarter-wave section to a different impedance. The following pairs of quarter-wave sections, being alternately of low and high characteristic impedance, will transform this higher impedance to a very low effective impedance appearing between guide 5 and T-R box 7. Thus, the wave energy is forced to travel between the guides and the interior resonant space of the device without an appreciable amount circumventing the device.

In the modification shown in Fig. 16, an odd number of quarter-wave sections are provided. Other numbers and arrangements of sections, including even sections of lengths different from a quarter-wave, may be devised by well known transmission-line theory by those skilled in the art.

It is seen that without the filter devices herein shown, including that of Fig. 16, the high frequency energy will be propagated in the annular channel between wall 53 and resonator 7 so as to bypass the T-R box at least in part. Any desired combination of the filter means herein shown may be utilized with T-R box holders, to prevent both axial and peripheral leakage of energy. The socket devices here shown are also applicable to other types of tubes or to other ultra high frequency devices, such as mixers, detectors, and the like, without being necessarily limited to use with T-R boxes.

For example, Fig. 17 illustrates the use of a holder similar to that of Fig. 7 with an ultra high frequency velocity modulation electron discharge device, such as of the "Klystron" type described in Varian Patent No. 2,242,275, issued May 20, 1941. In this figure, the two wave guides 4 and 5 cooperate with respective resonators 120 and 121 which are respectively the input and out-

put circuits of the "Klystron" device, here shown as being an amplifier as disclosed in the above-mentioned patent, and having a cathode 122.

It will be clear that many other types of high frequency device could be substituted for the T-R box or the "Klystron" device described in the present specification. Also, the holders of the remaining figures, such as Figs. 2, 9, 11, 13, 15 or 16 could be utilized in the same fashion as shown in Fig. 7. It is also evident that the T-R box herein disclosed may be rigidly fastened to the wave guides, or may be used in any other manner not described in the present disclosure. In particular, it is evident that the wave guide filter means of Fig. 16 may be used in many types of wave guide applications.

Wherever distance is given in terms of wavelength in the above, it is to be understood that the actual dimension is such as to give the same electrical effect as the given dimension would in vacuum, since all wavelengths given are those occurring in vacuum.

As discussed above, the term "higher mode of resonance" (or equivalent expressions) when used in the appended claims, signifies that the resonant frequency of the cavity resonator is higher than the lowest (fundamental mode) resonant frequency thereof.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A gas discharge device for ultra high frequencies comprising a cavity resonator having a gas-filled casing of a length for resonance at a higher mode, said casing having a rigid end wall, a flexible end wall, and a cylindrical side wall having a pair of apertures located substantially a quarter-wavelength from said rigid end wall and respectively providing an entrance and an egress in said resonator for high frequency energy; a reentrant tube coaxial with said casing and extending from said rigid end wall toward said flexible wall, said tube having an aperture in the end thereof adjacent said flexible wall; a first electrode fixed to said flexible wall; means operably connected to said first electrode for adjusting said first electrode toward and away from the end of said tube; a second electrode disposed within said tube and insulated therefrom; and means for maintaining a cold discharge between said second electrode and the apertured end of said tube, whereby a high intensity energy pulse entering one of said apertures will break down said gas to detune said cavity and prevent passage of said energy to the other of said apertures, while a low intensity energy pulse will pass through said cavity substantially unattenuated, the break-down level of said cavity being adjustable under the control of said adjusting means.

2. A gas discharge device for ultra high frequencies, comprising a gas-filled cavity resonator resonant at the operating frequency of said device, means operably connected to said resonator for coupling ultra high frequency energy to said cavity at a voltage anti-nodal position thereof, means operably connected to said resonator for abstracting energy from said cavity also at a voltage anti-node, and means connected to said resonator for maintaining a cold discharge there-

in at a voltage anti-node thereof spaced from said coupling and abstracting means.

3. A gas discharge device for ultra high frequencies, comprising a gas-filled casing providing a cavity having dimensions for providing a higher mode of resonance at the operating frequency of said device, means including a window in said casing for coupling high frequency energy thereto at a voltage anti-nodal position of the field within said cavity, and means within said casing responsive to high frequency energy of sufficiently high amplitude for causing a gas discharge in said cavity and thereby detuning said resonant cavity, said last-named means being spaced from said coupling means to prevent deterioration of said window by the action of said discharge.

4. A gas discharge device for ultra high frequencies comprising a gas-filled casing providing a cavity resonant at the operating frequency of said device, means including a window in said casing for coupling thereto energy at said operating frequency, and means within said casing responsive to high frequency energy of sufficiently high amplitude for providing a gas discharge within said cavity to detune said cavity, said last means being spaced from said window to prevent deterioration of said window by the action of said gas discharge.

