

April 10, 1945.

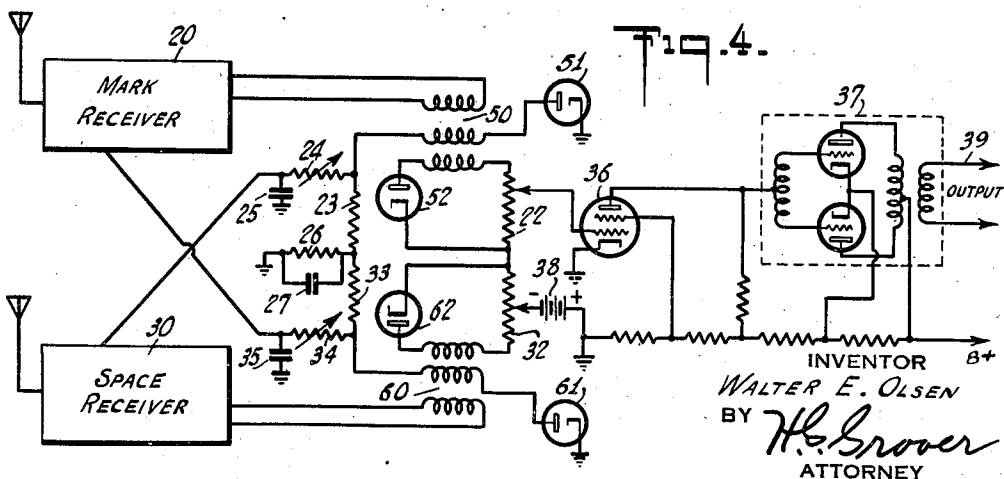
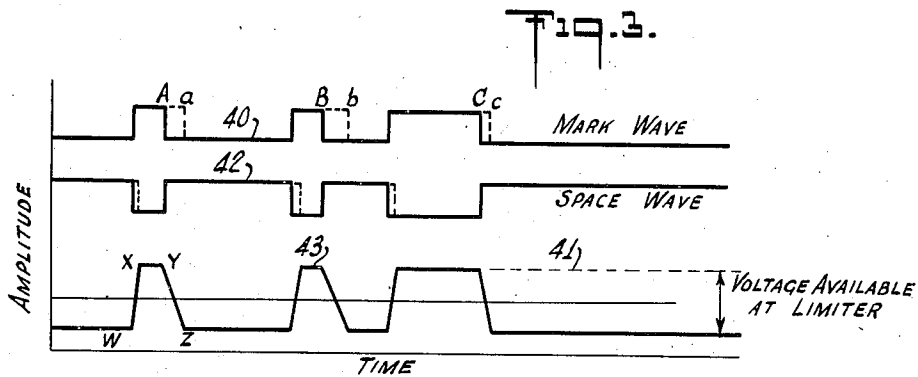
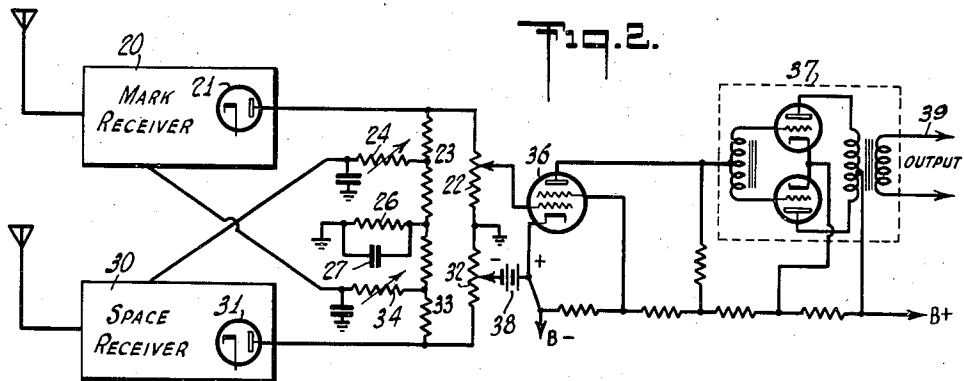
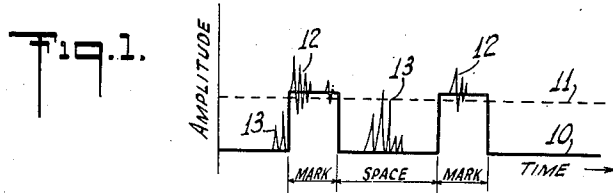
W. E. OLSEN

