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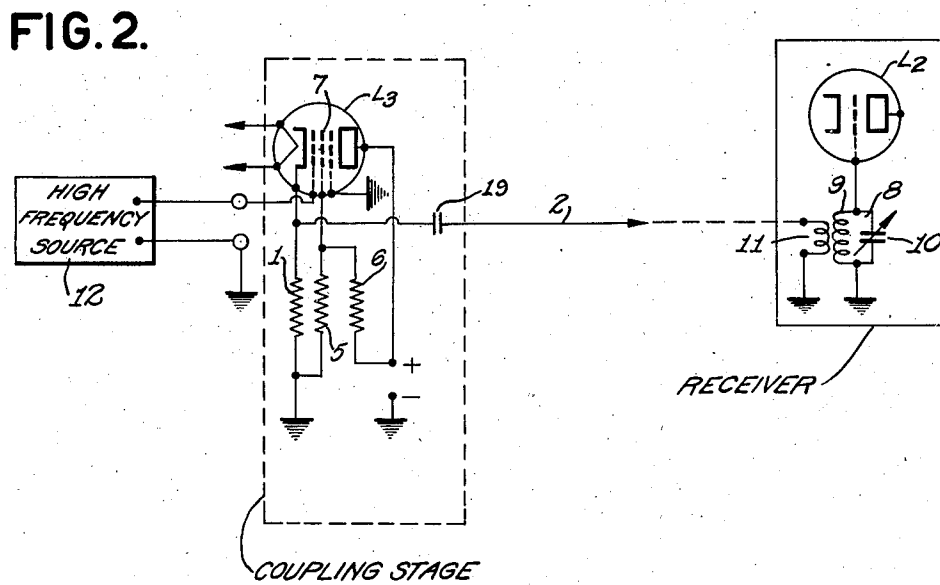
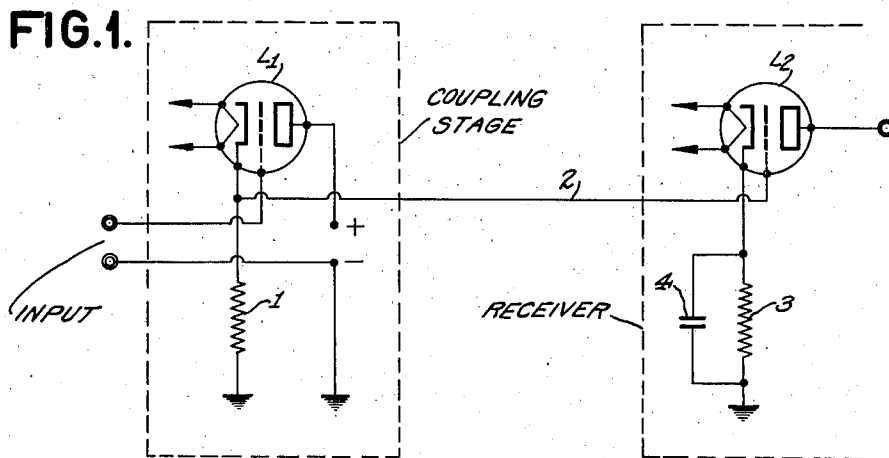
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2,393,971