5. Apparatus for use with ultra high frequencies comprising means providing a cavity resonator for an operating frequency higher than the lowest resonant frequency thereof, means coupled to said cavity resonator at a voltage anti-nodal position thereof for supplying energy thereto of said operating frequency, means coupled to said resonator for abstracting energy from said cavity resonator also at a voltage anti-node thereof, and means in said cavity resonator for preventing said abstraction of energy in response to high frequency energy input to said cavity above a predetermined value.

6. A gas discharge device for ultra high frequencies, comprising a gas-filled cavity resonator resonant at the operating frequency of said device, means coupled to said resonator for supplying ultra high frequency energy to said cavity resonator, means coupled to said resonator for abstracting energy from said resonator, and means operably connected to said resonator for maintaining a cold discharge within said resonator at a voltage anti-node thereof spaced from said energy supplying and abstracting means.

7. High frequency apparatus comprising an enclosed, gas-filled cavity resonator, means including a window in the wall of said resonator for coupling high frequency energy thereto at a voltage anti-node thereof and means including a second window in the wall of said resonator for coupling high frequency energy therefrom, said resonator having a higher mode of resonance at the operating frequency of said device, and said windows being located remote from the ends of said cavity resonator to facilitate fabrication thereof.

8. A high frequency system wherein a high frequency device is removably coupled to a pair of high frequency conductors, comprising means coupling said conductors to said device, said means comprising means fixedly holding said conductors in predetermined relation, means removably holding said device in predetermined relation to said conductors, and means for minimizing the impedance of the joint between said conductors and said device, said last means com-

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prising means forming a quarter-wave transmission line section having said joint as a termination, said section being connected at its outer end to a quarter-wave short-circuited transmission line section in series with a leakage gap whereby leakage of high frequency energy through said gap is minimized.

9. A high frequency system wherein a cylindrical high frequency device is removably coupled to a pair of rectangular high frequency wave guides, comprising a hollow cylindrical holder body surrounding said device and having said rectangular guides communicating with the interior thereof, a quarter-wave deep annular groove extending radially in said body at a distance of a quarter-wavelength above and below said guide, whereby leakage of high frequency energy axially of said device due to clearance between said holder and said device is minimized.

10. A high frequency system, wherein a cylindrical high frequency device is removably coupled to a pair of wave guides, comprising a hollow cylindrical holder body adapted to surround said device and having said guides communicating with the interior thereof, said body having a quarter-wave deep slot formed therein extending parallel to one edge of one of said guides and spaced a quarter-wavelength therefrom, whereby leakage of high frequency energy due to clearance between said holder and said device is minimized.

11. The combination as in claim 10 wherein the depth of said slot is formed axially and wherein said slot extends annularly about said holder to prevent leakage axially of said holder and device.

12. The combination as in claim 10 wherein the depth of said slot extends circumferentially about said holder, said slot extending axially of said holder to prevent leakage circumferentially of said device.

13. High frequency apparatus comprising an enclosed hollow holder for a high frequency device, a high frequency energy conductor fixed to said holder and communicating with the interior thereof, and a high frequency device removably and rotatably supported by said holder and comprising a casing having an opening therein for passage of high frequency energy, said opening being normally opposite the end of said high frequency energy conductor communicating with said holder and being adapted to cooperate variably therewith according to the rotary position of said device in said holder.

14. Apparatus comprising a high frequency device adapted to have high frequency energy flow therethrough, a hollow holder removably supporting said device, said holder surrounding said device and having high frequency energy conductors communicating with the interior thereof, said holder being spaced from said device, and means in said holder for preventing leakage of high frequency energy between said conductors and around said device.

15. High frequency apparatus wherein an enclosed high frequency device having apertures for the passage of high frequency energy is removably coupled to high frequency conductors, comprising a holder for said device including a hollow holder body surrounding said device and having a pair of rotatable sections, each opposite one of said apertures, each of said sections being fixed to one of said conductors to permit said holder to be utilized with any one of a plurality of devices having differing circumferential locations of said apertures.

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16. The combination as in claim 15, further including means at the joint between said conductors and said apertures for preventing leakage of energy therefrom.

17. High frequency apparatus comprising an enclosed, gas-filled cavity resonator having a cylindrical inner wall and two ends, and means including a window in said cylindrical wall for coupling high frequency energy thereto, said resonator having a higher mode of resonance at the operating frequency of said device, and said window being located remote from said ends of said resonator to facilitate fabrication thereof.

18. High frequency apparatus comprising a high frequency energy utilization device having openings for the entrance and egress of high frequency energy, and a holder removably supporting said device positioned adjacent to and spaced from said device, said holder supporting high frequency energy conductors opposite said openings and spaced therefrom by gaps, said holder including means therewithin for preventing leakage of high frequency energy at said gaps between said conductors and said openings.

