Feb. 3, 1953 H. J. RIBLET 2,627,573

WAVE GUIDE DUPLEXER

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FIG. 1.

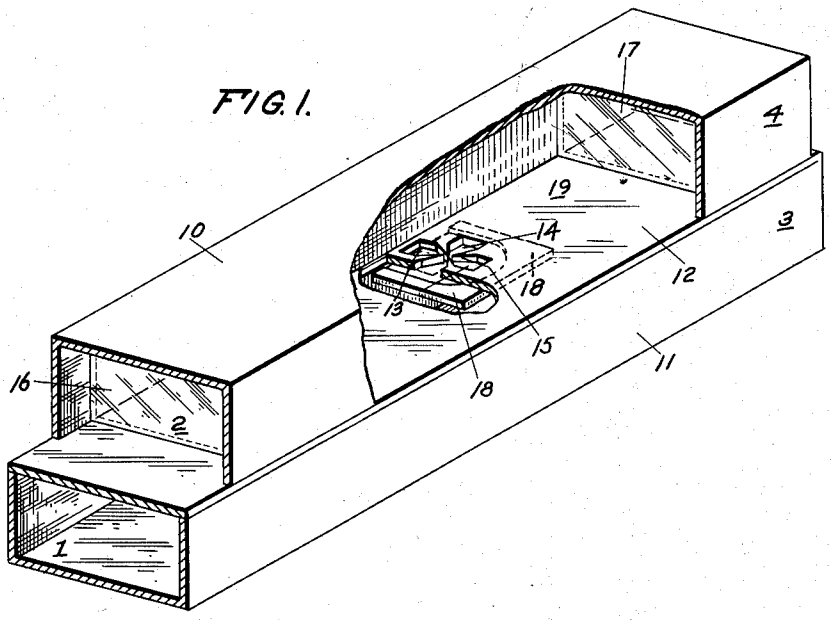


FIG. 2.

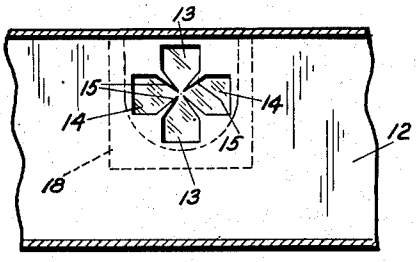


FIG. 3.

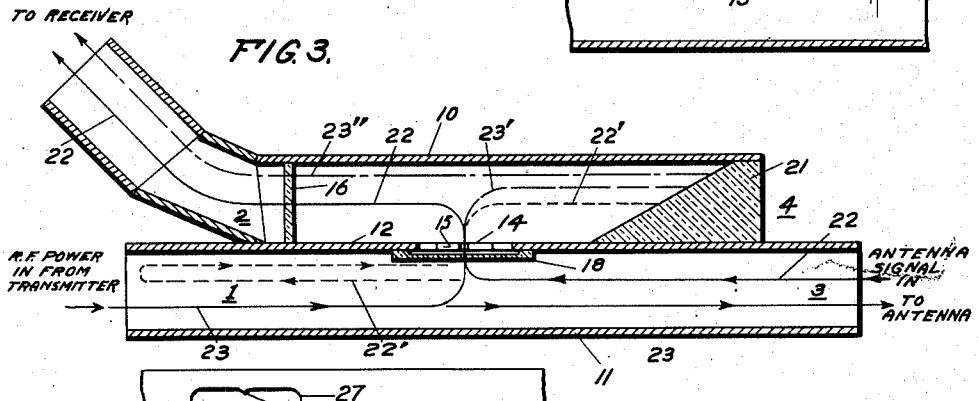
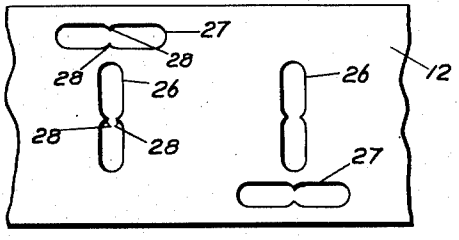


FIG. 4.



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WAVE GUIDE DUPLEXER

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FIG. 5.