RADIO RECEIVING SYSTEM

Filed March 22, 1941

3 Sheets-Sheet 1



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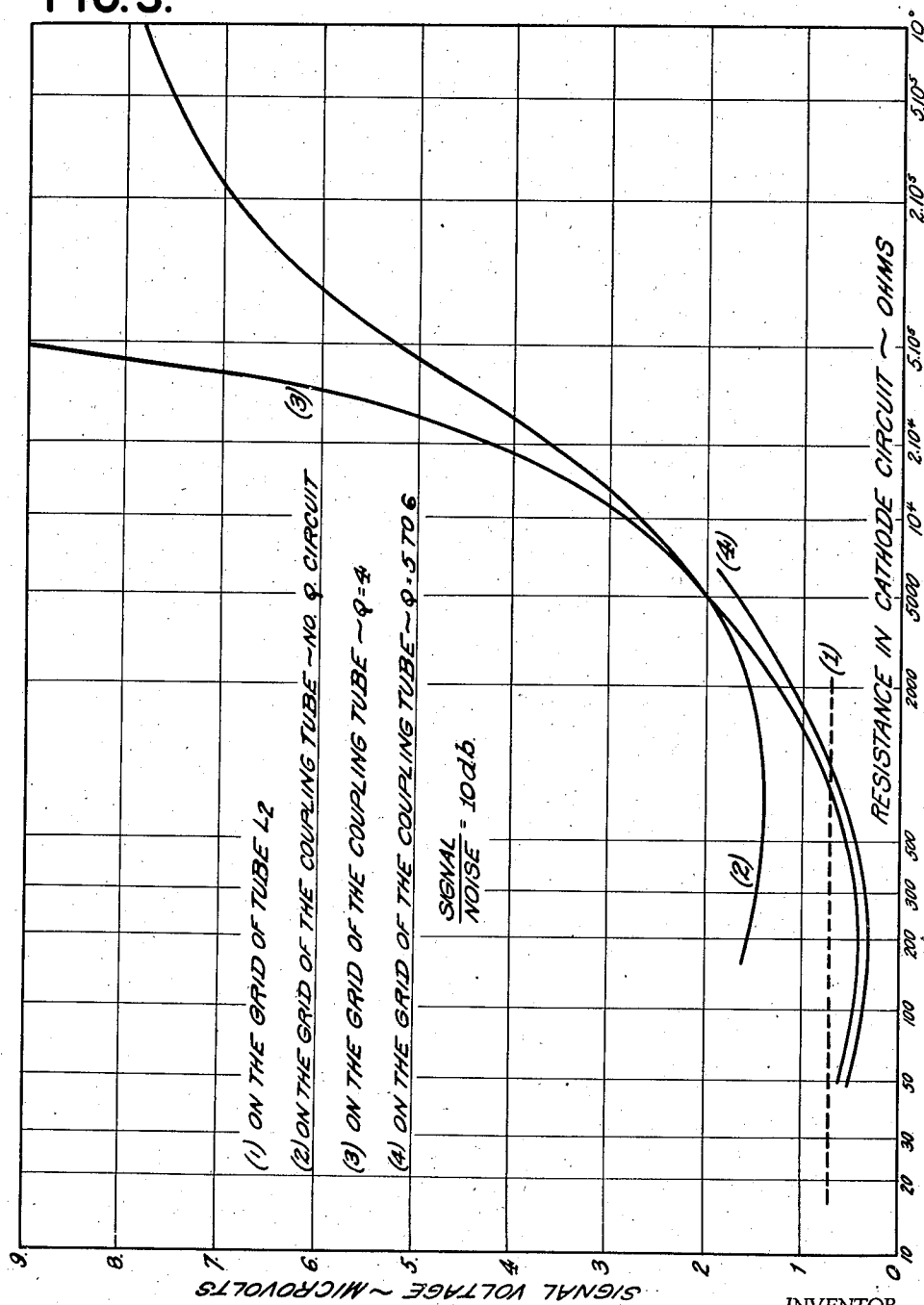
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FIG. 3.



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3. Sheets-Sheet 3

FIG. 4.

