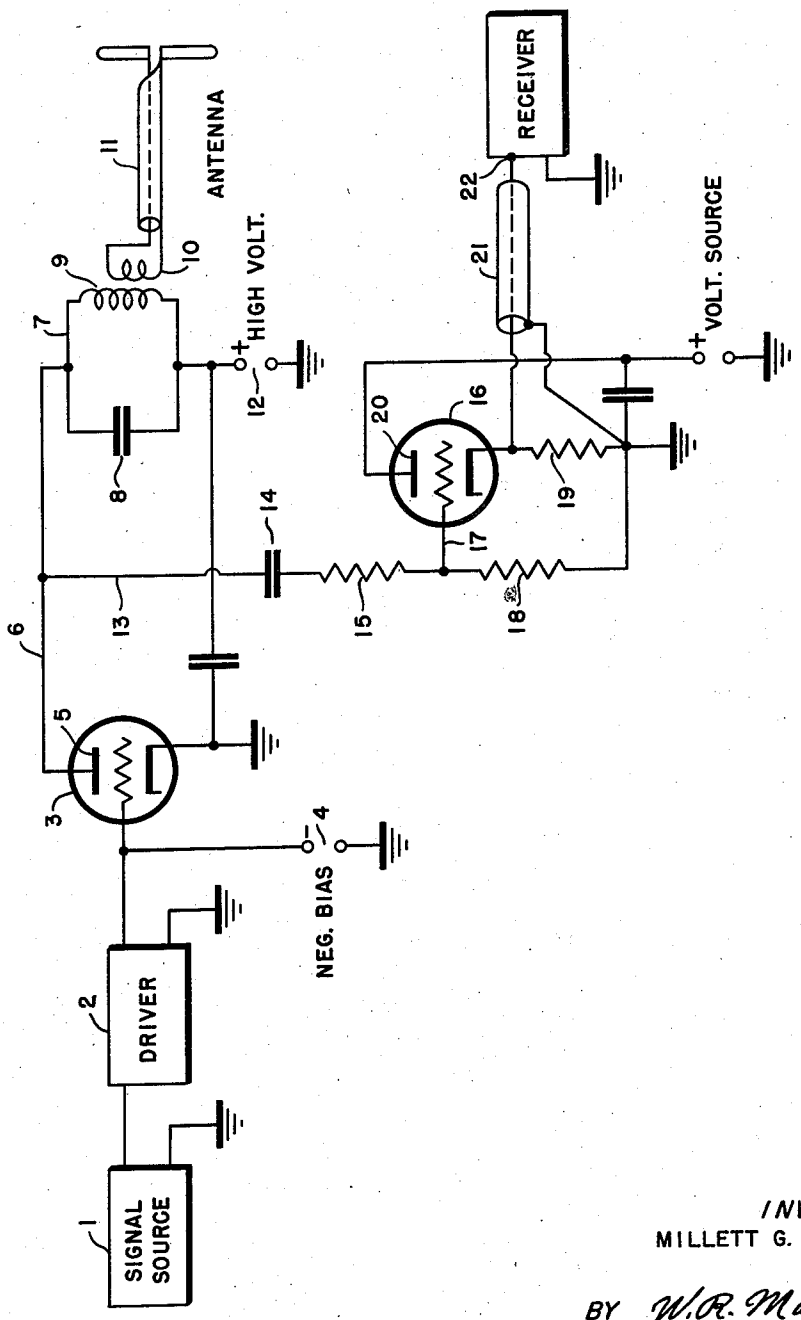
May 12, 1959 M. G. MORGAN 2,886,812

DUPLEXER

Filed April 17, 1953



INVENTOR
MILLETT G. MORGAN

BY W.R. Malthy
D.C. Siegler

ATTORNEYS

United States Patent Office 2,886,812 Patented May 12, 1959

2,886,812

DUPLEXER

Millett G. Morgan, Hanover, N.H., assignor, by mesne assignments, to the United States of America as represented by the Secretary of the Navy

Application April 17, 1953, Serial No. 349,386

2 Claims. (Cl. 343—17.1)

This invention relates generally to radiant energy signalling systems and more particularly to a duplexing circuit for a radio frequency signalling arrangement whereby the same antenna may serve both the transmitting and receiving apparatus during their respective operational cycles.

In radar practice, the term "duplexer," by accepted usage, has come to mean any electronic switching device which permits the directional antenna to be alternately associated with the transmitting and receiving equipment. Essentially, the duplexer must perform the following functions: First, during periods of transmission, connect the antenna to the transmitter and disconnect it from the receiver; second, isolate the receiver during the high power pulse to prevent damage to the sensitive receiver components; and third, after transmission, rapidly disconnect the transmitter and reestablish the antenna connection to the receiving apparatus.

