Feb. 18, 1947. N. E. LINDENBLAD 2,416,105

TRANSMIT-RECEIVE SWITCH

Filed Sept. 30, 1943 2 Sheets-Sheet 1

Fig. 3.

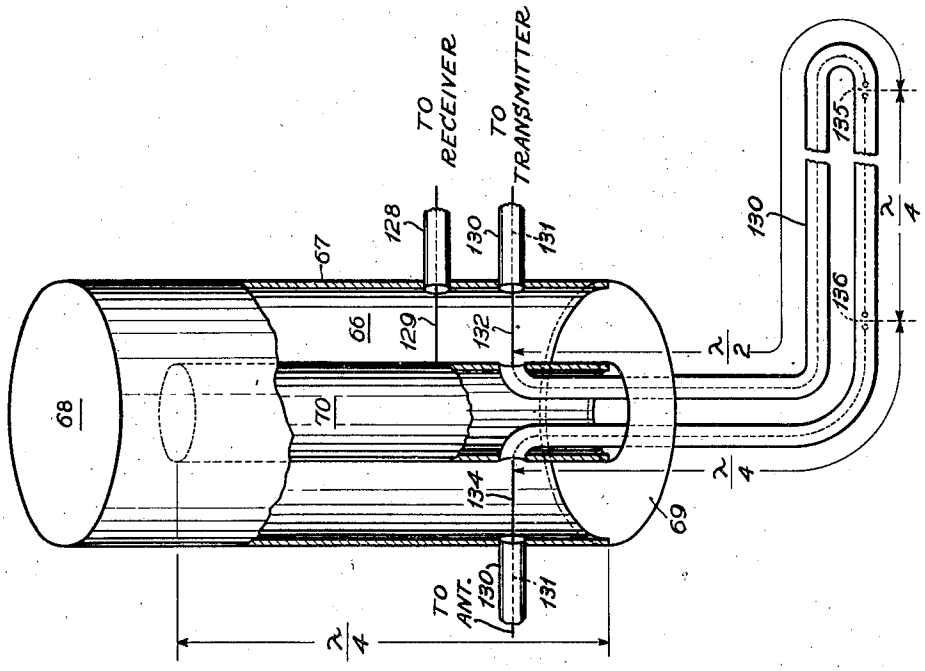
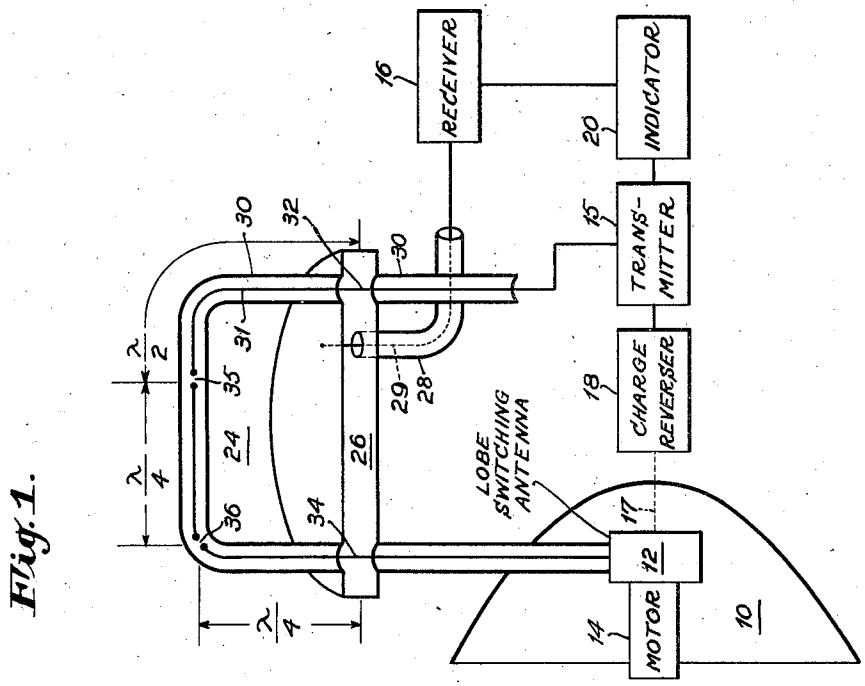


Fig. 1.