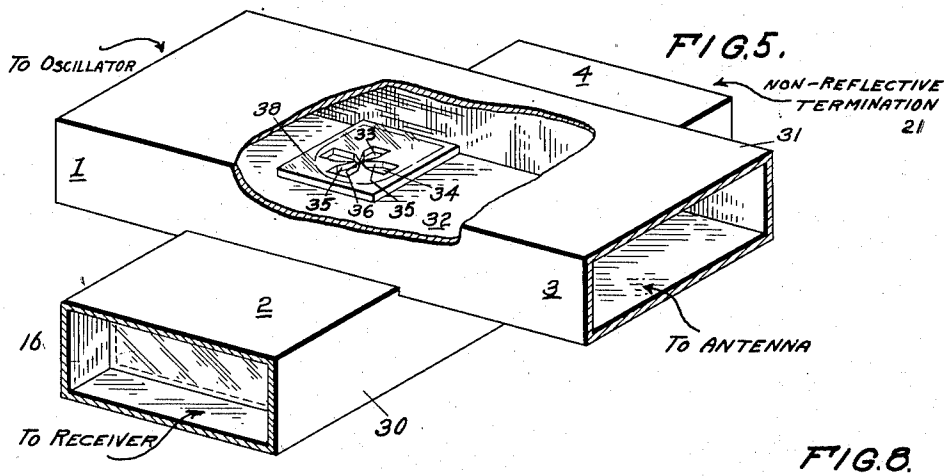


FIG. 6.

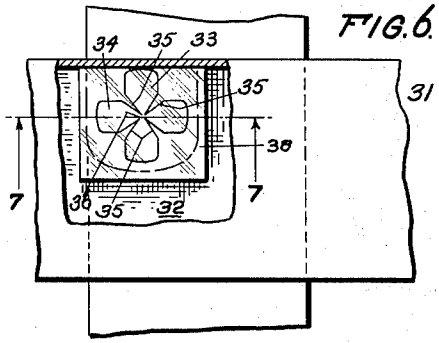
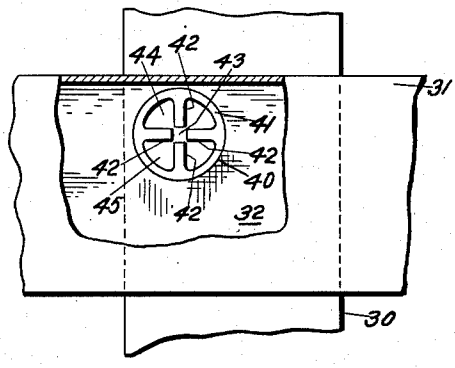


FIG. 8.



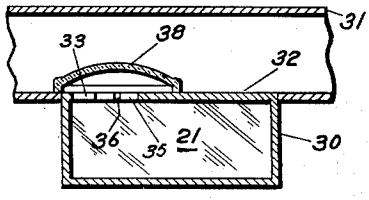


FIG. 7.

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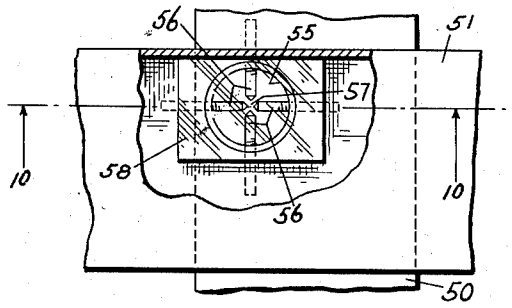


FIG. 9.

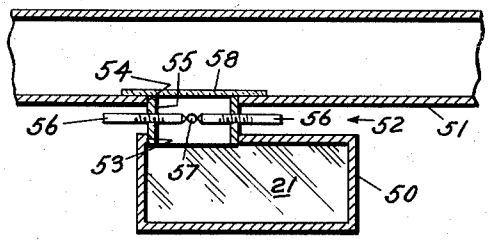
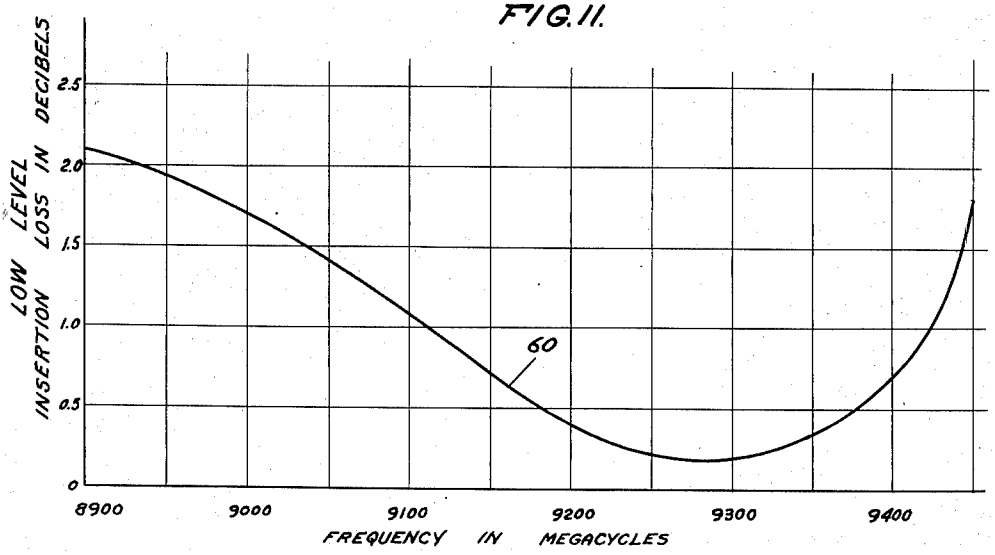


FIG. 10.

