Jan. 29, 1963 T. E. MANWARREN 3,076,157

HIGH POWERED DUPLEXING ARRANGEMENT

Filed June 29, 1959

2 Sheets-Sheet 1

FIG.IA.

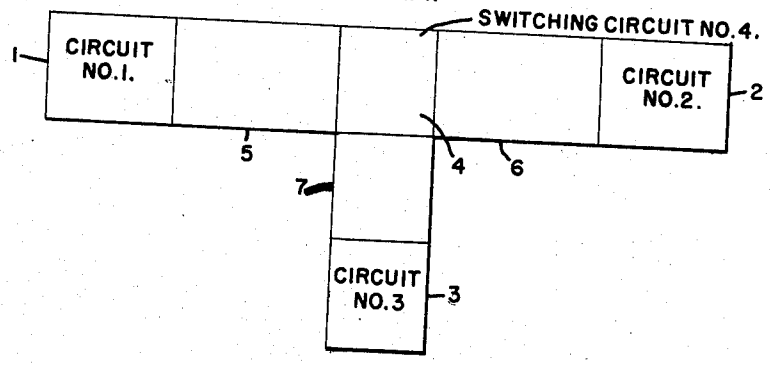


FIG.IB.

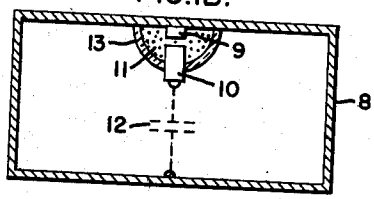
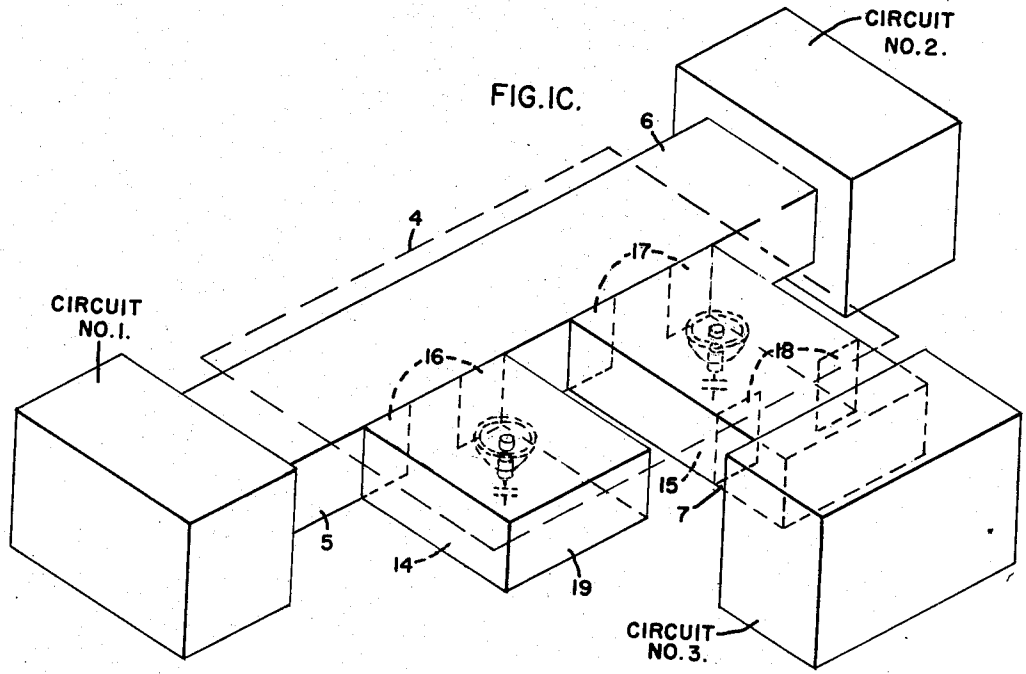


FIG.IC.



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FIG.2.

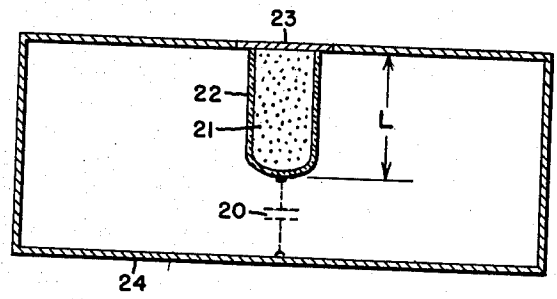


FIG.3.