Heretofore, it has been customary in radio pulse ranging systems to employ gas-tube switches, resonant lengths of transmission line and resonant cavities as the so-called duplexing means. In theory, such apparatus may be designed for use in all frequency ranges, from the ultrahigh to the relatively low frequencies; however, as a practical matter, their unreasonably large dimensions at the lower ranges effectively restrict their usefulness to ultrahigh frequency circuits. Also, present duplexers, of which the aforementioned are representative, by their structural natures possess inflexible electrical characteristics and do not lend themselves to variable frequency operation without comparatively extensive and time-consuming adjustments.

It is, accordingly, a primary object of the present invention to provide a duplexing arrangement which may be conveniently used in relatively low-frequency pulse signalling systems.

A second object of the present invention resides in the provision in a signalling system of a duplexer that may be adapted to variable frequency operation.

A further object of the present invention is to provide a relatively low-frequency duplexer which may be utilized in signalling systems wherein the pulse frequency rate is subject to relatively wide variations due to operational requirements.

In applying the present invention to a pulse travel-time radar system, to illustrate a preferred embodiment thereof, the high power pulse transmitter is connected to a class "C" amplifying stage, which in turn has its plate directly connected to the tuned input circuit of the antenna and indirectly coupled via an R-C circuit to a cathode follower circuit, across whose cathode resistor the input to the receiving equipment is taken. The cathode follower circuit duplicates the function of the conventional switching devices hereinbefore mentioned and becomes, after a few R.F. cycles, effectively biased to cut-off during each pulse by so-called grid-leak action, to prevent large positive signals from apearing in the receiving input circuit. During reception, the blocking bias developed across the cathode follower's input circuit is removed, and the tube is then capable of reacting to any incoming signals present on the antenna to reproduce them in the receiver's input circuit.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawing wherein the sole figure is a schematic diagram of a preferred embodiment of the present invention illustrating its application to a pulse travel-time ranging system.

Referring now to the drawing, which schematically illustrates a preferred embodiment of the invention, a source of R-F time modulated pulse groups, for example, 100 μ second pulses recurring ten times per second with a carrier frequency adjustable from 2–12 megacycles is diagrammatically represented by reference character **1**. Pulses originating at this source are amplified and shaped in driver **2** and are then fed to the control grid of triode **3** which is normally negatively biased by voltage source **4** beyond cut-off to perform as a class "C" amplifying stage. Directly connected to the plate **5** of triode **3**, such as by means of conductor **6**, is a tuned circuit **7** having as its constituent reactive elements capacitor **8** and inductance **9**. Coupled to the latter element is a coil **10** which serves as the power transforming and impedance matching element between the tuned circuit and the low impedance coaxial line **11**. The single antenna means which is to be successively coupled to transmitting and receiving apparatus is connected to the remote end of line **11** and for simplicity's sake has been schematically shown. Operating potential for the amplifier stage is derived from high voltage supply **12** and reaches plate **5** via inductance **9** and conductor **6**. Attached to conductor **6** by means of line **13** is an R-C coupling circuit consisting of capacitor **14** and resistor **15** which functions, as will be explained hereinafter, in conjunction with resistor **18** and triode **16**, to protect this tube and the sensitive receiving apparatus from being damaged while the transmitter is operating. Triode **16** is connected in cathode-follower relationship with respect to low impedance coaxial line **21**. The receiving equipment, also diagrammatically shown, is secured to the other end of line **21** so that the potential developed across cathode resistor **19** constitutes the input voltage to terminal **22** of the receiver.

In the operation of the system, self bias develops on the control grid **17** of cathode follower **16** by conventional action during the transmission of each R-F pulse group. This bias once developed has sufficient magnitude to restrict the period of conduction of the cathode follower to only a brief interval at the crest of each positive swing of plate **5**. In each complementary negative swing of this plate, the cathode follower is nonconductive and the receiver is completely isolated from the system. Thus the signal input to the receiver during the transmission cycle is prevented from reaching a high positive value.

However, during the first few positive swings of plate **5** in each R–F pulse group, while capacitor **14** is changing its average charge and the voltage thereacross is considerably below the peak voltage reached by this plate, a large charging current flows in the system. Since this charging current, as is well known, flows through the grid-cathode interelectrode space, there is the danger of tube **16** being destroyed during this transient period. To protect against this, a current limiting resistor **15** is placed in series with capacitor **14**. Also by having triode **16** perform as a cathode follower, further protection is ob-

tained from cathode resistor 19. The combined effect of resistors 15 and 19 is to limit this transient charging current to a permissive value. Within a few cycles of the R-F wave, capacitor 14 reaches its average charge and the danger from excessive charging current is no longer present. Thereafter, triode 16, as mentioned above, conducts only at the crest of each positive swing of plate 5 and during this time the small amount of charge lost from capacitor 14 during the negative swing of this plate is restored.

