Sept. 11, 1945. J. R. DAVEY 2,384,456

RADIO RECEIVING SYSTEM

Filed May 23, 1944 3 Sheets-Sheet 1

FIG. 1

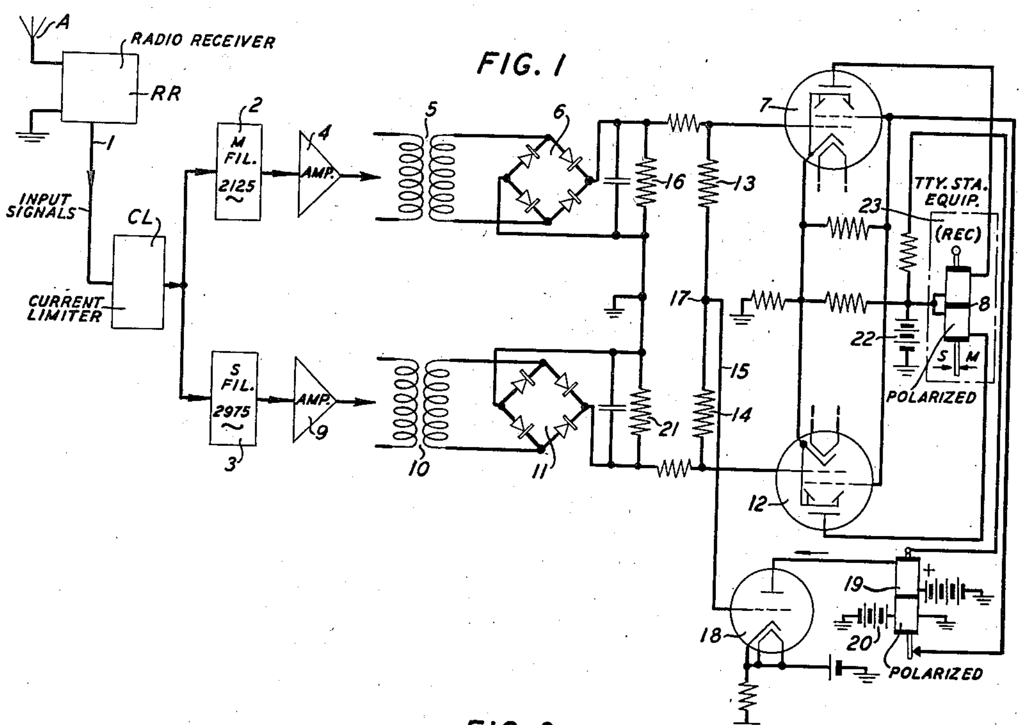
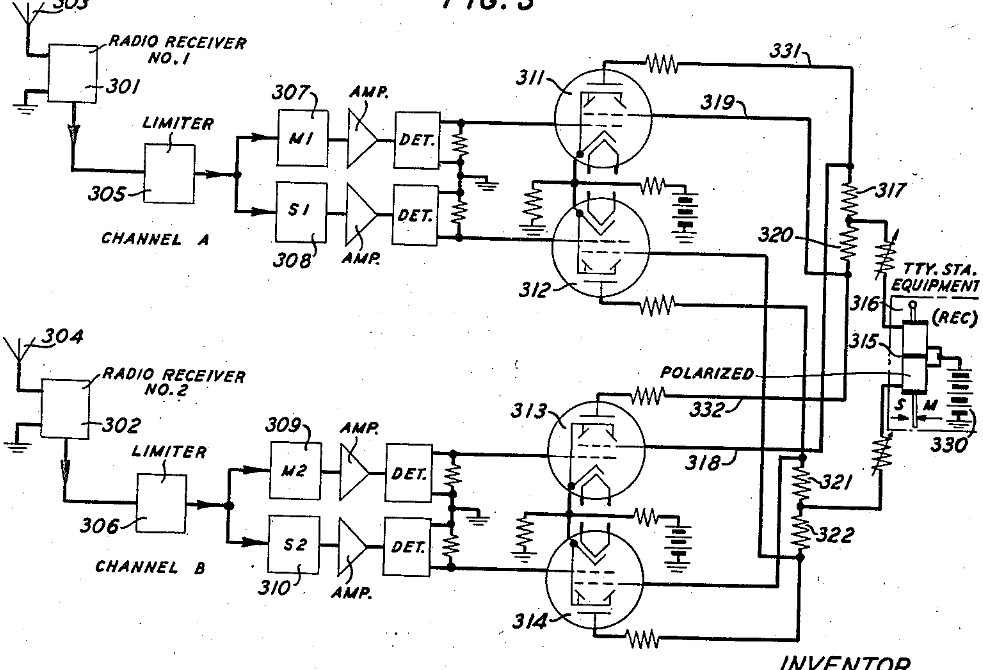