2,373,495

RECEIVING SYSTEM

Filed May 5, 1942

2 Sheets-Sheet 1



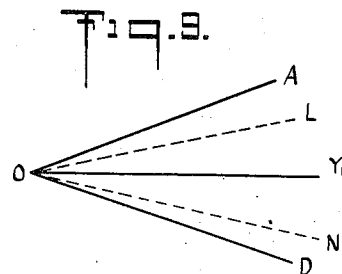
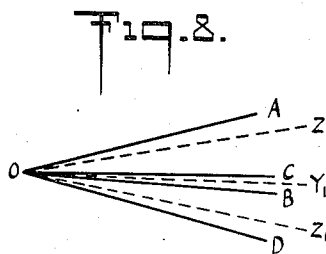
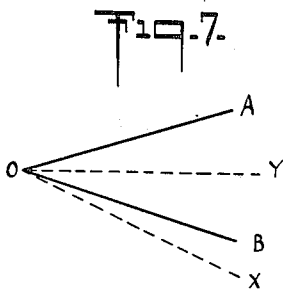
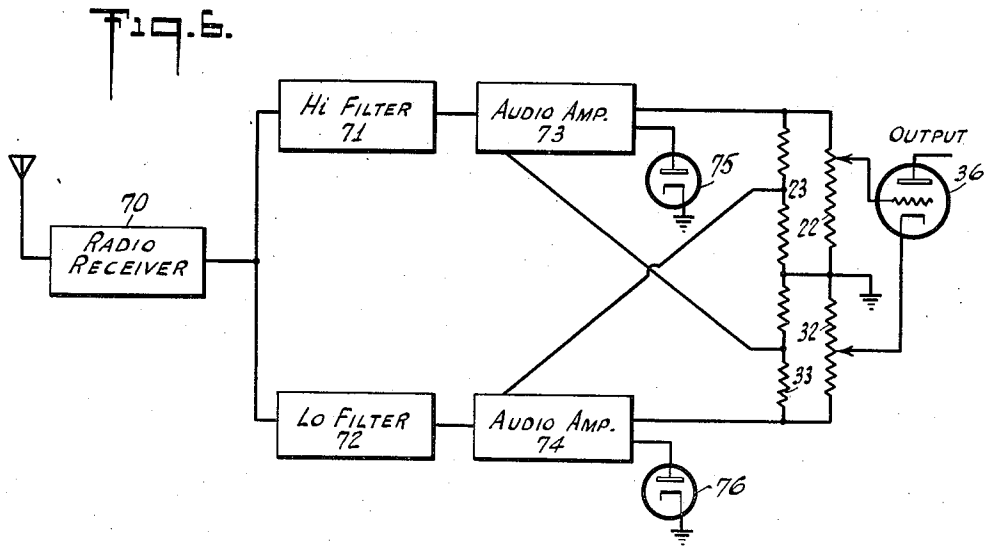
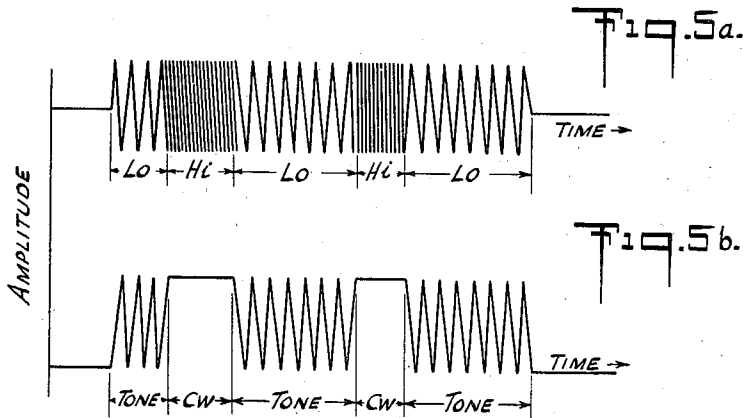
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2 Sheets-Sheet 2