19. High frequency apparatus comprising a high frequency energy utilization device having an opening for coupling high frequency energy thereto, a holder removably supporting said device positioned adjacent to and spaced from said device, and a high frequency energy conductor fixedly supported by said holder opposite said opening, said holder including means therewithin for preventing leakage of high frequency energy at the gap between said conductor and said opening.

20. A high frequency system wherein a high frequency device is removably coupled to a high frequency conductor, comprising means coupling said conductor to said device, said coupling means comprising means removably holding said device in a predetermined relation to said conductor to form an effective junction therebetween, and including means therewithin for minimizing the impedance of the joint between said conductor and said device.

21. Apparatus as in claim 20, wherein said last-named means comprises means forming a quarter-wave transmission line section having said junction as a termination, said section being connected at its outer end to a quarter-wave short-circuited transmission line section in series with the leakage gap between said device and said holding means, whereby leakage of high frequency energy through said gap is minimized.

22. High frequency apparatus wherein an enclosed high frequency device having apertures for the passage of high frequency energy is removably coupled to a pair of high frequency conductors, comprising a holder for said device including a hollow holder body surrounding said device and having a pair of sections each opposite one of said apertures, each of said sections supporting one of said conductors, whereby high frequency energy may be led toward and away from said device.

23. High frequency apparatus wherein an enclosed cylindrical high frequency device having axially displaced apertures in the cylindrical wall thereof for the passage of high frequency energy is removably coupled to high frequency conductors, comprising a holder for said device including a hollow holder body surrounding said device and having a pair of sections each opposite one of said apertures, each of said sections carrying one of said conductors.

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24. High frequency apparatus comprising a high frequency energy utilization device having openings for the entrance and egress of high frequency energy, and a holder for removably supporting said device and positioned adjacent to and spaced from said device, said holder supporting high frequency energy conductors opposite said openings and spaced therefrom by gaps and including means therewithin for preventing leakage of high frequency energy at said gaps between said conductors and said openings, said leakage preventing means including resonant transmission line means.

25. A high frequency system, wherein a cylindrical high frequency device is removably coupled to a pair of wave guides, comprising a hollow cylindrical holder body adapted to surround said device and having said guides communicating with the interior thereof, said body having a quarter-wave deep slot formed therein, the depth of said slot being formed radially of said body, said slot extending annularly of said body and parallel to one edge of one of said guides and spaced a quarter-wavelength therefrom, whereby leakage of high frequency energy axially of said holder due to clearance between said holder and said device is minimized.

26. A high frequency system, wherein a cylindrical high frequency device is removably coupled to a pair of wave guides, comprising a hollow cylindrical holder body adapted to surround said device and having said guides communicating with the interior thereof, said body having a quarter-wave deep slot formed therein, the depth of said slot being formed radially of said

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body, said slot extending axially of said body and parallel to one edge of one of said guides and spaced a quarter-wavelength therefrom, whereby leakage of high frequency energy circumferentially of said holder due to clearance between said holder and said device is minimized.

27. Apparatus comprising a high frequency device adapted to have high frequency energy flow therethrough, a hollow holder removably supporting said device, said holder surrounding said device and having high frequency energy conductors communicating with the interior thereof, said holder being spaced from said device, and means in said holder for preventing leakage of high frequency energy between said conductors and around said device, said leakage-preventing means comprising quarter-wave sections of alternately wide and narrow clearance between said device and said holder, whereby said energy is prevented from flowing in the space between said device and said holder.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

30 Number	Name	Date
2,106,770	Southworth et al.	Feb. 1, 1938
2,106,771	Southworth	Feb. 1, 1938
2,128,234	Dallenbach	Aug. 30, 1938
2,153,728	Southworth	Apr. 11, 1939
35 2,300,052	Lindenblad	Oct. 27, 1942

Certificate of Correction

Patent No. 2,454,761.

November 30, 1948.

WILMER L. BARROW ET AL.

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows:

Column 11, line 56, claim 1, after "means" insert *coupled to said second electrode*; line 58, after the word "tube" strike out the comma and insert instead a period; same line beginning with "whereby" strike out all to and including the word and period "means." in line 66 same claim; column 13, line 64, beginning with "15. High frequency" strike out all to and including the word and period "therefrom." in line 4, column 14, and insert instead the following:

15. High frequency apparatus comprising an enclosed, gas-filled cavity resonator having a cylindrical wall, and means in said wall for coupling thereto energy of a frequency required to form voltage antinodes at a plurality of positions therein, said coupling means being located adjacent one of said positions.

16. Apparatus as in claim 15, wherein said resonator includes a pair of opposed reentrant portions providing an internal gap near one end of said resonator.

and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 5th day of July, A. D. 1949.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.