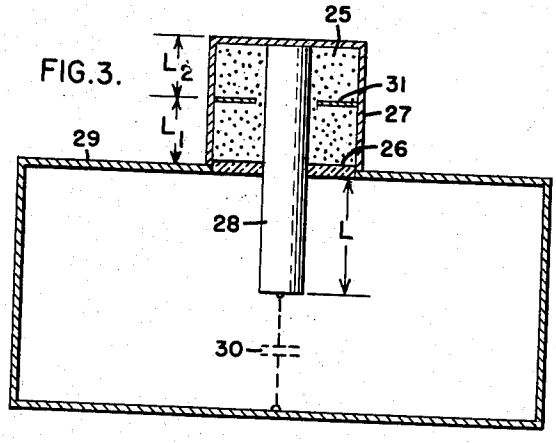
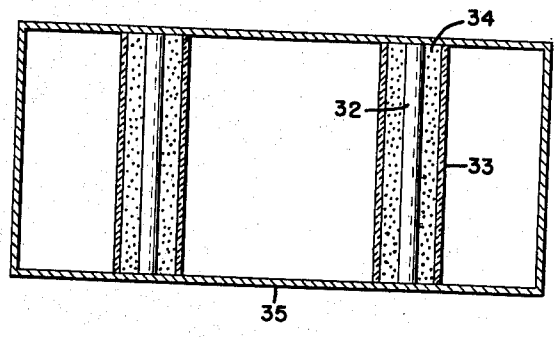


FIG.4.



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3,076,157

HIGH POWERED DUPLEXING ARRANGEMENT

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2 Claims. (Cl. 333—83)

This invention relates generally to the transmission and reception of electromagnetic waves and more particularly to a method and means for automatically and selectively switching waves of high and low power level to predetermined circuits. Reference can be made to Patent 2,408,055 issued to M. D. Fiske on September 24, 1946 for a detailed description of the manner in which a duplexing arrangement functions to switch electromagnetic waves between various load circuits.

In effecting the propagation of electromagnetic waves along wave guiding structures such as waveguides, coaxial lines, etc., it is oftentimes desirable to selectively switch waves of different power to respective load circuits. For example, in the field of radar obstacle detection it is a common practice to operate the pulse transmitter and the pulse echo receiver in conjunction with a common antenna. By providing a waveguide switch in a section of the waveguide feeding the antenna which is common to both the transmitter and the receiver, it is possible to limit substantially all the transmitted energy to the antenna and all the received energy to the receiver with an acceptable minimum of interchange of energy between the transmitter and receiver. If the switching apparatus were made non-linear, that is, dependent upon the intensity of applied wave energy, then an automatic switching circuit results.

It is an object of the present invention to provide an improved method for operating a transmitter into and a receiver from a common antenna system.

A further object of the invention is to provide an improved transmit-receive switching device which can effectively handle a larger amount of power from a transmitter than heretofore possible.

It is another object of my invention to provide a novel method and means for selectively routing electromagnetic waves of different energy intensity into separate channels.

It is another object of my invention to provide a method and means for automatically changing the impedance of an electrical network in accordance with the intensity level of propagated waves to effect switching of said waves in a desired manner.

It is a further object of my invention to provide an improved signal processing arrangement.

The novel features which are believed to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with other objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings in which:

FIGS. 1*a*, 1*b* and 1*c* illustrate schematically wave energy switching in an electrical network employing an ionizable medium;

FIG. 2 illustrates schematically an embodiment of the

invention wherein an ionizable medium in series with a capacitive reactance constitutes a switching network;

FIG. 3 illustrates schematically an embodiment of the invention wherein the ionizable medium is physically located outside the waveguide structure wherein electrical waves are to be controlled; and

FIG. 4 illustrates schematically a circuit network arrangement in which a reactance is placed in parallel with an ionizable medium for effecting control of waves propagated in a waveguide.