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2,373,495

RECEIVING SYSTEM

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Application May 5, 1942, Serial No. 441,791

7 Claims. (Cl. 250—8)

The present invention relates to radio receiving systems and, more particularly, to such systems which are particularly adapted to reduce the effects of interference from undesired sources of radiant energy.

Various receiving systems have heretofore been devised to overcome the effects of static, multi-path phenomena, fading and interference from undesired stations, from diathermy and motor ignition. These effects may be reduced to some extent by the use of limiting systems in the receiver. The limiting stage in the receiver is adjusted so as to pass to the terminal apparatus only signals below a certain predetermined amplitude. Signals below this level are amplified normally while signals above the predetermined level, including static crashes, etc., are suppressed. The output of the system is, therefore, substantially of constant amplitude.

In addition to limiting, automatic gain control is also used to maintain a constant output level. The signal may then vary over a great range and the output of the system still remain constant, the only effect of fading being an increase of noise level in the receiver when the signal is very weak due to the higher amplification in use at such times.

In heretofore known systems, as above described, it is apparent that while the system effectively suppresses static and other interference during the marking intervals of a signal, during spacing intervals when no signal is received by the receiver, the interference will be amplified and passed on to the output substantially unhindered. This effect is aggravated by the fact that with no signal the gain control bias is removed from the amplifiers in the receiver and the amplification therefore rises. The rise in amplification may be prevented to some extent by using a time delay circuit in conjunction with the automatic bias. The time delay circuit is adjusted to have a time constant which is long compared to the length of the signalling intervals so that the bias will be maintained for a short time after the signal ceases. However, such systems are at a disadvantage as the speed of keying is increased. With higher speeds a smaller time constant is desirable and, furthermore, the automatic gain control tends to keep the gain of the receiver, or receivers lower than might be desirable when receiving a weak signal through heavy interference.

An object, therefore, of the present invention is to provide a receiving system in which the gain is automatically varied to a maximum value during

the marking intervals and to a minimum during spacing intervals.

Another object of the present invention is to provide a radio receiving system which is affected by static interference and fading to a much lesser extent than are receivers heretofore known in the art.

A further object of the present invention is to overcome the disadvantages of heretofore known receiving systems utilizing directive antennas by automatically controlling the direction of maximum directivity in accordance with the direction of arrival of the desired signal.

The foregoing objects, and others which may appear from the following detailed description, are attained in accordance with the principles of the present invention by providing a pair of separate receivers coupled to the same or different receiving antennas, one receiver being tuned to the marking component of the signal to be received and the other, to the spacing component of the signal to be received. The signal is transmitted by shifting the transmitter frequency in accordance with the signalling impulses. Both receivers are provided with automatic gain control. The gain control from one receiver is used to bias down the other receiver during the period that it is idle, that is, when it is not receiving a receiving impulse. The second receiver, in turn, biases down the first during its idle period. The marking and spacing waves are both used, the outputs of the two receivers being so combined as to have an additive effect on a common output limiter tube.

In another embodiment of the present invention it is contemplated using a pair of separate directive antennas, one for each receiver, and so arranging the antennas that their directivity patterns are directed in slightly different directions but still overlap to some extent. The receiver circuits are then so arranged that the receiver obtaining the maximum response contributes the greater portion of the output signal, while at the same time biasing down the other receiver to such an extent that its effect is not noticeable in the output.