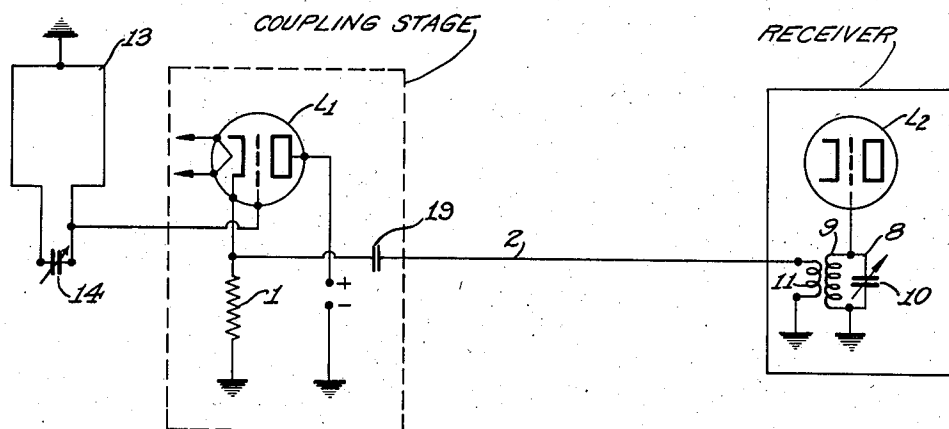
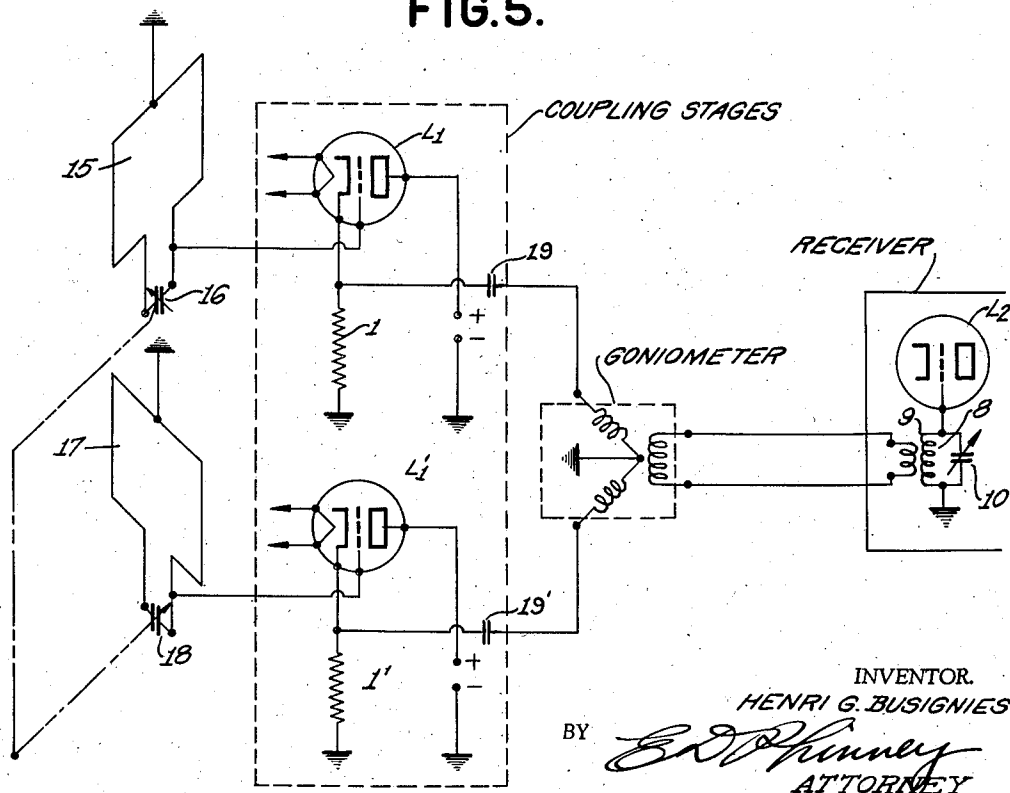


FIG. 5.



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RADIO RECEIVING SYSTEM

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Application March 22, 1941, Serial No. 384,670
In France December 20, 1940

14 Claims. (Cl. 250—20)

The present invention relates to a radio receiving system and more particularly to methods and apparatus for improving the signal-to-noise ratio in a radio receiver.

The causes of background noise in the input circuits of receivers are well known and consist primarily of the Johnson effect or the effect due to thermal agitation in the component parts of the circuit and effects due to irregularities of electron emission from the cathode of the tube in the input circuit and ionization within the tube. Numerous precautions have been taken to reduce to a minimum the background noise in a good receiver. For example, a tube having a high value of amplification is employed in the input circuit and in the plate circuit of this tube, a high quality circuit is inserted which enables one to use all of the amplification of the tube. In the grid circuit of the tube another high quality circuit is inserted which raises the value of the signal to a high level with respect to the noise caused within the tube. When all of these precautions are taken it is found generally that the tuned circuit of the grid causes an increase of the background noise apparently due to the Johnson effect in this circuit.

It is known that the ratio of the signal-to-noise diminishes with the decrease of amplification of the first stage of a receiver and it is common practice in circuits employing radio goniometers (where this ratio has a particular importance) to use the maximum possible of amplification in the first stage tube. It has been found that when the amplification of the tube is decreased, the noise decreases less rapidly than the signal and the receiver functions as a whole less well than when the amplification is greater.

It is also known that the output power of the noise increases proportionally to the band width of the receiver. Therefore, in a good quality receiver all the selectivity possible is utilized for a given modulated-signal.

