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METHOD AND APPARATUS FOR ADJUSTING
RADIO ECHO DETECTION SYSTEMS
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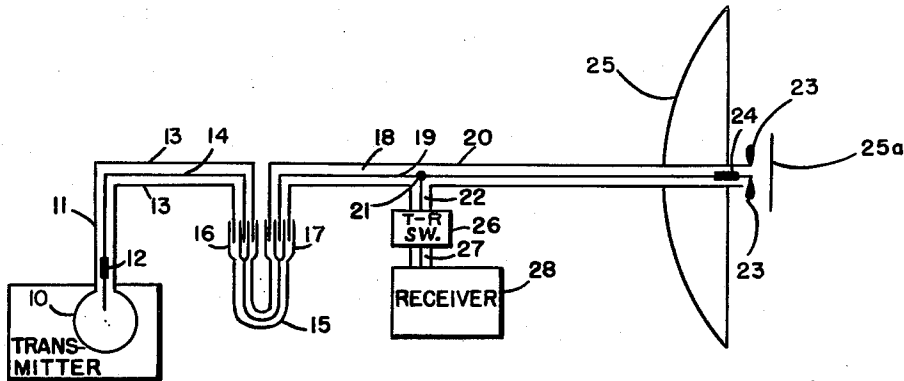


FIG. 1

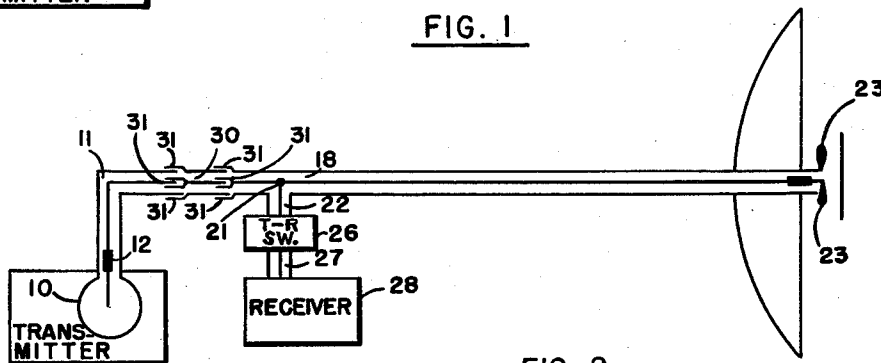


FIG. 2

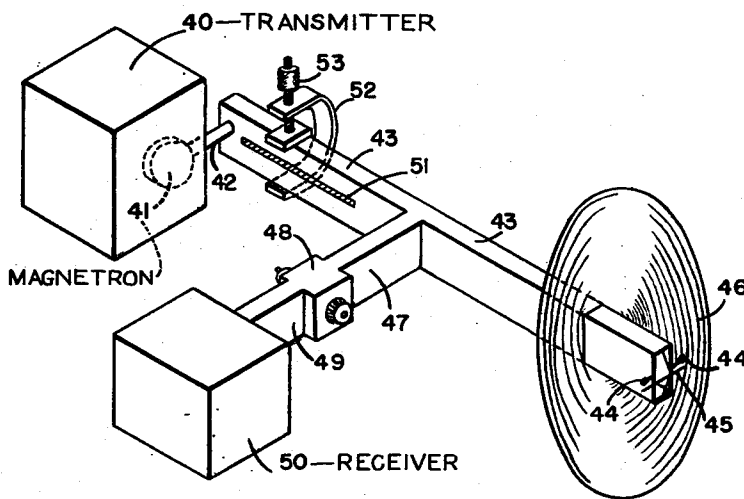


FIG. 3

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METHOD AND APPARATUS FOR ADJUSTING
RADIO ECHO DETECTION SYSTEMS

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5 Claims. (Cl. 250-13)

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This invention relates to signalling, locating and detection systems employing high-frequency electromagnetic waves in which a transmitting device and a receiving device are used with a common antenna. More particularly, this invention concerns arrangements in systems of the type referred to for the purpose of reducing loss of signal energy in that part of such a system which includes the transmitter.

It is an object of this invention to provide a method whereby the absorption of signals which are desired to be received, resulting from signal energy going into the transmitter part of the system, may be inhibited and minimized, thereby increasing the signal strength at the receiver.