The present invention will be more fully understood by reference to the following detailed description, which is accompanied by drawings in which Figure 1 is a curve illustrating the effects of static crashes in previously known systems, while Figure 2 is a diagram in schematic block formation of an embodiment of the present invention; Figure 3 is a curve illustrating the embodiment of Figure 2; Figure 4 illustrates a modifica-

tion of the structure shown in Figure 2, while Figures 5a and 5b illustrate diagrammatically signal trains of the type used in the circuit of Figure 6 which is a further modification of the present invention, while Figures 7, 8 and 9 illustrate diagrammatically the variable directivity feature of the present invention.

In Figure 1 I have represented by means of curve 10 the typical operation of a limiting receiver system. The curve 10 illustrates the action of the limiter in clipping the variable signal level along dotted line 11. It will be seen that due to the limiting action, static crashes 12 on the tops of the marking impulses are clipped off and do not appear in the output of the receiver. However, crashes 13 appearing during spacing intervals are passed through the receiver practically unchanged. This is an effect that the present invention is designed to overcome.

The modification of the present invention shown in Figure 2 embodies a pair of receivers 20 and 30. The antennas supplying energy to receivers 20 and 30 may, if desired, be separate similar antennas arranged at closely adjacent locations or they may be widely separated to give space diversity effects or of different types to give polarization diversity effects. In some cases a single antenna for both receivers is satisfactory. Receiver 20 is tuned to the marking frequency radiated by a remote transmitter (not shown) while receiver 30 is tuned to the spacing frequency as radiated by the transmitter. The amplified radio frequency signal in receivers 20 and 30 is rectified by rectifiers 21 and 31. The anode circuits of the rectifiers are connected to a common output circuit including series connected resistors 22 and 32 having the junction therebetween grounded. A potential divider system, including resistors 23 and 33, is also connected across the common output of the two receivers. At suitable tap points on resistors 23 and 33 are connected the automatic gain control circuits of receivers 20 and 30. The connections are arranged in a crossed relationship, that is, the potential developed across resistor 23 is utilized to control the gain of receiver 30 while the potential developed across resistor 33 is utilized to control the gain of receiver 20. Adjustable time constants 24 and 34 are connected in each of the gain control leads. The time constant circuits are so arranged that only a small delay is introduced in the gain control potentials. Thus the gain of the receivers follows the keying of the transmitter and cuts off whichever receiver is idle. It also causes the receiver which is receiving the largest signal to contribute most to the common output resulting in frequency diversity. The common output is applied to a limiter tube 36 which assures a constant amplitude output. The output from limiter tube 36 is connected through a conventional amplifier system 37 to a desired output circuit 39. A source of potential 38 is provided to so bias the grid of limiter tube 36 that it cannot be driven positive during spacing intervals.

The operation of the circuit of Figure 2 is as follows. At an instant when the space receiver 30 receives a signal the lower end of resistor 32 becomes negative with respect to the grounded midpoint. At such an instant there is no potential drop across resistor 22 due to signal voltage from the mark receiver 20. The gain, therefore, of the space receiver 30 is at a maximum. At the end of the spacing interval the mark receiver 20 receives a signal impulse. With no potential drop, due to a spacing signal across the resistor 32 the

grounded junction between receivers 32 and 22 becomes less positive with respect to the lower end of resistor 32. Thus, it is seen that the voltage drops across resistors 22 and 32 are additive and together have an effect on the common limiter tube equal to twice that which would result if the limiter tube were connected across either resistor alone.

This is apparent from the relationship shown in Figure 3 wherein curve 40 represents the mark wave received by receiver 20 and curve 42 the space wave received by receiver 30. The combined curve 43 is seen to be double in amplitude to that of either curve 40 or 42 alone. The dotted line 41 represents the available limiting amplitude of the signal. During the cross-over period, that is, when the mark wave is ending and the space wave beginning, the gain of receivers 20 and 30 are equal. Equal and opposite voltages are, therefore, set up across the output resistors 22 and 32 and cancel one another in the input circuit of the limiter tube 36.

