

July 28, 1942.

H. O. PETERSON

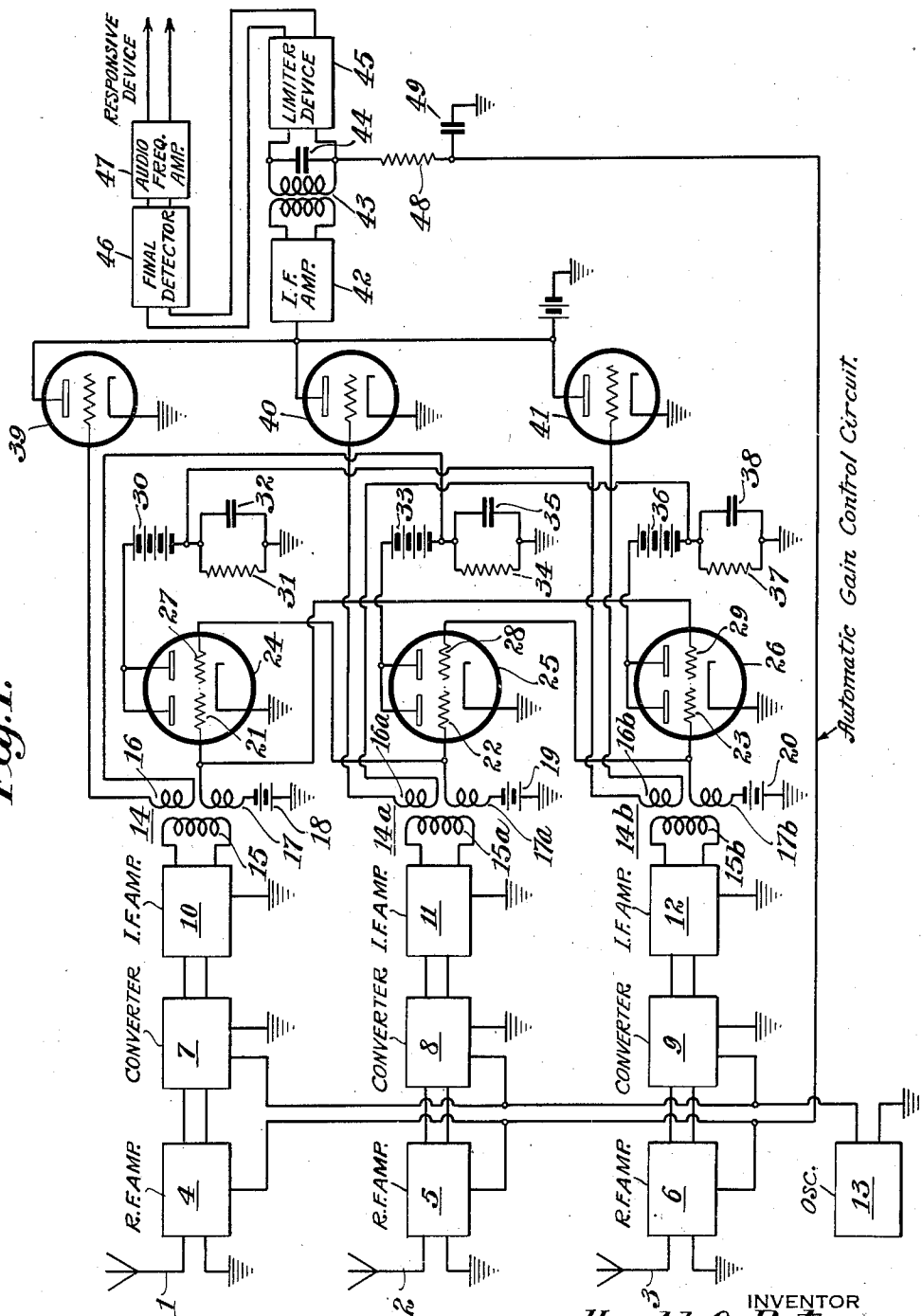
2,290,992

DIVERSITY RECEIVING SYSTEM

Filed July 27, 1940

3 Sheets-Sheet 1

Fig. 1.



Automatic Gain Control Circuit.

INVENTOR
Harold O. Peterson
 BY *H.S. Grover*
 ATTORNEY

July 28, 1942.