I have found that transmitting tubes, such, for instance, as multi-cavity magnetrons, when quiescent may present an impedance to the transmission lines to which they are normally coupled which is quite different from the impedance exhibited during periods when oscillations are being generated in the transmitting tube. Thus, although the transmitter is normally matched to the line for maximum energy transfer during periods of activity, during periods of quiescence it will be mismatched to the line and reflections will occur. By my method I utilize these reflections in such a way that a minimum of energy is accepted by the line connecting the transmitter to the junction of the receiver and transmitter lines.

According to this invention the foregoing result is obtained by adjusting the length of the line connecting the transmitter and the aforesaid junction.

The invention may be better understood with reference to the accompanying drawings in which:

Fig. 1 shows one form of apparatus with which this invention may be applied in order to improve the performance of a high-frequency radio system;

Fig. 2 shows another arrangement for applying this invention to high-frequency radio systems, and

Fig. 3 shows still another arrangement for applying this invention to a high-frequency radio system.

Referring to Fig. 1, there is shown at the left a transmitter which includes a multi-cavity magnetron for generating high-frequency electromagnetic oscillations, which magnetron is diagrammatically shown at 10. The transmitting tube 10 is matched to the coaxial transmission line 11 by a suitably designed matching transformer 12 which consists of a quarter wave section of line with the relative radii of the inner and outer conductors differing from the corresponding dimensions of the transmission line 11 in such a manner as to produce matching of impedances under conditions of transmitter opera-

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tion, in accordance with principles which are well understood in the art. The coaxial transmission line 11 includes an outer conductor 13 and an inner conductor 14. The coaxial transmission line 11 leads to a section of coaxial transmission line which may be described as a "trombone section," because said section of coaxial transmission line is connected by sliding contacts at its end so that the total length of the transmission line of which it forms a part may be varied and adjusted in any desired position. The so-called trombone section is shown at 15 and the two sliding connections are shown at 16 and 17. It is to be noted that the sliding connections must provide for a good contact between the inner conductors as well as good contact between the outer conductors. From the "trombone section" 15 the coaxial transmission line is continued by a further length of coaxial transmission line shown at 18 having an inner conductor 19 and an outer conductor 20. At the point 21 there is a T-junction formed by the coaxial transmission line 18 and another coaxial transmission line 22, the inner conductor of which connects with the conductor 19 and the outer conductor of which connects with the conductor 20. The coaxial transmission line 18 leads beyond the junction 21 to an antenna 23, which is usually provided in the customary fashion with a matching transformer 24, a parabolic reflector 25, an auxiliary reflector 25a and various other mechanical and electrical arrangements not shown and having no bearing on this particular invention. The transmission line 22 leads to an automatic electrical breakdown device designed to short-circuit this transmission line while the transmitting tube 10 is active. This device is shown at 26 and is of the type commonly known as a resonant transmit-receive switch or "T-R box" and is more fully described in one of my copending applications; Serial No. 479,662, filed March 18, 1943 and entitled, "Protection of Receiver Against Overload." From the T-R switch 26 a transmission line 27 leads to a receiver 28.

When the length of the line between the transmitting tube 10 and the junction 21 has certain values, the length of the line and the impedance of the quiescent transmitting tube will combine to present a very high impedance at the junction 21 during periods when the transmitting tube is quiescent. For other lengths of the line between the transmitting tube 10 and the junction 21 a lower impedance will be presented at the junction 21 which will cause a portion of the energy of any received signal from being absorbed in the transmitting tube and the associated transmission line, thus reducing the signal strength at the receiver. For a certain line length, and for other line lengths differing therefrom by an integral number of half wave lengths, a very low impedance will be

presented at the junction 21 and a considerable portion of the energy of received signals will be absorbed in the transmitting tube and its associated line.

I have found that the signal strength can be maintained practically unimpaired by proper adjustment of the line length. I find further that the maxima of signal absorption by the transmitter system are much sharper with respect to changes in line length than are the minima of signal absorption. Consequently my preferred method for adjusting the line length for maximum received signal consists in first adjusting the line length (which in the apparatus shown in Fig. 1 would be accomplished by moving the trombone section 15 back and forth on its sliding contacts) until a minimum signal is obtained in the receiver 28 and then by adding or subtracting one-quarter wave length in the effective length of the line between the transmitter 10 and the junction 21 by a further movement of the trombone section 15. In this fashion not only is it assured that the highest impedance will be presented by the transmitter line at the junction 21 to a signal of the desired frequency (whereas the adjustment would be less certain if it was attempted simply to adjust for maximum received signal in the receiver, the maximum not being very sharp with respect to variation in the line length) but also an adjustment is obtained which is as far as possible from the undesired condition of maximum absorption in the transmitter line, so that the system is given the best possible immunity against loss of reception upon small changes in frequency or small changes in line length resulting from thermal expansion and the like.