As a further feature of the present invention it is contemplated additionally providing a small amount of common bias arising from both receivers. This is developed across resistor 26 which is suitably by-passed by condenser 27. The capacity of condenser 27 is so related to the resistance of resistor 26 that any variation in the common bias is slow compared to the keying frequency. It should be noted that the common bias developed across resistor 26 is effective to control the gain of the two receivers simultaneously and in like senses thus counteracting simultaneous fading of both mark and space waves.

Due to the fact that at times the incoming signal may arrive by way of several paths of different and continuously variable lengths, the effect of an elongation of the code impulses may result. The transmitted characters are, in effect, prolonged as indicated by points A, a, B, b, C, c of the mark wave in Figure 3.

The present invention is inherently suited to overcome this difficulty for when two signal voltages are received simultaneously by the receivers they cancel out in the common limiter input circuit. There may be some changing of the shape of the combined wave due to the elongation effect, as shown on curve 43 at points W, X, Y, Z. However, this may be overcome to a great extent by varying the time constant of the cross-bias of one receiver in relation to that of the other. The points of connection of limiter tube 36 to resistors 22 and 32 are made variable so that the combination of the mark and space wave results in a uniform output wave.

The modification of the present invention shown in Figure 4 differs from that shown in Figure 2 in that the radio frequency output of the mark receiver 20 is applied to a multi-winding coupling transformer 50 and that of the space receiver 30 is applied to a similar coupling transformer 60. Thus, the rectifier tubes 51 and 61 which supply automatic cross-bias effect to the receivers through the network 23, 33 are isolated from the signal rectifiers 52 and 62 which supply the limiter tube 36 from their load resistors 22 and 32. Furthermore, this arrangement allows one side of the output circuit of the signal rectifier tubes to be grounded so that a standard limiter and keying circuit may be used.

The modification shown in Figure 4 may also be used for applying the cross-bias principle to phone reception. The transmitter, having a center frequency midway between the frequen-

cies of the mark and space waves heretofore mentioned, is effectively frequency modulated between those frequencies or limits. Then receivers 20 and 30 are so tuned as to receiver amplitude modulated waves, one on the low side of the frequency modulated carrier and the other on the high side of the same carrier. The rectified output of one receiver is then the inverse wave of the output of the other. Their combination in the common output circuit in opposing phase relationship results in a double amplitude wave in the same way as in the case of telegraph signals. The cross-biasing effect is the same as before described.

In the previously described systems one radio frequency channel was used to transmit the mark wave while another radio frequency channel was used to transmit the space wave.

The modification shown in Figure 6 illustrates how the principles of the present invention may be adapted to a single radio frequency channel. The signal received by radio receiver 70 is carried on a single radio frequency channel and is modulated alternately by two different tones, as shown in Figure 5a, one tone in accordance with the mark portion of the signal and the other in accordance with the space portion of the signal. The two tone audio output is separated into two channels by the high frequency filter 71 and low frequency filter 72. The channels contain audio amplifiers 73 and 74 which are adapted to have their gain controlled by bias variation. The audio frequency signal in the output of audio amplifier 73 is rectified by rectifier 75 while the output of amplifier 74 is rectified by amplifier 76. The rectified audio frequency signals are utilized in the same way as the rectified radio frequency signals of the previously described modifications. A suitable proportion of the voltage developed across resistor 22 as determined by the voltage divider 23 is applied to audio amplifier 74 to control the gain thereof, while similarly voltage divider 33 supplies gain control voltage to audio amplifier 73. Thus, the high frequency portion of the wave of Figure 5a is applied to audio amplifier 73 and provides, for example, the marking portion of the signal in the output. The voltage developed across resistor 23 is applied to audio amplifier 74 to bias that amplifier to substantially cut-off during the continuance of the high frequency portion of the signal. When the high frequency portion of the wave is concluded and the low frequency portion begins, it passes through the low frequency filter 72 and is amplified by audio amplifier 74. The resultant rectified signal appearing across resistor 33 biases audio amplifier 73 to cut-off. It should be noted that the system, as so far described with reference to Figure 6, may require nearly the same total radio frequency band width as does the system of Figure 2. This is due to the fact that the low tone must be much higher than the keying frequency to key properly at high speed. Then the high tone must be separated from the low tone by a great enough distance to prevent cross-talk between the two channels in the audio apparatus. In order to reduce the required band width of the radio frequency channel the lower tone may be reduced to zero frequency, as shown in Figure 5b. In this system audio amplifier 74 must be capable of amplifying direct current and, of course, the rectifier 76 is not necessary. Except for these changes the operation of the amplifier of Figure 6 with the signal as shown in