The following table gives an example of the signal-to-noise ratio that can be obtained under good conditions for a given selectivity:

Selectivity	High frequency voltage on first grid	Type of signal	Signal to noise-ratio at low frequency output
2 kc.—6 db down 4 kc.—20 db down	Microvolts 0.7 to 0.9	Modulated 30 per cent with 400 cycles/sec.	10 db—being 5 milliwatts noise and 50 milliwatts signal.

Under the same conditions for a band width of one kilocycle the power ratio of signal-to-noise increases to 20, being in effect 16 db.

The signal-to-noise ratio in a receiver is evidently dependent on the amplitude of the high frequency voltage applied to the input circuit of the receiver. If the magnitude of the high frequency voltage is increased, the signal-to-noise ratio is increased. Under many conditions the input signal can be increased by increasing the effective height of the wave collector or antenna system. However, on aircraft it is difficult to substantially increase the effective height of the antenna system since the space available for the system is extremely limited. In direction finding systems employing loop antennas and goniometers on aircraft, an indication of direction is obtained by moving the goniometer or, in some cases, the loop antenna until a minimum signal is received. The precision of the indication depends on the signal-to-noise ratio. For very weak signals, the ratio determines the amount the loop or goniometer must be balanced to find both sides of the angle blurred by the noise. Also, when the receiver is installed at a considerable distance from the antenna system, the indication becomes less precise, due to the loss in the line between the antenna and the receiver. The loss which results from transmitting the signal along a line is definitive.

It is an object of my invention to improve the signal-to-noise ratio in a radio receiver.

It is another object of my invention to improve the ratio of signal-to-noise in receiving systems wherein the antenna system is at some distance from the receiver.

In accordance with one embodiment of my invention I provide a coupling stage having a large amount of negative feed-back adjacent the receiving antenna. The transmission line of the receiving system is connected between a resistance or impedance in the cathode circuit of the coupling stage and the input of the receiver.

In accordance with another embodiment of my invention I provide in a receiving system a coupling stage having a large amount of negative

feedback between the receiving antenna system and the receiver and a voltage step-up network in the input stage of the receiver. The voltage step-up network may be a transformer or transformer and tuned circuit or other similar networks.

In accordance with another embodiment of my invention, a circuit having a low value of Q , where Q represents the ratio of the reactance of the circuit to the resistance of the circuit, as a high frequency transformer giving an increase of impedance, is inserted in either the coupling stage or the input of the receiver. By suitably adjusting the value of Q or the transformation ratio in the manner described in connection with the detailed description of the invention an improved signal-to-noise ratio in the receiver can be obtained.

My invention will be more clearly understood by referring to the following particular description made in connection with the accompanying drawings, wherein:

Fig. 1 illustrates a coupling stage having a large amount of feedback, the input stage of a receiver and a transmission line interconnecting these two stages;

Fig. 2 illustrates a modification of the circuit of Fig. 1 including a circuit having a low value of Q ;

Fig. 3 is a diagram used in describing the operation of the apparatus of the invention;

Figs. 4 and 5 show the application of my invention to radio compass systems employing loop antennas.

In Fig. 1 there is shown a coupling stage comprising a triode L_1 whose grid may be coupled to any radio frequency source, such as a loop antenna. The resistance 1 in the cathode circuit of the tube L_1 acts as a load for the tube L_1 and a coupling resistance for the transmission line 2 . Preferably, the transmission line 2 is a low impedance line such as a coaxial line, and the impedance 1 is adjusted to match the impedance of the line or alternatively the impedance of the line is adjusted to match the impedance 1 , the magnitude of the impedance 1 being controlled by the type of tube L_1 employed. If desired, a decoupling condenser may be included in series with the line 2 . Except for the impedance in the input circuit of the coupling stage and the anode supply, the grid of tube L_1 is coupled directly to the plate of the tube. This means that there is a large amount of negative feedback between the plate circuit and the grid circuit and this large amount of feedback makes the signal voltage produced across the resistance 1 less than the signal voltage applied to the grid. In other words, the output signal of the stage is less than its input signal but the output signal is across a much lower impedance. There is no voltage amplification, but substantial power amplification. At the receiver input the transmission line 2 is connected to the grid of triode L_2 . The cathode circuit of the receiver input tube shown in Fig. 1 comprises the usual biasing resistor 3 and by-pass condenser 4 .