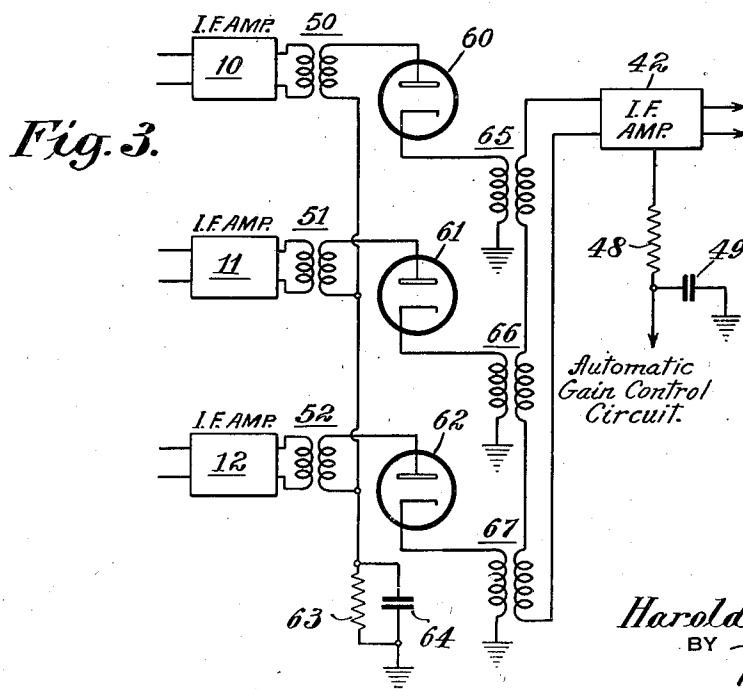
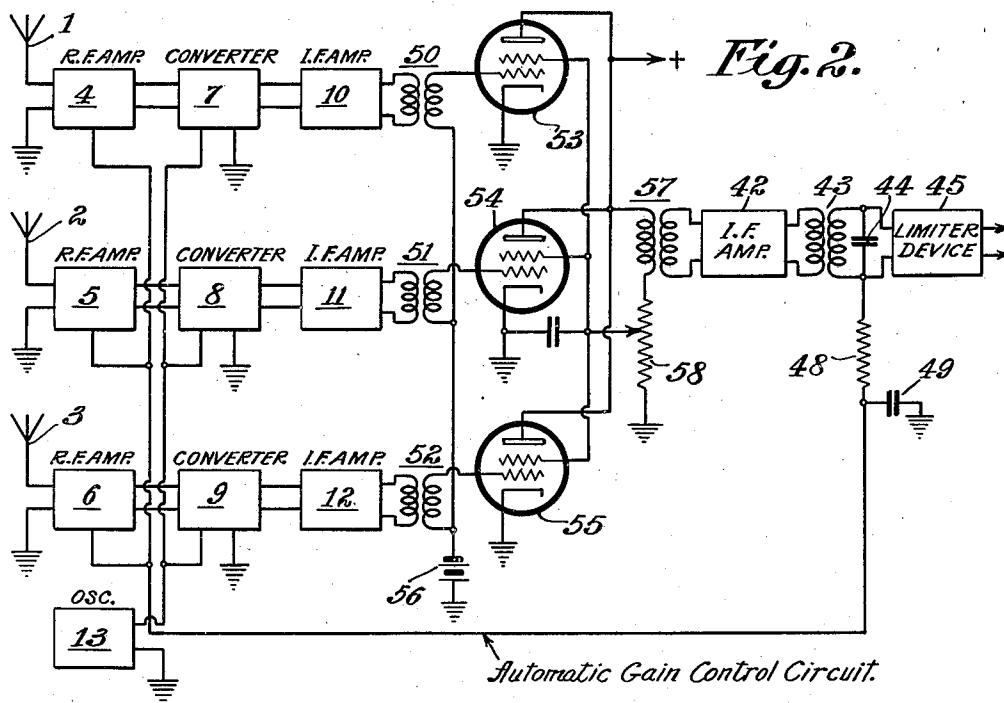
H. O. PETERSON

2,290,992

DIVERSITY RECEIVING SYSTEM

Filed July 27, 1940

3 Sheets-Sheet 2



INVENTOR
Harold O. Peterson
BY *W. S. Snover*
ATTORNEY

July 28, 1942.

