

Aug. 3, 1948.

J. H. HAMMOND, JR

2,446,279

AERIAL BOMB CONTROL SYSTEM

Filed Sept. 19, 1942

4 Sheets-Sheet 1

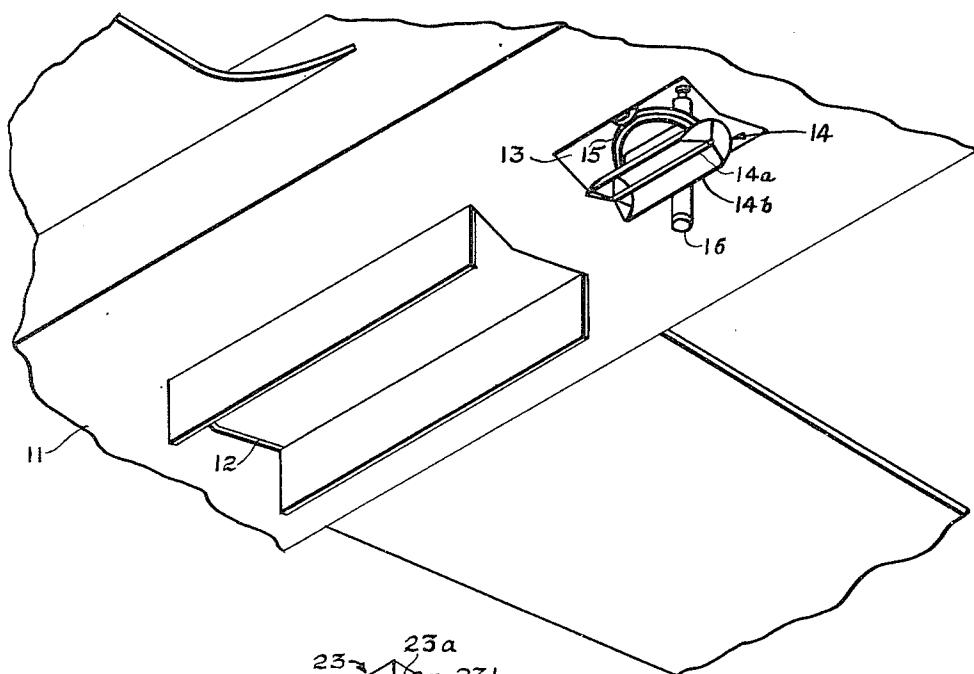


Fig. 1.

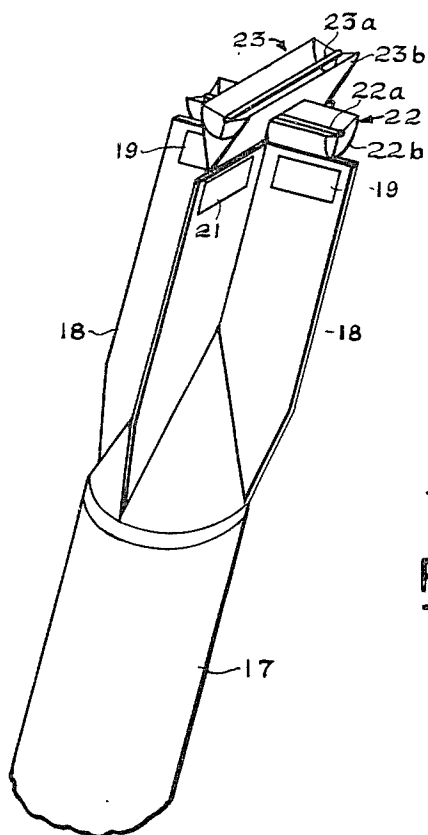


Fig. 1a

INVENTOR
JOHN HAYS HAMMOND, JR
BY *[Signature]*
ATTORNEY

Aug. 3, 1948.