Instead of the resistor 1 , shown in the cathode circuit of the tube L_1 , a circuit comprising a resistor and a series condenser and inductance in parallel therewith, may be inserted in the cathode circuit to provide a selective effect at the frequency of the input signal. Also, instead of the triode, as shown, other types of tubes may be employed, such as pentode tubes.

The circuit shown in Fig. 1 improves the transmission of the high frequency signal from the

antenna system to the receiver because of the impedance transformation effected by coupling stage. The mere inclusion of an ordinary pre-amplifier adjacent the antenna system would not produce the results obtained by the coupling stage described above. While it is true that the coupling stage does not compensate for the transmission circuit loss, the signal at the input of the receiver is greater than what it would be with ordinary transmission methods and no coupling stage, and hence the signal-to-noise ratio in the receiver is improved. An ordinary pre-amplifier would increase the signal at the receiver, but at the same time it would introduce noise which would offset the advantage of increased signal. The coupling stage of the present invention has a large amount of negative feedback and hence does not introduce noise into the system due to noise within the coupling stage itself. Also the coupling stage, due to the feedback does not amplify in voltage the received signal before transmission to the receiver, but instead it merely improves the transmission efficiency. It should be understood that other methods of obtaining negative feedback may be employed, but I prefer the method shown due to the ease with which large amount of correctly phased negative feedback may be obtained.

A modification and preferred embodiment of my invention is shown in Fig. 2. In this figure, the coupling stage comprises a tube L_2 , cathode resistance 1 , and dropping resistors 5 and 6 , which supply a positive potential to the grid 7 . As in Fig. 1, the tube L_3 of Fig. 2 may also be a triode. A transmission line 2 coupled to the resistance 1 by the coupling condenser 19 couples the coupling stage to the receiving stage. A coupling circuit having a low value of Q is designated generally at 8 . This low Q circuit comprises a coil 9 and a condenser in parallel therewith designated 10 . A coupling coil 11 couples the transmission line 2 to the coil 9 and the input circuit of the receiver.

The introduction of the low Q circuit 8 in the transmission circuit between the coupling stage and the receiver produces an unusual and important effect. The curves shown in the diagram of Fig. 3 will help to describe this effect. With the oscillator 12 , which produces a signal of about 500 kilocycles modulated 30% with a 400 cycle note, as a signal source the characteristics shown in Fig. 3 were obtained. Curve 1 illustrates the voltage on the grid of receiver tube L_2 with the oscillator connected directly thereto. The voltage measured at this grid was found to be .70 microvolt for a signal-to-noise ratio of 10 db at the receiver output. Throughout the tests the signal-to-noise ratio at the output of the receiver was maintained constant at 10 db. With no Q circuit 8 in the input circuit of the tube L_2 (with only a direct high frequency connection between the resistance 1 and the grid of tube L_2) the voltages required on the grid of the tube L_2 with varying values of cathode resistance for the tube L_2 are shown by the values of curve 2 . It was found that by introducing a low Q circuit 8 , as shown in Fig. 2, having a Q of about 4, the curve designated 3 was obtained. In a similar manner, by increasing the value of Q from about 5 to 6, the curve designated 4 was obtained. As shown by curve 2 of Fig. 3, the circuit of Fig. 2 without a low Q circuit in the transmission circuit produced a loss in the signal-to noise ratio of about 4 to 5 db.

The curves of Fig. 3 show the magnitude of the

variation of the received signal required to produce a given signal-to-noise ratio at the receiver output as a function of the cathode resistance. The variations of the signal voltage required illustrate the improvements given by the invention for a given value of signal-to-noise ratio. When the signal voltage required at the grid of tube L_3 is less for a given signal-to-noise ratio at the output of the receiver, the transmission of the signal voltage between the antenna and the receiver is more efficient. With a more efficient transmission of the signal and a substantially constant background noise the ratio of signal-to-noise in the receiving system increases for a given signal.

With the insertion of a circuit having a Q of about 4 and a cathode resistance of about 200 ohms for a coupling tube type 1852, the transmission efficiency is considerably increased over the value obtained when the Q circuit is omitted as shown by curve 3. At this point the input signal necessary to produce an output having a signal-to-noise ratio of 10 db is approximately 1.1 microvolts less than the signal necessary when no Q circuit is provided in the transmission circuit between the coupling tube and the receiver input. With an increase of the Q to a value between 5 and 6 the amount of input signal necessary is again reduced. However, if the Q is further increased it is found by experiment that no further benefit is obtained, and instead, the background noise introduced by the first tube of the receiver begins to decrease the ratio of the signal-to-noise. Therefore, to effect an improvement in the signal-to-noise ratio, I prefer to insert circuits in the transmission circuit having a value of Q of approximately 1.0 to 10.