Referring to FIG. 1 there is shown an arrangement involving circuits 1, 2 and 3. In a particular application it is desired to selectively communicate electromagnetic waves between various combinations of the circuits while preventing the communication of waves between other combinations of these circuits. To effect this control there is provided a switching circuit 4 which couples the various circuits 1, 2 and 3 by means of waveguide sections 5, 6 and 7. In a specific embodiment, circuit 1 might comprise a radar transmitter which transmits high powered pulses of electromagnetic energy at a particular recurrence rate. It is desired to couple these high powered transmitter pulses to a load circuit 2 which might comprise an antenna for radiating the high frequency energy out into space. In effecting the coupling of high powered pulses from circuit 1 to circuit 2, it is desired to prevent the coupling of high powered pulses into circuit 3 which might comprise a receiver for receiving the relatively weak echo pulses returned from a remote object which has been illuminated by the transmitted pulses. After a predetermined interval of time dependent upon the distance from the antenna 2 to the illuminated object, a weak echo pulse is received in antenna 2 and it is a function of the switch 4 to couple the weak pulse over waveguide sections 6 and 7 to the receiver 3 while preventing the coupling of the weak pulses to the transmitter by way of waveguide section 5. This switching action is commonly referred to as duplexing wherein high intensity pulses and low intensity pulses are coupled to different channels. It is the function of the switching circuit 4 to respond automatically to the intensity of the wave being propagated between the waveguide sections 5, 6 and 7 to effect the proper switching.

Referring to FIG. 1*b*, there is shown in accordance with one embodiment of the invention a switching arrangement for use in a section of rectangular waveguide 8. FIG. 1*b* is a cross-section view through a resonant cavity formed in part by the walls of waveguide 8 with a switching network included therein comprising electrically conductive posts 9 and 10 coupled by an ionizable medium 11. The circuits comprising 9, 10 and 11 are connected in series with the distributed capacity, shown as 12, formed between the post 10 and the waveguide walls. The ionizable medium may comprise an enclosed vessel formed of a dielectric wall material 13 containing an ionizable gas such as argon, neon, crypton, zenon, etc. Under normal conditions with no or little wave energy being propagated through the cavity, the gas is non-ionized and the electrical circuit comprising 9, 10, 11 and 12 has a first impedance value affecting control of the waves propagated through the cavity in one manner. In response to the intensity of

waves propagated in the cavity above a predetermined level, the ionizable gas responds to become ionized and effect a change in the impedance value of the electrical circuit comprising elements 9, 10, 11 and 12 to effect control of the waves propagated in the cavity 8 in a manner different from said first manner. In the non-conducting, non-ionizable state the posts 9 and 10 are effectively connected to one another only by the high capacitive reactance of the gap between the posts. When the gas is ionized, a virtual short circuit joins the elements 9 and 10 together. However, all current which flows through the ionized medium 11 must also flow through the series reactance 12 and, therefore, the magnitude of current is reduced. This accomplishment effectively increases the power handling capacity of the duplexer.

Reference is now made to FIG. 1*c* wherein the functioning of the switching network shown in 1*b* is illustrated in greater detail. Wherever possible, common reference numerals have been retained in FIG. 1*c* to agree with those used in FIG. 1*b* and 1*a*. Actually, two electrical switching component networks, shown as 14 and 15, are employed in the arrangement of FIG. 1*c*. It should be noted that the resonant cavities are shown as being formed of rectangular waveguide sections with input and output coupling susceptances 16, 17 and 18. Briefly, these susceptances comprise conductive walls introduced at the junction of waveguides 5, 6 and 7 with the resonant cavities. Before describing the functioning of the arrangement of FIG. 1*c*, it may be well to consider for a moment the functioning of a cavity resonator which is coupled to a wave guiding structure. Briefly, the input impedance of the resonant cavity approximates very closely a short circuit when the resonant cavity is detuned from the operating frequency of the waves being propagated therethrough, thereby blocking passing of waves through the cavity. If the resonant cavity is tuned to the operating frequency of the waves being propagated therethrough, wave energy is permitted to be passed through the cavity resonator. This effectively constitutes an unblocked condition of the cavity.