Figure 5b is the same as though the signal of Figure 5a were used.

In all of the previously described embodiments directive receiving antennas may be used. These are of great advantage since they reduce interference from static due to their directivity and, therefore, result in higher signal-to-noise ratios than simple non-directional antennas. The signal-to-noise ratio rises as the sector over which the antenna receiver is narrowed. A point is reached, however, beyond which any increased directivity results in erratic operation. This is believed to be due to the fact that the angle of arrival of a given signal usually varies from instant to instant and will at times, therefore, arrive from such a direction as to be outside the sector of reception and apparent fading effects result. If the directivity of the antenna system is automatically varied in accordance with the shift of angle of arrival of the signal, then more highly directive antennas may be used resulting in still better signal-to-noise ratios. This desirable result may be obtained with the present invention in the same manner now to be described with reference to Figures 7, 8 and 9.

To simplify the illustrations the received signal is represented by a straight line as if it consisted of a simple ray. Also, the illustrations show only one plane, the horizontal for instance. Actually, automatic directivity may be used in a vertical plane to an even greater advantage.

In Figure 7 the angle AOB represents the sector over which an antenna system receives signals with a satisfactory signal-to-noise ratio, the center line OY being pointed in the direction from which signals are received. Any signal which arrives from such an angle as to be outside the sector is received with a much lower signal-to-noise ratio, or not at all. This is illustrated by the line OX, for example.

Now, in Figure 8, an additional antenna system is set up which is so directed as to receive over sector COD. The two sectors COD and AOB overlap slightly with center line OY₁ in the direction from which the signals are normally received. Then, if the receiver of Figure 2 is arranged to switch automatically from one sector to the other as the angle of arrival varies, each sector may be made approximately 1/2 as wide as that of the system illustrated in Figure 7. The cross-bias system of Figure 2 when used with a mark-space signal performs this switching operation very effectively. The antenna represented by the angle AOB may be connected to the mark receiver 20 of Figure 2, while the antenna represented by the angle COD may be connected to the space receiver 30. Now, if a signal is received along line OY₁ both portions, mark and space, contribute equally to the rectified output. The signal-to-noise ratio in this case is an optimum. When the angle of arrival of the signal shifts toward a line ZO, or beyond, the space signal drops out and the cross-bias operates to cut off the idle sector, in proportion to the strength ratio of the signal in the two sectors. Likewise, if the angle of arrival shifts towards a line Z₁O the space signal will contribute most to the common output and the sector AOB will be cut off proportionally by the cross-bias to prevent reception of noise by way of the idle sector. The net result of such a system is automatic directivity over the sector AOB with good signal-to-noise ratio. Also, by adjusting the movable arms connected to resistors 22 and 32 of the input circuit of the limiter tube 36, either the mark or

the space signal may be made to have the greatest effect on the limiter tube, as desired. This permits manual control of directivity in addition to the automatic control. It may be desirable, furthermore, in some cases, to space the two antennas represented by the angles AOB, COD a sufficient distance geometrically to obtain an additional space diversity effect.

