

July 18, 1933.

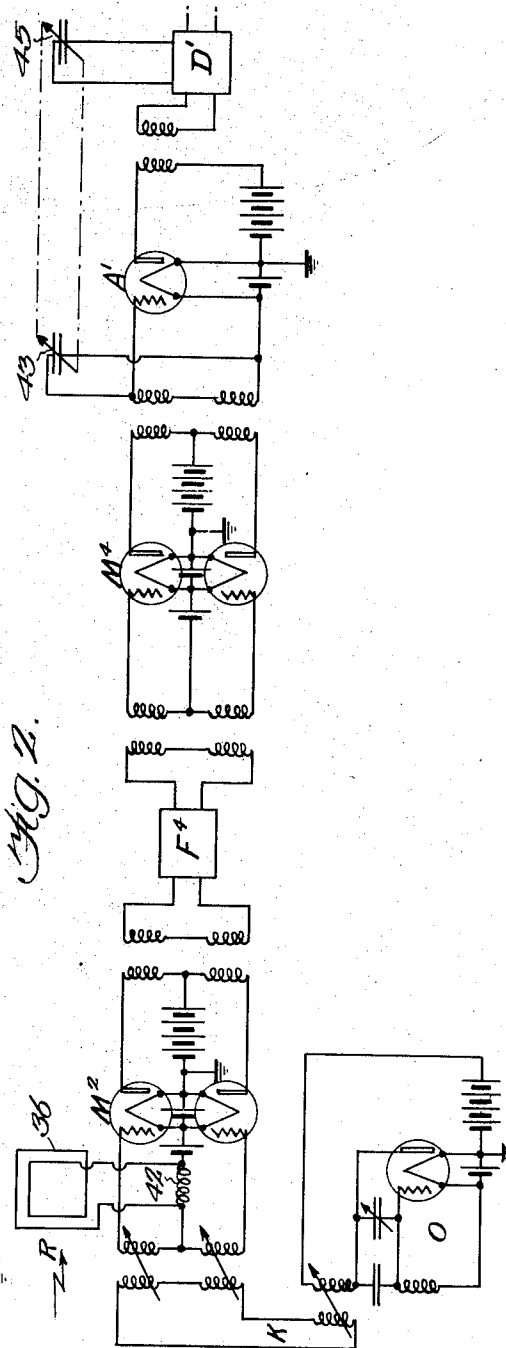
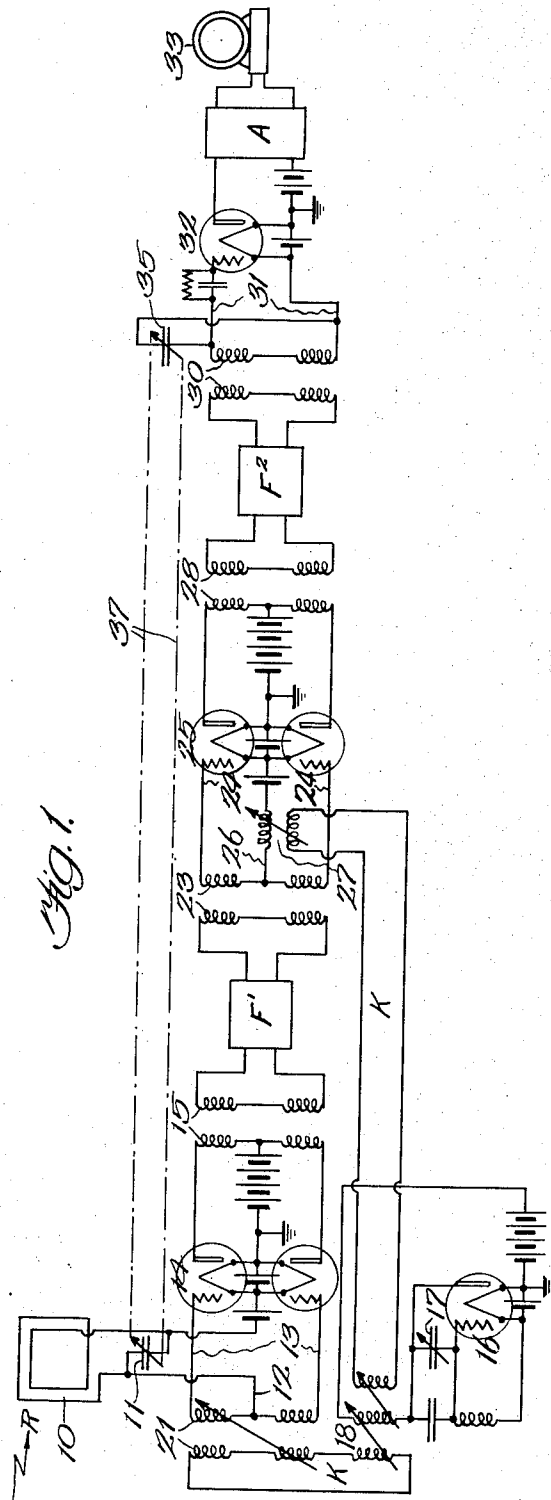
E. H. SMYTHE

1,918,433

SIGNALING SYSTEM

Filed Jan. 22, 1929

3 Sheets-Sheet 1



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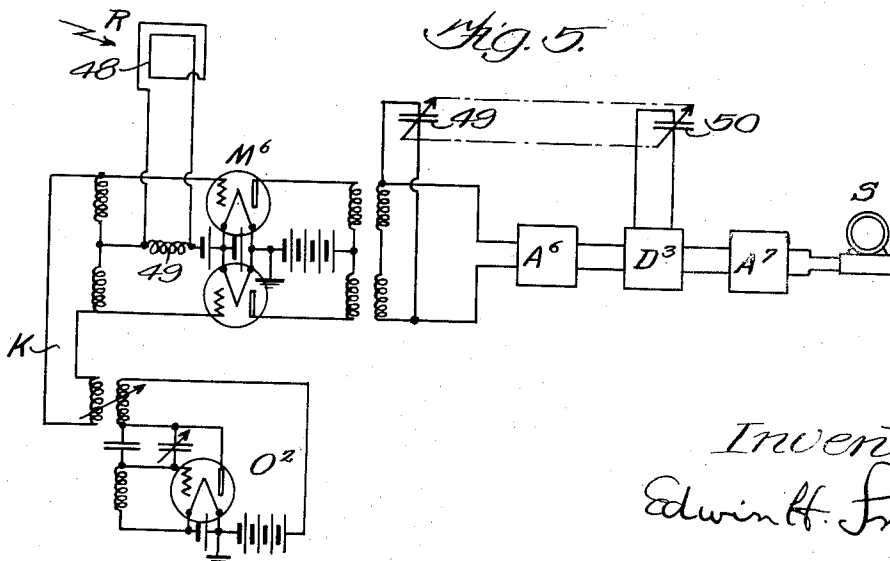
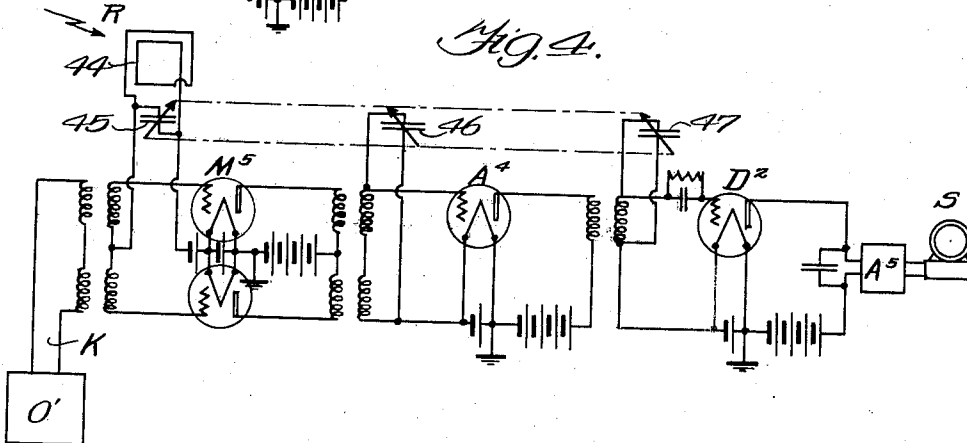
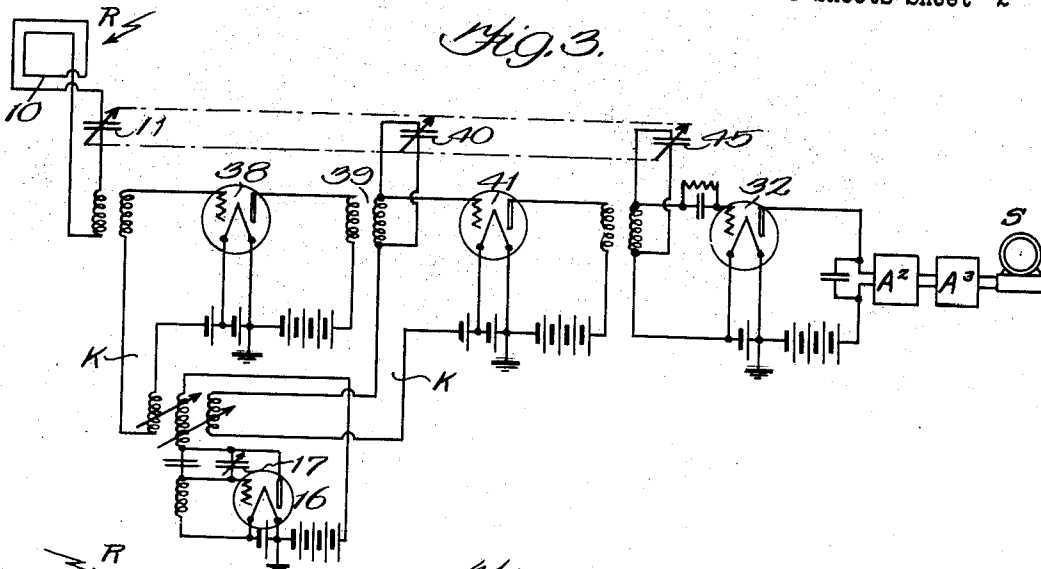
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SIGNALING SYSTEM