H. O. PETERSON

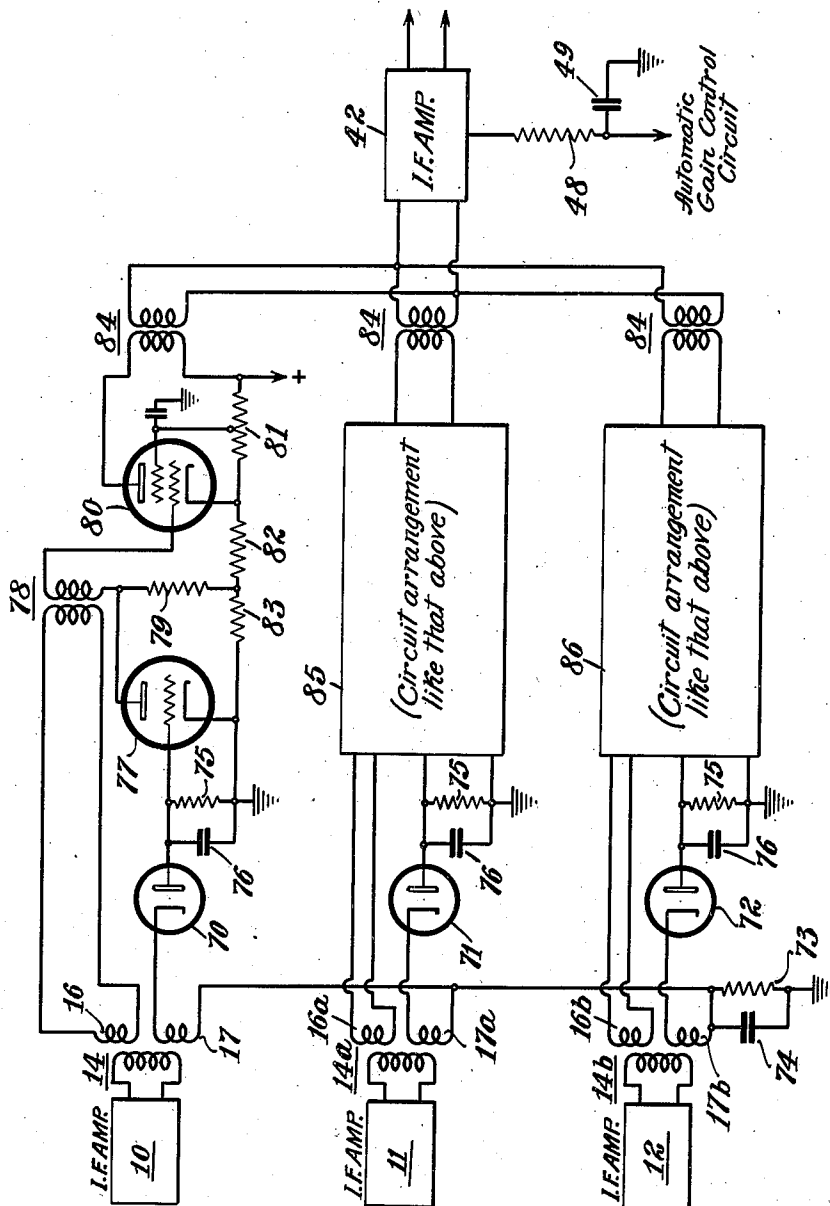
2,290,992

DIVERSITY RECEIVING SYSTEM

Filed July 27, 1940

3 Sheets-Sheet 3

Fig. 4.



INVENTOR
Harold O. Peterson
BY *H. S. Snover*
ATTORNEY

UNITED STATES PATENT OFFICE

2,290,992

DIVERSITY RECEIVING SYSTEM

Harold O. Peterson, Riverhead, N. Y., assignor to
Radio Corporation of America, a corporation of
Delaware

Application July 27, 1940, Serial No. 347,853

12 Claims. (Cl. 250—20)

This invention relates to diversity receiving systems and more particularly to an arrangement for automatically selecting the best receiving circuit out of a number of simultaneously operative circuits all tuned to the same radio wave, and all feeding to a common responsive device.

It is well known that reception may be improved, particularly with respect to signals from a distant station, by the employment of a number of geographically spaced antennas or a number of antennas having differently oriented directional or polarization characteristics. In order to avoid interference of the signals as amplified and detected on different receiving circuits when the signals themselves are out of phase in different circuits, arrangements have been used in the past whereby the strongest of the amplified signals is switched into connection with the responsive device and the other receiving circuits are automatically switched out. In the past relay means have been used for this purpose.

It is a prime object of my invention to provide electronic switching means for causing the strongest of the signals received on different antennas and receiving amplifiers to be utilized in the common responsive device.

It is another object of my invention to provide a superheterodyne receiving system wherein automatic gain control is provided for a number of different receiving circuits and detectors, each circuit being fed with energy from its own antenna, and to obtain from this arrangement, rectification of the radiant energy in the one detector having the strongest signal voltage.