Although I have disclosed a circuit having a low value of Q in the preferred embodiment of my invention, it is possible to use other voltage step-up networks or devices such as wide band transformers to produce the results of my invention. That it is possible to use such networks will be apparent from a brief outline of the principle of my invention. Suppose, for example, that an ordinary amplifier stage is inserted between the antenna system and the receiver. If there is no transmission line between the amplifier stage and the receiver input, the effect is the same as though another stage had been added to the receiver, and thus there is no improvement in the signal-to-noise ratio at the receiver output. Instead, there is a slight decrease due to the introduction of additional noise by the additional stage. If there is a transmission line between the amplifier and the receiver input, then impedance matching networks must be employed at the output of the amplifier and the input of the receiver. These networks introduce losses in the system, and although the signal voltage at the input of the receiver may be increased by this arrangement, the additional amplifier reduces the signal-to-noise ratio at the input and the networks themselves may introduce noise and further reduce the ratio. When a coupling stage or amplifier having a large amount of negative feedback is employed according to the teaching of the present invention, there is an impedance match between the stage and the line with a small loss in signal voltage and no increase of noise. In the previously described arrangement using an ordinary amplifier, an impedance match between the amplifier and the line required a considerable reduction of the signal voltage on the line, and in order to com-

pensate for this reduction, a line terminating network having a large voltage step-up was required. The noise introduced in a system by these networks increases with the transformation ratio required. In the system of the present invention, since there is substantially no decrease in the signal voltage on the line by the use of the negative feedback amplifier for impedance matching, a network having a small step-up may be employed to terminate the line. There is thus produced on the grid of the tube of the input stage of the receiver a signal voltage equal to or greater in magnitude than the signal voltage produced thereon by the above system without the use of any noise adding circuits. The output of the coupling stage being of low impedance (200 ohms, for example) the noise made by thermal agitation in the coupling stage is only the noise corresponding to the small noise voltage produced across this low impedance. A similar result may also be produced in systems that do not require transmission lines, the negative feedback amplifier being directly coupled to the step-up network in the receiver input. It is also possible to further improve the signal-to-noise ratio by connecting a number of coupling stages of the type shown in Fig. 2 in cascade with associated step-up networks. In this arrangement, however, the improvement gained by the addition of each stage gradually decreases. When several stages are connected in cascade, they may all be connected before the transmission line or some may be connected before the line and some after the line.

The amount of step-up employed in the system of the present invention is primarily determined by the impedance introduced by the step-up network. It has been found that the impedance of the step-up network alters the impedance in the feedback path and the operation of the feedback amplifier, and in order to avoid the introduction of noise by the amplifier, the feedback must be large and be produced by a substantially resistive network. It is thus desirable to keep the step-up low, for example between 1.0 and 10 and preferably between 3 and 7, the value of 5 being the optimum value.

A coupling coil may be used in place of, or in conjunction with, the cathode resistance 1. When this coupling coil is used, it is possible to couple the low Q circuit to the coupling stage end of the transmission line rather than to the receiving stage end. In this case, the transmission line 2 may be connected directly to the grid of the tube L_2 , or by means of a coupling impedance. However, with this modification, care must be taken to keep the impedance of the cathode circuit of tube L_3 at a low value, and hence, the coupling between the coupling coil in the cathode circuit of the tube L_3 and the low Q circuit must be loose. Also, the coupling must be loose so that the low Q circuit will have substantially no effect on the negative feedback of the coupling stage. In the preferred embodiment, in order to avoid the coupling difficulties, the low Q circuit is inserted in the input stage of the receiver. Also, to avoid any harmful effect on the negative feedback of the coupling stage, instead of employing a value of which produce a maximum signal voltage, I prefer to use a value of Q equal to 5. In all cases, the value of Q is for the frequency of reception.

If desired, it is also possible to provide two lines between the coupling stage and the receiver input and to connect these lines so that the coil

11 is in series with the resistance 1. In this case the circuit from cathode to ground would be as follows: from the cathode to one end of coil 11 by one line; return from the other end of coil 11 by the other line to one end of resistance 1; and through resistance 1 to ground. Also, a decoupling condenser may be connected in parallel with resistance 1.