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3 Sheets-Sheet 2



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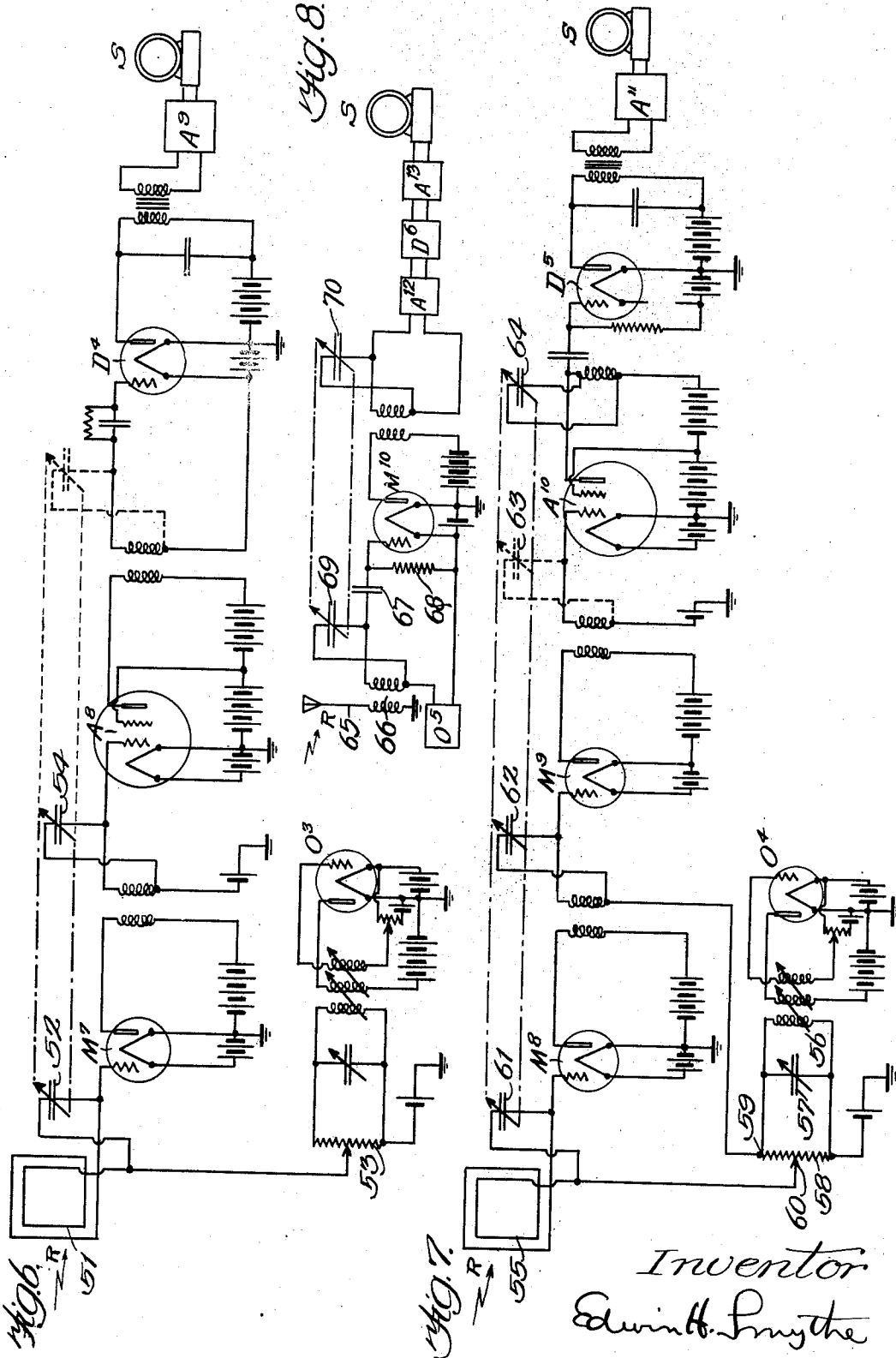
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SIGNALING SYSTEM

Filed Jan. 22, 1929

3 Sheets-Sheet 3



## UNITED STATES PATENT OFFICE

EDWIN H. SMYTHE, OF EVANSTON, ILLINOIS

## SIGNALING SYSTEM

Application filed January 22, 1929. Serial No. 334,228.

My invention relates to signaling systems employing high frequency waves as the medium of communication, and more particularly to the selective reception and amplification of modulated carrier waves.

It is well known that signal carrier waves, under favorable conditions, may be received with a high degree of selectivity when subjected to modulation with a locally generated wave of appropriate frequency. It is also well known that there are certain effects attendant upon this type of carrier wave reception which lead to troublesome interference between stations. The modulating action between the locally generated and received frequencies produces side frequencies each of which carries a signaling frequency component which side frequencies may cause interference between stations to a greater extent than the corresponding original received wave frequencies. In many receivers employing the so-called superheterodyne type of modulation, two or more distinct settings of the selecting mechanism cause a selection of the same station frequency, although these settings are separated by other settings wherein this station is not selected. Furthermore, any one of the settings may select more than one station frequency owing to the coincidence of two or more side frequencies representing different stations.

Among the objects of my invention are to provide a convenient and efficient method of and means for receiving carrier waves with a high degree of selectivity and freedom from interference throughout a wide frequency range; to effect heterodyne amplification of the carrier waves from a plurality of stations while at the same time limiting the selection of each station to a single setting of the station selecting device; to modulate incoming waves in such a way as to avoid interference by undesired products of modulation; to effect amplification of the received waves by modulating the same with a locally generated wave of fixed frequency value; to so relate the frequency of the locally generated modulating wave to the fre-

quencies comprised in the carrier wave range received from a plurality of stations as to minimize or eliminate interference between stations; to amplify the received waves by a plurality of heterodyne modulations; to effect multi-stage heterodyne amplification by means of the same locally generated wave; to effect amplification with accompanying change of frequency in order to permit selective tuning while avoiding the tendency to feed-back and oscillations; to effect multi-stage amplification of a particular carrier wave in which successive stages are tuned to different frequencies; to relate the tuning means operating at different frequencies in such a way as to permit unitary variable tuning control; to increase the amplification factor by adjusting the frequency of the received carrier wave; to minimize or substantially prevent the radiation of the locally generated wave; and generally to improve and properly coordinate the relation of the local and received wave frequencies and the apparatus utilized in different parts of a heterodyne wave receiving system.

In accordance with one aspect of the present invention, the frequencies of the incoming waves and the locally generated modulating wave are so chosen in relation to each other that no interference can take place between the selected side frequency of the desired station and the side frequencies of the other stations, or between groups of side bands which it is desired to keep separated. Only one setting of the selecting mechanism can select a station of given frequency, and no other station can be selected by this setting. The locally supplied wave is so applied to the modulator or adjusted to have such a frequency relation with respect to the received waves that radiation of the locally supplied wave is minimized or eliminated. The side frequencies utilized from the output of the modulator are preferably non-overlapping as between stations, and in the neighborhood of the received frequency range so as to be susceptible of convenient control by means of elements having constants which are similar to those of the elements used for selecting the incoming waves. The methods

and means of my invention are adapted for selecting waves from any desired frequency position within a wide band of incoming wave frequencies. When the receiving circuit is  
5 organized in accordance with certain features of my invention, this band may have a width as large as one of the wave frequencies within the band.