My invention is adaptable to radio receiving systems in which either phase modulation, frequency modulation, or amplitude modulation of the carrier wave is provided. In the case of phase modulation or frequency modulation, where a limiter is applied ahead of the final detector, the tendency is for the output of the limiter to remain constant and consequently the selection process must in this case take place ahead of the limiter. In certain instances where antenna selection is of a special type it is possible to derive the final output from a single detector circuit. Accordingly, it is a further object of my invention to provide simplified apparatus to meet this condition.

My invention will now be described in more detail, reference being made to the accompanying drawings in which

Figure 1 shows diagrammatically a circuit ar-

rangement which illustrates a preferred embodiment of the invention;

Fig. 2 shows an alternative arrangement in which certain of the fundamental principles of the invention are exemplified, but with special apparatus having different characteristics from that of the arrangement shown in Fig. 1;

Fig. 3 illustrates diagrammatically still another modification of my invention; and,

Fig. 4 shows also diagrammatically a diversity receiving system the feature of which is the use of special diode circuits for rectification of the signal voltage.

Referring now to Fig. 1, I show illustratively a diversity receiving system in which a plurality of receiving antennas 1, 2 and 3 is provided, each of these antennas being respectively arranged to feed the collected signal energy into its own radio frequency amplifier 4, 5 or 6. The output from each of these amplifiers is fed to an appropriate converter 7, 8 or 9. A local oscillator 13 provides energy of a suitable frequency for heterodyning with the amplified signals in each of the converters 7, 8 and 9, thus producing a heterodyned frequency which is then fed to the intermediate frequency amplifiers 10, 11 and 12.

Three twin-triode discharge tubes 24, 25 and 26 are shown in Fig. 1 for the purpose of producing an electronic switching action upon the signal energies simultaneously collected on the three antennas 1, 2 and 3. This switching action causes the gain in one of the receiving channels to remain normal while that in the other two channels is substantially suppressed.

The intermediate frequency amplifier 10 is provided with an output transformer 14 having a primary 15 and two secondaries 16 and 17. The secondary 17 is in circuit between the negative terminal of a grid biasing source 18 and the grid 21 in twin triode discharge tube 24. In parallel with grid 21 is another grid 29 in a similar twin triode tube 26. In operation energy induced in the secondary winding 17 controls grids 21 and 29 in the two tubes 24 and 26. In like manner energy induced in the secondary 17a of transformer 14a connected to the intermediate frequency amplifier 11 serves to control grid 27 in tube 24 and in parallel therewith grid 22 in tube 25. Also the output transformer 14b connected to the intermediate frequency amplifier 12 induces a signal voltage in the secondary winding 17b which controls grid 23 in tube 26 and grid 28 in tube 25.

As previously stated, the tubes 24, 25 and 26 are utilized as switching control tubes. All of

their grids are normally biased to cut-off. The anodes of tube 24 are served with anode potential from a direct current source 30 the negative terminal of which is connected through a load resistor 31 to ground. Resistor 31 is shunted by a capacitor 32.

With respect to the circuit arrangements including twin triode tubes 25 and 26 similar anode potential sources 33 and 36 are provided, as well as load resistors 34 and 37. Load resistor 34 is shunted by a capacitor 35 while load resistor 37 is shunted by a capacitor 38.

When a signal voltage is impressed on any of the grids of the tubes 24, 25 and 26 plate current is caused to flow in the load resistors 31, 34 and 37. These currents in the load resistors will be approximately proportional to the square of the signal voltage impressed upon the grids. Hence the grids receiving the greatest signal voltage will cause their associated plate circuits to draw a predominant amount of current through their respective load circuits.

These three load circuits 31, 34 and 37 are connected to grid biasing circuits for each of three amplifier tubes 41, 39 and 40 respectively. The grid of tube 39 is in circuit with the secondary winding 16 on output transformer 14 whose primary winding 15 is connected to the output circuit of the first I. F. amplifier 10 and is completed to ground through load resistor 34. Similarly the grid of amplifier tube 40 is in circuit with secondary 16a on transformer 14a which is fed with output energy from a first I. F. amplifier 11. This grid circuit is completed to ground through the load resistor 37. In the same manner the grid amplifier tube 41 is in a grid biasing circuit which includes the secondary winding 16b of transformer 14b, controlled by signal energy from the I. F. amplifier 12, and this grid biasing circuit is completed to ground through load resistor 31.

Current flowing in load circuit 31 will increase the negative bias on amplifier stage 41 and thereby reduce the amount of signal contributed by the I. F. amplifier 12. Now the current through the load circuit 31 may be caused by signal potential on either of the grids 21 or 27 in tube 24, but these grids are respectively controlled by signal potentials derived from the antennas 1 and 2. When either of these signal potentials predominates over the potential derived from antenna 3, tube 41 will be blocked.