Considering now the interval between adjacent composite power pulses and ignoring for the time being the discharge action of element 14, it will be seen that control grid 17 is at ground potential. Hence, in the interim between adjacent pulses, amplifying stage 16 is biased for conduction and any imput or echo signals arriving at the antenna at this time will be passed by the cathode-follower stage to the input circuit 22 of the receiving apparatus, diagrammatically shown, terminating coaxial line 21. Substantially, the full value of these input signals will appear in the grid-cathode circuit of triode 16 across resistor 18 because of the relative magnitudes of series resistors 15 and 18.

In determining the various circuit constants of the present duplexing circuit, it is important that the division of voltage between the R-C circuit and the grid-to-cathode resistor 18 be such that the voltage developed across the latter element during the negative excursion of plates does not cause breakdown in the tube. In a particular circuit application utilizing the present invention and with a pulse rate corresponding to that previously mentioned in the opening paragraphs of this description, it was found possible, with a plate voltage of 4,000 volts and pulse power of 2 kw. delivered to a 50 ohms line, to adjust the duplexer so that tube failure did not occur during transmission and so that the amplitude of the signal delivered to the receiver at 50 ohms was substantially the same as that when the receiver was connected directly to the 50 ohms line. In the particular case mentioned, the tube functioning as the cathode follower was a 6AG7, connected as a triode.

A further factor that must be considered in the operation of the duplexing circuit is the time taken for capacitor 14 to discharge after cessation of the transmitted pulse group. This discharging action tends to develop a blocking potential across resistor 18 in the grid-cathode circuit of cathode-follower amplifier 16 and render the receiver unresponsive to weak incoming signals. While this undesirable effect cannot be completely eliminated from the system, by properly selecting the values of condenser 14 and resistors 15 and 18, it is possible to minimize this reaction so that the receiver's sensitivity is only affected while signals reflected from objects close to the transmitter are being received. In this regard, the present duplexing circuit was utiiized in conjunction with a radar ranging circuit to investigate ionosphere conditions and no difficulty was experienced in selecting the circuit parameters mentioned above so that E-layer echoes could be readily observed.

While the preceding description has covered a preferred embodiment of the present invention as applied to a pulse travel-time radar ranging system, it will be

appreciated, by those skilled in the art, that the present duplexing circuit can be used not only in recurrent pulse systems but also in conventional comunicating circuits, without departing from the spirit of the invention or its scope as covered in the appended claims. For instance, the duplexing circuit can be used in CW and voice communication systems. In the latter case, some kind of automatic control of the carrier must be used to remove the carrier during periods of reception. However, if single side band suppressed carrier transmission is employed and the last stage of the transmitter is a class "B" linear amplifier, true duplex voice operation can be had on the same communicating channel.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A duplexing arrangement comprising, in combination, means for generating recurrent pulses each of which contains a multiplicity of radio frequency cycles, means for feeding said pulses to an antenna, a receiver, an electron tube having at least a control grid and a cathode, a first resistor connected between said cathode and a reference potential, a grid leak resistor connected between said control grid and said reference potential, means for coupling the input circuit of said receiver across said first resistor, a capacitor and a current limiting resistor in series between the control grid of said electron tube and said antenna, said current limiting resistor having a relatively low value as compared with that of said grid leak resistor whereby said capacitor reaches its average charge after a few radio frequency cycles of each pulse and whereby a blocking bias is developed by grid leak action at the control grid of said electron tube and limits the conduction of said tube to only a brief interval at the crest of the positive portions of the remaining radio frequency cycles in each pulse and means including said current limiting resistor and said grid leak resistor for discharging said capacitor after each pulse, whereby said blocking bias is removed and said electron tube rendered responsive to any echo pulses arriving at said antenna in the interval between successive pulses.

2. In a duplexing arrangement as defined in claim 1 wherein said capacitor has a charging path which includes the grid-cathode interelectrode space of said electron tube and wherein said current limiting resistor and said first resistor limit the charging current of said capacitor to a value that can be safely carried by said interelectrode space during the development of said blocking bias.

References Cited in the file of this patent

UNITED STATES PATENTS

2,176,663	Browne et al.	Oct. 17, 1939
2,435,960	Fyler	Feb. 17, 1948
2,456,952	Kluender	Dec. 21, 1948
2,482,128	Schmid	Sept. 20, 1949
2,496,998	Hershberger	Feb. 7, 1950
2,624,871	Meagher	Jan. 6, 1953
2,654,834	Zarky	Oct. 6, 1953