FIG. 3



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RADIO RECEIVING SYSTEM

Filed May 23, 1944 3 Sheets-Sheet 2

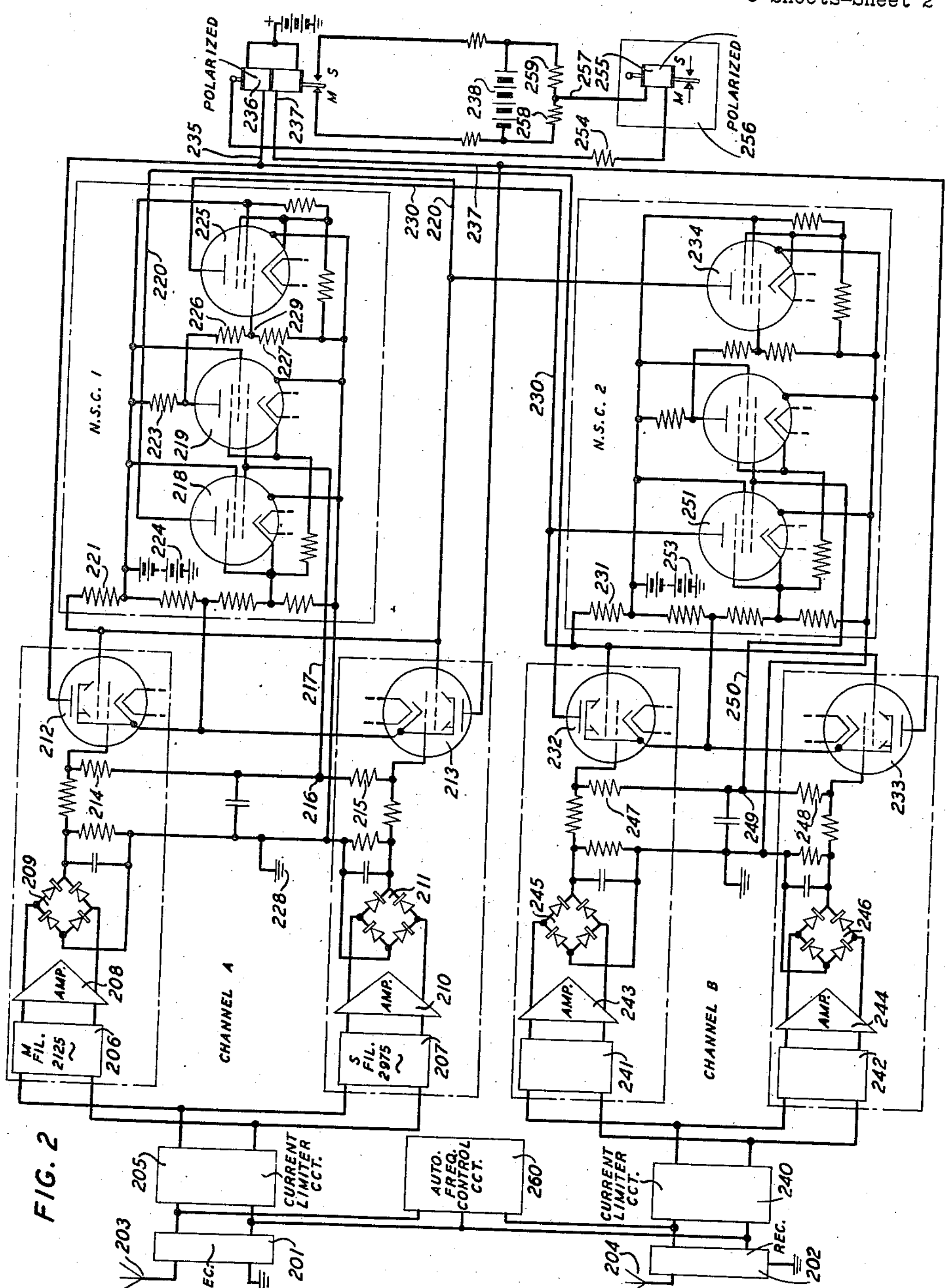

FIG. 2

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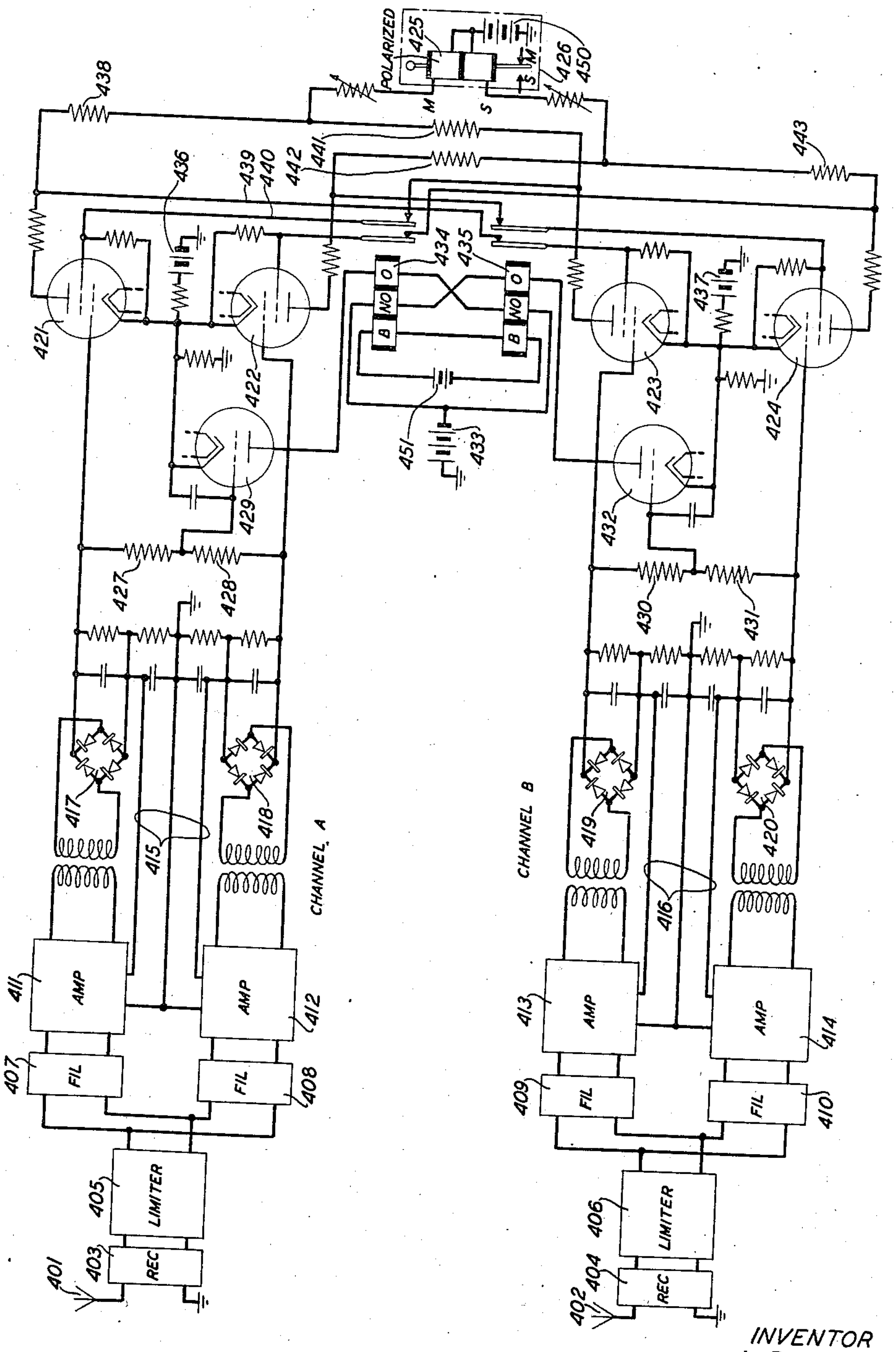
FIG. 4



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Patented Sept. 11, 1945 2,384,456

UNITED STATES PATENT OFFICE

2,384,456

RADIO RECEIVING SYSTEM

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Application May 23, 1944, Serial No. 536,925

23 Claims. (Cl. 250—8)

This invention relates to radio-telegraph receiving circuits and more particularly to diversity receiving circuits for use in radio-telegraph systems employing different frequencies for marking and spacing signals.

It is an object of the invention to provide a radio receiving system with improved means for detecting noise currents.

It is also an object of the invention to provide a radio receiving system with improved means for preventing excessive noise currents from causing errors in the recording of signals.

It is also an object of the invention to minimize the objectionable effects of fading and to increase the reliability of reception in a diversity radio receiving system.

An additional object of the invention is to provide a diversity radio receiving system with improved means for selecting among its diversity channels that channel which has the best instantaneous signaling conditions.

Another object is to provide a diversity radio receiving system with improved means for separately detecting noise currents in each of the diversity channels.

A further object is to provide a diversity radio receiving system with improved means for decreasing the gain of a channel having poor signaling conditions while increasing the gain of a channel having good signaling conditions.

Another object is to supply a diversity radio receiving system with means for effectively disconnecting one of its diversity receiving channels whenever the differential between the currents in the marking and spacing paths in that channel becomes low due to poor signaling conditions.

Still another object is to supply the receiving relay of a diversity radio receiving system with approximately constant current from the signal input circuits in spite of variations in signaling conditions in the individual input crcuits.