Fig. 2 shows a system similar to that of Fig. 1 employing a different method for varying line lengths in which the arrangement has the disadvantage of failing to present continuous variability but has some advantages of convenience in practice and the achievement of better electrical contacts than are usually obtainable with sliding joints. The apparatus of Fig. 2 again contains a transmitter with a transmitting tube 10, matching transformer 12, coaxial lines 11, 18, 22 and 27, a junction 21, an antenna 23, a T-R switch 26 and a receiver 28.

Instead of the trombone section 15, one or several of a number of short sections of coaxial line, which may be called "spacers," are inserted in the line, as the section 30 in Fig. 2 is inserted between the line 11 and the line 18. Suitable joint contact arrangements are provided at the points of contact indicated on Fig. 2 at 31. Since these contacts do not have to permit a continuously variable sliding movement, spring pressure and frictional engagement may be used to good advantage for maintaining electrical contact as is common in many types of electrical connectors. If desired, the contact of the outer conductor may be further tightened by a threaded clenching ring (not shown). The method for applying this invention to the system shown in Fig. 2 is essentially the same as that previously described in connection with Fig. 1. Although the desired results may sometimes be obtained by simply trying various spacer lengths between the lines 11 and 18 until maximum receiver response is obtained, for more certain results are obtained by the preferred method which consists of first determining which length of spacers gives a minimum receiver response and then either adding or subtracting one-quarter wave length (of the oscilla-

tions in the line) respectively to or from the total length of spacers previously determined.

In cases where it is possible to provide replacement transmitting tubes sufficiently similar to the tube to be replaced to permit dispensing with the readjustment of the line length when one tube is substituted for another, the desired line length, in accordance with the present invention, between the transmitting tube and the junction 21 may be determined as herein described and then incorporated into the design of an apparatus with nonadjustable lines. The elimination of sliding or separable joints thereby achieved has advantages of simplicity and of transmitting efficiency.

The advantages of this invention may also be realized by a similar procedure in systems which employ hollow pipe wave guides instead of coaxial transmission lines for the transmission of energy in the system. In the case of wave guides of the hollow pipe variety a great many methods are available for varying the effective electrical length of the wave guide system in addition to trombone sections and methods involving the insertion of spacing lengths. One method consists in simply cutting a slot in the wall of a hollow pipe wave guide. The slot is cut longitudinally of the wave guide, preferably for a distance of several wave lengths. Mechanical arrangements are then provided for squeezing the wave guide together in the neighborhood of the slot. Variation of the width of the wave guide in this fashion causes the wave length of the oscillations in the wave guide to vary, so that although the physical length of the wave guide remains the same, the electrical length calculated in wave lengths may be made to vary quite considerably. Other methods of varying the electrical length of a wave guide include methods involving the moving of masses of dielectric material within the wave guide in such a fashion as to alter the velocity of propagation and consequently also the wave length.

Fig. 3 illustrates the application of the invention in the manner just mentioned to a system in which hollow pipe wave guides are used for transfer of energy from one part of the system to another and in which, as above mentioned, the effective electrical length of the wave guide between the transmitter and the transmitter-receiver junction is varied by squeezing a slotted section of the wave guide. Referring to Fig. 3, the transmitter is shown generally at 40 and includes a multi-cavity magnetron tube 41 which is coupled by a short section of coaxial line 42 to a rectangular hollow pipe wave guide 43. The wave guide 43 is also connected with an antenna system including an antenna 44, a reflector dipole 45, and a parabolic reflector 46. In order to simplify the illustration, arrangements for changing the orientation of the antenna system are omitted in the drawing, although they are frequently provided in apparatus of this class. The end of the wave guide 43 adjacent to the antenna 44 is of course open.

Another wave guide 47 forms a junction at one of its ends with the wave guide 43 and at the other end is connected to an automatic electric breakdown device 48. The latter device is connected by means of a wave guide 49 to a receiver shown generally at 50.