The local oscillator frequency should preferably be outside of the received frequency range, but may be either above or below said range, and may also lie within said range provided certain other requirements are complied with, as will hereinafter be pointed  
10 out. In case the fixed local oscillator frequency is below the received frequency range and the difference frequencies of modulation are to be utilized, the received range in certain modifications of the application of my  
15 invention should be limited in width to a value not greater than twice the minimum frequency in said range. The oscillator frequency in this case should be not greater than the minimum frequency in the received frequency range, and should be not less in value  
20 than one-half the frequency width of the received range.

By subjecting the incoming carrier wave energy to one or more heterodyne modulations, at least one of which provides the desired selectivity characteristics, the desired signal bearing carrier wave energy may be  
25 efficiently translated into waves of convenient frequency free from feed-back and self-oscillation tendencies. The heterodyne modulation or modulations at the same time may be employed to increase the energy of the waves that it is desired to utilize without depending therefor upon cascade amplification  
30 with its inherent tendency to cause energy feed-back.

One of the characteristic features of my invention in one of its aspects is that of modulating an incoming carrier wave with a fixed  
35 locally generated wave, and associating with the modulator a variable selective input and a variable selective output adapted to have maintained between them a tuning frequency difference equal to the frequency of the locally supplied modulating wave. In the well-known superheterodyne system, for instance,  
40 the selective input to the modulator is variable with respect to frequency, the selective output is fixed, and the local modulating frequency is variable. In the present invention the selective input and the selective output are both variable and the local modulating frequency is fixed. Again, in the superheterodyne system the locally generated frequency  
45 is a variable frequency within the received frequency tuning range. In the present invention the locally generated frequency is a fixed frequency outside the received frequency tuning range.

More broadly, the application of the prin-

ciple of the fixed heterodyne modulation and amplification, as hereinafter more particularly described, may involve merely the impressing with or without preliminary individual  
50 selection of all of the received carrier wave or station frequencies upon the input circuit of the modulator to which the local fixed frequency is applied, and the selection of any or all of the upper side band frequencies of the received waves or the selection of any or all  
55 of the lower side band frequencies of the waves in the output circuit of the modulator or in a circuit operatively associated therewith. The selected range of upper or lower side band frequencies includes an amplified carrier wave corresponding to each carrier wave lying within the received range, and the corresponding station frequency may either be individually selected and further amplified  
60 and detected at its changed frequency level, or the range of modulated waves or a selected individual wave may again be acted upon by the local fixed frequency in a second stage of modulation and the resultant side band frequency or frequencies, thus further amplified  
65 in energy and restored to the original frequency value of the originally received wave or waves, may be subjected to further amplification and detection in the ordinary way.

There are many advantages resulting from the fixed heterodyne amplification of the received carrier waves with attendant change  
70 in frequency level which may be secured in accordance with the principles of my invention and by the employment of the methods and organizations hereinafter to be set forth. Amplification being accompanied by change of frequency level, the tendency to objectionable feed-back of energy is avoided. The frequency level difference between stages  
75 having an invariable value dependent upon the fixed frequency of the local oscillator, the tuning elements of successive stages may be mechanically coupled and coordinated. The signal bearing frequency values operating within the receiving circuit may be set and predetermined by the frequency value assigned the local oscillator to such values as will minimize or prevent interference between stations; and may also be adjusted to such a level as to take advantage of the most favorable amplification factor in the amplifying stages which may succeed the stage or stages in which the heterodyne amplification  
80 is effected.

These and other advantages which arise from the employment of the various features of my invention will be understood more clearly in view of the following detailed description and the accompanying drawings, in which:

Figs. 1 to 8, inclusive, are circuit diagrams of wave receiving and utilizing organizations embodying the various features of

my invention, and exemplifying modifications the distinguishing characteristics of which will be made clear in the detailed description which follows.

5 For the purpose of more clearly showing the relation of the input wave frequencies and the output wave side frequencies in a heterodyne modulator employed in the reception of signal waves, the tables lettered A  
10 to E, inclusive, are given below.

| 15 | Table | Station | Wave frequencies, cycles per second |            |                             |                      |
|----|-------|---------|-------------------------------------|------------|-----------------------------|----------------------|
|    |       |         | Modulator input                     |            | Modulator output            |                      |
|    |       |         | Received                            | Oscillator | Difference side frequencies | Sum side frequencies |
|    |       |         | R                                   | K (fixed)  | R-K                         | R+K                  |
| 20 | A     | 1       | 1,500,000                           | 100,000    | 1,400,000                   | 1,600,000            |
|    |       | 2       | 1,300,000                           | 100,000    | 1,200,000                   | 1,400,000            |
|    |       | 3       | 1,100,000                           | 100,000    | 1,000,000                   | 1,200,000            |
|    |       | 4       | 900,000                             | 100,000    | 800,000                     | 1,000,000            |
|    |       | 5       | 700,000                             | 100,000    | 600,000                     | 800,000              |
|    |       | 6       | 500,000                             | 100,000    | 400,000                     | 600,000              |
| 25 | B     | 1       | 1,500,000                           | 900,000    | 600,000                     | 2,400,000            |
|    |       | 2       | 1,300,000                           | 900,000    | 400,000                     | 2,200,000            |
|    |       | 3       | 1,100,000                           | 900,000    | 200,000                     | 2,000,000            |
|    |       | 4       | 900,000                             | 900,000    | 0                           | 1,800,000            |
|    |       | 5       | 700,000                             | 900,000    | -200,000                    | 1,600,000            |
|    |       | 6       | 500,000                             | 900,000    | -400,000                    | 1,400,000            |
| 30 | C     | 1       | 1,500,000                           | 2,000,000  | 500,000                     | 3,500,000            |
|    |       | 2       | 1,300,000                           | 2,000,000  | 700,000                     | 3,300,000            |
|    |       | 3       | 1,100,000                           | 2,000,000  | 1,000,000                   | 3,000,000            |
|    |       | 4       | 900,000                             | 2,000,000  | 1,100,000                   | 2,900,000            |
|    |       | 5       | 700,000                             | 2,000,000  | 1,300,000                   | 2,700,000            |
|    |       | 6       | 500,000                             | 2,000,000  | 1,500,000                   | 2,500,000            |
| 35 | D     |         |                                     | K (varied) |                             |                      |
|    |       | 1       | 1,500,000                           | 1,550,000  | 50,000                      | -----                |
|    |       | 2       | 1,300,000                           | 1,450,000  | 50,000                      | -----                |
|    |       | 3       | 1,100,000                           | 1,350,000  | 50,000                      | -----                |
|    |       | 4       | 900,000                             | 1,250,000  | 50,000                      | -----                |
|    |       | 5       | 700,000                             | 1,150,000  | 50,000                      | -----                |
| 40 | E     |         |                                     | K (fixed)  |                             |                      |
|    |       | 1       | 1,500,000                           | 500,000    | 1,000,000                   | 2,000,000            |
|    |       | 2       | 1,300,000                           | 500,000    | 800,000                     | 1,800,000            |
|    |       | 3       | 1,100,000                           | 500,000    | 600,000                     | 1,600,000            |
|    |       | 4       | 900,000                             | 500,000    | 400,000                     | 1,400,000            |
|    |       | 5       | 700,000                             | 500,000    | 200,000                     | 1,200,000            |
| 45 |       | 6       | 500,000                             | 500,000    | 50,000                      | 1,050,000            |

Referring to Table A, it is assumed that  
50 incoming wave frequencies, R, to be received, are located within a frequency range extending from 1,500,000 cycles to 500,000 cycles. For convenience, only one wave frequency is represented for each station, but it  
55 is to be understood that ordinarily each different station frequency is a signal modulated carrier wave consisting of a constant frequency wave together with the upper and lower side bands produced by modulation of the signal with the constant frequency wave.

The received waves R, together with waves  
60 K, from a local oscillator or other source, when impressed upon the input of an ordinary modulator produce in the output circuit, in a well known manner, not only am-  
65

plified waves of frequencies K and R, but also modulated waves consisting of the sum side frequencies R+K, and the difference side frequencies R-K. Waves from station 1, having a frequency R, of 1,500,000 cycles, are modulated with waves of a fixed frequency K, of 100,000 cycles and produce in the output of the modulator difference side frequencies R-K, of 1,400,000 cycles and sum side frequencies R+K, of 1,600,000 cycles. Each of the frequencies represented as R, R-K, and R+K bear the same signal derived from station 1. Similarly, incoming received waves of 1,300,000 cycles, are modulated with the same fixed frequency K, of 100,000 cycles, and produce the difference side frequencies of 1,200,000 cycles and sum side frequencies of 1,400,000 cycles, and so on for the other stations listed in Table A. The width of the received frequency range in Table A, as shown by column R, is 1,000,000 cycles, and the oscillator frequency K, in Table A, lies below this range. As a result of the relation between K and the received frequency range, it will be noted that difference side frequencies R-K, for station 1, and sum side frequencies R+K, for station 2, are the same in value, each being 1,400,000 cycles, and thus interfere, unless the incoming waves R are sharply restricted to a single station in the modulator input, as by sharply tuning the input. In a similar manner, serious interference tends to occur between the other stations listed in Table A.