INVENTOR
Nils E. Lindenblad
BY
H. S. Grover
ATTORNEY

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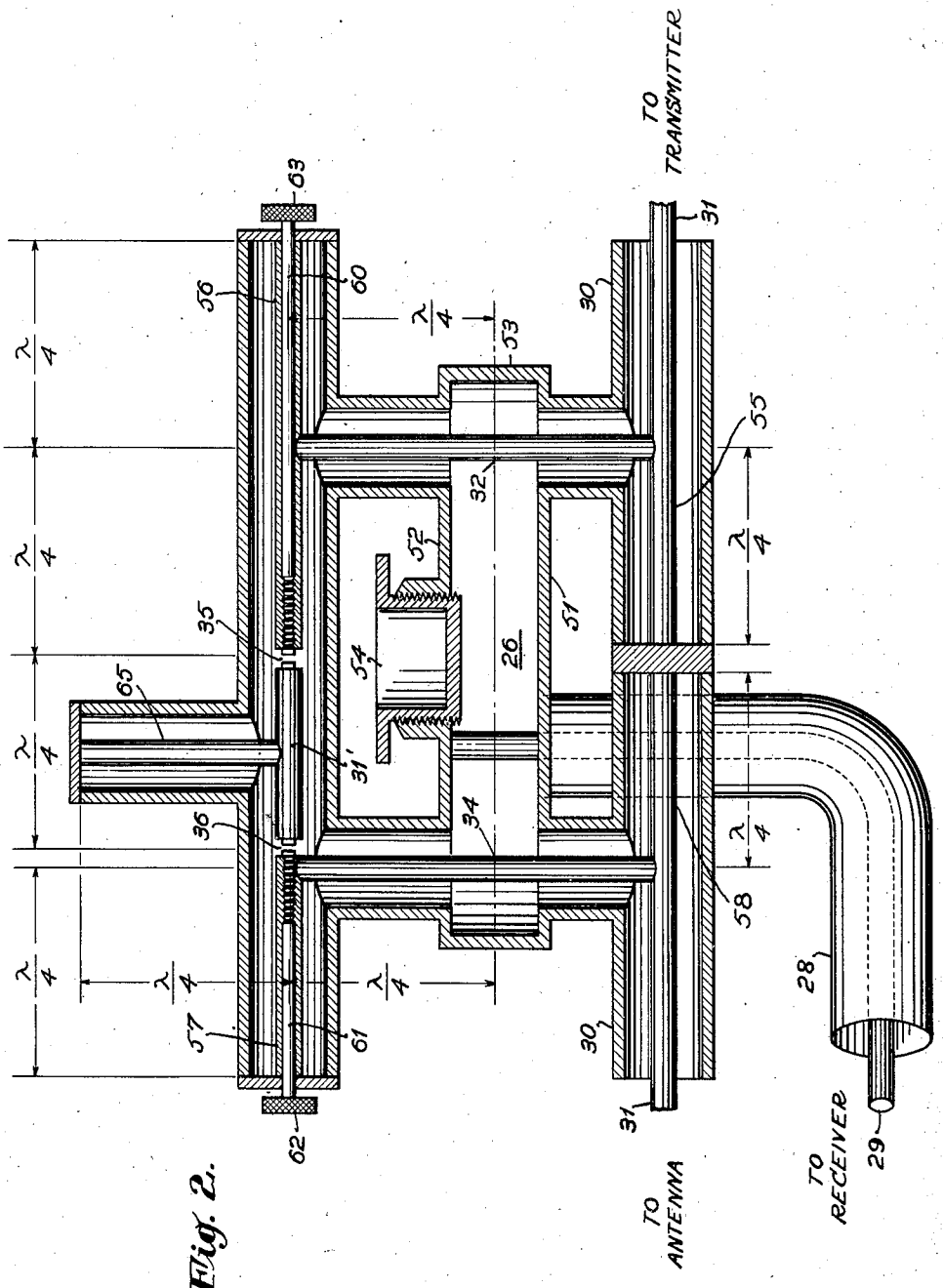


Fig. 2.