FIG. 11.



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UNITED STATES PATENT OFFICE

2,627,573

WAVE GUIDE DUPLEXER

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Application April 28, 1948, Serial No. 23,822

20 Claims. (Cl. 250—13)

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This invention relates in general to duplexing equipment for radar systems and the like, and in particular to a novel duplexer for microwave systems which combines in a single unit the functions of T–R and anti T–R.

In radar systems, there is usually a single antenna for use in both transmitting and receiving. To prevent the strong bursts of energy that are available during transmission from entering the receiver, an electronic switch is provided which has the effect of decoupling the receiver from the system and coupling the antenna to the transmitter alone during transmission. When transmission ceases, the receiver is effectively recoupled to the system. This switch is generally known as a "duplexer," or a "transmit-receive" device, or, simply, a "T–R," and includes as an element a spark gap, properly located in the transmission lines that interconnect the receiver and transmitter with the antenna, and adjusted to break down when power of the order of that available from the transmitter is flowing through the transmission line between the transmitter and the antenna, but not when the lower order power such as is available during reception is present. It is now customary to provide a certain amount of auxiliary unidirectional potential, for example, about 300 volts, as a "keep alive" in the vicinity of the spark gap, to maintain an amount of residual ionization of the gases surrounding the gap and thereby assure firing of the gap during transmission. During reception, some of the received energy attempts to enter the transmitter, which is at that time poorly matched impedancewise to the transmission line, and is mostly reflected. To prevent this energy from disturbing the system, a second spark gap device is employed, properly located in the transmission line system with respect to the first. This second device functions during receiving to decouple the transmitter from the system, and is known as an "anti T–R" or "R–T." The two spark gap devices are intended to have the effect of decoupling the transmitter from the receiver at all times.

It is an object of this invention to provide an improved duplexer which is small, compact, and rugged in construction.

It is a further object to provide an improved duplexer which reduces the number of discharge tubes required in radar systems and generally simplifies the construction of such systems.

It is a still further object to provide such a duplexer which is readily installed in a radar system with known installation techniques.

The invention consists essentially of a four-terminal network composed of two waveguides directionally coupled together, for example, at a common wall by means of slots in said wall, and is based on the discovery that the directional coupler character of the network is not destroyed when the coupling slots are short-circuited, for example, by an ionic discharge. The network is connected in a radar system by coupling three of the terminals thereof to the radio frequency power source or transmitter, the antenna, and the receiver, respectively, and providing the fourth terminal with a non-reflective termination. Other and further advantages and characteristics of the invention, as well as the details of certain particular embodiments thereof, will become apparent from the discussion that follows, reference being made to the accompanying drawings, wherein:

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Fig. 1 illustrates a duplexer constructed in accordance with the invention;

Fig. 2 is a top plan view of the coupling slot arrangement of Fig. 1;

Fig. 3 is a side-sectional view of a duplexer like that of Fig. 1, showing the manner of connecting it into a radar system;

Fig. 4 illustrates another form of duplexer constructed in accordance with the invention;

Fig. 5 illustrates a preferred form of the duplexer shown in Fig. 1;

Fig. 6 is a top plan view of the duplexer shown in Fig. 5;

Fig. 7 is a view taken on the line 7—7 of Fig. 6;

Fig. 8 is a top plan view of a modification of the duplexer of Fig. 5;

Fig. 9 is a top plan view of another modification of the duplexer shown in Fig. 5;

Fig. 10 is a view along line 10—10 in Fig. 9; and

Fig. 11 is a performance curve illustrating a certain broad band characteristic of the invention.

Referring now to Fig. 1, two parallel waveguides 10 and 11 are joined together at a common wide wall 12. A pair of rectangularly crossed slots 13 and 14 is cut in this common wall, in a region to one side of the longitudinal center line thereof. At each of the four points where the walls of the slots intersect, the material of the wall 12 is continued in the form of a pointed extension 15 in the direction of a diagonally oppositely-disposed intersection point. The extensions 15 extend toward the geometric center of the slot configuration, and all terminate just short thereof, so that their ends are all very near to but do not touch each other. This con-

struction is shown more clearly in Fig. 2. The slots 13 and 14 are each resonant to the mid-band frequency of the operative frequency band, and consequently tend to effect practically 100 percent transfer from one waveguide to the other of power at that frequency. The upper waveguide 10 is sealed at both sides of the slot arrangement with suitable gas impervious but electromagnetic wave pervious windows 16, 17 made of glass, mica, or the like, and a similar window 18, shown in dotted line in Fig. 1 but more clearly in Fig. 3, is provided in the other waveguide 11, mounted on the common wall 12 and covering the slots 13 and 14. There is thus provided a sealed chamber 19 in the upper waveguide 10, and the extensions 15 are in this chamber. The chamber 19 is partially evacuated, and may contain any suitable gas, for example, hydrogen or argon, and water-vapor at a pressure below that of the atmosphere.