By suitably adjusting the Q of the circuit 8 and the coupling between the coupling coil and the circuit, the loss due to the transmission line may be compensated for. A loss in the transmission line may be equalized by an increase in voltage gain across the low Q circuit. However, as above, the voltage gain must not be increased to too high a value, because if this is done, the background noise introduced by the coupling stage offsets the increase in signal-to-noise ratio, obtained by the use of the low Q circuit.

The improvement produced by the present invention is desirable in all types of receiving systems and it is particularly desirable in systems employing antennas of low effective height, such as radiogoniometer and radio compass systems. In Fig. 4, an application of my invention to a radio compass system is shown.

In many radio-compass receiving installations, the receiving loop is located at some point remote from the receiver. In these installations, I propose to mount the coupling stage immediately adjacent the receiving loop and to couple the coupling stage to the receiver by a low impedance line. In Fig. 4 a loop 13 tunable by a condenser 14 is coupled to the coupling stage. The loop 13 is located at a point remote from the receiver and the coupling stage is mounted immediately adjacent the loop. The remaining elements of Fig. 4 are the same as in Fig. 2. The loop 13 may, or may not be tunable. When the loop 13 is tunable, as shown, the tuning may be performed by known types of remote control mechanisms.

In radio-compass systems employing two loops and a goniometer, the coupling stage may be connected in the receiving circuit immediately after the goniometer. In this case only a single coupling stage is necessary. Preferably, however, two coupling stages are employed, one in each line between a loop and its corresponding goniometer coil. Fig. 5 illustrates this latter arrangement, and in this figure, loops 15 and 17 which may be tuned by condensers 16 and 18 respectively, are coupled to the goniometer by two coupling stages comprising tubes L_1 and L'_1 . Separate cathode resistances 1 and 1' are associated with the tubes L_1 and L'_1 . These coupling stages and the remainder of the circuit of Fig. 5 are the same as the coupling stage and the transmission line and receiver circuit of Fig. 2. As explained in connection with the showing of Fig. 4, the coupling stages are preferably mounted immediately adjacent the loop antenna. Also, although I have shown the loop 16 and 17 as tunable loop, the loop may or may not be tunable as desired.

In fixed receiving systems, such as receiving systems at ground stations, there is frequently a long transmission line between the receiving antenna and the goniometer. In these systems the coupling stage may be placed just ahead of the goniometer, but preferably the coupling stage is mounted adjacent the receiving antenna. In order to obtain all of the benefits of the present invention, it is expedient in these systems to

raise the impedance of the circuit preceding the coupling stage in order to match the input impedance of the stage.

It may be noted that when goniometers are employed in receiving systems, a considerable transmission loss results for the coefficient of coupling of these goniometers is not very high. As a result the chain of circuits comprising the goniometer, does not have a high Q . Instead, these circuits have a relatively low Q , and since it is an object of the present invention to include a circuit having a low Q in the circuit after the coupling stage, my invention is especially applicable to systems employing goniometers, both because of compensation for transmission loss and because of the co-operation between the coupling stage and the goniometer circuits.

By experiment, I have found that in the above system, a loss of 6 db in the goniometer can be replaced by a gain of 4 db when the circuit is arranged in accordance with the present invention. There is thus an increase of 10 db from the value of signals normally obtained. If these systems employ tuned loops, a further gain of from 6 to 8 db may also be obtained, but of course, this latter gain is not due to the circuit of the present invention. When the loops are tuned at a distance, much of the advantage obtained by tuning the loop is lost due to the transmission loss between the tuned loop and the input circuit of the receiver if a circuit of the present invention including a coupling stage is not employed.

By experiment, I have found that in ground station receiving system installation when the antenna system is 2 kilometers from the receiver the high frequency loss in the line is of the order of 6 db. If, as in the present invention, a circuit having a Q of from 3 to 5 is inserted between the coupling stage and the receiver it is possible to compensate for this loss of 6 db, and it is possible in some cases to replace the loss of 6 db by a gain of some decibels. When one considers that an increase of 6 db in the signal above the value normally obtained doubles the range of the receiving system without decreasing the precision, it may readily be seen that the apparatus of the present invention is particularly desirable in direction finding systems.