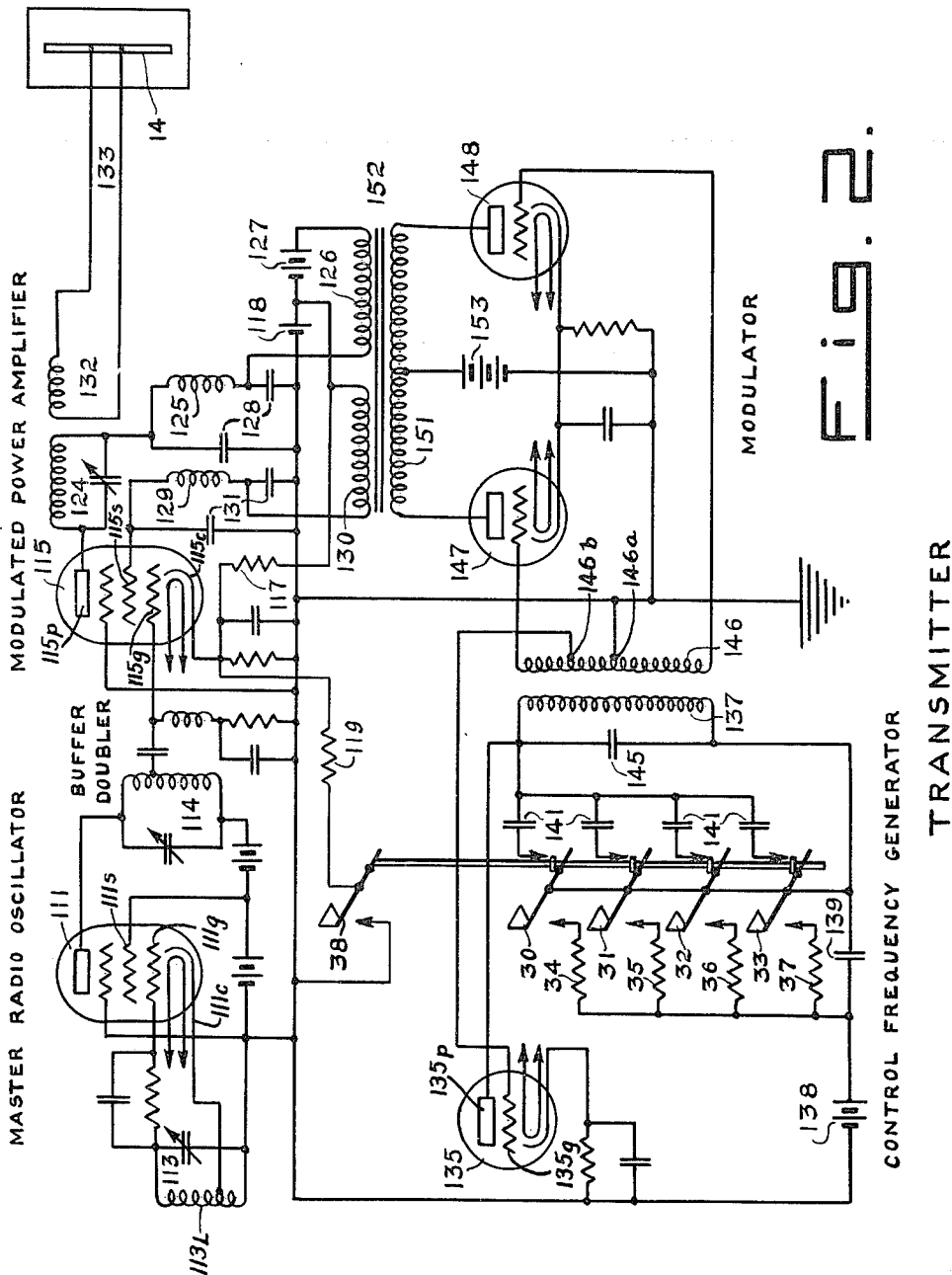
J. H. HAMMOND, JR

2,446,279

AERIAL BOMB CONTROL SYSTEM

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4 Sheets-Sheet 2



INVENTOR
JOHN HAYS HAMMOND, JR.
BY *W. Leek*
ATTORNEY

Aug. 3, 1948.