Referring to Table B, it will be noted  
100 that the received frequency range is the same as used in Table A, but that a different oscillator frequency K, of 900,000 cycles, is employed. In Table B, the oscillator frequency lies within the frequency range of the received waves R, and hence, unless special provision is made to prevent it, may reach the antenna or other incoming conductor, and radiate energy therefrom to disturb neighboring stations. In addition to this objection, it will be noted also that unless the modulator input is sharply tuned, serious interference occurs between stations 2 and 6 in the difference side frequencies R-K, and similar interference occurs between the difference side frequencies of at least two stations for every selected station within the received range from 500,000 to 1,300,000 cycles.

In Table C, the received frequencies lie within the same range as in Tables A and B. The oscillator frequency K, of 2,000,000 cycles is outside of and above the range of the received frequencies R. It will be noted that the difference side frequencies R-K in Table C start low and increase in value in reading down the column, while the station frequencies in column R decrease in value. As a result of this relationship there are produced in the output of the modulator, dif-  
120  
125  
130

ference side frequencies lying very close to the frequencies of the received waves  $R$  which give rise to these side frequencies, the station 3 frequency of 1,000,000 cycles being identical with the side frequency 1,000,000. Under these conditions, unless means are provided for preventing it, there will be a tendency for the modulator to oscillate and for resulting waves to escape to the incoming conductor as in the case of Table B.

Table D shows the relationship of the wave frequencies in the ordinary superheterodyne type of receiver wherein the oscillator frequency  $K$  is varied in order to produce the same difference side frequencies for each station frequency,  $R$ , these side frequencies having a fixed value of 50,000 cycles. It will be seen that station 1 may be selected by adjusting frequency  $K$ , to either 1,550,000 cycles or 1,450,000 cycles, the fixed difference frequency 50,000 cycles being produced in each case. Furthermore, when the oscillator frequency  $K$ , is adjusted to 1,450,000 cycles, stations 1 and 2 both appear in the output of the modulator on the 50,000 cycle difference frequency waves, and thus interfere. Similar interference and multiplicity of settings of the selecting mechanism arise in connection with each setting of the oscillator frequency  $K$ . Only sharp tuning of the input circuit of the modulator can prevent interference between two stations on any given setting of the oscillator frequency  $K$ , but such tuning of the modulator input, is of no value for reducing the multiplicity of settings of the station selecting mechanism.

Table E shows a relation of wave frequencies which may be employed to avoid the interference and lack of selectivity of the kinds referred to above. The received frequency range has a width equal to one of the frequencies within this range; that is, 950,000 cycles, this range being limited in width to a value not greater than twice the lowest frequency within said range. It will be observed that the oscillator frequency  $K$  of 500,000 cycles is close to the received frequency range but is spaced sufficiently below the received range to make it feasible to detune the receiving circuit to prevent any tendency of the waves  $K$  to escape. It will also be seen that the oscillator frequency  $K$ , in this case is greater than one-half the frequency width of the received range.

Waves of frequency  $K$ , of 500,000 cycles, in Table E, modulate with the incoming wave frequencies  $R$ , thereby producing side frequencies of one sign which do not interfere with each other by coincidence of their frequencies, and do not interfere by coinciding in frequency with side frequencies of opposite sign. The band of difference side frequencies  $R - K$ , extends from 50,000 to 1,000,000 cycles and is spaced 50,000 cycles, a convenient amount to permit of discrimination,

from the band of sum side frequencies  $R + K$ , extending from 1,050,000 to 2,000,000 cycles.

It will be noted that both bands of side frequencies are as close as practicable in the frequency scale to the range of received frequencies  $R$ , of 550,000 to 1,500,000 cycles, thereby avoiding the use of extremely high or extremely low wave frequencies, and thus being susceptible to convenient control. The separation of 50,000 cycles between the frequency of the locally supplied waves  $K$  and the lowest received frequency  $R$ , provides a suitable margin to prevent the waves  $K$ , from reaching the antenna or input circuit of the modulator and causing objectionable escape of the waves  $K$ , to disturb neighboring stations. The value of the locally supplied wave frequency  $K$ , in relation to the received frequency range is such that no side frequency coincides in the frequency scale with the corresponding station frequency from which it is derived. Either the sum or the difference side frequencies may be selected from the output of the modulator for further utilization, without incurring interference between stations and without resorting to special tuning of the modulator input to separate wave frequencies within the limits of the received range.

It will be noted that both the sum and difference side frequencies overlap over part of their range with a part of the received frequency range. Possible interference effects due to such overlapping are prevented in certain embodiments of my invention, hereinafter to be described, by employing a modulator of the carrier suppression type. In other forms of my invention, as will hereinafter appear, overlapping is permitted but interference effects are prevented by coordinated tuning of different stages of the receiving circuit at different frequency levels.

Referring now to the wave receiving circuit shown in Fig. 1, the radio loop antenna 10 is tuned by a variable condenser 11 to selectively receive signal carrier waves  $R$  of the desired station frequency. The selected waves are transmitted to the common or parallel input path 12 of balanced modulator 14 of the kind described in the Carson Patent No. 1,343,306. Oscillator 16, which is shown as being of the well-known Hartley type, but which may be of any type desired, has the variable or trimmer condenser 17 in shunt with the main frequency determining capacity of the oscillator. This variable condenser may have only such capacity as may be necessary to keep the oscillator adjusted to the desired fixed frequency after it is once set for that frequency. Waves from oscillator 16 are picked up by the coupling coil which forms a part of transformer 18 and are applied through the medium of transformer 21 to the series input path 13 of modulator 14.

The characteristic relationships which

exist in the balanced modulator 14 are such as to produce in the secondary winding of the output transformer 15 signal carrier waves of frequencies  $R-K$  and  $R+K$  produced by the modulation of the received radio waves  $R$  with the oscillator waves  $K$ , and to suppress the amplified carrier wave frequencies  $R$  and the double frequencies of both  $R$  and  $K$ . The sum and difference frequency products of modulation are transmitted from transformer 15 to the selective network  $F^1$ , which is preferably an electric filter of any well known construction, such as the Campbell type designed to selectively transmit side frequencies of only one sign and substantially to suppress waves of other frequencies. Network  $F^1$  may be a high pass or a low pass filter. The selected waves  $R-K$  or  $R+K$  are transmitted through transformer 23 to the series input paths 24 of the balanced modulator 25 which is similar to modulator 14. Locally generated waves from the oscillator 16 are carried from a pick-up coil of oscillator transformer 18 and applied by way of transformer 27 to the parallel input path 27 of modulator 25.

Resulting waves, produced by modulation in modulator 25, are transmitted through transformer 28 to network  $F^2$ , which is preferably an electrical filter of similar type to that of network  $F^1$ . Network  $F^2$  may, in an assumed case, be designed to pass signal bearing side frequency waves of only one sign, and of the same frequency as the waves selectively received on antenna 10, it being noted that modulator 25 combines the locally generated waves  $K$  with the side frequencies  $R-K$  or  $R+K$  selected by network 22. The result of this second modulation is to produce other side bands of which ever signal bearing side bands have been passed through the preceding electrical network  $F^1$ . If the network  $F^1$  has been chosen to pass the lower side bands of the received carrier waves, the sum products of the second modulation are of a frequency corresponding to the original received frequency; and if the selective network  $F^1$  has been chosen to pass the upper side bands or sum products of modulation, the lower side bands or difference products of the second stage of modulation are of the original received carrier frequency. There are other frequency products of the second stage of modulation in modulator 25; but these are either neutralized or suppressed in the output circuit of the balanced modulator itself or are suppressed in the selective network or electrical filter  $F^2$ .

The signal bearing carrier waves of frequency  $R$  are selected by the network  $F^2$ , and are transmitted by way of transformer 30 to the input circuit 31 of detector 32, which may be of any well known construction. The detected waves of signal frequency, which are of the ordinary audible frequencies, may be

transmitted to a loud speaker 33 to produce an audible signal or may be utilized in any other desired manner. An amplifier 34 may be inserted, if desired, between detector 32 and loud speaker 33 to amplify the signal waves.