Assuming that the strongest signal is received on antenna 1, this will be amplified in the I. F. amplifier 10 and fed through secondary 16 to the grid of tube 39. The grid 21 in tube 24 and the grid 29 in tube 26 will at the same time render these tubes conductive, thus producing a potential drop in the load resistors 31 and 37. This action biases the grids of tubes 40 and 41 to cut-off. It will thus be seen that the gain of both of these tubes 40 and 41 will be reduced while the strong signal is amplified still further in tube 39. The output from the I. F. amplifier 10 thus predominates over the outputs from I. F. amplifiers 11 and 12. For the duration of this condition tube 39 alone continues to deliver its output to I. F. amplifier 42, although the latter is common to all three receiving circuits. The control characteristics of the amplifiers 39, 40 and 41 can be made such that this selective action is greatly accentuated.

The output of amplifier 42 represents the signal voltage from practically only one antenna and this is conveyed through transformer 43 op-

tionally to a limiter device 45, and thence, after final detection by the unit 46 to an audio frequency amplifier 47. An automatic gain control circuit is shown connected to the secondary of the transformer 43. This secondary is preferably tuned by means of a capacitor 44. A resistor 48 and capacitor 49 serve to introduce a suitable time lag in the action of the automatic gain control circuit. Any suitable responsive device (not shown) may be connected to the output side of the audio frequency amplifier 47.

The use of the limiter device 45 is particularly required in connection with a frequency-modulation receiver, a phase-modulation receiver, a telegraph or facsimile system. The limiter is not essential, however, in amplitude modulation systems.

In order to improve the operating characteristics of the diversity receiving system as shown in Fig. 1, I preferably provide an automatic gain control circuit common to the three separate R. F. amplifier stages 4, 5 and 6. Also, if desired, well known practice may be followed in controlling the frequency of the oscillator 13 in dependence upon the relative loads in two slightly differently tuned circuits, each of which is controlled by output energy from the I. F. amplifier stage 42, thus maintaining the oscillator 13 at a suitable frequency for heterodyning with the incoming signal as accomplished by the converters 7, 8 and 9.

Referring now to Fig. 2, I show radio frequency amplifiers 4, 5 and 6, converters 7, 8 and 9, and intermediate frequency amplifiers 10, 11 and 12, each of these units being arranged in connection with antennas 1, 2 and 3 in the same manner as shown in Fig. 1. The outputs from the intermediate frequency amplifier units 10, 11 and 12 feed through transformers 50, 51 and 52 to input circuits for each of three different amplifier tubes 53, 54 and 55. These input circuits, however, are connected in common to a grid biasing source 56 which normally biases the grids to cut-off. Hence a signal voltage must exceed a certain value before any effect is produced in the load circuit constituted by the primary of transformer 57 and a suitable resistor 58 leading to the positive terminal of an anode supply source, not shown. The negative terminal of this source is grounded, as are the cathodes of the tubes 53, 54 and 55. In general it will be seen that the signal voltages from the intermediate frequency amplifier units 10, 11 and 12 would be different due to the variables of the transmitting media through which the signal energy passes in order to be collected by the antennas 1, 2 and 3 respectively. The output from one of the amplifiers 10, 11 and 12 will, therefore, at any given moment deliver a voltage which is stronger than the output from the other two I. F. amplifiers. This predominating signal voltage will be amplified in the unit 42 to the exclusion of inferior signal voltages, since the latter fail to overcome the initial negative bias from the D. C. source 56.

Apparatus similar to that shown in Fig. 1 may, of course, be connected to the output side of the I. F. amplifier 42. In other respects, therefore, the system of Fig. 2 may be considered the same as that of Fig. 1 and may include optionally a limiter device 45 as well as an automatic gain control circuit whose time constant elements are shown at 48 and 49. In Fig. 2, as well as in Fig. 1, the oscillator 13 may be controlled as to frequency in dependence upon the frequency of

the output energy which traverses the transformer 43.

The action of the automatic gain control circuit serves to supplement that of the negatively biased tubes 53, 54 and 55. When the output from one of the I. F. units 10, 11 and 12 reaches the load circuit 57, 58, it serves to reduce the gain of the amplifiers 4, 5 and 6 sufficiently so that, generally speaking, no output will be used from more than one of the I. F. units 10, 11 and 12.