The wave guide 43, between the end which is coupled to the transmitter and the junction with the wave guide 47 is provided with a longitudinal slot 51. The slot 51 should be cut in one of the walls of the wave guide 43 which is perpendicular

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lar to the direction of the electric vector of the oscillations in the wave guide so that an electric field will not appear across the slot and propagations along the wave guide of the oscillatory energy in question will not be appreciably impeded. A clamping device 52 provided with a screw thread adjustment 53 is mounted on the wave guide 43 in the neighborhood of the slot 51 in such a way that the width of the slot 51 may thereby be adjusted. In the form of device shown in Fig. 3 the resilience of the metallic walls of the wave guide 43 are relied on for expanding the slot 51 upon the removal of clamping pressure previously applied. Other types of devices could of course be substituted for regulating the width of the slot 51 in a double acting fashion which would be independent of the resilience of the wave guide wall. As previously mentioned, the variation of the width of the slot 51 is accompanied by a variation of the width of the wave guide 43, which in turn causes a change in the effective electrical length of the wave guide 43 in terms of wave length. In order to carry out the invention in an apparatus arranged such as that of Fig. 3, according to the preferred method of adjustment, two different settings of the screw thread adjustment 53 of the clamp 52 are first found at which a minimum received signal is observed by the receiver 50 when a given signal is introduced into the system. These two settings of the adjusting device 53 should be consecutive minimum signal settings, that is, there should be no minimum signal setting between them. After such minimum settings have been determined, the device 53 is then adjusted to a mean position intermediate of the two minimum signal positions, which will then represent an adjustment of the electrical line length of the wave guide 43 such that absorption by the transmitter and its line of the received signal is at a minimum and the received signal is at a maximum, and consequently the wave guide 43 is then adjusted so that a relatively large change in line length (of the order of one-quarter wave length, that is) will be necessary to cause appreciable absorption of the incoming signal in the transmitter and its associated wave guide system, minimizing the effect of the thermal expansion of the transmitter line.

In the foregoing description of the arrangements for carrying out the present invention, the experimental technique of determining the desired adjustment of line length has been described without adverting to the theoretically desired line length. In practice, the experimental method described is generally more useful, especially where the line between the resonant cavities of the magnetron transmitting tube and the junction of the transmitter and receiver feed lines may be composed of sections of transmission line or hollow pipe wave guide of different characteristics. In apparatus where the design research has proceeded so far that the length of the transmission line can be adjusted in manufacture to a desired electrical length, theoretical calculations of the desired line lengths may sometimes supplement the experimental procedures outlined above.

A transmitting tube, such as a multi-cavity magnetron, when quiescent presents an impedance at a given point, such as at the loop which couples to the oscillating field of the tube, which impedance is considerably different than the impedance presented as such point during transmitter operation. The difference of impedance may be due to a number of causes, such as (1) a

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difference between the resonant frequency when the transmitter is in operation and the resonant frequency of the tube structure in the absence of direct current anode voltage and, possibly, (2) resistive loading during operation of the transmitting tube.

Although no general rules are applicable to all multi-cavity magnetrons with respect to the impedance change between transmitting conditions and quiescent conditions, for certain fixed types of magnetron tubes as designed for operation within certain wave length limits, this impedance change, when referred to a particular point in the apparatus, may be satisfactorily predicted on the basis of measurement of samples. In such case the desired electrical length between the said point of reference and the junction of the transmission means leading to the receiver with that leading from the transmitter to the antenna can be reasonably well determined by calculation. If at such point of reference the impedance of the transmitting tube is considerably lower when quiescent than when energized, the electrical distance from such point to a junction such as the junction 21 should be an odd number of quarter-wave lengths. The electrical distance from such point to a junction such as that formed by the wave guides 43 and 47, should, however, be an integral number of half-wave lengths in the aforementioned case. This difference between the desired lengths for coaxial conductor and hollow pipe wave guide systems respectively lies in the fact that total reflection at the junction from the transmitter branch in the coaxial conductor system is obtained by producing a high impedance at the junction, whereas in the hollow pipe wave guide case the desired total reflection at the junction is obtained by having the transmitter branch of the system exhibit a low impedance at the junction.

In a case in which the transmitting tube shows a "cold" impedance considerably greater than the "hot" impedance, at the point of reference in question, the situation is reversed and the desired distance from such point to the junction would be an integral number of half-wave lengths for the coaxial conductor case and an odd number of quarter-wave lengths for the hollow pipe wave guide case. If at the point of reference no considerable difference between "hot" and "cold" impedance of the tube appears, this signifies either that another point of reference should be chosen or that the invention is not applicable to that particular variety of transmitting tube.