J. H. HAMMOND, JR

2,446,279

AERIAL BOMB CONTROL SYSTEM

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4 Sheets-Sheet 3

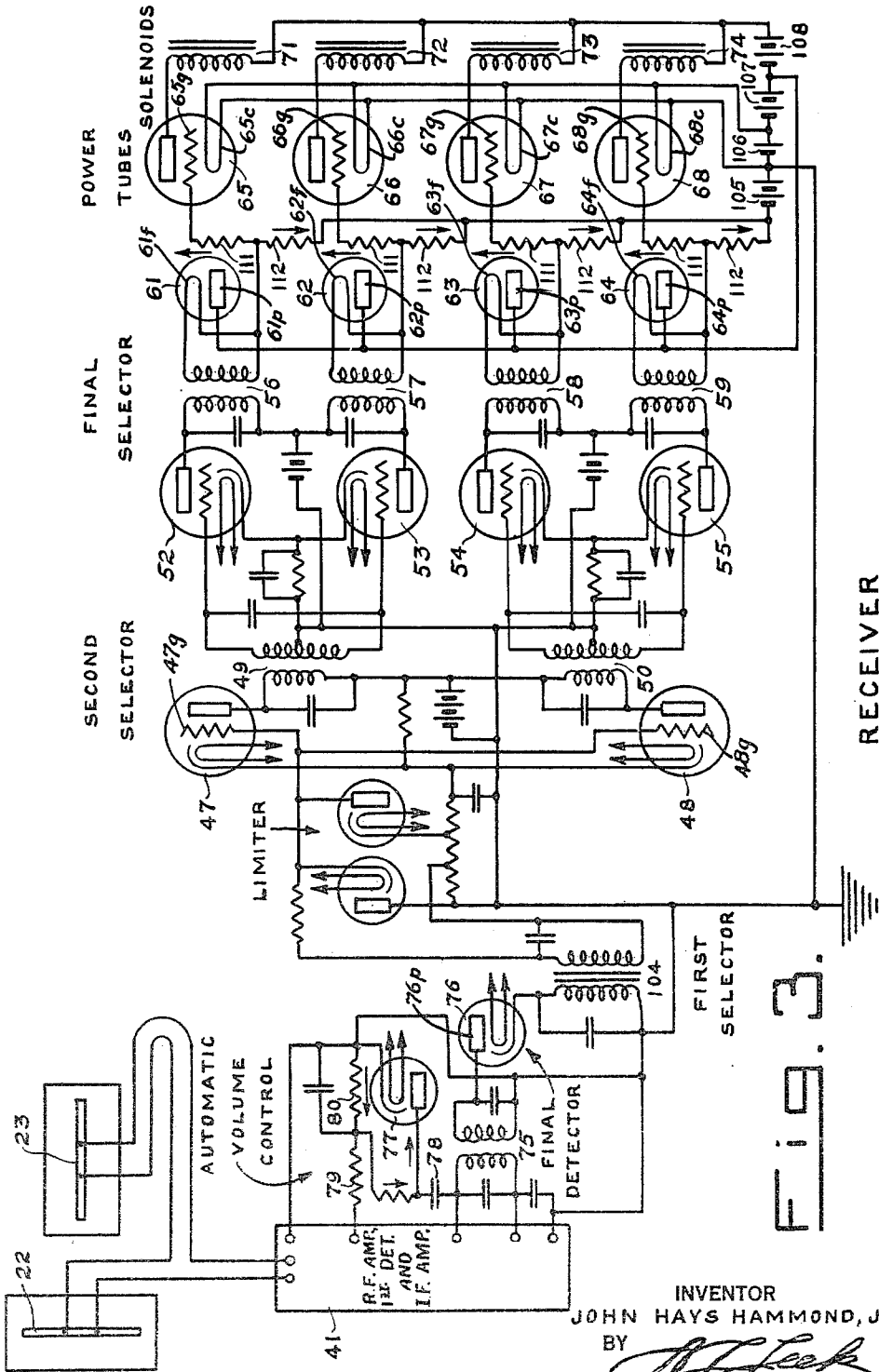


Fig. 3.

INVENTOR
JOHN HAYS HAMMOND, JR.
BY *[Signature]*
ATTORNEY

Aug. 3, 1948.