These and other objects are accomplshed by means outlined in the following brief description of the invention. In a radio receiving system for receiving, for example, marking and spacing radio-telegraph signals having different frequencies, the received currents of the two frequencies are first subjected to amplitude limitation and are then selectively amplified in separate amplifiers. An electronic tube is connected to the center tap of a large resistance bridged between the control grids of the marking and spacing output amplifier tubes for detecting average noise currents. Since the amplitude limitation is performed at a point in the circuit ahead of the resistance, a change in the amplitude of the noise currents represents by itself a change in the signal-to-noise ratio. When a poor signal-to-noise ratio exists, such as when the signal is weak or absent, the differential between the currents in the marking and spacing paths becomes low thereby increasing the voltage at the center tap of the resistance. This causes an increase in the plate current of the electronic tube which, in one embodiment of the invention, is utilized for energizing a cut-off relay to remove the voltage normally applied to the screen grids of the marking and spacing output amplifier tubes. This method of noise detection is applied to a diversity radio receiving system by connecting a similar center tapped resistance with corresponding tube and relay circuits in each diversity channel. The cut-off relays in these diversity channels are energized differentially to cut off only the noisiest channel thereby avoiding the possibility of disabling all the diversity channels at the same time.

In accordance with a modification of the invention, the receiving relay of a diversity radio receiving system is supplied with approximately constant current from the diversity signal input circuits by connecting the output of the electronic tube, described above, in each diversity channel to a series of amplifying tubes. The output of these amplifying tubes in each channel is applied to reduce the screen grid voltage of the output amplifier tubes in that channel and to increase the screen grid voltage of the output amplfier tubes in the other channel. Thus, noise currents in one channel will cause a reduction in the gain of that channel and a corresponding increase in the gain of the other channel so that the value of the combined currents supplied by both channels to the receiving relay remains approximately constant.

Another modification of the invention for supplying constant current to the receiving relay of a diversity radio receiving system, even under conditions where fading may occur in one channel during an absence of noise, comprises employing a common series resistance in the plate supply circuit for each output amplifier tube and in the screen grid supply circuit for the corresponding output amplifier tube in the other channel. This compensates for a weakening of the strength of the signals in one channel by causing the receiving relay to be provided with approximately constant current whether one or both of the channels is receiving signals because a decrease in the plate current of one tube will effect a proportional increase in the screen grid voltage of the corresponding tube in the other channel which will in turn effect a corresponding reduction in the screen grid voltage of the first tube. Thus a weakening of the signal strength in one channel causes a reduction in the gain of that channel and a proportional increase in the gain of the other channel independently of the signal-to-noise ratio in either channel.

These and other features of the invention are more fully described in connection with the following detailed description of the drawings in which:

Fig. 1 shows a radio receiving system for receiving marking and spacing radio-telegraph signals and having means for detecting the average noise currents present in the marking and spacing paths of the system;

Fig. 2 represents a dual diversity radio receiving system having means for reducing the gain of a noisy channel while correspondingly increasing the gain of the other channel in order to provide the receiving relay of the system with approximately constant current during the time that signals are being received;

Fig. 3 represents a modification of the invention for supplying the receiving relay of a diversity radio receiving system with nearly constant current from the diversity signal input circuits in spite of variations in the signal-to-noise ratio; and

Fig. 4 illustrates a dual diversity radio receiving system provided with the noise detecting circuit of Fig. 1 and the constant current receiving relay circuit of Fig. 3.

In Fig. 1 the signal input to a radio-telegraph receiving circuit is represented by an antenna A connected to a radio receiver RR which is connected by a conductor 1 to a current limiter CL. The output of the current limiter CL is connected to two parallel band-pass filters 2 and 3 which perform the function of separating the marking and spacing telegraph signals. In this embodiment of the invention the marking signals have a frequency of 2125 cycles and pass through filter 2, while the spacing signals have a frequency of 2975 cycles and pass through filter 3.

Following filter 2, the marking signals pass through an amplifier 4 which may be of any conventional design, such as a thermionic tube. Amplifier 4 has its output coupled by a transformer 5 to a detector 6 which is represented as being a full-wave copper-oxide rectifier. The rectifier current which has a wave shape similar to the envelope of the alternating current signal wave appears across the resistance 16 and is impressed on the control grid of the marking output thermionic amplifier 7 where it is amplified. The output of amplifier 7 passes from the plate of the tube 7 through the upper winding of the polarized receiving relay 8 in the teletypewriter station equipment 23. This causes the relay 8 to move its armature to its marking contact for controlling other apparatus (not shown) in the teletypewriter station equipment 23 to effect the recording of a marking signal.

Similarly, spacing signals travel from filter 3 through an amplifier 9 and through the transformer 10 to the spacing detector 11. The rectified spacing signals appear across the resistance 21 and are supplied to the control grid of the spacing output thermionic amplifier 12 which has its output connected to the lower winding of the receiving relay 8 for causing the armature of relay 8 to move to its spacing contact to effect the recording of a spacing signal.

A relatively large resistance in the form of two equal series-connected resistances 13 and 14 is bridged across the control grids of the marking and spacing output amplifier tubes 7 and 12. The instantaneous value of the voltage at the mid-point 17 between the resistances 13 and 14 will be the average of the voltages impressed at that particular instant upon the grids of the marking and spacing output amplifier tubes 7 and 12. A center tap 15 connects the mid-point 17 between the resistances 13 and 14 with an electronic tube 18, which in this particular form of the invention is a triode. As the amplitude limitation by the current limiter CL is performed at a point in the circuit ahead of the detectors 6 and 11, a change in the amplitude of the noise represents, by itself, a change in the signal-to-noise ratio. Thus the tube 18 serves to detect the instantaneous value of the average of the noise currents in the marking and spacing paths.

For example, when a marking signal well above the noise level is received, a voltage will be applied to the control grid of the marking amplifier 7. This voltage will be equal to the cathode potential which is held at some positive potential. As no rectified voltage will appear at this time across the resistance 21, the control grid of the spacing amplifier 12 will be at ground potential and its plate current will be cut off. However, the plate current of the marking amplifier 7 will be of substantial value and will so energize the receiving relay 8 as to cause it to operate its armature to its marking contact. Under these conditions, the voltage at the mid-point 17 will be one-half of the value of the voltage supplied to the control grid of tube 7. Similarly, when a spacing signal well above the noise level is received, the voltage conditions described above become interchanged between tube 7 and tube 12 with the result that the voltage at the mid-point 17 will now have a value equal to one-half the voltage of the rectified signal applied to the control grid of the tube 12. As these marking and spacing signals have been assumed to be of full strength and well above the noise level, the voltage at the mid-point 17 remains at the same value as long as this condition exists regardless of whether the signals are marking or spacing.

However, when transmission and other conditions are such that a poor signal-to-noise ratio exists, such as when the signal is weak or absent, and the noise currents or other interfering waves have frequency values corresponding to the signaling frequencies so that they are passed through filters 2 and 3, the differential between the currents in the marking and spacing paths becomes low thereby increasing the voltage at the mid-point 17. When a marking signal is received under these conditions, the output of the spacing detector 11 will not be zero but will be some positive value depending upon the value of the noise currents passed by the spacing filter 3. The voltage at the mid-point 17 will now not be merely one-half that applied to the control grid of tube 7, but will have a larger value which is equal to the average of the rectified signal current applied to the control grid of tube 7 and the rectified noise currents applied to the control grid of tube 12. A similar condition will exist when a spacing signal is received. Thus under these conditions the voltage at the mid-point 17 will be increased to a larger value than it was when such noise currents were absent.