INVENTOR
Nils E. Lindenblad
BY H. S. Grover
ATTORNEY

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TRANSMIT-RECEIVE SWITCH

Nils E. Lindenblad, Rocky Point, N. Y., assignor to Radio Corporation of America, a corporation of Delaware

Application September 30, 1943, Serial No. 504,373

23 Claims. (Cl. 250—13)

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The present invention relates to high frequency filter systems for connecting together one or more transmitters and receivers to a common antenna system and, more particularly, to such systems for use in pulse transmitting and receiving systems used in radio detecting and ranging.

An object of the present invention is the provision of a filter device for the selective coupling of a transmitter and receiver to a common antenna system without requiring the use of mechanical switches.

Another object of the present invention is the provision of a filter network, the operating characteristics of which are controlled by power applied thereto.

Still another object of the present invention is the provision of an antenna and filter device for pulse transmitting and receiving equipment which utilizes no moving parts or mechanical switches for diverting outgoing and incoming impulses to the appropriate directivity equipment.

Still another object of the present invention is the provision of a circuit which may be used in a self-synchronized system for effecting the switching of transmitter and receiver line connections to an antenna.

A further object of the present invention is the provision of a circuit, as aforesaid, in which the ineffectiveness of the switch during certain portions of its operating cycle is eliminated.

Still a further object of the present invention is the provision of a circuit, as aforesaid, which operates efficiently over a considerable band of frequencies.

The foregoing objects and others, which may appear from the following detailed description, are attained in accordance with the principles of the present invention by coupling the transmission line from the transmitter to the antenna to a resonant circuit twice at a spacing of one wavelength between the coupling points. The coupling is in opposing phase relationship at the two coupling points so that when the line is energized, the resonant circuit is inactive. Two spark gaps are provided in series with the line in the loop between the two coupling points to the resonant circuit. The first spark gap is at a distance of a half wave from the coupling point of the line coming from the transmitter. The next gap is a quarter wave from the other point of coupling of the transmission line to the resonant circuit. A receiver is coupled to the resonant circuit at a third point.

Now when the line from the transmitter to the antenna is energized, there is no current at

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the point where it is coupled to the resonant circuit since this point is located a half wave from the first gap. When the first gap breaks down, the second gap also breaks down. As the two gaps break down, there is a cancellation in the resonant circuit from the effect of the equal and oppositely applied current through the two points. The resonant circuit, therefore, remains inactive and the receiver is, therefore, entirely uncoupled from the transmission line.

When a received signal comes from the antenna, the distance between the first gap and the resonant circuit is a quarter wavelength. A current maximum develops at this point of coupling and the resonant circuit becomes energized. This energization cannot, however, affect the coupling of the transmitter since this line is opened by the second gap at a distance of a half wave from the coupling point, thereby introducing a very high series line impedance at the coupling point. None of the received power is applied to the transmitter and all of the received power is coupled to the receiver. The couplings to the resonant circuit may be very close so that in the receiving condition the resonant circuit is highly loaded and circulating currents are kept low. This also increases the effective band width of frequencies over which the device operates over that permissible in previous systems, of which I am aware.

The present invention will be more fully understood by reference to the following detailed description, which is accompanied by drawings, in which:

Figure 1 illustrates diagrammatically an application of the invention to a complete radio direction and ranging system;

Figure 2 illustrates in cross-sectional view an embodiment of the invention; and

Figure 3 illustrates a modification of the form of the invention shown in Figure 2.