The circuit of Fig. 1 has been described thus far as requiring the adjustment of only one tuning element, antenna condenser 11, in order to select any desired station. The selectivity of the circuit may be increased by connecting variable condenser 35 with input circuit 31 of detector 32. Circuit 31 may thus be sharply tuned to the same frequency  $R$  as that for which the antenna 10 is tuned. When condenser 35 is employed, sufficient selectivity may be obtained without employing network  $F^2$ . For convenience in adjustment the mechanical coupling 37 may be provided to connect the movable elements of the two condensers 11 and 35 so that the movement of the coupling synchronously adjusts both condensers and maintains circuits 10 and 31 tuned to the same frequency.

As is well known, modulation of the type described, wherein a received carrier wave is caused to interact with a locally generated oscillation, has the effect not only of changing the frequency level of the modulation products of the received and locally generated waves, but also of greatly increasing the voltage of the products of modulation. The result therefore in the circuit that has been described is not only to increase selectivity as between simultaneously received waves of different stations, but also to effect, in the two stages of modulation, a large voltage amplification of the received signal bearing carrier wave; and by two stages of modulation with the same locally generated frequency the selected and amplified signal bearing carrier wave reaches the detector at its original received frequency value. The coupling circuits by means of which the locally generated oscillations are applied to the modulators are shown variable with respect to the degree of coupling employed in order that the locally generated oscillation may be applied to the modulators at the correct voltage to secure maximum amplification of the resulting products of modulation.

When the receiver shown in Fig. 1 is adjusted in accordance with Table E condenser 11 is preferably given fixed limits of adjustment so that circuit 10 may be tuned only between the broadcast frequency limits of 1,500 and 550 kilocycles, the oscillator 16 being adjusted to supply waves  $K$  of 500 kilocycles. The trimmer condenser 17 in this case may be merely a vernier condenser, which may have only such adjustment as would keep the frequency of the oscillator at approximately 500 kilocycles. Any gradual change likely to occur in the frequency of the oscillator does not affect the operation of the receiver as the ef-

fect of any such change is automatically compensated in modulator 25 when the carrier wave energy is restored to its original frequency R. Network  $F^1$  may be designed to transmit difference side frequency waves shown in column R-K, and suppress all other frequencies, or it may be designed to transmit only sum side frequencies shown in column R+K. Waves selected by network  $F^1$  are combined in modulator 25 with waves of frequency K, thereby restoring the signal carrier wave energy to its original frequency R.

In the modification illustrated in Fig. 2 it may be assumed that the signal bearing carrier waves R received upon the antenna 36 are within the usual broadcast range of 550 to 1,500 kilocycles. The antenna is connected directly with the common portion of the input circuit of a balanced modulator  $M^2$  of the type hereinbefore referred to, a radio frequency choke 42 being included in the common circuit between the antenna terminals. A locally generated wave K, which may in the present instance be assumed to have a frequency of 500 kilocycles, is applied from oscillator O to the series input circuit of the balanced modulator by way of an inductive link circuit the coupling of which is made adjustable. As a result of the intermodulation of the received waves R and the locally generated wave K, there appears in the output circuit of the modulator  $M^2$  the amplified sum and difference products of modulation and the amplified locally generated wave.

In the present instance the electrical filter  $F^4$  connected with the output circuit of the modulator has its elements so proportioned as to act as a low pass filter adjusted to transmit frequencies up to and including 1,000 kilocycles and substantially to suppress the products of modulation lying higher in the frequency range. Consequently the lower side bands or difference frequency products of modulation of the locally generated wave with all of the carrier waves received upon the antenna are transmitted through the filter  $F^4$ ; and as the locally generated frequency lies within the transmission band of the filter, that also is amplified and transmitted, for use in the second stage of modulation.

After passing through the filter these frequencies are applied to the input circuit of balanced modulator  $M^4$  where intermodulation again takes place. The sum frequency products of this second modulation are at frequency levels corresponding to the frequencies of the signal bearing carrier waves received upon the antenna 36; and consequently the frequencies that are applied to the input circuit of radio frequency amplifier  $A'$  are the originally received frequencies with their intensities increased by two stages

of heterodyne amplification under circumstances, as explained, which prevent the transmission to the radio frequency amplifier  $A'$  of more than a single signal bearing carrier wave for each station.

The input circuit of amplifier  $A'$  is provided with a tuning condenser 43 by means of which the wave of the desired station is selected; and after amplification the audio frequency components of this wave are detected in detector  $D'$  and hence may pass through the usual audio frequency amplifying stages to the loud speaker. The detector  $D'$  is also provided with a tuning condenser 45 which, if desired, may be mechanically coupled to and coordinated with the tuning condenser 43 associated with the amplifier  $A'$ .

As will appear from the foregoing, in the circuit of Fig. 2 the broad station selection is effected in the electrical filter  $F^4$  which is adapted to pass only one of the sets of side bands resulting from intermodulation in the modulator  $M^2$ , and the frequency level of which differs from the frequency level of the broadcast range received on antenna 36 to a degree determined by the frequency level for which the fixed oscillator O is set. After this broad selection of a single set of side bands representing the stations within the broadcasting frequency range, the desired individual station selection is accomplished by means of the tuning circuits controlled by the condensers 43 and 45.

In the form of the invention illustrated in Fig. 3 the carrier waves received by antenna 10 are limited in selection by condenser 11 to the desired range of frequencies R, which may be the broadcasting range of from 550 to 1,500 kilocycles. Assuming that the local oscillator 16 is set to generate a 500 kilocycle wave K, below and just outside of the range of received frequencies, the selected carrier frequency and the local frequency of 500 cycles are transmitted to the input of modulator 38, the output circuit of which modulator contains the primary winding of transformer 39. Variable condenser 40, in shunt with the secondary winding of transformer 39, tunes the input circuit of the modulator 41 to the frequency of the modulation product of the particular carrier wave that has been selected by antenna tuning condenser 11. Assuming that the selected station carrier is one that has a frequency of 1,500 kilocycles and that the tuning condenser 40 is such as to give it a tuning range covering the upper or sum side band frequency of the various received stations, then the condenser 40 in the assumed case will be adjusted to make its associated circuit resonant to a frequency of 2,000 kilocycles. This 2,000 kilocycle wave therefore flows in the input circuit of modulator 41 together with a 500 kilocycle wave K derived from the local oscillator 16. The 2,000 kilocycle wave and the

locally generated 500 kilocycle wave there-  
upon intermodulate to produce sum and dif-  
ference frequencies, which flow in the output  
circuit of modulator 41 and are communicat-  
ed through the output transformer to the  
input circuit of detector 32. The input cir-  
cuit of detector 32 is provided with a tuning  
condenser 45 having a range adapted to en-  
able the input circuit of detector 32 to be  
tuned for waves of frequencies between 1,500  
kilocycles and 550 kilocycles. In the case  
that has been assumed, the difference product  
of modulation of the 500 kilocycle local fre-  
quency and the selected 2,000 kilocycle car-  
rier side band in the second modulator 41  
has a frequency of 1,500 kilocycles, which is  
the original frequency of the signal bearing  
carrier wave for which the antenna 10 is as-  
sumed to be tuned. After demodulation in  
the detector 32 the signal or audio frequency  
components are carried through the audio  
frequency amplifiers  $A^2$  and  $A^3$  to the loud  
speaker S.

It will be noted that there is a fixed tuning  
difference between antenna tuning condenser  
11 and tuning condenser 40 which is equal to  
the frequency value of the local oscillator 16,  
and that this same tuning difference exists  
between condenser 40 and condenser 45, the  
tuning range of condenser 45 coinciding with  
that of condenser 11. These three tuning  
condensers may therefore be mechanically  
coupled together and coordinated in their  
tuning movements, and are so indicated in the  
drawings. The mechanical coupling of tun-  
ing condensers is well understood in the art,  
and it is thought unnecessary to show any  
specific means for accomplishing this result.  
It will be noted that the tuning coordination  
of the condensers may be accomplished by  
the proper shaping of the plates of their mov-  
able or fixed elements or by establishing the  
proper gearing relations between the mov-  
able elements, or in any other well known  
way. It is also obvious that the coordinated  
variation of the tuning of the stages of the  
circuit may if desired be accomplished by set-  
ting up the required relation between in-  
ductance rather than capacity tuning ele-  
ments or by proper combinations of coordi-  
nated movable capacity and inductance ele-  
ments. In the particular case assumed the  
tuning range of the antenna condenser is  
between 550 kilocycles and 1,500 kilocycles.  
Therefore the tuning circuit controlled by  
variable condenser 45 will have this same  
range, and that controlled by tuning con-  
denser 40 will have a range equal to the sum  
or difference between this range and the fixed  
frequency of the oscillator 16. If the oscil-  
lator frequency is assumed to be 500 kilo-  
cycles and the sum products of modulation  
are to be selected by the tuning circuit of  
variable condenser 40, then that tuning cir-  
cuit will be made variable within a range

extending from 1,050 to 2,000 kilocycles. If  
the tuning circuit of condenser 40 is to be  
adapted to select the difference frequencies  
of modulation, then it will be so adjusted  
with respect to tuning condenser 40 that that  
condenser in its movement comprehends a  
tuning range extending from 50 to 1,000  
kilocycles. If the local oscillator is set for  
a lower frequency value, then the tuning fre-  
quency difference between the circuits of con-  
densers 43 and 45 on the one hand and con-  
denser 40 on the other hand will be corre-  
spondingly less. Whatever the frequency  
value of the local oscillator 16 may be, the  
tuning circuits of condensers 11 and 45 will  
always be set for identical frequency ranges.  
If there is any slight change in the frequency  
of the wave generated by oscillator 16 tend-  
ing to alter the frequency value of the side  
band for which variable condenser 40 is co-  
ordinately set in the tuning operation, this  
may be corrected by occasional slight adjust-  
ment of the trimmer condenser 17 of the  
oscillator.