In the arrangement of FIG. 1*c*, the electrical switching networks have been dimensioned such that when electromagnetic waves are being propagated with an intensity below a predetermined intensity level, or waves of the relatively low intensity level of reflected echoes, the cavity resonators are tuned to the system operating frequency. Assuming the tuned status of the resonators 14 and 15, we shall now describe a cycle of events illustrating the functioning of the switching circuits to provide the desired coupling of high and low intensity waves. Assuming circuit 1 is a generator of high powered pulses of megawatt intensity, these high powered radar pulses are transmitted over waveguide section 5 through the switching circuit 4, the waveguide section 6 to circuit 2 which might comprise a radar antenna for beaming the energy out to a remote object. A portion of the high powered pulse being communicated to the antenna 2 is coupled into the resonant cavities 14 and 15. Both cavities respond by having their ionizable mediums become ionized and effectively detune the cavity resonators with the help of the distributed capacity 12 and the conductive posts 9 and 10, shown in FIG. 1*b*. This detuning of the cavities results in an effective short circuit being exhibited at the cavity input ports across the susceptance walls 16 and 17. Thus very little wave energy is coupled to the load circuit 3, which might comprise the receiver. In effect, high powered pulses from circuit 1 are coupled to circuit 2 with substantially no electromagnetic reflections occurring in the intermediate waveguide couplings.

The transmitted pulse is reradiated from a remote object as a so-called echo pulse. This echo pulse of relatively low intensity of the order of microwatts is received at the circuit 2 which might comprise the same antenna. It is desired to couple this weak echo pulse to the receiver circuit 3 without losing any of the energy by coupling into the transmitter circuit 1. At the conclusion of the transmitted pulse, the ionizable mediums in cavities 14 and 15 become de-ionized, and return the cavities to their tuned condition. As previously mentioned, in the tuned condition waves are coupled through the cavity 15 to circuit 3. To optimize coupling, the impedance of circuit 3 is matched with the impedance of the circuit feeding it. In the case of cavity 14, the short circuiting wall at 19 reflects an impedance at the input ports to cavity 14, which in combination with the susceptance 16 presents an effective open circuit at the junction of the main waveguide wall and the cavity 14. The open circuit exhibited at the input port to the cavity 14 reflects an effective short circuit across the waveguide section 5 feeding the transmitter located at circuit 1, thus preventing low intensity echoes from being absorbed in the transmitter circuit. The waveguide and cavity structure is dimensioned such that the short circuit across the transmitter waveguide feed 5 is reflected as a short circuit across the waveguide sections connecting 5 and 6 such that the echo pulses are effectively all communicated to the resonator 15. The cavity resonator 15 is coupled by means of a waveguide section 7 to the load circuit or receiver 3. As previously mentioned, the characteristics of the resonant cavity 15 are such that in the tuned condition it exhibits at its input port effectively the impedance of the receiver which is coupled to the output port of the cavity resonator. Accordingly, practically all of the input echoes are coupled to the receiver and little of the received energy is lost in the remaining circuitry of the system shown.

Referring to FIG. 2, there is shown a further embodiment of an electrical switching network wherein the ionizable medium comprises essentially the only coupling to the distributed capacity 20. The ionizable medium 21 comprises effectively a vessel having a wall portion formed of a dielectric material 22 such as glass or ceramic and containing the gases, argon, neon, etc., previously mentioned. The ionizable medium has the wall material 22 cemented to a conductive plate 23 which can form a part of the wall of the cavity resonator 24. The cavity resonator normally has one particular tuning in the condition where ionizable medium is not ionized and upon ionization in response to waves propagated in the cavity above a predetermined intensity the medium becomes ionized and effectively exhibits properties of an electrically conductive post for the distance L. This effective conductive post, together with the distributed capacity 20, operates to alter the tuning of the cavity resonator such that the electrical switching network comprising 20, 21, 22 and 23 controls the waves in a different manner than in the condition when the medium is un-ionized and effectively is out of the circuit. The current which flows through the ionized medium 21 also flows through the series reactance 20. Therefore, the magnitude of this current is reduced, thereby effectively increasing the power handling capacity of the duplexer.

Referring to FIG. 3, the ionizable medium 25 is contained in a vessel formed by a dielectric wall portion 26 and an electrically conductive wall portion 27 which may comprise steel, copper, or some other suitable electrically conductive material. In a preferred embodiment, the vessel was in the form of a cylinder with an electrically conductive post 28 conductively connected to the wall material 27 at one end and protruding into the cavity resonator through the walls 29. The post can be formed of any suitable electrically conductive material, such as metal. In its non-ionized state the electrical switching circuit comprises an annulus 31 formed of a conductive material, such as metal, which is concentric with the post 28 and spaced on its inner diameter therefrom and electrically conductively connected to the wall portions 27 at the outer periphery thereof.