Referring, now, to Figure 1, there is shown a radio detection and ranging system including a directional antenna 10 having mounted at the focus thereof a radiating member 12 so arranged that as motor 14 is operated, the beam of radiated energy from the antenna system is successively deflected in a circular path coaxial with the axis of symmetry of the reflector 10. Thus the beam of radiated energy passes successively through, for example, for quadrantal positions. A transmitter 15 is so energized that a short pulse of energy is radiated in each quadrant of the circle. Also, receiver 16 is connected to the antenna during each quadrantal position of the

beam to receive energy reflected from a distant object. The timing of the energization of the transmitter for radiating the impulses at the desired times is accomplished by charge reverser 15 driven by a synchronizing link, diagrammatically indicated by dotted line 17. The charge reverser 18 applies high amplitude pulses of energy to the transmitter electron stream circuits at the desired moments.

Energization of the transmitter also is caused to control deflection and control circuits of cathode ray tubes in indicator 20. Circuits from receiver 16 apply received reflected signal impulses to other deflecting and control circuits in indicator 20, whereby the direction and range of the reflecting object may be determined.

The structural details and manner of operation of the charge reverser and transmitter are more fully disclosed in my prior application United States Serial No. 441,311, filed May 1, 1942 (RCA D.#20978), to which reference may be made for a more detailed disclosure.

The antenna 12 is arranged to be selectively coupled to transmitter 18 and receiver 22 through a transmitter-receiver switch, indicated generally as reference numeral 24. This transmitter-receiver switch, in accordance with the present invention, includes an entirely enclosed drum-like chamber 26 having its interior dimensions so chosen as to be space-resonant to the operating frequency of the system. A concentric cable transmission line from receiver 22 is coupled to the resonant cavity 26 by having its inner conductor 29 pass through the space within cavity 26 from one end wall to the other and connect to the far wall of the cavity. There is likewise a coaxial cable transmission line 30 connected from the transmitter to the antenna 12. The inner conductor 31 of this transmission line passes through the resonant cavity 26 at points 32 and 34 and is thus coupled to the cavity twice in opposing relationships. The distance along transmission line 30 between coupling points 32 and 34 is chosen as one wavelength. Thus circuits passing through the line are in phase at the two coupling points 32 and 34, and since they pass through the cavity in opposite directions, the net coupling is zero. At a distance equal to half of an operating wavelength from point 32 in conductor 31 is a series gap 35 with a second series gap 36 located at a distance equal to one quarter of the operating wavelength from point 34 in conductor 31.

If transmission lines 28 and 30 have the same characteristic impedance it is desirable to make the couplings at 29, 32 and 34 of equal magnitude thus avoiding any transformation from the intercoupled cavity 26. The degree of the couplings to cavity 26 may be very high so that in the receiving condition the cavity is so loaded down that circulating currents are kept low. This also increases the effective band width of frequencies over which the device operates.

Now in the operation of the system shown in Figure 1, as motor 14 operates to switch the directivity of the antenna around the axis of the antenna, the control means, indicated by dotted line 17, is caused to operate the charge reverser 18 at, for example, four equally spaced positions of the beam about the axis. As the charge reverser 16 is operated, the transmitter 15 generates a sharp pulse of radio frequency energy which is applied by means of transmission line 30 to the antenna 12. Since gap 35 is at a distance of one-half wavelength from coupling point 32, as long as gap 35 is open, there is no coupling between conductor 31 of the transmission line 30 and the space between cavity 26. As soon as gap 35 breaks down, due to the potential gradient built up thereacross, gap 36 simultaneously breaks down and the energy flows to the antenna 12. Since conductor 31 passes through cavity 26 at points 32 and 34 in opposite direction and the points 32 and 34 are one wavelength apart, there is a cancellation of energy coupled to the cavity and the cavity remains inactive. Therefore, no energy is applied from the transmitter 15 to the receiver 16.