As this increase in the value of the voltage at the mid-point 17 follows closely the rise in telegraph distortion caused by noise currents, it provides a means for detecting the existence of high distortion conditions due to poor mark-space discrimination. It also provides means for detecting the instantaneous value of the average of the noise currents in the marking and spacing paths of a signaling channel. The detecting function of tube 18 is not directly responsive to the signal-to-noise ratio, since an increase in the voltage at the mid-point 17 represents by itself a change in the signal-to-noise ratio.

This voltage increase can be utilized to perform various useful functions. For example, it can be applied to the grid of the electronic tube 18 to effect a proportional increase in its plate current. The plate circuit of tube 18 includes the operating winding of a polarized cut-off relay 19 which has its biasing winding supplied with biasing current from a battery 20. This biasing current tends to hold the armature of relay 19 against its contact as is shown in Fig. 1. Normally, the plate current of tube 18 is not sufficiently large to overcome the biasing current. However, when a poor signal-to-noise ratio exists, the differential between the currents in the marking and spacing paths becomes low due to the presence of rectified noise currents and the value of the voltage at the mid-point 17 becomes increased thereby effecting a proportional increase in the plate current of tube 18. When this plate current becomes large enough to overcome the effect of the biasing current, the cut-off relay 19 will operate its armature away from its contact. This opens the path from battery 22 to the screen grids of the marking and spacing output amplifier tubes 7 and 12 so that they will remain cut off during the time that excessive noise currents are present.

When the strength of the noise currents diminishes, the value of the voltage at the mid-point 17 will be lowered and will effect a proportional decrease in the plate current of tube 18. As soon as the plate current becomes sufficiently low, the biasing current from battery 20 will again operate the armature of relay 19 to its contact. This closes the path from battery 22 to the screen grids of tubes 7 and 12 to enable these tubes to resume their amplifying functions. Thus the deleterious effects, such as errors in the recording of signals, of selective fading or excessive noise currents are avoided.

In Fig. 2 the principles of the invention that were described above for detecting the existence of high distortion conditions in a radio telegraph receiving circuit are shown applied to a dual diversity radio receiving system for decreasing the gain of the signaling channel having the poorer signal-to-noise ratio while increasing the gain of the other signaling channel. This system is shown to be provided with two separate radio receivers 201 and 202 connected to their respective antennas 203 and 204 for receiving radio-telegraph signals from the same transmitting station.

The receiving antennas 203 and 204 are installed at different locations for minimizing the effects of selective fading in accordance with the principles of space diversity reception. The advantage of space diversity reception lies in the fact that a fading out of the signals does not usually occur at both receiving antennas simultaneously. This invention enhances the benefits derived from space diversity reception by preventing the energy in a channel having a poor signal-to-noise ratio due to a faded signal and having an output consisting chiefly of noise from impairing the reception of signals by the other channel. Therefore, one of the objects of the circuit shown in Fig. 2 is to use the noise voltage detected in each channel for reducing the gain in that channel. In other words, if signals in one of the channels are decreased in amplitude due to fading, that channel may receive considerably more noise or static energy than the other channel. When this occurs, the noise suppression circuits shown in Fig. 2 will reduce the strength of the signals supplied by the noisier channel to the windings of the receiving relay 236 and, at the same time, will increase the strength of the signals supplied by the quieter channel.

The principal utility of the circuit shown in Fig. 2 lies in protecting the system against noise in the faded out channel; that is, the noise suppression circuits function when the signals in one of the channels are very weak or have disappeared. If the signals were strong, the current limiter would suppress most of the noise and no other protection would be necessary. If the signals were absent and no noise were present, no protection would be needed. Therefore the noise suppression circuits are of greatest utility when the signals are weak or absent and the noise is strong.

It can be seen that the first portion of the circuit of Fig. 2 is similar to that of Fig. 1 in that the output of the radio receiver 201 in channel A is connected to a current limiter 205 which has its output connected to the parallel band-pass filters 206 and 207. Filter 206 passes the marking signals having a frequency of 2125 cycles and filter 207 passes the spacing signals having a frequency of 2975 cycles. The marking filter 206 has its output connected to an amplifier 208 and a rectifier 209 while the spacing filter 207 has its output connected to a similar amplifier 210 and rectifier 211. The output of the marking rectifier 209 supplies the rectified signals to the control grid of the marking output amplifier tube 212 and the output of the spacing rectifier 211 supplies the control grid of the spacing output amplifier tube 213. A center tapped resistance consisting of two equal series resistances 214 and 215 is bridged across the control grids of the amplifier tubes 212 and 213. A point 216 which is electrically one-half way between the control grids of tubes 212 and 213 forms a junction between the resistances 214 and 215. A conductor 217, which is the center tap of the resistance constituted by the resistance elements 214 and 215, connects the junction point 216 to the control grids of two electronic tubes 218 and 219 in the noise suppression circuit NSC1.

In channel B, the radio receiver 202 has its output connected to a current limiter 240. It should be noted that the outputs of the radio receivers 201 and 202 are also connected to an automatic frequency control circuit 260. The current limiter 240 in channel B has its output connected to the parallel marking and spacing filters 241 and 242. These filters supply the amplifiers 243 and 244 and the detectors 245 and 246 which, in turn, supply the rectified signals to the control grids of the marking and spacing output amplifier tubes 232 and 233. A resistor consisting of the two equal series resistances 247 and 248 is bridged across the control grids of tubes

232 and 233. The mid-point 249 between the resistances 247 and 248 is connected by conductor 250 to the control grids of two electronic tubes 251 and 252 in the noise suppression circuit NSC2.

As was described above in connection with the description of the operation of Fig. 1, the instantaneous value of the voltage at the junction point 216 will be the average of the voltages supplied to the control grids of tubes 212 and 213 and, likewise, the instantaneous value of the voltage at the mid-point 249 will be the average of the voltages supplied to the control grids of tubes 232 and 233.

When conditions are such that a poor signal-to-noise ratio exists in either the marking or spacing paths of either channel A or B, the voltage at the mid-point in such channel will rise to a more positive value. As this rise in voltage follows closely the rise in telegraph distortion caused by the noise, it provides a means for detecting when high distortion conditions exist due to poor mark-space discrimination. This rising voltage is utilized by the noise suppression circuits NSC1 and NSC2 to reduce the rectified currents from a channel when the noise in its output becomes excessive and to correspondingly increase the rectified currents from the other channel.

During operation of the system, the rectified signals from each channel are combined so that the combined output of the marking output amplifier tubes 212 and 232 is supplied over conductor 235 to the upper winding of the polarized receiving relay 236 and, alternatively, the combined output of the spacing output amplifier tubes 213 and 233 is supplied over conductor 237 to the lower winding of the relay 236. In the case of a marking signal, relay 236 will operate its armature to its left contact to connect the negative pole of battery 238 over the armature of relay 236, through resistance 254, winding of the polarized receiving relay 255 in the teletypewriter subscriber's set 256, and then along conductor 257 to the mid-point of a potentiometer comprising the resistances 258 and 259. Similarly, in the case of a spacing signal, relay 236 will operate its armature to its right contact to connect the positive pole of battery 238 over a corresponding path through the winding of the receiving relay 255 to the mid-point of the potentiometer comprising the resistances 258 and 259.