Referring now to Fig. 3, I show a slight variation from the arrangement of Fig. 2, particularly as regards the means for selecting the output from that one of the intermediate frequency amplifiers 10, 11 and 12 which exceeds the outputs from those remaining. In this case transformer 50 has a secondary winding which is in circuit with a diode rectifier 60. Likewise the secondary of transformer 51 is in circuit with a diode rectifier 61, while the secondary of transformer 52 is in circuit with a diode rectifier 62. One terminal of each of the secondaries on the transformers 50, 51, 52 is connected to a common load circuit consisting of a resistor 63, shunted by capacitor 64, both of these elements being grounded. The cathodes of the tubes 60, 61 and 62 are each connected respectively with an impedance which is here shown as the primary winding of a transformer. The three transformers 65, 66 and 67 possess secondary windings which are connected in series and are in circuit with the input leads to the I. F. amplifier 42. The complete circuit arrangement for which the portion shown by Fig. 3 is adapted may be understood to be similar in other respects to that shown in Fig. 2 or Fig. 1. That is to say, only the alternative elements which intervene between the I. F. amplifiers 10, 11 and 12, on the one hand, and the I. F. amplifier 42, on the other hand, are necessary to consider in this case.

The same general principle applies to the operation of the embodiment of Fig. 3, as will be understood in the operation of the system of Fig. 2. The diodes 60, 61 and 62 bias themselves negative to a point where current will flow at a given moment only in one of these diodes, and in the particular one upon which the strongest signal is impressed. This is true for the reason that any signalling energy which is derived from the secondaries of the transformers 50, 51 and 52 will produce a potential drop across the common load resistor 63. This potential drop renders all of the anodes of the tubes 60, 61 and 62 negative with respect to their cathodes. However, the potential induced in the secondary of one of the transformers 50, 51 and 52, which exceeds the potential drop in resistor 63, will render its associated rectifier tube conductive and no current will flow through the remaining ones of diodes 60, 61 and 62. Therefore, the amplifier 42 will receive an intermediate frequency voltage from that one of the transformers 65, 66 or 67 to which energy is delivered by its associated diode.

The embodiment represented by Fig. 4 includes diversity antennas, radio frequency amplifiers and converter units. These units, however, are not shown in Fig. 4 since they will be understood to be connected to the intermediate frequency amplifiers 10, 11 and 12, according to Fig. 1. Each of the intermediate frequency amplifiers has an output circuit which includes a transformer such as 14, 14a and 14b. These transformers have each two secondaries 16 and 17, 16a

and 17a, and 16b and 17b. The secondaries 17, 17a and 17b are parallel connected in parallel to a common load resistor 73. Each of these transformer secondaries, however, is individually connected to the cathode of an appropriate diode rectifier tube 70, 71 and 72. In each diode circuit is a resistor 75 and capacitor 76 connected in parallel between its anode and ground. A signal voltage which produces a potential drop across the common load circuit 73 causes the diodes to be biased to the same extent so that current will flow only in that diode to which the strongest signal voltage is supplied. The individual load circuits 75 for the respective diodes exhibit a potential drop between the anode and ground in dependence upon the sole action of the strongest signal. This is true for the reason that signalling currents of lesser voltage induced in the secondaries 17, 17a or 17b will not be rectified.

A direct current voltage amplifier tube 77 is provided for the purpose of controlling the bias on the grid of a signal amplifier tube 80. The input circuit of tube 77 extends from its grounded cathode through resistor 75 to a connection between the anode of the diode 70 and the grid of the amplifier tube 77. The output circuit of this latter tube includes resistors 83 and 79. Resistors 83, 82 and 81 constitute a potentiometer which extends between the plus and minus terminals of a D. C. source (not shown). The cathode of amplifier tube 80 is connected to the junction between the resistive elements 81 and 82 of the aforesaid potentiometer. The screen grid of amplifier 80 is connected to a tap on resistor 81. The input circuit of tube 80 includes resistors 82, 79 and the secondary of a transformer 78. The primary of this transformer is in circuit with the secondary 16 on transformer 14. The output circuit of tube 80 includes resistor 81 and the primary of a transformer 84 leading to the anode of tube 80.

Assume for the moment that the signal is strongest on the I. F. amplifier 10, the diode 70 will become conductive. This action will produce a potential drop across resistor 75, thus biasing the tube 77 to cut-off. Current will cease to flow in resistor 79, thus raising the voltage on the anode of tube 77 and correspondingly reducing the negative bias on the grid of tube 80. This action causes the tube 80 to amplify the signal which is directly applied thereto by means of the secondary winding 16 on transformer 14 which feeds to the transformer 78, where the secondary of this last mentioned transformer is in the input circuit of the amplifier tube 80. The output circuit of the amplifier 80 includes a transformer 84. Similar transformers are provided in the respective output circuits of the units 85 and 86, these last named units including circuits as shown in connection with the amplifier 10.