With the cessation of the impulse from transmitter 15, gaps 36 and 35 cease to be conductive, and the system is then ready to receive an incoming impulse reflected from a distant object. When the reflected impulse is received in the antenna 12, it is conducted along conductor 31 to point 34 where conductor 31 is coupled to resonant chamber 26. Since point 34 is spaced from gap 36 by a distance equal to a quarter of the operating wavelength and 36 is open, conductor 31 is effectively grounded at point 34. Therefore, conductor 31 is coupled to the resonant chamber 26 in the same way as conductor 29 of transmission line 30 is coupled to chamber 26. Therefore, the received impulse is picked up by transmission line 28 conveyed to receiver 16. Since point 32 of the transmission line 30 is one-half wavelength from the open circuit at gap 35, there is a high impedance at point 32, and no coupling exists between the cavity 26 and conductor 31 of transmission line 30 where it emerges to go to transmitter 18. Therefore, none of the received power is applied to the transmitter.

The received impulse applied to receiver 22 is rectified and applied to indicator 20 to operate, for example, the vertical deflection circuits of a cathode ray tube, the horizontal deflection circuits being controlled by pulses from the charge reverser 16. From the indications on the cathode ray tubes contained in indicator 20, the range and direction of the object from which the received impulse was reflected can be determined in a manner well known in the art and which will, therefore, not be further described at this time.

Figure 2 of the drawings shows in greater detail a preferred form of construction of the transmitter-receiver switch 24 of Figure 1. Here it will be seen that the resonant cavity 26 may be constructed in the form of a short cylinder having end plates 51 and 52 and a cylindrical side wall 53. For the purpose of tuning chamber 26 to the desired operating frequency, end wall 52 carries a threaded plug 54 which may be screwed into or out of the chamber 26 to change its operating frequency. The transmission line 28 from the receiver has its outer shell connected to end wall 51, while the inner conductor 29 passes through the chamber 26 and is conductively connected to the end wall 52. End walls 51 and 52 also each contain a pair of aligned apertures through which conductor 31 of transmission line 30 passes. The outer shell of transmission line 30 is conductively connected to the end walls 51 and 52 of each of the apertures. In order to maintain the conductor 31 in rigid alignment where it passes through cavity 26, short-circuited quarter wave stubs 55 and 56 are provided at one passage point, while stubs 57 and 58 are provided at the other passage. Each stub is connected in shunt between the inner conductor 31 and the outer shell of the transmission line.

These stubs might as far as their supporting function is concerned, be substituted by insulating rings, if desired. However, shorted-quarter-wave stubs result in lower losses than would the insulating rings. In addition, stubs 56 and 57 carry through the inner conductor portions thereof threaded rods 60 and 61 by means of which the spacing of spark gaps 35 and 36 may be adjusted from the exterior by means of knobs 62 and 63. The quarter-wave portion of inner conductor 31' between gaps 35 and 36 is supported in position by another shunt-connected shorted-quarter-wave stub 65.

The modification of the present invention shown in Figure 3 is particularly useful for longer wavelength systems, where the resonant chamber 26 of Figures 1 and 2 would be unduly large. Therefore, the functions of the resonant chamber 26 in this figure are taken over by a resonant circuit 66 including an outer shell 67 closed at the ends by end plates 68 and 69 and an inner central conductor 70 having an electrical length equal to one quarter of the operating wavelength. Central conductor 70 is connected at one end to end plate 69, while the other end is unconnected. If desired, the actual physical length of central conductor 70 may be somewhat less than one quarter of the operating wavelength, and it may carry at its free end a capacitive loading member such that its electrical length is equal to a quarter wavelength at the operating frequency.

In this modification, concentric transmission line 130 from the transmitter has its inner conductor 131 passed through outer shell 67 radially inwardly through the space between the shell 67 and the inner conductor 70, and out through end wall 69. Thus transmission line 130 forms a one wavelength loop and again passes up through end wall 69 to the interior of inner conductor 70. There the inner conductor 131 again passes radially outwardly through to the outer shell 67. From there transmission line 130 is connected to the antenna, not shown. The transmission line 128 from the receiver has its inner conductor 129 passed radially through the outer shell 67 and conductively connected to the inner conductor 70. The transmission line 131 contains in the looped portion a pair of series gaps 135 and 136. Gap 135 is spaced one half of the operating wavelength from the point where the transmission line from the transmitter passes through the central conductor 70, and gap 136 is spaced one quarter of the operating wavelength from the point where the transmission line again passes through the central conductor 70. The operation of this modification of the invention is exactly the same as that heretofore described.