It can be seen from this that marking signals will cause current from battery 238 to flow through the circuit to the receiving relay 255 in one direction and that spacing signals will cause an equal current to flow in the opposite direction. Thus the transmission of signals to the receiving relay 255 is on a polar signaling basis. If current from a rectifier is used instead of current from battery 238, the above-described circuit will permit the polar transmission of signals to the receiving relay 255 to be practically independent of ordinary variations in the rectifier voltage.

Considering now the noise suppression circuit NSC1, the plate current for tube 218 flows from battery 224 and through a resistance 221, which is also the series screen resistance for tubes 212 and 213, and then along a conductor 220 to the plate of tube 218. Tube 218 is normally biased to near cut-off. If channel A becomes noisy some of the noise currents will be rectified in the spacing detector 211 while marking signals are being rectified in the marking detector 209 and vice versa. As was stated above, this will raise the voltage at the junction point 216 and this increased voltage will be supplied over conductor 217 to the control grids of tubes 218 and 219 to effect a proportional increase in the plate currents of these tubes. The increased plate current of tube 218 will flow over conductor 220 and through the resistance 221 and will thereby cause an added voltage drop through the resistance 221. Since resistance 221 is a series screen resistance for the marking and spacing output amplifier tubes 212 and 213, the screen voltage and plate currents of these tubes will be correspondingly reduced thereby producing a proportional reduction in the gain of channel A with a corresponding reduction in the output supplied from this channel to the receiving relay 236. Thus the noise components in channel A are suppressed in amplitude by an amount proportional to the amount of noise.

The increased voltage at the junction point 216 is also supplied to the control grid of tube 219 for proportionally increasing its plate current which flows through the resistance 223 to battery 224. In order to obtain a turn-over in phase relation, tube 219 is coupled to tube 225 in such a manner as to produce an opposite effect in tube 225. Accordingly, tube 225, which normally has a plate current near maximum value, will have a decreasing plate current as the voltage at point 216 increases. This coupling is effected by a potentiometer consisting of two series resistances 226 and 227, resistance 226 being connected to the plate of tube 219 and resistance 227 being connected to ground 228. The mid-point 229 between resistances 226 and 227 is connected to the control grid of tube 225.

The potentiometer consisting of resistances 226 and 227 is designed to maintain the potential on the control grid of tube 225 at one-third of that on the plate of tube 219. Thus when the plate current of tube 219 flowing through resistance 223 increases due to the presence of noise in channel A, the plate voltage of tube 219 will decrease and the grid of tube 225 will become less positive thereby effecting a corresponding decrease in the plate current of tube 225. The circuit elements are so designed that the sum of the plate currents of tubes 218 and 225 remains practically constant.

Plate current for tube 225 passes along conductor 230 and through the resistance 231 to battery 253. Resistance 231 is the series screen resistance for the marking and spacing output amplifier tubes 232 and 233 in channel B. Therefore, when the plate current of tube 225 decreases, the voltage supplied to the screen grids of tubes 232 and 233 increases proportionally and causes the current supplied by tubes 232 and 233 to the receiving relay 236 to be correspondingly increased. In other words, the current supplied to the receiving relay 236 by the noisy channel A is reduced by a certain amount while the current supplied by channel B is increased by the same amount so that the result is that the combined current supplied to the receiving relay 236 by both channels A and B is maintained at a nearly constant value. This suppression of the noise currents in channel A also produces a reduction in the amount of telegraph distortion due to the fact that since the proportion of current supplied by the noisy channel A is lowered below the normal one-half condition, its noise components are not able to cause any appreciable amount of distortion.

The noise suppression circuit NSC2 in channel B is similar in construction to the noise suppression circuit NSC1 in channel A and its operation and function are the same as explained above in connection with the description of the noise suppression circuit NSC1.

If both channels A and B are equally noisy, the potentials of the junction points 216 and 249 are raised equal amounts so that although the plate currents in tubes 218 and 225 in the noise suppression circuit NSC1 in channel A and the plate currents in tubes 251 and 234 in the noise suppression circuit NSC2 in channel B will change, this change will be symmetrical. Therefore, both the sum of the plate currents of tubes 218 and 234 and the sum of the plate currents of tubes 251 and 225 will remain constant. Consequently, as no voltage change will occur on the screen grids of the marking and spacing output amplifier tubes in either channel A or B, no suppression will be effected at this time.

It is to be understood that the forms of the invention shown and described herein are preferred embodiments disclosed for purposes of explaining the nature of the invention. The invention is not to be limited to these specific forms as it may be applied to other systems, such as interrupted tone or interrupted continuous wave systems provided such systems had two current paths between which a comparison could be made of the current values.

Fading may sometimes occur in some diversity receiving systems on occasions when there may be little noise effects and the net result of such selective fading may be to cause the absence of marking or spacing currents in one of the channels for some period of time. If the marking or spacing currents fade out of one channel for a period of time and if the receiving relay in the teletypewriter station equipment is supplied by a simple parallel connection between the two channels, then this type of fading may result in the armature of the receiving relay being operated to one of its contacts by the output of two channels and to the opposite contact by current from but one channel. If the signal wave shape is rounded considerably, this two-to-one current condition will cause considerable bias of the signals and increase the distortion.

To avoid errors in the recording of signals which might otherwise be caused by such selective fading, the circuit shown in Fig. 3 is designed to supply constant current to the receiving relay 315 in the teletypewriter station equipment 316 even under conditions where fading may occur in one channel during the absence of noise currents. In the circuit of Fig. 3, signal current of reduced strength in one channel effects a decrease in the gain of that channel and a corresponding increase in the gain of the other channel. Although the constant current circuit is shown applied to a dual diversity receiving system for receiving radio-telegraph signals employing waves of different frequencies for marking and spacing signals, the circuit is not restricted to merely this type of signaling system but may be applied to various other types of diversity receiving systems such as interrupted tone or interrupted continuous wave systems.

The system shown in Fig. 3 comprises two channels A and B each having a radio receiver 301 and 302 for receiving signals from the same transmitting station over the separate antennas 303 and 304 which are located at different points in accordance with space diversity principles. Each radio receiver has its output connected to a current limiter 305 and 306. The output of each current limiter is connected in parallel to a set of marking and spacing filters 307 and 308 in channel A and 309 and 310 in channel B. The output of each of these filters is separately amplified and rectified in separate amplifiers and detectors as was described above in connection with the description of the operation of Figs. 1 and 2. The resulting rectified signal currents are supplied to the control grids of the marking and spacing output amplifier tubes in each channel, tubes 311 and 312 being located in channel A and tubes 313 and 314 being located in channel B.

In order to supply nearly constant current to the polarized receiving relay 315 in the teletypewriter station equipment 316 regardless of differences in the strength of the signal currents in channels A and B, the plate of each amplifier tube is supplied from a battery and through a resistance which is common to and in series with the supply circuit for the screen grid of the corresponding output amplifier tube in the other channel. Specifically, the marking output amplifier tube 311 in channel A has its plate connected by the conductor 331 through the resistance 317 to the battery 330 and the supply circuit for the screen grid of the marking output amplifier tube 313 in channel B extends along the conductor 318 through the common series resistance 317 to the battery 330. The screen grid supply circuit for tube 311 extends along conductor 319 and through the resistance 320 to the battery 330 and the plate of the marking output amplifier tube 313 in channel B is connected by conductor 332 through the common series resistance 320 to battery 330. The spacing output amplifier tubes 312 and 314 in channels A and B have their plates and screen grids similarly supplied from battery 330 through the common series resistances 321 and 322.