In the circuit organization of Fig. 3 that  
has just been described the locally generated  
wave was assumed to have a frequency value  
lying slightly below the lowest carrier fre-  
quency of the received range, and the sum  
or upper side band frequencies were assumed  
to be those selected and utilized in the output  
circuit of the first modulator. In the ar-  
rangement of Fig. 4, which will now be de-  
scribed, it is assumed that the locally gen-  
erated wave has a frequency value above the  
highest frequency of the carrier wave range,  
and that the lower side band of modulation is  
selected and utilized in the output circuit of  
the first modulator. In this circuit the car-  
rier waves are received by the antenna 44  
which is selectively tuned for a particular  
station by the variable condenser 45. The  
selected carrier frequency R is applied to  
the divided input circuit of balanced modu-  
lator  $M^5$  while at the same time the locally  
generated wave K from oscillator O' is ap-  
plied to the series input circuit of the modu-  
lator. These two waves intermodulate and  
their sum and difference products appear in  
the output circuit of the modulator. In the  
present instance it may be assumed, for ex-  
ample, that the locally generated wave has  
a frequency of 2,050 kilocycles. If the se-  
lected carrier wave has a frequency of 550  
kilocycles the difference product of modula-  
tion will have a frequency of 1,500 kilocycles.  
If the selected carrier wave is a 1,500 kilo-  
cycle wave the difference product of modu-  
lation will have a frequency value of 550  
kilocycles. The difference products of modu-  
lation selected and utilized in the output of  
modulator  $M^5$  therefore extend over the same  
frequency range as the original carriers  
themselves, but in an inverted relation to  
the carrier frequencies. The highest received

carrier frequency corresponds to the lowest utilized modulation frequency in the modulator output circuit, and the lowest received carrier frequency corresponds with the highest utilized modulation frequency in the output circuit, and the intermediate frequencies in the range are similarly represented by complementary frequencies in the output range. Therefore if, as shown in Fig. 4, the station selection associated with the input and output circuits of modulator  $M^5$  is accomplished by means of tuning condensers, the movements of the movable elements of these condensers are so related that as the capacity of the input condenser is increased, the capacity of the output condenser is correspondingly decreased. Hence the two condensers may be, and are indicated as being, mechanically coupled and coordinated to operate in this way.

The tuning condenser 46 that controls the selection of the appropriate modulation product of modulator  $M^5$  is connected in the input circuit of amplifier  $A^4$ . After amplification in amplifier  $A^4$  the selected wave is applied to the input circuit of detector  $D^2$ ; and the detected audio frequency components of the selected carrier wave may then be amplified in audio frequency amplifier  $A^5$  and conveyed to the loud speaker  $S$ . Additional selectivity with respect to the selected carrier wave may be secured by the tuning condenser 47 associated with the input circuit of detector  $D^2$ , and this variable condenser may also be mechanically coupled and coordinated with the tuning condensers 45 and 46, as indicated. The tuning effected by condenser 47 is in the same sense as that effected by condenser 46, and both of these are in an opposite sense to the tuning movement of condenser 45. This is indicated in the drawing by the direction of slant of the arrows which indicate variability of the condensers.

At some point as the tuning controlled by condenser 45 is varied downwardly and that controlled by condensers 46 and 47 is varied upwardly or vice versa, a point is reached where the input and output circuits of modulator  $M^5$  are tuned to the same frequency. But the tendency to oscillation which might otherwise occur when this condition is reached is prevented by the conjugate relation existing in the balanced modulator between the parallel relation of the antenna input circuit and the series relation of the modulator output circuit controlled by condenser 46. By making the frequency value of the locally generated wave of oscillator  $O'$  sufficiently high so that the range of difference products of modulation lies entirely above the frequency range of the received oscillations, which can be done by making the frequency of the locally generated wave slightly over 3,000 kilocycles, such coincidence between the resonant frequencies of the modulator input

and output circuits may be entirely avoided. In such case the tuning range of the antenna input circuit would remain as it is, between 550 and 1,500 kilocycles, while the resonant circuits controlled by condensers 46 and 47 would have a range extending approximately from 2,500 to 1,550 kilocycles.

It will be noted that in the circuit of Fig. 4 there is but a single stage of heterodyne modulation and amplification, that which occurs in the modulator  $M^5$ . In the arrangement of Fig. 5, which will now be described, there is also but a single stage of heterodyne modulation and amplification. The received carrier waves in the broadcast range are picked up by antenna 48 and applied, without individual tuning, to the divided input circuit of balanced modulator  $M^6$ , a radio frequency choke 49, as in the circuit of Fig. 2, being inserted if desired. A locally generated wave from oscillator  $O^2$  is applied to the series input circuit of balanced modulator  $M^6$ , and the resultant products of modulation are communicated to radio frequency amplifier  $A^6$  across the input circuit of which is connected the tuning condenser 49 by means of which the desired modulation frequency may be selected. The selected and amplified wave is demodulated and the audio frequency components separated in detector  $D^3$  which also has associated with it a tuning condenser 50. From detector  $D^3$  the audio frequency components are amplified in audio frequency amplifier  $A^7$  and may then be communicated to loud speaker  $S$ .

As a result of the intermodulation of the received carriers  $R$  and the local wave  $K$  in modulator  $M^6$  there are produced in the output circuit of the modulator the sum and difference products of modulation of the two. If it is assumed that the locally generated wave is given a frequency value, say 500 kilocycles, which is greater than half the frequency range (950 kilocycles) of the received frequencies, then the range of side band frequencies representing the sum products of modulation are entirely separated from and non-coincident with the lower frequency side bands representing the difference products of modulation, and the amplified carrier waves of the original received frequency values are suppressed in the output circuit of the modulator. Assuming 500 kilocycles for the local oscillator frequency and 550 to 1,500 kilocycles for the range of received frequencies, the upper side band products of modulation appearing in the output circuit of modulator  $M^6$  cover a range extending from 2,000 to 1,050 kilocycles, while the lower side band products of modulation cover a frequency range extending from 1,000 kilocycles to 50 kilocycles. Assuming in the present instance that the upper side band frequencies are to be used, the tuning condensers 49 and 50, which are in-

indicated as being mechanically coupled and coordinated, have such capacity value that their associated circuits have a possible resonant or tuning range extending from 1,050 kilocycles to 2,000 kilocycles.

In the circuit arrangement illustrated in Fig. 6, the carrier waves R and the locally generated wave from oscillator  $O^3$  are applied to the input circuit of modulator  $M^7$ . The carrier waves are picked up by the antenna 51 which is tuned to any desired frequency within the broadcast frequency range by means of variable condenser 52. The locally generated modulated frequency is derived from oscillator  $O^3$  through the medium of a potentiometer coupling 53. This potentiometer coupling is of a high resistance which is properly proportioned with respect to the impedance of the modulator input circuit and the operating requirements of the oscillator  $O^3$ , and is preferably made initially variable so that the voltage derived from the oscillator and applied to the input circuit of the modulator may be such as to give optimum heterodyne amplification effects in the modulator. It may be noted at this point that cumulative grid rectification or modulation, of the well-known grid condenser and grid leak type, may if desired be substituted for the anode rectification or modulation that is shown.

After intermodulation has taken place in the modulator  $M^7$ , the resultant combination frequency of the selected carrier wave is applied to the input circuit of a screen grid amplifier  $A^8$ , the input circuit being tuned by means of the variable condenser 54. The operating circuits of the screen grid amplifier are well known, and need not be particularly described. After amplification in amplifier  $A^8$  the selected carrier wave side band is rectified in detector  $D^4$ , the rectified components of the carrier wave being then amplified in audio frequency amplifier  $A^9$  and carried to the loud speaker S.