The four terminals of the duplexer of Fig. 1 are denominated 1, 2, 3, and 4, the ends of the lower, unsealed waveguide 11 being terminals 1 and 3, respectively, and the ends of the upper, sealed waveguide 10 being terminals 2 and 4, respectively. This duplexer is connected with a complete system as shown in Fig. 3. Terminal 1 is connected to the transmitter, or source of radio frequency power (not shown), which is usually the magnetron. Terminal 2 is connected to the receiver (not shown). Terminal 3 is connected to the antenna (not shown). Terminal 4 is connected to a non-reflective termination 21, which may replace and assume the sealing function of the window 17 shown in terminal 4 in Fig. 1. Alternatively, the window 17 may be retained, and terminal 4 may be connected to a suitable dummy load (not shown) which does not reflect energy. In Fig. 3, the window 18 at the slots is shown in cross section, and it should be noted that this window is spaced away from the wall material in the immediate vicinity of the slots 13 and 14 and the extensions 15. The purpose of this will be presently explained.

As has already been set forth, the present duplexer is essentially a directional coupler. Considering first the relatively low power that is available as a received signal from the antenna, this power enters terminal 3, in the direction of line 22, and proceeds to the left along the lower waveguide 11. When the received signal arrives at the resonant slots 13 and 14, it is directionally coupled over into the upper waveguide 11, and proceeds through terminal 2 to the receiver (not shown). A small fraction of the received signal fails to be coupled over into the upper waveguide 10, and, as indicated by a dotted line 22', proceeds toward terminal 1 and the transmitter.

Here, however, there is a marked impedance mismatch, due to the fact that the transmitter is dormant, and this stray signal power is reflected back toward terminal 3. On arriving at the slots 13 and 14, however, the stray signal power is directionally coupled into the upper waveguide 10, and therein to the non-reflective termination 21, where it is completely absorbed for all practical purposes. This action of the present duplexer renders unnecessary the special anti T–R circuits that have heretofore been employed in radar systems, for, with the present duplexer, the transmitter is effectively decoupled from the receiver.

Considering now the relatively high radio frequency power that is available from the transmitter, this power enters the duplexer at terminal 1 and proceeds to the right along the lower waveguide 11 as indicated by line 23. When this power arrives at the slots 13 and 14, it tends normally to proceed through the slots into the upper waveguide 10 and toward terminal 4 and the non-reflective termination 21. However, the voltage produced across the slots is so great that the gaps between the ends of the extensions 15 are highly ionized, and, since the gas that surrounds the gaps is at a low pressure, the gaps break down, as in the low pressure gap tubes that are employed in prior art duplexing devices. The window 18 is spaced away from the extension 15 so that it will not be burned during the breakdown of the gaps. The conductive path that is thereby provided across the gaps effectively detunes the slots and they are for all practical purposes absent, so that the great bulk of the oscillator power proceeds to the antenna through terminal 3. A small amount of transmitter power is coupled into the upper waveguide 10, however, and proceeds toward the non-reflective termination 21. I have discovered and verified experimentally that the directional coupler nature of the present device is not destroyed by the firing of the gaps between the ends of the extensions 15, and that the portion of the transmitter power that is coupled through the slots 13 and 14 during firing of the gaps is coupled directionally, as indicated by the dashed line 23', as though the gaps were not fired. In other words, that the present duplexer has high level directivity as well as low level directivity is an experimental fact which distinguishes the present duplexer in performance from conventional balanced duplexers. The non-reflective termination 21 absorbs practically all of the stray transmitter power that is coupled into the upper waveguide 10, so that only a very small amount of such stray power is reflected therefrom. The small amount of this power that is reflected proceeds to the receiver, as indicated by the dot-dashed line 23'', since the gaps are still fired and it cannot be coupled back in any appreciable quantity to the transmitter.

The voltage level of the transmitter power that eventually finds its way to the receiver is so low that it cannot burn out the crystal detector that is ordinarily found there. Thus the present duplexer combines in one device the functions of the T–R and the anti T–R circuits of the known art.