By thus employing common series resistances in the plate and screen grid supply circuits for the marking and spacing output amplifier tubes in channels A and B, the receiving relay 315 will be provided with approximately constant current. This is true whether one or both of the channels is receiving signals because a decrease in the plate current of one output amplifier tube in one channel will increase the screen grid voltage on the corresponding output amplifier tube in the other channel which will in turn reduce the screen grid voltage on the first tube. In other words, a weakening of the signal strength in one channel causes a reduction in the gain of that channel and a corresponding proportional increase in the gain of the other channel independently of the signal-to-noise ratio.

For example, a decrease in plate current of the marking output amplifier tube 311 in channel A causes a higher screen grid voltage to be applied to the marking output amplifier tube 313 in channel B. This causes a proportional increase in the plate current of tube 313 which, in turn, by means of the above-described employment of the common series resistances 317 and 320 reduces by a proportional amount the screen grid voltage applied to the marking output amplifier tube 311 in channel A. The value of the common series resistances is not made high enough to cause instability in the normal approximate equal division of the relay current supplied by the two tubes. The result, however, is that the relay current remains approximately the same whether both channels are receiving signals or only one is receiving signals. The amount of bias caused by the fading out of either the marking or spacing current in one channel is reduced to a small amount. This constant current circuit finds its greatest utility in a system using narrow band-pass filters where the signals are rounded to such an extent that large amounts of bias would otherwise result.

It should be noted that there is a distinction between the method of operation of the circuit of Fig. 3 and the circuit of Fig. 2 described above. This distinction resides in the fact that in the circuit of Fig. 2 the changes in the gain of the signaling channels is responsive to changes in the strength of the noise currents present in the channels, whereas in the circuit of Fig. 3 similar changes in the gain of the channels are effected in response to changes in the strength of the signaling currents present in these channels. In neither of these circuits is the gain control action responsive directly to the signal-to-noise ratio.

Fig. 4 shows a dual diversity radio-telegraph system employing different frequencies for marking and spacing signals and which combines the inventive features of the noise detecting circuit shown in Fig. 1 with the constant current receiving relay circuit of Fig. 3. The circuit elements function in the same manner as described above in connection with the descriptions of the operation of the circuits of Figs. 1 and 3. The system includes two antennas 401 and 402 located at different points for receiving signals from the same radio transmitter. These signals are supplied separately by the antennas 401 and 402 to the radio receivers 403 and 404 which are separately connected to the current limiters 405 and 406. The output of each limiter is connected to two parallel band-pass filters 407, 408, 409 and 410 for separating the marking and spacing signals.

Each filter has its output connected to one of the amplifiers 411, 412, 413 and 414 which are provided with automatic volume control means of any suitable design including the conductors 415 in the upper channel A and the conductors 416 in the lower channel B. The outputs of the amplifiers are rectified in the detectors 417, 418, 419 and 420 and the rectified signal currents are then supplied to the control grids of their respective output amplifier tubes 421, 422, 423 and 424. The plates of the marking amplifier tubes 421 and 423 in channels A and B are connected together so that their combined output is applied to the upper winding of the receiving relay 425 in the teletypewriter station equipment 426. Similarly, the plates of the spacing amplifier tubes 422 and 424 are connected together so that their combined output is applied to the lower winding of the receiving relay 425.

A center tapped resistance comprising the equal series resistors 427 and 428 is bridged across the control grids of tubes 421 and 422 in channel A and has its mid-point connected to the control grid of a triode 429. Likewise, a similar center tapped resistance comprising the equal series resistors 430 and 431 is bridged across the control grids of tubes 423 and 424 in channel B and has its midpoint connected to the control grid of a triode 432. The plate circuit of tube 429 includes the operating winding of the cut-off relay 434, the non-operating winding of the cut-off relay 435 and the battery 433. The plate circuit of tube 432 includes the operating winding of relay 435, the non-operating winding of relay 434, and the battery 433. The holding or biasing winding of both relays 434 and 435 is supplied with biasing current from battery 451 for holding its armature against its contact when the currents from tubes 429 and 432 are equal.

As was explained above in connection with the description of the operation of the circuit shown in Fig. 1, the instantaneous value of the voltage at the mid-point between the resistances 427 and 428 will be the average of the voltages impressed at that particular instant upon the grids of the marking and spacing output amplifier tubes 421 and 422 in channel A. The result is that an excessive amount of noise in channel A will increase the plate current of tube 429. If the increased plate current of tube 429 is greater than the combined value of the currrents in the biasing and non-operating windings of relay 434, then relay 434 will operate its armatures thereby opening the paths leading from battery 450 to the screen grids of tubes 421 and 422 so that these tubes will remain cut off during the time that excessive noise currents are present in channel A. Similarly, if excessive noise currents in channel B cause the plate current of tube 432 to become greater than the combined value of the currents in the biasing and non-operating windings of relay 435, then relay 435 will operate its armatures thereby opening the paths extending from battery 450 to the screen grids of tubes 423 and 424 to cut off these tubes during the time that excessive noise currents are present in channel B. This method of differentially operating relays 434 and 435 avoids the possibility of cutting both channels off at the same time and insures that at least one channel will always be operative and that only the channel having the poorer noise condition will be disabled or cut off. The presence of biasing current in the biasing windings of relays 434 and 435 prevents either of these relays from operating unless the difference between the plate currents of tubes 429 and 432 is greater than the value of the biasing current. If this difference is less than the value of the biasing current, both channels A and B will remain connected to the receiving relay 425. Likewise, if the plate currents of tubes 429 and 432 are equal, their difference will be zero and the armatures of relays 434 and 435 will remain in the condition shown in Fig. 4.

To provide the receiving relay 425 with approximately constant current regardless of differences in the strength of the signal currents in channels A and B which may occur because of selective fading during an absence of noise, as explained above in connection with the description of the operation of Fig. 3, the plate of the marking output amplifier tube 421 in channel A is connected through the resistance 438 to battery 450 and the supply circuit for the screen grid of the marking output amplifier tube 423 in channel B extends along the conductor 439 and through the common series resistance 438 to battery 450. The screen grid supply circuit for tube 421 extends along conductor 440 and through the resistance 441 to battery 450 and the plate of tube 423 in channel B is connected through the common series resistance 441 to battery 450. The spacing output amplifier tubes 422 and 424 in channels A and B have their plates and screen grids similarly supplied from battery 450 through the common series resistances 442 and 443.

By thus employing common series resistances in the plate and screen grid supply circuits for the marking and spacing output amplifier tubes in channels A and B, as was explained above in connection with the description of the operation of the circuit shown in Fig. 3, a decrease in the plate current of one output amplifier tube in one channel will increase the screen grid voltage on the corresponding output amplifier tube in the other channel which will in turn reduce the screen grid voltage on the first tube. Thus a weakening of the signal strength in one channel causes a reduction in the gain of that channel and a corresponding proportional increase in the gain of the other channel. This is accomplished independently of the signal-to-noise ratio. The result is that the combined current supplied from channels A and B to the receiving relay **425** remains approximately the same whether both channels are receiving signals or whether only one is receiving signals.