It will be seen by reference to Figure 9 that the present system is generally less affected by fading than heretofore known systems. Assume that the angle AOD is the sector of reception of a moderately wide directive antenna system and that LO and NO represent two rays arising from the same signal, but arriving from slightly different directions due to variations in the paths traversed. It is generally accepted that fading is due to phase differences between two or more such rays. Now, the cross-bias systems cuts the sector AOD into two parts which are received by separate antennas. If the mark wave also has a ray into the space sector it is, of course, not accepted by that receiver and so is eliminated. Similarly, if the space wave has a ray arriving in the mark sector it is not accepted by that receiver.

While I have particularly shown and described several modifications of my invention, it is to be distinctly understood that my invention is not limited thereto but that improvements within the scope of the invention may be made.

I claim:

1. A receiving system adapted to operate with a space wave keyed signal including a pair of receivers each adapted to be tuned to one component of said signal, a common output circuit for said receivers and means for automatically controlling the gain of each receiver in accordance with the signal intensity in the other of said receivers, and further means for simultaneously controlling the gain of both receivers in accordance with the signal intensity in both of said receivers, said further means having a long time constant.

2. A receiving system adapted to operate with a space wave keyed signal including a pair of receivers each adapted to be tuned to one component of said signal, signal rectifying means in each receiver, a pair of serially connected resistors, each having one end connected to one of said signal rectifying means, the junction between said resistors being connected to a point of zero reference potential, an output circuit connected across a portion of said resistors and means for applying the potential developed across each of said resistors to the other of said receivers to reduce the gain thereof.

3. A receiving system adapted to operate with a space wave keyed signal including a pair of receivers each adapted to be tuned to one component of said signal, signal rectifying means in each receiver, a pair of serially connected resistors each having one end connected to one of said signal rectifying means, the junction between said resistors being connected to a point of zero reference potential, an output circuit connected across a portion of said resistors and

means for applying a portion of the potential developed across each of said resistors to the other of said receivers to reduce the gain thereof.

4. A receiving system adapted to operate with a space wave keyed signal including a pair of receivers each adapted to be tuned to one component of said signal, signal rectifying means in each receiver, a pair of serially connected resistors each having one end connected to one of said signal rectifying means, the junction between said resistors being connected to a point of zero reference potential, an output circuit connected across a portion of said resistors and means for applying a portion of the potential developed across each of said resistors to the other of said receivers to reduce the gain thereof, said junction being connected to said point of zero reference potential through another resistor wherein is developed a potential for reducing the gain of both of said receivers.

5. A receiving system adapted to operate with a space wave keyed signal including a pair of receivers, each adapted to be tuned to one component of said signal, signal rectifying means in each receiver, a pair of serially connected resistors, each having one end connected to one of said signal rectifying means, the junction between said resistors being connected to a point of zero reference potential, an adjustable connection from a point on each of said resistors to oppositely acting control electrodes of an amplifier tube and means for coupling signal translating means to said amplifier tube.

6. A receiving system adapted to operate with a space wave keyed signal including a pair of receivers, each adapted to be tuned to one component of said signal, signal rectifying means in each receiver, a pair of serially connected resistors, each having one end connected to one of said signal rectifying means, the junction between said resistors being connected to a point of zero reference potential, an adjustable connection from a point on each of said resistors to oppositely acting control electrodes of an amplifier tube, means for coupling signal translating means to said amplifier tube, and means for applying the potential developed across each of said resistors to the other of said receivers to reduce the gain thereof.

7. A receiving system adapted to operate with a space wave keyed signal including a pair of receivers, each adapted to be tuned to one component of said signal, signal rectifying means in each receiver, a pair of serially connected resistors, each having one end connected to one of said signal rectifying means, the junction between said resistors being connected to a point of zero reference potential, an adjustable connection from a point on each of said resistors to oppositely acting control electrodes of an amplifier tube, means for coupling signal translating means to said amplifier tube, and means for applying a portion of the potential developed across each of said resistors to the other of said receivers to reduce the gain thereof.

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