Another method of utilizing the variation of the length of the output line connected to a magnetron type of transmitting tube in order to prevent absorption of energy by the transmitting tube when the latter is quiescent relates to systems in which two magnetron transmitter tubes are employed to provide alternate single pulses to a common radiating system. In such a system there will be a junction of the two output lines of the respective transmitting tubes. The principle of this invention would then be applied for adjusting the length of the output lines of one of the magnetrons so that the total length of line between the two magnetrons is such that one will not appreciably absorb power while the other is operating. The danger of damage to the magnetron during operation of the other may, however, seriously limit the utility of such an arrangement. Such a system would not, moreover, be practical unless two magnetrons operating on exactly the same wave lengths

were used and in addition it would be necessary to provide some means other than that described above for preventing either of the magnetrons from absorbing energy from the signal which it is desired to obtain in the receiver. Other means not covered in this invention are practical in certain types of installations—for instance a choke or a resonator acting as a choke could be associated with the transmission line leading from the transmitting tubes to the junction of the transmitter and receiver lines, which choke would be adapted to be short circuited by breakdown of a discharge gap during periods of transmission.

Prior to this invention, it was difficult, if not impossible, to adjust radio signalling apparatus using a transmitter, a receiver, and a common antenna system so that the received strength would not drop off upon extremely slight changes (such as thermal effects) which would cause much of the received signal energy to be absorbed in the transmitter part of the system. If by some piece of good luck an arrangement might have been put together in which adequate received signal strength was obtained under some conditions there was no assurance that the signal strength would not drop off suddenly due to effects then unknown, but now known to be due to the line length between the transmitter and the junction being such that only an extremely small change in its length, such as might be caused by thermal effects, would bring the transmitter branch of the line to a length corresponding to maximum absorption of energy in that line.

What I desire to claim and secure by Letters Patent is:

1. In a radio echo detection system including a transmitter, an antenna, a receiver, first wave energy transmission means connecting said transmitter to said antenna, and second wave energy transmission means connected to said receiver and forming a junction with said first transmission means, the method of sharply adjusting said system to minimize loss of received echo signals to said receiver which consists in directing said antenna at a remote target, operating said transmitter to launch energy toward said target, adjusting the electrical length of that portion of said first wave transmission means between said transmitter and said junction for minimum echo signal reception in said receiver, and then changing the electrical length of said portion by a quarter wave length of the waves transmitted in said system.

2. In a radio echo detection system including a transmitter, a receiver, a common antenna, first wave energy transmission means connecting said transmitter to said antenna, and second wave energy transmission means connected to said receiver and forming a junction with said first transmission means, the method of sharply adjusting said system to minimize loss of received echo signal to said receiver which consists in introducing a signal into said system while said transmitter is quiescent, adjusting the electrical length of that portion of said first wave transmission means between said transmitter and said junction for maximum energy absorption in said transmitter, and then changing the electrical length of said portion by a quarter wave length of the waves transmitted in said system.

3. In a radio echo detection system including a transmitter, a receiver, a common antenna, a first hollow pipe wave guide connecting said transmitter to said antenna, and a second hollow

pipe wave guide connected to said receiver and forming a junction with said first wave guide, the method of sharply adjusting the system to minimize the loss of received echo signals to said receiver which consists in introducing a signal into said system, modifying a dimension of that portion of said first wave guide between said transmitter and said junction to obtain a first minimum received signal in said receiver, further modifying said dimension to obtain a second minimum received signal in said receiver, which second minimum is consecutive to said first minimum, and then modifying said dimension to the mean intermediate value of the two minimum signal values.

4. In a radio echo detection system including a transmitter, a receiver, a common antenna, first wave energy transmission means connecting said transmitter to said antenna, and second wave energy transmission means connected to said receiver and forming a junction with said first transmission means, the method of sharply adjusting said system to minimize the loss of received echo signals to said receiver which consists in introducing a signal of the frequency of said transmitter into said system, mechanically modifying that portion of said first wave transmission means between said transmitter and said junction, thereby modifying the effective electrical length of said portion to obtain minimum signal reception in said receiver, and then further mechanically modifying said portion of said first transmission means to change the effective electrical length thereof by a quarter wave length of said signal.

5. In a radio echo detection system including a transmitter, an antenna, a receiver, first wave energy transmission means connecting said transmitter to said antenna, and second wave energy transmission means connected to said receiver and forming a junction with said first transmission means, the method of tuning said system which consists in directing energy from said system toward a remote target, adjusting the electrical length of that portion of said first transmission means between said transmitter and said junction for minimum echo signal reception in said receiver, and then changing the electrical length of said portion by a quarter wave length of the waves transmitted in said system.

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