While I have illustrated a particular embodiment of the present invention, it should be clearly understood that it is not limited thereto since many modifications may be made in the several elements employed and in their arrangement and it is, therefore, contemplated by the appended claims to cover any such modifications as fall within the spirit and scope of the invention.

I claim:

1. A switching device including a resonant circuit, a transmission line adapted to be connected between a transmitter and an antenna, means for coupling said transmission line to said circuit at two points along the length of said line spaced apart a distance substantially equal to one operating wavelength, said couplings being in opposing phase relationships, a receiver coupled to said resonant circuit, and means serially connected in said transmission line between said points of coupling for selectively controlling the continuity of said line.

2. A switching device including a resonant circuit, a transmission line adapted to be connected between an intermittently operative transmitter and an antenna, means for coupling said circuit to said transmission line at two points, said couplings being in electrically opposing relationships, a receiver coupled to said resonant circuit, and means associated with said transmission line for causing both of said couplings to be effective during operating periods of said transmitter and for causing only the coupling associated with said antenna to be effective between such periods.

3. A switching device including a resonant circuit, a transmission line adapted to be connected between an intermittently operative transmitter and an antenna, means for coupling said circuit to said transmission line at two points, said couplings being in opposing phase relationships, a receiver coupled to said resonant circuit, resonant elements associated with each of said coupling means, said resonant elements causing said couplings to be ineffective during operating periods of said transmitter, and means associated with said transmission line for causing both of said couplings to be effective during operating periods of said transmitter and for causing only the coupling associated with said antenna to be effective between such periods.

4. A switching device including a resonant chamber, a transmission line adapted to be connected between a transmitter and an antenna, means for coupling said transmission line to said chamber at two points along the length of said line spaced apart a distance equal to a multiple including unitary of one operating wavelength, said couplings being in opposing phase relationships, a receiver also coupled to said resonant chamber, and means serially connected in said transmission line between said points of coupling for selectively controlling the continuity of said line.

5. A switching device including a resonant circuit, a transmission line adapted to be connected between a first transducer and a second transducer, means for coupling said transmission line to said circuit at two points along the length of said line spaced apart a distance substantially equal to one operating wave-length, said couplings being in opposing relationships, a third transducer coupled to said resonant circuit, and means serially connected in said transmission line between said points of coupling for selectively controlling the continuity of said line.

6. A switching device including a resonant circuit, a transmission line adapted to be connected between an intermittently operative first transducer and a second transducer, means for coupling said circuit to said transmission line at two points, said couplings being in opposing phase relationships, a third transducer coupled to said resonant circuit, and means associated with said transmission line for causing both of said couplings to be effective during operating periods of said first transducer and for causing only the coupling associated with said second transducer to be effective between such periods.

7. A switching device including a resonant circuit, a transmission line adapted to be connected between a transmitter and an antenna, means for coupling said transmission line to said circuit at

two points along the length of said line spaced apart a distance equal to one operating wavelength, said couplings being in opposing relationships, a receiver coupled to said resonant circuit, and means serially connected in said transmission line between said points of coupling for selectively controlling the continuity of said line, said means being so arranged that when said line is discontinuous between said points said antenna is coupled to said circuit.

8. A switching device including a resonant circuit, a transmission line adapted to be connected between a transmitter and an antenna, means for coupling said transmission line to said circuit at two points along the length of said line spaced apart a distance equal to one operating wavelength, said couplings being in opposing relationships, a receiver coupled to said resonant circuit, and means serially connected in said transmission line between said points of coupling for selectively controlling the continuity of said line, said means being so arranged that when said line is discontinuous between said points said antenna is coupled to said circuit and said transmitter is uncoupled from said circuit.