The modulation of the selected carrier wave by the heterodyne action of local oscillator  $O^3$  greatly amplifies the voltage of the received wave, and at the same time produces sum and difference side bands of frequencies differing from the received carrier frequency. Consequently the selective tuning of the modulator output circuit is for a frequency differing from that of the selective tuning of the modulator input circuit, with the result that tendency to feed back and oscillation in the modulator are avoided. Furthermore, the frequency changing characteristic of heterodyne modulation may be taken advantage of to obtain a modulation wave for application to the input circuit of the screen grid amplifier which modulation wave has a lower frequency than the corresponding received carrier wave. This reduction of frequency enables the screen grid

amplifier to be operated under conditions which give a larger and more favorable amplifying factor. If for instance the local oscillator  $O^3$  is set for a frequency of 500 kilocycles, and the difference side bands of the received carrier frequencies are selected in the tuned input circuit of the screen grid amplifier  $A^8$ , these difference modulation product frequencies extend over a range that is 500 kilocycles lower than the received carrier frequency range, and are therefore capable of more effective amplification in the amplifier. If the tuning range of the variable condenser 54 extending from 50 kilocycles to 1,000 kilocycles presents difficulties in connection with the design of the variable capacity and inductance of the tuning circuit, a less degree of reduction of the frequency range at this point in the circuit may be obtained by setting the local oscillator to deliver a wave of lower frequency value, say 100 kilocycles. In this case the frequency range to be provided for in the tuning circuit controlled by variable condenser 54 will extend from 450 kilocycles to 1,400 kilocycles, which will lie within an easily practicable range of design for the variable elements of the amplifier input tuning elements, and at the same time will render possible the obtaining of a better amplification factor in the amplifier  $A^8$ . As indicated, the tuning condensers 52 and 54 are mechanically coupled and coordinated, and, if desired, may also be coupled and coordinated with a tuning condenser associated with the input circuit of detector  $D^4$ .

The circuit arrangement of Fig. 7 is a similar to that of Fig. 6 with respect to the employment of heterodyne and screen grid amplification, but differs from the circuit of Fig. 7 in the provision of two stages of heterodyne modulation and amplification from the same local oscillator. The oscillator  $O^4$ , like oscillator  $O^3$  of Fig. 6, is of a type in which the frequency of the oscillator is determined by the coupling of the grid and plate circuits of the oscillator with a local resonant circuit 56. The frequency of the resonant circuit 56 is controlled by variable condenser 57 which, it may be assumed, is made variable only to the extent necessary to keep the oscillator in adjustment after its frequency is once fixed. The resonant circuit 56 is connected with the terminals of the high resistance 58. As optimum heterodyne effects are obtained by a proper proportioning of the voltage of the locally generated wave with respect to the voltage of the carrier wave in the input circuit of the modulator, there are shown in the present instance two taps 59 and 60 from the high resistance 58, the tap 59 serving to apply the full voltage across resistance 58 to the input circuit of the second modulator  $M^8$ , and intermediate initially variable tap 60 being

adapted to apply a lesser part of the voltage drop to the input circuit of modulator  $M^8$ . As the control circuit 56 of the oscillator  $O^4$  is resonant only for the frequency which the oscillator is set to produce, the circuit 56 presents a low impedance path to any frequencies other than the oscillator frequency which may tend to be fed back by way of the tap connections from the circuits of the two modulators  $M^8$  and  $M^9$ , and therefore tends to operate to minimize or prevent any feed back or coupling between the two modulator circuits. It may be noted that in any of the circuits described wherein two heterodyne modulators are supplied from the same local oscillator, any possible tendency for feed back or coupling between the two may readily be eliminated by the inclusion of an electron tube amplifier in one of the local wave supplying branches, preferably in the branch to the second modulator where the voltages of the carrier wave should preferably be greater than in the input circuit of the first modulator.

In the circuit of Fig. 7 the carrier waves are picked up by the antenna 55 which is tuned by means of the variable condenser 61 to comprehend the desired frequency range. The tuned antenna circuit is included in the input circuit of modulator  $M^8$  which derives its locally generated wave by way of tap 60 from the oscillator  $O^4$ . The output circuit of modulator  $M^8$  is connected with the input circuit of modulator  $M^9$  in which there is included the variable tuning condenser 62 that comprehends in its range of adjustment one of the sets of combination frequencies produced by the modulation of the received carrier waves with the locally generated wave. The modulation frequency selected by variable tuning condenser 62 is applied to the grid of modulator  $M^9$  together with the locally generated wave supplied by way of tap 59 from oscillator  $O^4$ . The combination frequencies in the output of modulator  $M^9$  are applied (either with or without further selection by means of variable condenser 63, as desired) to the input circuit of screen grid amplifier  $A^{10}$ . The amplified frequency corresponding to that for which variable condenser 62 is set is selected by variable condenser 64 in the tuned plate circuit of the screen grid amplifier, and is capacitatively coupled, according to a well known circuit arrangement of screen grid amplifiers, with the input circuit of detector  $D^5$ . The audio or signaling frequency components obtained by demodulation in the detector  $D^5$  pass by way of audio frequency amplifier  $A^{11}$  to the loud speaker S.

If it is assumed that the tuning range of frequencies for which variable condenser 61 is adapted extends from 550 to 1,500 kilocycles and that the local oscillator is set to

produce a wave having a frequency value of 100 kilocycles, the tuned circuit controlled by variable condenser 62 may have a range of adjustment extending from 450 kilocycles to 1,400 kilocycles, and the tuning circuit controlled by variable condenser 64 (and also the tuning circuit controlled by variable condenser 63, if used,) will be adapted for a frequency range of 550 to 1,500 kilocycles corresponding to that of variable condenser 61, the tuning condensers being mechanically coupled and coordinated, as indicated.

In the circuit of Fig. 8 the carrier waves are received by the open antenna 65 and applied to the input circuit of modulator  $M^{10}$  through the medium of coupling transformer 66. Modulator  $M^{10}$  is shown to be of the modulating type employing grid condenser 67 and grid leak path 68 in its input circuit. Selection of the desired station carrier wave is effected by tuning condenser 69, and the selected wave together with the locally generated wave from oscillator  $O^5$  intermodulate and produce combination frequencies in the modulator output circuit, these being communicated to the input circuit of amplifier  $A^{12}$ . Further selection is effected by tuning condenser 70 which is mechanically coupled and coordinated with tuning condenser 69. Condenser 70 has a tuning range equal to that of condenser 69 but at a frequency level difference equal to the frequency of oscillator  $O^5$ . Amplifier  $A^{12}$  may be of the screen grid type, and the modulation frequencies selected by variable condenser 70 may be lower than the corresponding received carrier frequencies in order to take advantage of a more favorable amplification factor in the amplifier. After detection in detector  $D^6$  and audio frequency amplification in amplifier  $A^{13}$  the signal components of the selected carrier wave may be carried to loud speaker S, or otherwise utilized.

It will be understood that, in accordance with usual practice, the oscillator and radio frequency stages of the receiving circuits that have been described are to be properly screened in order to prevent undesirable coupling and feed back of energy. It will also be understood that proper and customary precautions are to be taken to ensure that the modulating frequency as supplied by the local oscillator shall be a pure frequency, substantially free from harmonics.

What is claimed is:

1. The method of selective signal reception, which consists in selecting one of a number of signal carrier waves lying within a certain frequency range, modulating the selected carrier wave with a locally applied wave of fixed frequency lying outside said range and of such a frequency as to produce with said selected wave, side frequencies which are readily separable from waves of

said selected frequency, and detecting and utilizing the signal component of a combination frequency of the fixed frequency wave and the selected carrier wave.

5 2. The method of selective signal reception, which consists in receiving a plurality of signal carrier waves lying within a limited frequency range, selecting one of said carrier waves, supplying a local modulating  
10 wave of fixed frequency lying outside said range and of such a frequency as to produce with said selected wave, side frequencies which are readily separable from waves of said selected frequency, modulating said selected carrier wave with said local wave, and  
15 simultaneously and coordinately selecting a combination frequency resulting from the modulation of said selected carrier wave and local wave.

20 3. The method of selective signal reception, which consists in selecting one of a number of signal carrier waves lying within a limited frequency range, modulating the selected carrier wave with a local wave of  
25 fixed frequency lying outside said frequency range and of such a frequency as to produce with said selected wave, side frequencies which are readily separable from waves of said selected frequency, and selecting and  
30 utilizing a combination frequency of the local wave and the selected carrier wave.

4. The method of selective signal reception which consists in modulating a plurality of signal carrier waves lying within a  
35 limited frequency range with a wave of fixed frequency lying outside said range, and selecting and utilizing a combination frequency produced by the modulation of the fixed frequency wave and a particular one of the  
40 carrier waves.

5. The method of selective signal reception, which consists in maintaining a fixed frequency tuning difference between variable input and output tuning circuits of a  
45 modulator, and combining in said modulator received carrier waves with a local wave of substantially fixed frequency equal to said frequency tuning difference.