J. H. HAMMOND, JR

2,446,279

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4 Sheets-Sheet 4

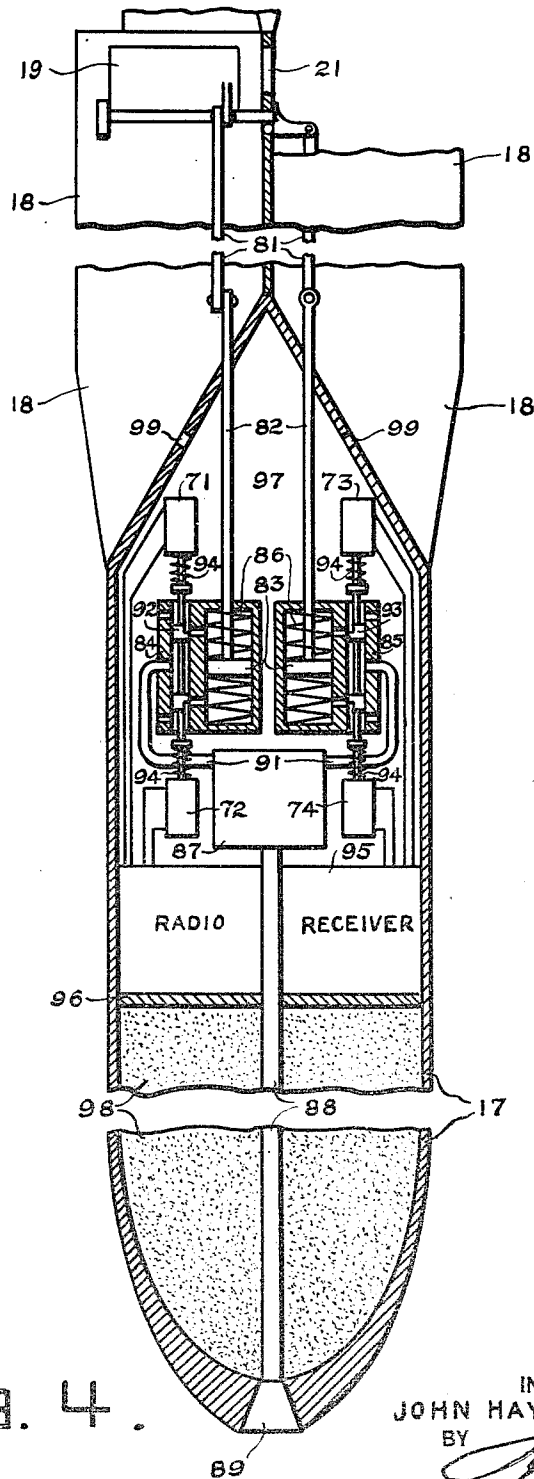


Fig. 4.

INVENTOR
JOHN HAYS HAMMOND, JR.
BY
W. H. H. H.
ATTORNEY

UNITED STATES PATENT OFFICE

2,446,279

AERIAL BOMB CONTROL SYSTEM

John Hays Hammond, Jr., Gloucester, Mass., assignor to Radio Corporation of America, New York, N. Y., a corporation of Delaware

Application September 19, 1942, Serial No. 458,938

4 Claims. (Cl. 250-2)

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This invention relates to the radio-dynamic control of aerial bombs and more particularly to a radio control system of the above type which cannot be interfered with from the ground.

The invention provides means for controlling the direction of descent of a bomb in two planes perpendicular to each other so that the bomb may be guided by remote control in any desired direction.

The invention also consists in certain new and original features of construction and combinations of parts hereinafter set forth and claimed.

Although the novel features which are believed to be characteristic of this invention will be particularly pointed out in the claims appended hereto, the invention itself, as to its objects and advantages, the mode of its operation and the manner of its organization may be better understood by referring to the following description taken in connection with the accompanying drawings forming a part thereof, in which

Figure 1 is a diagrammatic illustration of a portion of an airplane, including the bomb bay;

Figure 1a is a perspective view of a bomb as released from the airplane of Figure 1;

Figure 2 is a schematic diagram of the transmitting circuits on the airplane;

Figure 3 is a schematic diagram of the receiving circuits located in the bomb; and

Figure 4 is a partial section through a bomb illustrating diagrammatically the control apparatus for steering the bomb during its descent.