9. A switching device including a resonant chamber, a transmission line adapted to be connected between a transmitter and an antenna, said transmission line passing through said resonant chamber at two points spaced along the length of said line a distance equal to one operating wavelength, said passes through said resonant chamber being in opposite directions, a second transmission line coupled to said resonant chamber, said first transmission line having a pair of series gaps therein between said two passes through said resonant chamber, one of said gaps being one quarter of the operating wavelength from one pass and the other gap being spaced one half of the operating wavelength from the other pass.

10. A switching device including a resonant circuit, a transmission line adapted to be connected between a transmitter and an antenna, said transmission line being coupled to said resonant circuit at two points spaced along the length of said line a distance equal to one operating wavelength, said couplings being in opposite senses, a second transmission line coupled to said resonant circuit, said first transmission line having a pair of series gaps therein between said two points of coupling to said resonant circuit, one of said gaps being one quarter of the operating wavelength from the one of said couplings adjacent said antenna and the other gap being spaced one half of the operating wavelength from the other of said couplings.

11. A switching device including a resonant circuit, a transmission line adapted to be connected between a transmitter and an antenna, said transmission line being coupled to said resonant circuit at two points spaced along the length of said line a distance equal to one operating wavelength, said couplings being in opposite senses, a second transmission line coupled to said resonant circuit, said first transmission line having a pair of series gaps therein between said two points of coupling to said resonant circuit, one of said gaps being one quarter of the operating wavelength from the one of said couplings adjacent said antenna and the other gap being spaced one half of the operating wavelength from the other of said couplings, said resonant circuit including a conductive outer shell surrounding a quarter wave inner conductor, said inner conductor being connected to said shell at one end.

12. A switching device including a resonant circuit, a transmission line adapted to be connected between a transmitter and an antenna, said transmission line being coupled to said resonant circuit at two points spaced along the length of said line a distance substantially equal to one operating wavelength, said couplings being in opposite senses, a second transmission line coupled to said resonant circuit, said first transmission line having a pair of series gaps therein between said two points of coupling to said resonant circuit, one of said gaps being one quarter of the operating wavelength from the one of said couplings adjacent said antenna and the other gap being spaced one half of the operating wavelength from the other of said couplings, said resonant circuit including a conductive outer shell surrounding a quarter wave inner conductor, said inner conductor being connected to said shell at one end, said transmission line passing radially between said outer shell and inner conductor near said one end.

13. A switching device including a resonant chamber, a transmission line adapted to be connected between a transmitter and an antenna, said transmission line having a conductor passing through said resonant chamber at two points spaced along the length of said line a distance substantially equal to one operating wavelength, said passes through said resonant chamber being in opposite directions, a second transmission line coupled to said resonant chamber, said first transmission line having a pair of series gaps in said conductor between said two passes through said resonant chamber, one of said gaps being one quarter of the operating wavelength from one pass and the other gap being spaced one half of the operating wavelength from the other pass.

14. A switching device including a resonant chamber, a concentric transmission line having an outer shell and an inner conductor and adapted to be connected between a transmitter and an antenna, the inner conductor of said transmission line passing through said resonant chamber at two points spaced along the length of said line a distance substantially equal to one operating wavelength, said passes through said resonant chamber being in opposite directions, a second transmission line coupled to said resonant chamber, said first transmission line having a pair of series gaps in its inner conductor between said two passes through said resonant chamber, one of said gaps being one quarter of the operating wavelength from one pass and the other gap being spaced one half of the operating wavelength from the other pass, said inner conductor being supported in concentric relationship with the outer shell at each side of each passage through said chamber by shunt-connected short-circuited quarter wave stubs, each also including an outer shell and an inner conductor.

15. A switching device including a resonant chamber, a concentric transmission line having an outer shell and an inner conductor and adapted to be connected between a transmitter and an antenna, the inner conductor of said transmission line passing through said resonant chamber at two points spaced along the length of said line a distance substantially equal to one operating wavelength, said passes through said resonant chamber being in opposite directions, a second transmission line coupled to said resonant

chamber, said first transmission line having a pair of series gaps in its inner conductor between said two passes through said resonant chamber, one of said gaps being one quarter of the operating wavelength from one pass and the other gap being spaced one half of the operating wavelength from the other pass, said inner conductor being supported in concentric relationship with the outer shell at each side of each passage through said chamber by shunt-connected short-circuited quarter wave stubs, each also including an outer shell and an inner conductor, and means for adjusting the length of said series gaps passing through the inner conductor of adjacent quarter wave stubs.