In general and as will be discussed in detail in connection with Fig. 11, the amount of received signal power that is not coupled into the receiver is no greater than 2 db of total power furnished at terminal 3 over a band of frequencies of the order of 500 megacycles wide at 9300 mc. mean operating frequency and may be as low as 0.2 db thereof in a narrower band. Thus within the wider band, at least 63 percent of the received signal power arrives at the receiver. On the other hand, the transmitter power that is coupled out of the lower waveguide 11 into the upper waveguide 10 is at a level approximately 40 db below that in the lower waveguide 11, so that nearly 100 percent of the transmitter power is furnished to the antenna. The fraction of the transmitter power that is furnished to the receiver by reflection from the practically reflectionless termination 21 is at the still lower level of approximately 60 db below that of the original power in the lower waveguide 11, and this small fraction cannot damage the receiver

crystal even when energy at a 30 kilowatt level is furnished by the transmitter.

While the crossed arrangement of the two slots 13 and 14 is preferred, as will be explained below, the invention may be practiced with directional couplers of other forms, such as the directional coupler shown and described in my copending application Serial No. 784,277, filed November 5, 1947. Fig. 4 shows a slot arrangement in accordance with the disclosure of said copending application. Thus the common wide wall 12 may be provided with one or more pairs of individual mutually perpendicular slots 26 and 27. The transversely-directed slot 26 is centered at the longitudinal center line of the wall 12, and the longitudinally directed slot 27 is centered to one side thereof, so that, when the excited waveguide is excited in the fundamental mode, each will be in a position of advantage for coupling energy, all as is explained in said copending application. The present arrangement differs from that of said copending application, however, in that the slots are resonant to the mid-band frequency of the operating frequency band, for, in the present invention, it is desired to secure, as nearly as possible, 100 percent coupling from one waveguide to the other. Each slot is provided with confronting projections 28 disposed in the long walls thereof so that they originate at points of high potential difference, which function as discharge electrodes in a low pressure atmosphere, as do the extensions 15.

When the slots 26, 27, and discharge electrodes 28 are all enclosed in a proper low pressure gaseous atmosphere, as in Fig. 1, the directional coupler in accordance with Fig. 4 may be employed in place of the crossed slot arrangement of Fig. 1 to provide a duplexer which behaves basically like that of Fig. 1. It is possible, however, that one of the slots 26 or 27 of a pair will fire prior to the other during the T–R function, and, if that happens, the directional coupler action will be impaired and the output signal pulse at the antenna will not be sharp and distinct, but may be irregular, with some power lost through one of the slots into the termination 21 or perhaps even into the receiver, where damage might result to the crystal. Hence, one reason for preferring the crossed slot configuration shown in Fig. 1 is that, because the gaps of the two slots 13 and 14 are practically coextensive, the firing of one slot necessarily fires the other. In this way, the directional coupler behaves the same each time the gap is fired. The crossed slot configuration is set somewhat to one side of the longitudinal center line in the common wide wall 12 so that each slot will by itself transfer the same amount of power from one waveguide to the other.

Referring now to Figs. 5, 6, and 7, the embodiment of the invention there shown employs two waveguides 30 and 31 which are rectangularly disposed with relation to each other and joined together in a common wide wall section 32. The junction may be made by removing a portion of, for example, the lower wide wall of the top waveguide 31 and soldering together the two waveguides so that a portion 32 of the upper wide wall of the lower waveguide 30 is common to both waveguides. A crossed slot configuration similar to that of Fig. 1, made of two slots 33 and 34, is provided in one corner of the common wall area 32, so that it is to one side of the longitudinal center line of each waveguide. The lower waveguide 30 is sealed at both ends with the window 16 and the non-reflecting termination 21, and a sealing window 38, corresponding to the window 18 in Figs. 1 and 3, is provided in the upper waveguide covering the slots 33 and 34. A gap 36 is provided among four extensions 35, which correspond to the extensions 15 in Fig. 1. The covering window 38 is preferably arched as shown in Fig. 7 so that sparking across the gap 36 will not burn it. As will be readily appreciated, the lower waveguide 30 of Fig. 5 corresponds to the upper waveguide 10 of Fig. 1, and the upper waveguide 31 of Fig. 5 corresponds to the lower waveguide 11 of Fig. 1. The various terminals 1, 2, 3, and 4 of the duplexer shown in Fig. 5 are denominated the same as the corresponding terminals in Fig. 1, and are intended to be connected in a system in the same manner as shown in Fig. 3. The crossed waveguide configuration of Figs. 5, 6, and 7 provides an arrangement wherein equal powers are transferred by the two slots at all frequencies in the operative frequency band, thereby enhancing the bandwidth and overall performance of the device.