Referring to the accompanying drawings and more particularly to Figures 1 and 1a the airplane 11 is shown as provided with the usual bomb bay 12 behind which is an opening 13 in which is located the antenna system 14 of the transmitter to be described. This antenna system is mounted on suitable means, shown as gimbal rings 15, so that it may be pointed in any desired direction. A sighting means, shown as a telescope 16, is attached to the antenna system 14 to facilitate following the bomb in its descent. The antenna system 14 is of the type adapted to radiate polarized, directional, short waves in the form of a beam. In the embodiment shown this system comprises a dipole radiator 14a mounted in a reflector system 14b. It is to be understood, however, that any standard type of directional beam short wave radiator may be used.

As shown in Fig. 1a the bomb 17 is provided with the usual fins 18 in which are located two sets of rudders 19 and 21 whose axes of rotation are at right angles to each other. Mounted on the ends of the fins 18 are two directional re-

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ceiving antennas 22 and 23 the axes of which are located in planes at right angles to each other, and preferably in the planes of the axes of the rudders 19 and 21. The antennae 22 and 23 are shown as similar in construction to the antenna 14 and are of the type suited to receive polarized short waves from a given direction only, i. e. from above. The antennae are shown as comprising wave receiving members 22a and 23a and directional members 22b and 23b which correspond to the reflector 14b. The directional members are suited to make the receiving elements receptive to signals received from above and to shield the receiving members from waves propagated from the ground and from horizontal waves so that possibility of interference with the control beam transmitted from the airplane is eliminated.

Figure 2 depicts the transmitter which is installed on the airplane 11. This transmitter is generally of conventional design and only so much thereof is set forth herein as is necessary to an understanding of the present invention. The transmitter is shown as comprising a master radio frequency oscillator, a modulated power amplifier connected to feed the antenna 14, an amplitude modulator, and a control frequency generator.

The master radio oscillator comprises a pentode oscillator tube 111 the control grid 111g of which is connected to a frequency determining circuit 113. The inductor 113l of the frequency determining circuit 113 is tapped and connected to the cathode 111c to supply the necessary feed back from the plate circuit. The second or screen grid 111s is positively biased and the plate circuit includes a tuned circuit 114, which is tuned to double the frequency of the oscillator and is energized from the harmonic having double the frequency of the grid circuit of pentode 111.

The modulated power amplifier includes a pentode 115 of the self biased type, the cathode 115c of which is connected thru a bleeder resistor 117 to the positive terminal of a battery 118. The cathode 115c of the pentode 115 is also connected to one end of a keying resistor 119 the other end of which is connected to the arm of a key 38. The resistor 119 varies the bias of the tube 115 to render the power amplifier operative only when the key 38 is closed. The first control grid 115g is energized from the buffer doubler circuit 114.

The plate 115p of the tube 115 is connected thru an output tank circuit 124, filter choke 125 and a secondary winding 126 of a transformer 152 to the positive side of the plate battery 127. Radio frequency bypass condensers 128 are connected

across both ends of the choke 125 to ground. The second grid 115s of the tube 115 is connected thru a radio frequency choke 129 and a secondary 130 of the transformer 152 to the positive side of the battery 118. Radio frequency bypass condensers 131 are connected across both ends of the choke 129 to ground. The output tank circuit 124 is inductively coupled to a coil 132 feeding a transmission line 133 to the radiating doublet or dipole 14.

The control frequency generator includes a self biased triode 135. The plate circuit is connected thru oscillator coil 137 to the movable arms of the keys 30—33. Between the front contacts of the keys 30—33 and the positive side of a plate battery 138 are connected resistors 34—37, which are adjusted so that the amount of modulation is the same for all channels. A bypass condenser 139 is connected across the movable arms of the keys 30—33 to the positive side of the battery 138. The back contacts of the keys 30—33 are connected thru trimmer condensers 141 of different capacities to the plate 135p of the tube 135. The main oscillatory condenser 145 is connected across the oscillatory coil 137.

A secondary coil 146 is coupled to oscillator coil 137. The coil 146 is connected to feed modulator tubes 147 and 148. The center tap 146a is connected to ground and a second tap 146b suitably chosen on the proper side of center is connected to the grid 135g of the tube 135.

Each of the keys 30—33 is connected mechanically to the key 38 as by a rod 33a which is pushed upwardly by the respective keys 30 to 33 in such a manner that when any one of the keys 30—33 is closed the key 38 will also be closed.