The operation of the circuit of FIG. 3 is as follows: The switching circuit is composed of the series combination of the distributed capacitance 30, the conducting

post for the length L, and the impedance Z seen looking into the coaxial section at the dielectric window 26. The impedance seen looking into the dielectric window is composed of a combination of reactances formed in the coaxial transmission line of length L_1+L_2 in combination with the capacitive reactance of the annular disk 31.

During the application of power levels below those necessary to cause ionization of the gas 25, the short circuited coaxial transmission line of length L_2 places an inductive impedance at the annular disk which is of the same magnitude but opposite in sign to the capacitive reactance of the disk. As a result, the impedance at the disk being made up of two cancelling reactances in parallel is effectively an open circuit. This open circuit is seen as some reactance Z_1 at the input window in the coaxial section.

During the application of power levels high enough to cause ionization of the gas 25, a discharge forms at the gap between the annular disk 31 and the center conductor 28. As a result, a virtual short circuit is placed at the annular gap and is reflected as an impedance Z_2 at the input window of the coaxial line. The impedance at the annular disk has thus been changed from an open circuit during the application of low level energy to that of a short circuit for incident electromagnetic energy of a magnitude sufficient to cause ionization of the gas. Due to the characteristics of transmission lines and waveguides, the impedances Z_1 and Z_2 seen at the input window to the coaxial section are related essentially by the equation $Z_1=1/Z_2$. It is this change in the impedance Z which constitutes the switching action necessary for detuning the cavity in which the circuit of FIG. 3 is placed. Reactance 30 decreases the current flow on inductor 28 and consequently also the current through the glow discharge region. As a result, the power handling capacity of the duplexer is increased.

Referring to FIG. 4, there is shown a switching network which is composed of an inductive post 32, a dielectric cylinder 33 containing an ionizable medium 34 placed in a rectangular waveguide 35. During the application of electromagnetic energy below the value necessary to cause ionization of the gas, the network is composed essentially of the inductive post 32. At incident levels of energy of a magnitude great enough to cause ionization of the gas 34, the effective diameter of the post is increased and the reactance of the switching circuit is decreased. After ionization of the gas medium, the circuit is composed of the inductive post 32 in parallel with the ionized medium 34. The change in reactance of the switching circuit for power levels above the value necessary for ionization of the gas column effectively detunes the cavity in which the circuit is placed. The inductive post in parallel with

the glow discharge carries part of the current flow and therefore less current flows through the discharge region than without the parallel reactance of the post. As a result, the power handling capacity of the duplexer is increased.

While a specific embodiment has been shown and described, it will of course be understood that various modifications may yet be devised by those skilled in the art which will embody the principles of the invention and found in the true spirit and scope thereof.

What I claim and desire to secure by Letters Patent of the United States is:

1. In combination, a cavity resonator comprising a wave guide having two broad walls and two narrow walls, a non-linear switching circuit comprising a chamber containing an ionizable medium connected to one of said broad walls and extending in length only partially toward the other of said broad walls, said medium being ionizable in response to electromagnetic waves above a predetermined level to de-tune said resonant cavity and to provide a fixed impedance element serially connecting said medium across said broad walls to limit current flowing through said medium to non-destructive values during ionization, said ionizable medium providing the only path through said chamber in a direction from one broad wall to the other broad wall whereby a conductive path exists only when the intensity of said electromagnetic waves is above said predetermined level.

2. In combination, a cavity resonator tuned for propagating electromagnetic waves of a given frequency, an electrical circuit comprising a chamber containing an ionizable medium connected to one of a pair of walls of said cavity resonator, said medium being ionizable in response to electromagnetic waves above a predetermined level to de-tune said resonant cavity sufficiently to prevent the propagation of wave energy and to provide a fixed impedance element serially connecting said medium across said pair of walls of said cavity resonator to limit current flow through said medium to nondestructive values during ionization, said ionizable medium providing the only path through said chamber in a direction from one of said pair of walls to the other whereby a conductive path exists only when the intensity of said applied wave energy is above said predetermined level.

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