What is claimed is:

1. A radio-telegraph receiving system adapted to receive marking and spacing signals having different frequencies and including in combination a current limiter, a first band-pass filter for passing only waves of the marking frequency, a second band-pass filter for passing only waves of the spacing frequency, means for connecting the output of the current limiter to said filters in parallel, a marking output amplifier tube having a control grid, a spacing output amplifier tube having a control grid, a marking path extending from the output of the marking filter to the control grid of the marking output amplifier tube, a spacing path extending from the output of the spacing filter to the control grid of the spacing output amplifier tube, and detecting means for detecting the instantaneous value of the average of the noise currents in the marking and spacing paths, said detecting means comprising two equal series-connected resistances bridged between the control grids of the marking and spacing output amplifier tubes, an electronic tube having at least one electrode, and circuit means for connecting the mid-point between said resistances to an electrode of said electronic tube.

2. A radio-telegraph receiving system adapted to receive marking and spacing signals having different frequencies and including in combination a current limiter, a first band-pass filter for passing only waves of the marking frequency, a second band-pass filter for passing only waves of the spacing frequency, means for connecting the output of the current limiter to said filters in parallel, a marking output amplifier tube having a control grid and at least one other electrode, a spacing output amplifier tube having a control grid and at least one other electrode, each of said other electrodes having a supply circuit, a marking path extending from the output of the marking filter to the control grid of the marking output amplifier tube, a spacing path extending from the output of the spacing filter to the control grid of the spacing output amplifier tube, and control means for preventing excessive noise currents from causing errors in the recording of signals, said control means comprising two equal series-connected resistances bridged between the control grids of the marking and spacing output amplifier tubes, an electronic tube having at least two electrodes, circuit means for connecting the mid-point between the resistances to one electrode of said electronic tube, an instrumentality for alternatively opening and closing said supply circuits to said electrodes of the marking and spacing output amplifier tubes, operating means for operating said instrumentality in accordance with current conditions in said electronic tube, and circuit means for electrically connecting said operating means to the other electrode of said electronic tube.

3. A diversity radio receiving system including at least two signal receiving channels, each of said channels having detecting means for separately detecting noise currents, said detecting means comprising a center tapped resistance bridged across at least one of said channels, disabling means for selectively disabling said receiving channels individually, and operating means for operating the disabling means in response to the detection of excessive noise currents by said detecting means.

4. A diversity radio receiving system including at least two signal receiving channels and also including control means for preventing excessive noise currents from causing errors in the recording of signals, said control means comprising a plurality of center tapped resistances each being connected across a different channel, electroresponsive means in each channel adapted to effectively disable at least one of said channels, and connecting means for connecting the center tap of each of said resistances to a different one of said electroresponsive means.

5. A diversity radio receiving system including at least two signal receiving channels, a plurality of current limiters, each of said current limiters being connected into a different channel, detecting means for separately detecting noise currents in each channel, said detecting means comprising a plurality of electroresponsive means, a center tapped resistance bridged across each channel at a point subsequent to the current limiter in each channel, connecting means for connecting the center tap of each resistance to a different one of said electroresponsive means, disabling means for selectively disabling said channels individually, and operating means for operating the disabling means to disable the channel having the most noise currents at a particular instant as determined by the detection of noise currents by said detecting means.

6. A radio-telegraph receiving system for receiving marking and spacing telegraph signals having different frequencies, filter means for separating the marking and spacing signals, first rectifying means for separately rectifying the marking signals, second rectifying means for separately rectifying the spacing signals, and detecting means for detecting when the differential between the rectified currents from said rectifiers becomes low, said detecting means comprising a center tapped resistance bridged between the outputs of both of said rectifiers.

7. A radio-telegraph receiving system for receiving marking and spacing telegraph signals having different frequencies, filter means for separating the marking and spacing signals, first rectifying means for separately rectifying the marking signals, second rectifying means for separately rectifying the spacing signals, a first amplifier tube having an electrode connected to the output of the first rectifying means, a second amplifying tube having an electrode connected to the output of the second rectifying means, a center tapped resistance bridged between said electrodes, detecting means connected to the center tap of said resistance for detecting when the differential between the rectified currents from said rectifying means becomes low, control means adapted to render said amplifier tubes incapable of producing anode-cathode current flow, and governing means for governing the operation of

said control means in accordance with the detection performed by said detecting means.

8. A diversity radio-telegraph receiving system for receiving marking and spacing telegraph signals having different frequencies, said system including at least two diversity receiving circuits each comprising filter means for separating the marking and spacing signals, first rectifying means in each circuit for separately rectifying marking signals, second rectifying means in each circuit for separately rectifying spacing signals, a marking amplifier tube in each circuit connected to said first rectifying means, a spacing amplifier tube in each circuit connected to said second rectifying means, each of said tubes having a screen grid and an anode, a receiving relay for effecting the recording of said signals, said relay having at least two windings, first connecting means for jointly connecting the anodes of the marking amplifier tubes of both circuits to one winding of said receiving relay, second connecting means for jointly connecting the anodes of the spacing amplifier tubes of both circuits to another winding of said receiving relay, and control means for supplying constant current to the windings of the receiving relay for avoiding deleterious effects caused by selective fading of the telegraph signals, said control means including a plurality of resistances for separately coupling the anode of each amplifier tube to the screen grid of the corresponding amplifier tube in the other diversity receiving circuit.

9. A diversity radio receiving system having at least two diversity receiving circuits for receiving signals, each of said diversity receiving circuits having detecting means for detecting noise currents in each circuit separately, and control means for reducing the gain in a noisy diversity receiving circuit and for correspondingly increasing the gain in another diversity receiving circuit in response to the detection of noise currents by said detecting means, said control means including a plurality of electronic tubes connected in each diversity receiving circuit, each of said tubes having a plurality of electrodes, and coupling means for coupling an electrode of at least one tube in each circuit with an electrode of at least one tube in the other diversity receiving circuit.

10. A diversity radio receiving system including at least two signal receiving channels, a plurality of current limiters, each of said current limiters being connected into a different channel, detecting means for separately detecting noise currents in each channel, said detecting means including at least two equal series-connected resistances bridged across each channel at a point subsequent to the current limiter in each channel, disabling means for selectively disabling said channels, and operating means for operating the disabling means to disable all but at least one of the channels in accordance with the detection of noise currents by said detecting means.

11. A diversity radio receiving system, having a plurality of signal receiving channels, each of said channels having detecting means for deriving a voltage representative of the instantaneous value of excessive noise currents present in that channel, cut-off means for cutting off said channels individually, and differential operating means for comparing said voltages for selectively operating the cut-off means in accordance with the instantaneous noise conditions in the signal receiving channels.

12. A diversity radio receiving system, having a plurality of signal receiving channels, each of said channels having detecting means for deriving a voltage representative of excessive noise currents present in that channel, cut-off means for cutting off said channels individually, said cut-off means comprising a plurality of differential relays each having a plurality of windings, and operating means for separately applying said voltages to different windings of each of said relays for selectively operating said relays.

13. A dual diversity radio receiving system comprising two signal receiving channels, each of said channels having detecting means for deriving a voltage representative of the instantaneous value of excessive noise currents in that channel, cut-off means for cutting off said channels alternatively said cut-off means comprising two differential relays each having a plurality of windings, and circuit means for differentially applying said voltages to two windings of each of said relays for operating said relays alternatively in accordance with the instantaneous noise conditions in the signal receiving channels.