Referring now to Fig. 8, the embodiment there shown employs a replaceable slot and gap element 40, which is mounted in the common wall section 32. This element may be soldered or screw-threadedly engaged in the wall 32, as desired, and consist of a rim portion 41 and equally spaced around the circumference thereof four radially inwardly projecting arms 42, which extend toward the center to provide a gap 43. The arms define a pair of somewhat wing-shaped crossed slots 44 and 45, which together have the appearance of a four-leaf clover. In fact, the slots 13 and 14 or 34 and 35 may also be rounded at the outer ends to provide a similar appearance. The crossed-slot arrangement of the invention has therefore given rise to the term "clover-leaf duplexer" to describe the invention. As shown in Fig. 8, the slots may be directed diagonally with respect to the longitudinal axes of the waveguides 30 and 31, if desired. With the element 40 in place of the slots 34 and 35, the slot and gap portions may be changed if the gaps burn away after long use. Of course, the remaining features of the duplexer of Figs. 5, 6 and 7 are retained; that is, suitable windows corresponding to windows 16 and 38 and a suitable matched load or non-reflective termination like termination 21 are provided as set forth above.

The embodiment of the invention that is shown in Figs. 9 and 10 is electrically the same as those of Figs. 1, 5, and 8, but provides a different mechanical structure wherein the gap is adjustable and the electrodes are more easily renewed. Two waveguides 50 and 51 are disposed at right angles to each other, with wide walls confronting, and a small space 52 between them. Each waveguide is provided with an aperture 53, 54, respectively, in the wide wall confronting the other. The apertures are collinear and each is near an edge of its wall, so that, as shown in the top plan view of Fig. 9, they are disposed in a corner of the square region where one waveguide 51 is directly above the other 50. This disposition is the same as that of the slots in the embodiments shown in Figs. 5 and 8. A tube 55 of electrically conductive material connects the two apertures. This tube is in effect a short length of waveguide, and is preferably maintained as short as possible. The tube is provided with four radially inwardly directed screws 56 which approach but do not meet at the center. The space between

their inner ends provides a spark gap 57. The lower wave guide 50 is sealed at one end with the non-reflecting termination 21 or the like and at the other end with the window 16 (not shown). The aperture 54 of the upper waveguide 51 is closed inside that waveguide with a window 58. The spark gap 57 is thus completely sealed off from the atmosphere and can be surrounded with gas at a low pressure. The screws 56 provide for adjustment of the gap and can be replaced. The threaded fit of the screws into the tube 55 must be such that low pressure can be maintained around the spark gap. This can be assured by providing a solder seal (not shown) after the gap 57 is adjusted, thus assuring a permanently adjusted gap as well as a gas seal.

The crossed slot coupling of the present invention has the unique advantage that the duplexer employing it requires no keep-alive potential, as is required in prior known duplexers. Unlike the field in the gap of an ordinary T–R tube which is linearly polarized, the field in the cross slot gap of the present invention is circularly polarized. This means that the field is never zero and that the ionization products will tend to travel in circular paths. Of the experimental duplexers that have been built and tested, none has been provided with a keep-alive potential, and yet none has been known to hold off firing.

In the so-called X-band, which is in the region of 3 centimeter wavelengths, the duplexer according to Figs. 5 and 8 occupies a space which can be made as small as one cubic inch. This small space includes both the T–R and the anti T–R equipment, which is a vast saving in space over the prior known arrangements.

As has been pointed out above in the discussion of Fig. 3, the duplexer of the present invention is actually a directional coupler at both high and low levels, with a practically non-existent amount of loss at high levels, and the directional coupler feature at high levels provides for protection of the receiver. For example, the high level loss due to the duplexer has been found on some samples to be from 0.1 to 0.3 db. At low levels, however, that is, during receiving, the duplexer is a directional coupler in the ordinary sense, the slots being in the un-fired condition, and there is a loss of energy due to the insertion thereof between the antenna and the receiver. Fig. 11 shows the amount of the insertion loss for a typical duplexer operating in the X-band. The curve 60 shows that over a wide band, from 8900 to greater than 9400 megacycles per second, the insertion loss was never greater than 2.1 db. In the band from 9180 to 9375 megacycles, the loss was 0.5 db or less.

Further measurements that have been made indicate that the recovery time of the present duplexer is at least as good as that of prior known duplexers. In other characteristics, such as leakage power, it is likewise as suitable as other duplexers. In its lower losses at both high and low levels, its savings in space, cost, and weight, and in many other features that have been pointed out above, it is vastly superior to the prior known duplexers.

Duplexers constructed in accordance with the present invention may take many physical forms, and no attempt has been made herein to illustrate more than but a few examples. Accordingly, it is intended that the claims that follow shall not be limited by the herein described details, but only by the prior art. In the claims that follow, the term "directional coupler" shall be understood to mean a device consisting of a first or main transmission line and a second or auxiliary transmission line, each line having two ends, or terminals, the lines being coupled together at a point or points intermediate the ends of each, which, when there exist waves travelling in both directions in the main line, delivers to one end of the auxiliary line a voltage which is largely a function of the amplitude of the wave going in one preferred direction in the main line, and relatively independent of the wave going in the opposite direction in the main line.