In the operation of the transmitter of Figure 2 a radio frequency is generated by the master radio oscillator and is impressed on the power amplifier. When the key 38 is open the radio frequency is not radiated by the antenna 14, however, due to the high positive bias on the cathode of the amplifier tube 115, which prevents its operation. When the key 30 is depressed an "A" control frequency is generated by the control frequency generator from which it passes through the modulator and is impressed upon the modulated power amplifier. At the same time the key 38 is closed reducing the positive bias on the tube 115 to normal and unblocking the same, whereupon the radio frequency is modulated in a well known manner. The modulated wave is then radiated from the directional antenna 14 in the form of a plane polarized wave.

When the keys 31, 32 and 33 are individually depressed "B," "C" and "D" control frequencies respectively are generated and modulate the radio frequency generated by the master radio oscillator accordingly. In this way when any one of the keys 30—33 is depressed a plane polarized wave is radiated from the antenna 14, this wave being modulated at a different predetermined frequency for each key.

In Fig. 3 is depicted the receiving circuits installed in the bomb 17. These circuits comprise a radio receiver of the superheterodyne type which is connected to the directive antenna system 22—23 and includes a final detector and an automatic volume control. The output of the final detector is connected to a selector system including a first selector, a limiter and a second selector which is connected through two transformers 49 and 50 to a final selector, comprising four tubes 52—55. The output circuits of the tubes 52—55 are connected through four trans-

formers 56—59 respectively to four diodes 61 to 64, which form a thermal type A. C.-D. C. converter system. The four diodes 61 to 64 are connected to the grids 65g—68g of four power tubes 65—68 the output circuits of which include the windings of four solenoids 71—74.

The leads from the antennas 22 and 23 are connected in series and the transmission line from the antenna 23 is a quarter wave length longer than that for the antenna 22. The superheterodyne receiver is of standard construction and includes the usual R. F. circuits, first detector and I. F. circuits, indicated by the rectangle 41 terminated by an I. F. output transformer 75 and a diode 76 which constitutes a second detector and may be provided with an automatic volume control circuit which includes a diode 77, a condenser 78 and resistors 79 and 80. If desired the selectivity may be increased by including a resistor in series with the plate 76p of the diode 76.

The first selector includes a transformer 104 the secondary of which is connected to the grids 47g, 48g of the second selector tubes 47 and 48 in parallel.

The plates 61p—64p of the diodes 61—64 are connected to the junction of batteries 107 and 108. The grids 65g—68g of the power tubes 65—68 are connected through resistors 111 and 112 to the negative side of a battery 105. The cathode filaments 65c—68c of the power tubes 65—68 are shown as supplied from a battery 106.

The receiver is responsive to energy radiated from the transmitter of Fig. 2 and picked up by one of the two antennas 22 and 23, which are mounted at right angles to each other in a plane perpendicular to the direction of radiation from the transmitter. The transmission line from the antenna 23 is a quarter wave length longer than that for the antenna 22; so that at the receiver the signals due to the two antennas are quadrature related in phase, provided they are in phase at the antennae. That is, if ϕ is the angle of the electric vector of the incident plane polarized wave with the rod of antenna 23 then for a wave $A \sin \omega t$ impressed on the system, the voltages picked up at the two antennas will be $A \sin \omega t \cos \phi$ and $A \sin \omega t \sin \phi$, respectively. Assuming no loss of voltage in transmission over the line to the receiver 41, there will be a phase lag in waves received by antenna 23 of a quarter wave length or 90 electrical degrees with respect to waves received by antenna 22, whereby the voltage e_r at the receiver terminals will be

$$e_r = A \cos \phi \sin [(\omega t - \alpha)] + A \sin \phi \sin [(\omega t - \alpha) - 90^\circ]$$

$$e_r = A \{ \cos \phi \sin (\omega t - \alpha) - \sin \phi \cos (\omega t - \alpha) \}$$

$$e_r = A \sin (\omega t - \alpha - \phi)$$

Therefore the strength of the signal at the receiver is independent of the angle of polarization. This is of importance if the angle ϕ is a slow variable, and it is desired to maintain constancy of signal.