The secondaries of all three transformers 84 are preferably connected in parallel, although they might well be connected in series, if desired. All of these secondaries are arranged to feed signal energy to the input circuit of the intermediate frequency amplifier 42. Output energy from the I. F. amplifier 42 may be utilized in the same manner as shown and described in connection with the same amplifier in the embodiment of Fig. 1.

If desired, the D. C. amplifier which intervenes between the diode 70 and the input circuit of the amplifier tube 80 may include more than one stage, but preferably an odd number of stages so that the same phase relation may obtain as is indicated in Fig. 4. Normally, the system would

be set up so that with no current flowing in resistor 75 the grid of tube 80 would be biased to cut-off. When the voltage drop in resistor 75 exceeds a predetermined value tube 77 is biased to cut-off, establishing a fixed value of amplification in the amplifier 89. Thus the system serves to operate as a definite control of the passage of signal currents from unit 10 to the output circuit of the I. F. amplifier 42.

The operation of this system, therefore, is such that only one of the three load circuits 75 will carry current at a given moment and consequently the intermediate frequency signal will be passed into only one of the three transformers 84. This output is conveyed to the I. F. amplifier unit 42 and thence to such further units, including optionally a limiter device as are shown in Fig. 1 following the I. F. amplifier 42.

It will be understood that in any of the alternative arrangements shown in the several figures of the drawings, whether or not they are specifically indicated, automatic volume control devices and automatic frequency control devices may be utilized.

Although I have shown four different alternative embodiments of my invention, these are to be understood as merely typical and representative of a number of different arrangements, all of which would fall within the scope of the invention. The general principles applying to each of these embodiments will be understood to be of the same generic character. Specific variations in the circuit connections and in the elements in combination may be resorted to by those skilled in the art without departing from the essence of the invention. Accordingly the claims to follow are to be given as broad an interpretation as their limitations will permit.

I claim:

1. A diversity receiving system for frequency and phase modulated radio signals comprising a plurality of receivers, an antenna coupled to the input side of each receiver, the several antennae being so disposed with respect to each other as to cause a given transmission condition to produce different responses to the same signal in each of said receivers, a utilization circuit to which the output side of each receiver is coupled, selective means controlled by a predominant value of signal energy fed through any one receiver for instantly rendering that energy predominantly effective in said utilization circuit, said means being simultaneously and selectively effective to prevent the transfer of signal energy from the remaining receivers to said utilization circuit, and a common limiter device through which the output side of each receiver is coupled to said utilization circuit, said selective means being controlled by said signal energy before limiting the same.

2. A system in accordance with claim 1 and including electronic switching devices for mutually interchanging the effectiveness upon said utilization circuit of the signal energies fed through the several receivers.

3. A system according to claim 1 in which said selective means includes a discharge tube associated with each separate receiver and input circuit biasing means operative to render one of said tubes conductive while the others of said tubes are rendered non-conductive of said signal energy.

4. A diversity receiving system comprising a plurality of separate receivers each fed with signal energy by its own antenna, an output transformer for each receiver, each of said transformers having a primary and two secondaries,

a plurality of discharge tube amplifiers, each amplifier having an input circuit which includes one of the secondaries of a different one of said transformers, biasing means affording selective control of said amplifiers, said biasing means including the remaining secondaries of said output transformers, and a common utilization circuit to which signal energy is caused by said biasing means to be fed from that one of said amplifiers which is associated with the receiver delivering the strongest signal, said biasing means being operative to block the remaining amplifiers.

5. A system in accordance with claim 4 in which said biasing means comprises a plurality of multi-path discharge tubes, and a plurality of load resistors, a plurality of input circuits for each said multi-path tube, each said output transformer secondary of the biasing means being branched to individual input circuits of different multi-path tubes, each said load resistor being comprised in a common output circuit for the multi-paths of a respective one of said tubes, and each load resistor having a connection through a separate output transformer secondary of the amplifier input circuits to a different one of said amplifiers, whereby a voltage drop developed in one of said load resistors in response to relatively strong signals from either of two antennae tends to impress a blocking bias on a non-selected one of said amplifiers.

6. A diversity receiving system comprising a plurality of receivers each fed with signal energy by its own antenna, an amplifier stage in each receiver, the several said amplifier stages having input circuits which include a common control-grid biasing source, and having output circuits which include the primary winding of a common output transformer, a utilization circuit fed with energy through said transformer, and an automatic gain control device common to said receivers and operable by a portion of the energy fed through said transformer, said biasing source having a value such that, in cooperation with the effects of said automatic gain control device, one of said amplifier stages associated with the receiver which delivers the strongest signal is rendered conductive while the amplifier stages associated with those receivers which deliver signals of lesser strength are biased to cut-off.