I claim:

1. A duplexer adapted to be used with ultra-high frequency electromagnetic wave energy comprising a directional coupler consisting of first and second transmission lines each having two terminals and having at least one coupling element connected to each of said lines at a region intermediate the ends thereof, and electrode means connected in shunt with said element for positively short circuiting the input to said element when the coupled power exceeds a predetermined value.

2. A duplexer adapted to be used with ultra-high frequency electromagnetic wave energy comprising a directional coupler consisting of first and second transmission lines each having two terminals and having a coupling element tuned substantially to a prescribed frequency band of said energy and connected to each of said lines at a region intermediate the ends thereof, and electrode means connected in shunt with said element for positively short circuiting the input to said element when the coupled power exceeds a predetermined value.

3. A duplexer adapted to be used with ultra-high frequency electromagnetic wave energy comprising a directional coupler consisting of two waveguides having a wave conducting passage between them coupled to each waveguide through a side wall at a region intermediate the ends thereof for the coupling of wave energy from one waveguide to the other, and electrode means partially bridging said passage and arranged to provide an ionic discharge across the passage when the energy being coupled exceeds a predetermined value.

4. A duplexer adapted to be used with ultra-high frequency electromagnetic wave energy comprising a directional coupler consisting of two waveguides having a wave conducting passage between them coupled to each waveguide through a side wall at a region intermediate the ends thereof for the coupling of wave energy from one waveguide to the other, electrode means partially bridging said passage and arranged to provide an ionic discharge across the passage when the energy being coupled exceeds a predetermined value, and means providing an hermetically sealed cell about said electrode means.

5. A duplexer adapted to be used with ultra-high frequency electromagnetic wave energy comprising a directional coupler consisting of two waveguides having a wave conducting passage between them coupled to each waveguide through a side wall at a region intermediate the ends thereof for the coupling of wave energy from one waveguide to the other, electrode means disposed in said passage and arranged to provide an ionic discharge across the passage when the energy being coupled exceeds a predetermined value, and means providing an hermetically sealed cell about said electrode means, said cell

means consisting of a pair of gas impervious electromagnetic wave pervious windows disposed across one of said waveguides one at each side of said passage, and a third similar window disposed in the other of said waveguides and closing said passage.

6. A duplexer adapted to be used with ultra-high frequency electromagnetic wave energy comprising a pair of waveguides each having two terminals and having a common side wall, slot means in said common wall located intermediate the terminals of each waveguide and arranged directionally to couple said waveguides and electrode means partially bridging said slot means and effective substantially to close said slot means when the energy being coupled exceeds a predetermined value.

7. A duplexer adapted to be used with ultra-high frequency electromagnetic wave energy comprising a pair of rectangular waveguides each having two terminals and having a common wide wall, a pair of mutually perpendicularly crossed slots in said common wall located intermediate the terminals of each waveguide and centered at a point not on the longitudinal center line of either waveguide, and electrode means partially bridging said slot means and effective substantially to close said slots when the energy being coupled exceeds a predetermined limit.

8. A duplexer adapted to be used with ultra-high frequency electromagnetic wave energy comprising a pair of waveguides each having two terminals and having a common side wall, slot means in said wall located intermediate the terminals of each waveguide and arranged directionally to couple said waveguides, said means being resonant to the mid-band frequency of the operative frequency band, and electrode means partially bridging said slot means and effective substantially to close said slot means when the energy being coupled exceeds a predetermined limit

9. A duplexer adapted to be used with ultra-high frequency electromagnetic wave energy comprising; a pair of mutually perpendicularly disposed rectangular waveguides each having two terminals and coupled together through adjacent wide wall parts at regions intermediate the terminals of each waveguide, a slot configuration of two mutually perpendicular slots providing directional coupling, spark electrodes extending across said configuration, and a gap between said electrodes, of a size to break down when the energy being coupled exceeds a predetermined level.

10. In a microwave radio transmit and receive system having a transmitter, a receiver, and a single antenna for both functions, in combination: a first waveguide connected between the transmitter and the antenna, a second waveguide connected at one end to the receiver and terminated at the other end in a non-reflective termination, means directionally coupling said waveguides together intermediate their ends so that energy entering the first waveguide from the antenna is guided to the receiver and energy entering said first waveguide from the transmitter would normally be guided to said termination, and spark electrode means partially bridging the coupling means and having a gap of a size which breaks down each time the transmitter is operated.