14. A dual diversity radio receiving system comprising two signal receiving channels, each of said channels including at least one electronic amplifier, each of said amplifiers having at least one electrode, a current supply circuit extending to each of said electrodes, each of said channels having detecting means for deriving a voltage representative of the instantaneous value of excessive noise currents in that channel, disabling means for cutting off said current supply circuit from said electrodes alternatively for disabling said amplifiers alternatively in accordance with the instantaneous noise conditions in the signal receiving channels, and operating means for differentially applying said voltages to the disabling means for operating said disabling means.

15. A diversity radio receiving system having a plurality of signal receiving channels, a receiving relay having an operating winding, means for combining the currents in said channels and for supplying said combined currents to the winding of the receiving relay, each of said channels having detecting means for deriving a voltage representative of the instantaneous value of excessive noise currents present in that channel, regulating means for regulating the currents in the channels for stabilizing their combined value at an approximately constant amount, and operating means for applying said voltages to the regulating means for operating said regulating means in accordance with the instantaneous noise conditions in the signal receiving channels.

16. A diversity radio receiving system comprising in combination, a plurality of signal receiving channels, each of said channels including at least one variable gain amplifier, a receiving relay having an operating winding, means for combining the currents in said channels and for supplying said combined currents to the winding of the receiving relay, each of said channels having detecting means for deriving a voltage representative of the instantaneous value of excessive noise currents present in that channel, control means for varying the gain of said amplifiers for stabilizing their combined output currents at an approximately constant amount, and operating means for applying said voltages to the control means for operating said control means in accordance with instantaneous noise conditions in the signal receiving channels.

17. A diversity radio receiving system comprising in combination a plurality of signal receiving channels, each of said channels including at

least one variable gain amplifier, a receiving relay having an operating winding, means for combining the currents in said channels and for supplying said combined currents to the windings of the receiving relay, each of said channels having detecting means for deriving a voltage representative of the instantaneous value of noise currents present in that channel, control means for reducing the gain of the amplifier in a noisy channel and for correspondingly increasing the gain of the amplifier in another channel for stabilizing their combined output currents at an approximately constant amount, and operating means for applying said voltages to the control means for operating said control means in accordance with the instantaneous noise conditions in the signal receiving channels.

18. A diversity radio receiving system comprising in combination, a plurality of signal receiving channels, each of said channels including at least one variable gain amplifier and detecting means for deriving a voltage representative of the instantaneous value of excessive noise currents present in that channel, regulating means for reducing the gain of the amplifier in a channel in which excessive noise currents are present and for correspondingly increasing the gain of the amplifier in another of said channels, said regulating means comprising a plurality of multielectrode electronic tubes, and operating means for applying the voltage derived in one of said channels to an electrode of at least a first one of said tubes and for applying the voltage derived in another of said channels to an electrode of at least a second one of said tubes for controlling the current flow in said tubes in accordance with the instantaneous noise conditions in said channels.

19. A diversity radio receiving system comprising in combination a plurality of signal receiving channels, each of said channels including at least one variable gain multielectrode electronic amplifier and detecting means for deriving a voltage representative of the instantaneous value of excessive noise current present in that channel, regulating means for reducing the gain of the amplifier in a channel in which excessive noise currents are present and for correspondingly increasing the gain of the amplifier in another of said channels, said regulating means comprising a plurality of multielectrode electronic tubes, operating means for applying the voltage derived in one of said channels to an electrode of at least a first one of said tubes and for applying the voltage derived in another of said channels to an electrode of at least a second one of said tubes for controlling the current flow in said tubes in accordance with the instantaneous noise conditions in said channels, and control means for connecting another electrode of said first one of said tubes to an electrode of one of said amplifiers and for connecting another electrode of said second one of said tubes to an electrode of another of said amplifiers.

20. A dual diversity radio telegraph receiving system comprising two signal receiving channels for receiving marking and spacing signals having different frequencies, each of said channels having a first band-pass filter for passing only waves of the marking frequency and a second band-pass filter for passing only waves of the spacing frequency, each of said channels also having a marking output amplifier tube with a control grid and a screen grid and a spacing output amplifier tube with a control grid and a screen grid, each of said channels further comprising a marking path for connecting the output of its first band-pass filter to the control grid of its marking output amplifier tube and a spacing path for connecting the output of its second band-pass filter to the control grid of its spacing output amplifier tubes, a receiving relay having at least two windings, first supply means for combining the output currents of both of said marking output amplifier tubes simultaneously and for supplying said combined currents to one winding of the receiving relay, second supply means for combining the output currents of both of said spacing output amplifier tubes simultaneously and for supplying said combined currents to another winding of the receiving relay, each of said screen grids having a voltage supply circuit, regulating means for producing the gain of at least one of said output amplifier tubes in one of said channels and for proportionally increasing the gain of at least a corresponding one of said output amplifier tubes in the other channel for stabilizing the value of their combined instantaneous outputs supplied to said receiving relay at an approximately constant amount, said regulating means comprising control means for reducing the voltage supplied to the screen grid of at least one of said output amplifier tubes in one of said channels and for increasing by a proportional amount the voltage supplied to the screen grid of at least a corresponding one of said output amplifier tubes in the other channel, said control means including resistors connected in said screen grid voltage supply circuits.

21. A diversity radio receiving system comprising at least two signal receiving channels, each of said channels including at least one output amplifier tube having a screen grid, each of said screen grids having a voltage supply circuit, regulating means for reducing the gain of at least one output amplifier tube in one channel and for correspondingly increasing by an equal amount the gain of at least one output amplifier tube in another channel, said regulating means comprising control means for decreasing the voltage supplied to the screen grid of said tube in said first channel and for correspondingly increasing by an equal amount the voltage supplied to the screen grid of said tube in said second channel, said control means including resistors connected in said screen grid voltage supply circuits.

22. A diversity radio receiving system comprising at least two signal receiving channels for receiving signals, each of said channels having at least one output amplifier tube for amplifying said signals, each of said tubes having an anode and a screen grid, each of said electrodes having a voltage supply circuit, regulating means for increasing the gain of at least one output amplifier tube in one channel and for correspondingly decreasing by an equal amount the gain of at least one output amplifier tube in another channel, said regulating means comprising control means for increasing the voltage supplied to the screen grid of said output amplifier tube in said first channel and for correspondingly decreasing the voltage supplied to the screen grid of said output amplifier tube in said second channel, said control means including a first common series resistance connected in the voltage supply circuits for the anode of said first tube and for the screen grid of said second tube, and a second common

series resistance connected in the voltage supply circuits for the anode of said second tube and for the screen grid of said first tube.

23. A diversity radio receiving system comprising at least two signal receiving channels for receiving signals of varying strength, each of said channels having at least one output amplifier tube for amplifying said signals, each of said tubes having an anode and a screen grid, each of said electrodes having a voltage supply circuit, a receiving relay having an operating winding, compensating means for compensating for a weakening in the strength of the signals in one channel by supplying the winding of the receiving relay with approximately constant current, said compensating means including a first common series resistance connected in the voltage supply circuits for the anode of at least one output amplifier tube in one channel and for the screen grid of at least one output amplifier tube in another channel, and a second common series resistance connected in the voltage supply circuits for the anode of said second tube and for the screen grid of said first tube, said receiving relay having its operating winding connected to each of said voltage supply circuits.

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