The intermediate frequency energy due to the signal, which may be modulated by a control frequency, is impressed through the secondary of the transformer 75 on to the final detector 76 resulting in a pulsating current thru the circuit including the primary of the transformer 104 of the first selector 44. The rate of these pulsations corresponds to the rate of the modulations. The transformer of the first selector is so arranged

that substantially the same transmission is available for all the possible control frequencies.

The signal from the transformer of the first selector, which is broadly responsive to all the control frequencies A, B, C and D, is impressed through the limiter on the grids 47g, 48g of the tubes 47 and 48 of the second selector. In this way the voltage impressed on the grids 47g, 48g is independent of the strength of the signal over a considerable range of signal strengths. The construction of the limiter 45 and its operation are well known, being shown, for example, in U. S. Patent 1,560,206 to E. L. Chaffee. This type of limiter produces a square top or clipped wave from a sine wave. This device is an aid to the automatic volume control in making certain that the signals will be the same regardless of which transmitter key is used and regardless of the signal strengths.

The tubes 47 and 48 feed the transformers 49 and 50 respectively, which are each selective to the transmission of two of the possible control frequencies. Thus, for example, the transformer 49 may be selective to the frequencies A and B produced when the keys 30 and 31 are closed and the transformer 50 may be selective to the frequencies C and D produced when the keys 32 and 33 are closed. The transmission through the transformers 49 and 50 may be of the "double-humped" nature.

The output of the transformer 49 is connected in push-pull to the input circuits of tubes 52 and 53 and the output of the transformer 50 is connected in push-pull to the input circuits of tubes 54 and 55. The outputs of the tubes 52—55 are connected to transformers 56—59 respectively which are selective respectively to the signals produced when the individual keys 30—33 are closed. The energy from the transformers 56—59 is supplied to heat the filaments 61f—64f of the diodes 61—64, respectively, which become conductive from plate to filament in accordance with the well known Edison effect.

Take, for example, the top selective circuit starting with transformer 56. The plate 61p of the diode 61 is made positive with respect to its filament 61f by being connected to the junction of the batteries 107 and 108, the grid 65g of the tube 65 is biased in the vicinity of or beyond cut off by the battery 105 and the solenoid 71 is connected in the plate lead of the tube 65 from the highest potential point on the battery system 105—108. When the filament 61f of the diode 61 is sufficiently heated due to the signal energy received when the key 30 is closed the diode 61 becomes conductive in the direction of the arrow, producing a current flow in the resistor 112 in the direction of the arrow, which makes the grid 65g of the tube 65 less negative and increases the D. C. current in the solenoid 71. Resistor 111 limits the voltage that is impressed upon the grid of the tube 65 when the grid 65g current starts to flow due to the bias becoming zero.

It is thus seen that the signal current produced by closing the key 30 causes the filament 61f of the diode 61 to become heated, which in turn causes the tube 65 to pass plate current to energize the solenoid 71. In a like manner when the key 31, 32 and 33 are closed the corresponding solenoids 72, 73 and 74 will be energized.

While the usual type of rectifiers may be used for A. C.-D. C. conversion, the circuits would be much more complex to produce the desirable characteristics of high threshold of operation. Preferably the range of control frequencies is

made less than one octave to prevent harmonics of one control frequency from coinciding with the fundamental of another control frequency.

In Figure 4 is shown the apparatus for controlling the rudders 19 and 21 in response to the energization of the four solenoids 71—74 illustrated in Figure 3. The two sets of rudders 19 and 21 are connected by links 81 to piston rods 82 which are attached to pistons 83 which reciprocate in two cylinders 84 and 85. Balanced compression springs 86 are provided for normally holding the pistons 83 and therefore the rudders 19 and 21 in a central position.

The pistons 83 are actuated by air under pressure which is supplied from a tank 87. This tank is shown as being connected by a pipe 88 to a funnel shaped opening 89 in the nose of the bomb 17. A flask (not shown) containing air under pressure could also be used as a source of compressed air if desired. The tank 87 is connected to the cylinders 84 and 85 by means of conduits 91 and the supply of air to the interior of the cylinders 84 and 85 is controlled by two piston valves 92 and 93 respectively. The valve 92 is operated in opposite directions by means of the solenoids 71 and 72 and the valve 93 is operated in opposite directions by means of the solenoids 73 and 74. Balanced compression springs 94 are provided to maintain the valves 92 and 93 in a central position when the solenoids 71—74 are deenergized.