11. In a microwave radio transmit and receive system having a transmitter, a receiver, and a single antenna for both functions, in combination: a first waveguide connected between the transmitter and the antenna, a second waveguide connected at one end to the receiver and at the other end to a non-reflective termination, means substantially resonant to the frequency of operation of the transmitter for directionally coupling said waveguides together intermediate their ends so that energy entering the first waveguide from the antenna is guided to the receiver and energy entering said first waveguide from the transmitter would normally be guided to said termination, and spark electrode means partially bridging the coupling means and having a gap of a size which breaks down each time the transmitter is operated.

12. In a microwave radio transmit and receive system having a transmitter, a receiver, and a single antenna for both functions, a duplexer comprising: a four-terminal directional coupler having first and second waveguides, said first waveguide being connected between the transmitter and the antenna, and said second waveguide being connected to the receiver at the end to which energy from the antenna is normally directed and terminated at the other end with a non-reflective termination, the coupling between said waveguides being by way of a passage therebetween, spark electrodes extending part way across said passage, a gap between said electrodes, said gap being adjusted to break down each time the transmitter is operated.

13. A duplexer adapted to be used with ultra-high frequency electromagnetic wave energy comprising a pair of rectangular waveguides having a common wide wall, a pair of mutually perpendicular crossed slots in said common wall centered at a point not on the longitudinal center line of either waveguide, one of said slots being directed perpendicular to the longitudinal axis of one of said waveguides, and electrode means extending into said slots dimensioned substantially to close said slots when the energy being coupled exceeds a prescribed magnitude.

14. A duplexer adapted to be used with ultra-high frequency electromagnetic wave energy comprising a pair of mutually perpendicular waveguides having a common wide wall, a pair of mutually perpendicular crossed slots in said common wall centered at a point not on the longitudinal center line of either waveguide, one of said slots being directed perpendicular to the longitudinal axis of one of said waveguides, and electrode means extending into said slots dimensioned substantially to close said slots when the energy being coupled exceeds a prescribed magnitude.

15. A duplexer adapted to be used with ultra-high frequency electromagnetic wave energy comprising a pair of mutually perpendicular waveguides having a common wide wall, a pair of mutually perpendicular crossed slots in said common wall centered at a point not on the longitudinal center line of either waveguide, and electrode means extending into said slots dimensioned substantially to close said slots when the energy being coupled exceeds a prescribed magnitude.

16. A duplexer adapted to be used with ultra-high frequency electromagnetic wave energy comprising a pair of rectangular waveguides coupled together at a common wide wall, a slot configuration of two mutually perpendicular slots in said wall providing directional coupling, said configuration being disposed away from the longitudinal center line of said wall for either wave-

guide, spark electrodes extending across said configuration, and a gap between said electrodes, of a size adapted to break down when the energy being coupled exceeds a predetermined level.

17. A duplexer adapted to be used with ultra-high frequency electromagnetic wave energy comprising a pair of mutually perpendicularly disposed rectangular waveguides coupled together at a common wide wall, a slot configuration of two mutually perpendicular slots in said wall providing directional coupling, each slot being disposed parallel to the longitudinal axis of one of said waveguides, said configuration being disposed away from the longitudinal center line of said wall for either waveguide, spark electrodes extending across said configuration, and a gap between said electrodes, of a size adapted to break down when the energy being coupled exceeds a predetermined level.

18. A duplexer adapted to be used with ultra-high frequency electromagnetic wave energy comprising a directional coupler consisting of first and second transmission lines each having two terminals and having at least one coupling element connected to each of said lines at a region intermediate the ends thereof, and spark electrode means partially bridging said element for effectively short-circuiting the input to said element when the coupled power exceeds a predetermined value, said means providing a substantially circularly polarized ionic discharge across said input.

19. A duplexer adapted to be used with ultra-high frequency electromagnetic wave energy comprising a directional coupler consisting of two waveguides having a wave conductive passage between them coupled to each waveguide through a side wall at a region intermediate the ends thereof for the coupling of wave energy from one waveguide to the other, and electrode means partially bridging said passage and arranged to provide an ionic discharge across the passage when the energy being coupled exceeds a predetermined value, said electrode means being constructed to provide a substantially circularly polarized discharge.

20. A duplexer adapted to be used with ultra-high frequency electromagnetic wave energy comprising a directional coupler consisting of two waveguides having a wave conducting passage between them coupled to each waveguide through a side wall at a region intermediate the ends thereof for the coupling of wave energy from one wave guide to the other, electrode means disposed in and partially bridging said passage and arranged to provide an ionic discharge across the passage when the energy being coupled exceeds a predetermined value, and means providing a hermetically sealed cell about said electrode means, said cell means consisting of gas impervious electromagnetic wave pervious means closing said passage in one of said waveguides, and similar window means disposed in the other of said waveguides and closing said passage.

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