6. The method of selective signal reception, which consists in establishing a fixed frequency difference between broad band selective input and output circuits of a modulator, combining in said modulator a plurality of carrier waves with a local wave of  
50 substantially fixed frequency equal to said frequency difference, and selecting and utilizing the combination frequency of a desired one of said carrier waves.

7. The method of selective signal reception, which consists in receiving a plurality of signal carrier waves lying within a frequency range at least as large as one of the frequencies therein, modulating said carrier waves with a local wave having a fixed  
60 frequency such as to produce two non-overlap-

ping sets of carrier side bands, and selecting and utilizing any desired one of the carrier side bands in one only of said sets.

8. The method of selective signal reception which consists in receiving a plurality  
70 of signal carrier waves, modulating said carrier waves with a fixed frequency local wave to produce two non-overlapping sets of carrier side bands and to suppress the carrier waves, and selecting and utilizing any desired one of the carrier side bands in one  
75 only of said sets.

9. The method of selective reception, which consists in modulating the range of received signal carrier waves with a local wave of a fixed frequency not less than half the frequency difference comprehended in the received carrier wave range to produce non-overlapping sets of side bands, selecting any desired carrier side band in only one of said sets, and utilizing the selected band.

10. The method of selectively receiving signal carrier waves of any given frequency within a frequency band having a width at least as large as one of the frequencies therein, which consists in selecting incoming signal carrier waves of desired frequency and largely excluding waves of undesired frequency, limiting the frequency width of the band within which said selection can be made to a value which is not greater than twice the low frequency limit of said band, modulating said selected set of waves with another set of waves of a frequency relatively close to said band but no closer thereto than one frequency limit thereof, selecting side frequencies of only one of the two signs of side frequencies resulting from said modulation, and utilizing said selected side frequencies.

11. The method of selectively receiving signal carrier waves of any given frequency within a frequency band having a width at least as large as one of the frequencies therein, which consists in selecting incoming signal carrier waves of desired frequency and largely excluding waves of undesired frequency, modulating said selected waves with a second set of waves of such a frequency value that the side frequencies of at least one sign produced by said modulation are non-coincident in frequency with each other or with side frequencies of opposite sign, and selecting and utilizing said side frequencies of said one sign.

12. The method of selectively receiving signal carrier waves of any given frequency within a frequency band having a width at least as large as one of the frequencies therein, which consists in selecting incoming signal carrier waves of desired frequency and largely excluding waves of undesired frequency, modulating said selected waves with a second set of waves of such a frequency value that the side frequencies of at least one sign produced by said modulation are in the

neighborhood of the frequencies of said band and are non-coincident in frequency with each other or with side frequencies of opposite sign, and selecting and utilizing said side frequencies of said one sign.

13. The method of selectively receiving carrier waves, which consists in selecting incoming carrier waves, modulating said selected waves with a second set of waves, selecting from the resulting products of modulation a third set of waves consisting of side frequencies of only one sign, modulating said third set of waves with said second set of waves, selecting from the resulting products of modulation a fourth set of waves consisting of side frequencies of only one sign opposite to the sign of said previously selected side frequencies, confining said third set of waves to a path substantially free from exposure to outside interfering waves other than said second set of waves, and utilizing said fourth set of waves.

14. The method of selectively receiving signal carrier waves of any given frequency within a frequency band having a width at least as large as one of the frequencies therein, which consists in selecting incoming signal carrier waves of desired frequency and largely excluding waves of undesired frequency, limiting the frequency width of the band within which said selection can be made to a value which is not greater than twice the low frequency limit of said band, modulating said selected waves with another set of waves of a frequency not greater than said low frequency limit and not less than one-half the frequency width of said band, selecting side frequencies of only one of the two signs of side frequencies resulting from said modulation, and utilizing said selected side frequencies.

15. The method of high frequency amplification which consists in selectively receiving a wave, changing the frequency of said wave in one direction, preventing radiation of the resulting wave, changing the frequency of the resulting wave in the opposite direction, and increasing the voltage of the wave with each of said changes of frequency.

16. The method of high frequency amplification which consists in changing the frequency of a high frequency wave in one direction by a given amount, preventing radiation of the resulting wave, changing the frequency of the resulting wave by the same amount in the opposite direction, and increasing the amplitude of the wave with each of said changes of frequency.

17. The method of carrier wave amplification, which consists in changing the frequency of the wave in one direction, preventing radiation of the resulting wave, changing the frequency of the resulting wave in the opposite direction, said frequency

changes being by inharmonic fractional amounts, and increasing the amplitude of the wave with each of said changes of frequency.

18. The method of selective carrier wave reception and amplification, which consists in changing the frequency level of said wave, preventing radiation of the resulting wave, selecting the wave at the changed level, restoring the selected wave to the original frequency level, and increasing the amplitude of the wave at each change of frequency.

19. The method of selective carrier wave reception and amplification, which consists in changing the frequency and increasing the amplitude of the wave in a plurality of stages, and controlling the selection of said wave in each of a plurality of said stages by simultaneous adjustment of the different frequency levels of said wave in said stages.

20. The method of carrier wave amplification, which consists in modulating one or more carrier waves with a locally applied wave of fixed single frequency, modulating the side band or bands of one sign resulting from said modulation, with said locally applied wave, and utilizing in the resulting wave a side band of opposite sign from that of said first-mentioned side band or bands.

21. The method of selective carrier wave reception and amplification, which consists in modulating the waves of a band of carrier waves with a local wave of fixed frequency, selecting the side bands of frequencies of only one sign resulting from said modulation, restoring the frequency of said bands to the original carrier wave frequency values by modulating said selected side bands with said local wave, and utilizing the products of said second modulation.

22. The method of selective carrier wave reception and amplification, which consists in selectively receiving a carrier wave, modulating the same with a local wave of fixed frequency to produce a modulation product differing in frequency from the frequency of the received carrier wave by an amount equal to the frequency of said local wave, restoring the frequency of said resulting wave to the original frequency of the received carrier wave by modulating said modulation product with said local wave, and utilizing said second modulation product.

23. In a carrier wave receiving system, means for selectively receiving a range of carrier waves, a fixed frequency wave source, a modulator for combining the received carrier waves and the fixed frequency wave to produce upper and lower amplified sets of signal bearing side bands, and means for suppressing one of said sets of side bands and for selecting and utilizing the other of said sets of side bands.

24. In a carrier wave receiving system, means for receiving a plurality of carrier

waves lying within a certain frequency range, a fixed frequency wave source for generating a wave having a frequency lying outside the frequency range of the received carrier waves, a modulator for combining the received carrier waves with said fixed frequency wave to produce a set of upper and a set of lower side bands, and means for selecting and utilizing from one of said sets a combination frequency of any desired one of said carrier waves and for suppressing the corresponding combination frequency in the other of said sets.

25. In a carrier wave receiving system, means for receiving carrier waves within a certain range of frequencies, means for producing a local wave of fixed frequency lying outside said range and of such a frequency as to be capable of producing with said received waves, side frequencies which are readily separable from waves of said received frequency, a modulator, means for selecting one of said carrier waves and combining it with the fixed frequency wave in said modulator to produce a combination frequency, and means for selecting and utilizing said combination frequency.

26. In a carrier wave receiving system, a modulator having an input circuit and an output circuit, means for locally generating a wave of fixed frequency value, uncontrolled variable tuning devices coupled to said input circuit and said output circuit respectively and adapted to maintain a fixed tuning difference between the same equal to the frequency of said locally generated wave, means for receiving and applying a signal carrier wave together with said locally generated wave to the input circuit of said modulator to amplify and change the frequency of said carrier wave, and means for utilizing the cor-

responding changed frequency signal carrier wave derived from the output circuit of said modulator.

27. In a carrier wave receiving system, means for receiving signal carrier waves, two modulators each having an input circuit and an output circuit, means for locally generating a wave of fixed frequency, means for applying a signal carrier wave and said locally generated wave to the input circuit of the first modulator, connections between the output of the first modulator and the input of the second modulator, unitarily operated tuning devices associated respectively with the input of the first modulator and the connections between the output of the first modulator and the input of the second modulator, said tuning devices being adapted to maintain a fixed tuning difference between them equal to the frequency of said locally generated wave, means for modulating in the second modulator a product of modulation of the first modulator with said locally generated wave, and means for utilizing the product of modulation of said second modulator.

28. The method of selectively receiving carrier waves, which consists in selecting incoming carrier waves, modulating said selected waves with a second set of waves, selecting from the resulting products of modulation a third set of waves consisting of side frequencies of only one sign, modulating said third set of waves with said second set of waves, selecting from the resulting products of modulation, a fourth set of waves consisting of side frequencies of only one sign opposite to the sign of said previously selected side frequencies, and utilizing said fourth set of waves.

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