16. A switching device including a resonant chamber, a concentric transmission line having an outer shell and an inner conductor and adapted to be connected between a transmitter and an antenna, the inner conductor of said transmission line passing through said resonant chamber at two points spaced along the length of said line a distance substantially equal to one operating wavelength, said passes through said resonant chamber being in opposite directions, a second transmission line coupled to said resonant chamber, said first transmission line having a pair of series gaps in its inner conductor between said two passes through said resonant chamber, one of said gaps being one quarter of the operating wavelength from one pass and the other gap being spaced one half of the operating wavelength from the other pass, said inner conductor being supported in concentric relationship with the other shell at each side of each passage through said chamber by shunt-connected short-circuited quarter wave stubs, each also including an outer shell and an inner conductor, means for adjusting the length of said series gaps passing through the inner conductor of adjacent quarter wave stubs, and means for varying the resonant frequency of said chamber including a conductive plug screwed into an end wall of said chamber.

17. A high frequency circuit including a resonant device, a transmission line adapted to be connected between a transmitter and an antenna, means for coupling said transmission line to said resonant device at two points along the length of said line, said couplings being such as to normally tend to cancel one another, a receiver coupled to said resonant device, and means so arranged in said transmission line between said points of coupling as to selectively control the continuity of said line whereby only the coupling more closely adjacent said transmitter may be disabled.

18. A switching device including a resonant circuit, a transmission line adapted to be connected between an intermittently operative transmitter and an antenna, means for coupling said resonant circuit to said transmission line at two points, said couplings being such as to normally tend to cancel or neutralize one another, a receiver coupled to said resonant circuit, and means associated with said transmission line for effecting both of said couplings during operating periods of said transmitter and for disabling only the coupling more closely adjacent said transmitter between such periods.

19. A switching device including a resonant chamber, a transmission line adapted to be connected between a transmitter and an antenna, means for coupling said transmission line to said chamber at two points along the length of said line, said coupling means being so arranged that said couplings normally tend to substantially neutralize one another, a receiver coupled to said resonant chamber, and means serially connected in said transmission line between said points of coupling for selectively controlling the continuity of said line, said last-mentioned means being so located that when the continuity of said line is broken only said coupling more closely adjacent said transmitter is disabled.

20. A high frequency circuit including a transmitter, a receiver, and an antenna, a transmission line coupling said transmitter to said antenna, a resonant device coupled to said receiver, and two couplings between said resonant device and said transmission line, said couplings being in such relationship as to normally tend to neutralize one another.

21. A high frequency circuit including a transmitter, a receiver, and an antenna, a transmission line coupling said transmitter to said antenna, a resonant device coupled to said receiver, and two couplings between said resonant device and said transmission line, said couplings being in such relationship as to normally tend to neutralize one another, and means associated with said transmission line for disabling one of said couplings.

22. A high frequency circuit including a transmitter, a receiver, and an antenna, a transmission line coupling said transmitter to said antenna, a resonant device coupled to said receiver and two couplings between said resonant device and said line, said couplings being so arranged as to normally tend to neutralize one another, said transmission line having a portion forming a common path between said receiver and said antenna and said transmitter and said antenna.

23. A high frequency circuit including a transmitter, a receiver, and an antenna, a transmission line coupling said transmitter to said antenna, a resonant device coupled to said receiver and two couplings between said resonant device and said line, said couplings being so arranged as to normally tend to neutralize one another, said transmission line having a portion forming a common path between said receiver and said antenna and said transmitter and said antenna, and means for disabling one of said couplings between said resonant device and said transmission line.

NILS E. LINDENBLAD.

REFERENCES CITED

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

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