The solenoids 71—74 are connected to the radio receiver 95 the circuits of which are shown in Figure 3. The radio receiver 95 is mounted upon a transverse bulkhead 96 which divides the bomb into two compartments 97 and 98. The former contains the control apparatus just described and is provided with two vents 99. The latter is filled with a high explosive, such for example as TNT and is provided with the usual fuses, not shown, for detonating the explosive charge when the bomb reaches its target.

In the operation of the control mechanism shown in Figure 4, the descent of the bomb 17 causes air to enter the opening 89 and to flow thru the pipe 88 to the tank 87. A considerable air pressure will be built up within this tank due to the rapid descent of the bomb. When one of the solenoids, for example, solenoid 73, is energized by the transmission of the C frequency, the valve 93 will be moved upward and will allow air under pressure from the tank 87 to enter the upper end of the cylinder 85. This will cause the piston 83 to move downward which, by means of the rod 82 and link 81, will cause a rotation of the rudder 21 in a clockwise direction. This will cause the bomb to be deviated to the right.

When the transmission of the C frequency ceases the solenoid 73 will be deenergized and the valve 93 will be returned to its central position under the action of the springs 94. The piston 83 together with the rudder 21 will also be returned to a central position under the action of the springs 86. The bomb will then continue on its new course slightly to the right of its former course, the amount of deflection being determined by the length of the C frequency impulse.

When the solenoid 74 is energized by the transmission of the D frequency the opposite action will take place and the rudder 21 will be rotated in a counterclockwise direction to deflect the bomb to the left. By energizing the solenoids 71 or 72 by the A or B frequencies the bomb

17 will be deflected in a plane at right angles to the plane of the drawing.

It is thus seen that a control system for aerial bombs has been developed which permits the steering of the bombs in four directions at 90 degrees to each other by the depressing of a selected one of four keys located on the plane. In this way the bomb may be caused to deviate from its original course the amount of deviation depending on the length of time that the control key is depressed.

With the directional antennas mounted on the tail of the bomb only radiations from above will be received so that it would be impossible for anyone on the ground to interfere or control the bomb even though they were able to ascertain the frequency and modulation of the control wave. In order to eliminate any possible interference from broadcast type of transmitters the transmitter on the plane may be arranged to use supersonic modulation frequencies and the radio carrier wave may be artificially wobbled or frequency modulated to reduce interference from continuous wave transmitters. This control system relies chiefly for selectivity on the directive antenna effect, on the limited duration of the control impulses, on the receiver limiter and volume control action and upon the high threshold of signal for the operation of the solenoids.

For high altitude bombing the bombs may be released from one or more airplanes of a flight and controlled by a following plane which is in a position to observe their flight.

Although only a few of the various forms in which this invention may be embodied have been shown herein, it is to be understood that the invention is not limited to any specific construction but may be embodied in various forms without departing from the spirit of the invention or the scope of the appended claims.

What is claimed is:

1. A radio receiving means responsive selectively to a plurality of different signals, comprising a radio receiver having a final detector connected to detect any of said signals and a volume control means connected to render the output of said detector substantially independent of signal strength, a first selector circuit broadly tuned to respond to all of said signals, a second selector fed by said first selector circuit and having a pair of tuned circuits each tuned to receive a different set of said signals, a final se-

lector circuit including a plurality of circuits tuned individually to the respective signals and each fed by the second selector circuit which is tuned to pass the respective signal, and a control circuit actuated in response to the signals from each of said final selector circuits.

2. A receiving system in accordance with claim 1 in which a limiting circuit is included between said first selector and said second selector so as to make the response of said second selector substantially independent of input signal strength.

3. The invention set forth in claim 1 in which the control circuits comprise solenoids, power tubes feeding said solenoids and means feeding said power tubes respectively from the respective circuits of the final selector.

4. A signal receiving system as set forth in claim 1 comprising thermionic rectifiers fed by the respective circuits of said final selector to pass current only when the energization thereof exceeds a predetermined value, power tubes actuated by the respective thermionic rectifiers and control mechanism actuated in the output circuits of said power tube.

JOHN HAYS HAMMOND, JR.

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