7. A diversity receiving system comprising a plurality of receivers, a plurality of antennae, each antenna being coupled to the input side of a different receiver, the several antennae being so disposed with respect to each other as to cause a given transmission condition to produce different responses to the same signal in each of said receivers, a utilization circuit, a plurality of amplifier stages each directly interposed between the output side of a respective receiver and said utilization circuit, means for selectively rectifying a quantum of the alternating current signal energy derived from each receiver, means for amplifying said quantum of energy after rectification, and electronic switching means controlled by the selective action of the amplified quantum of energy for removing a normal cut-off bias from the input circuit of that particular amplifier stage which is associated with the receiver producing the strongest signal response.

8. In a diversity receiving system having a plurality of receivers feeding a common utilization circuit, a device for passing to said utilization circuit the energy from only that receiver having the largest incoming signal, said device including a rectifier associated with each re-

ceiver for diverting and rectifying a portion of the alternating current derived therefrom, means for selectively amplifying the output from one of said rectifiers in dependence upon the voltage drop in said load resistor, a plurality of discharge tube stages each coupled between a respective one of said receivers and said utilization device, and means for rendering said discharge tube stages conductive one at a time, the last said means including a plurality of amplifiers each controlled by one of said rectifiers respectively and each operable to control the input circuit bias applied to a respective one of said discharge tube stages.

9. In a signaling system subject to variable transmission conditions, a plurality of receivers each receiving the same signal and so related to each other that the received signals vary differently at the several receivers with variations in transmission conditions, a common utilization circuit, separate paths extending from each of said receivers to said common circuit, each of said paths including a space discharge device having an input circuit subject to the application of an independent control bias, amplitude discriminator means including rectifiers individual to each receiver and operable in dependence upon the relative amplitudes of the signals simultaneously passed through the several receivers for so applying said control bias as to render one only of said discharge devices conductive, thereby to feed to the utilization circuit only the strongest of the signals momentarily derived from the different receivers.

10. A diversity receiving system comprising a plurality of at least three heterodyne receivers each fed with signal energy by its own antenna and each comprising separate stages of radio frequency amplification, conversion and intermediate frequency amplification, a heterodyning oscillator common to the several receivers, an output circuit for each said stage of intermediate frequency amplification, a utilization circuit arranged to be fed with energy from a selected one of said output circuits, and electronic switching means controlled by the relative values of energy in said output circuits for making that selection in any order which admits the strongest of the simultaneously received signals and suppresses signals of weaker value, said switching means comprising a plurality of multi-path discharge devices, a like plurality of load impedances each in an output circuit individual to a different one

of said discharge devices, input circuits for said discharge devices arranged to derive separate control of the multi-paths in any one device by signal energy derived from a plurality of said receivers, a separate amplifier coupled to the output side of each receiver, the output side of each said amplifier being coupled to said utilization device, and a biasing circuit individual to each said amplifier and including a respective one of said load impedances.

11. A diversity receiving system comprising at least three receivers each fed with signal energy by its own antenna and each comprising serially connected stages of amplification, energy diversion means coupled to the output circuits of corresponding amplifier stages and arranged to integrate the effects of signal amplitudes in a plurality of said corresponding stages for control of a subsequent stage in a different receiver, said energy diversion means comprising supplementary coupling devices on inter-stage coupling means, and a plurality of multi-control discharge tubes each arranged to integrate the signal energy components from a different pair of receivers, and means applicable to each of said subsequent stages and responsive to said integrated effects for causing the amplification of signal energy in that receiver which derives a predominant signal control from its antenna, the last said means serving also to block said subsequent stages of the receivers which derive an inferior signal control from their antennas.

12. In a selective system comprising a plurality of parallel channels each having an amplifier which is fed with signal energy derived from a differently situated antenna, comparison means operative in response to relative magnitudes of signal energy in different channels for producing respectively different bias-control potentials simultaneously applicable to corresponding stages of amplification in each of said channels, means for blocking the translation of signal energies in non-selected channels, the last said means including a volume control circuit arrangement applicable to corresponding amplifier stages in the several channels and having the added function of increasing the gain in an amplifier stage of the channel wherein the input signal energy predominates, and a single limiter device arranged to be fed with energy from the amplifier stage last mentioned.

HAROLD O. PETERSON.