Although I have described my invention as particularly applicable to direction finding systems, it will be understood that my invention may be used in other receiving systems such as television receiving systems. Also, my invention is particularly applicable to ultra-short wave systems. In these latter systems the input impedance of the first tube of the receiver is usually of low impedance. Also, the Q of the input circuit of these systems is generally of a low value. As pointed out in connection with my invention, an improved signal-to-noise ratio can be obtained with the circuit of my invention even though the input impedance of the receiver may be low.

While I have described particular embodiments of my invention for purposes of illustration, it will be understood that various modifications and adaptations thereof may be made within the scope of the invention.

What is claimed is:

1. A radio receiving system comprising an antenna system, a complete receiver, a coupling stage comprising an amplifier having a large amount of negative feedback coupled to said antenna system, and a circuit having a low value of ratio of reactance to resistance at the operating frequency of said receiving system con-

nected between said coupling stage and said receiver.

2. A radio receiving system comprising an antenna system, a complete receiver, means for tuning said receiver to a desired frequency, a coupling stage comprising an amplifier having a large amount of negative feedback, means for coupling said coupling stage to said antenna system, and means for coupling said stage to said receiver comprising a voltage step-up network having a low value of step-up at said desired frequency.

3. A radio receiving system according to claim 2 wherein said means for coupling has a value of step-up between 1.0 and 10.

4. A radio receiving system according to claim 2 wherein said means for coupling has a value of step-up between 3 and 7.

5. A radio receiving system according to claim 2 wherein said means for coupling has a value of step-up equal to 5.

6. A radio receiving system comprising an antenna system, a receiver, a plurality of coupling stages coupled to each other in parallel and to said antenna system and said receiver, each of said stages comprising an amplifier having a large amount of negative feedback, coupling means for coupling each of said stages to each other comprising a voltage step-up network having a low value of step-up, and coupling means for coupling one of said stages to said receiver comprising a voltage step-up network having a low value of step-up.

7. A radio receiving system comprising an antenna system, a receiver, a coupling stage comprising an amplifier having a large amount of negative feedback, means for coupling said stage to said antenna system, and a transmission circuit between said coupling stage and said receiver comprising a resistance operatively connected in said amplifier, a transmission line coupled to said resistance, a circuit having a low value of ratio of reactance to resistance operatively connected in said receiver, and means for coupling said transmission line to said circuit having a low value of ratio of reactance to resistance.

8. A radio receiving system comprising an antenna system, a coupling stage comprising a vacuum tube having a cathode, a grid and an anode, a low impedance connected in series with said cathode, an anode circuit, a grid circuit and means for feeding energy from said anode circuit to said grid circuit in a negative sense, a receiver comprising a vacuum tube having a grid, a cathode and an anode and a grid circuit comprising a circuit having a low value of ratio of reactance to resistance, means for coupling the grid circuit of said coupling stage to said antenna system, a transmission line, means for coupling said transmission line to said low impedance, and means for coupling said transmission line to the grid circuit of said receiver.

9. A radio receiving system according to claim 6 wherein said coupling stage is mounted adjacent said antenna system.

10. A radio receiving system according to claim 15 6 wherein said antenna system comprises a loop antenna.

11. A radio receiving system according to claim 6 wherein said grid circuit of said receiver comprises a condenser and coil connected in parallel with each other, the ratio of reactance to resistance of said circuit being equal to 4.

12. A radio receiving system comprising a first antenna system, a second antenna system, a goniometer, a receiver, transmission circuits for coupling said antenna systems to said goniometer and for coupling said goniometer to said receiver, a coupling stage in at least one of said transmission circuits comprising an amplifier having a large amount of negative feedback and a circuit having a low value of ratio of reactance to resistance in at least one of said transmission circuits.

13. A radio receiving system according to claim 12 wherein a coupling stage is provided in each transmission circuit between said antenna systems and said goniometer and each of said stages is mounted adjacent its respective antenna system and said circuit having a low value of ratio of reactance to resistance is operatively connected in the input of said receiver.

14. The method of increasing the signal to noise ratio in a receiver using a coupling stage including an impedance element and having a large amount of negative feedback, and a transmission line which comprises feeding a received signal to said coupling stage, tapping off said signal from said stage at a reduced amplitude from said impedance element and transmitting the reduced signal to said receiver over said transmission line, the impedance in said stage matching the impedance of said line.

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