

Oct. 9, 1934.

J. H. HAMMOND, JR

1,976,393

SIDE BAND REVERSAL TRANSMISSION SYSTEM

Original Filed May 18, 1929 4 Sheets-Sheet 1

Fig. 1

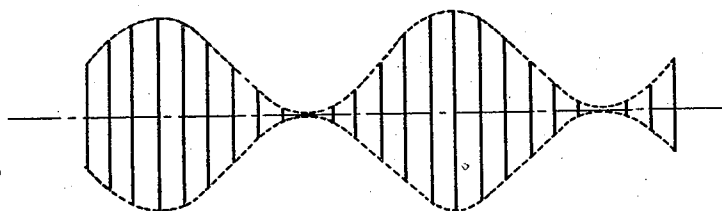


Fig. 2

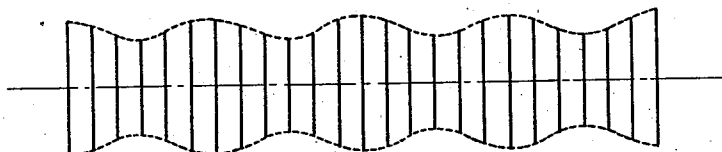
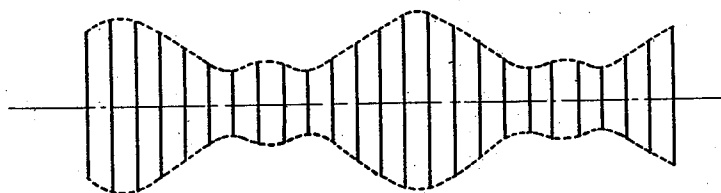


Fig. 3



INVENTOR
JOHN HAYS HAMMOND JR.
BY *J. H. Hammond*
ATTORNEY

Oct. 9, 1934.

J. H. HAMMOND, JR

1,976,393

SIDE BAND REVERSAL TRANSMISSION SYSTEM

Original Filed May 18, 1929 4 Sheets-Sheet 2

Fig 4

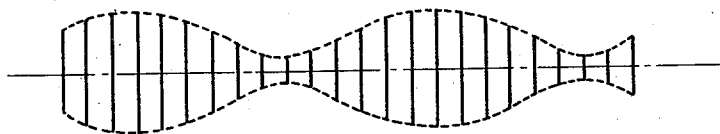


Fig 5

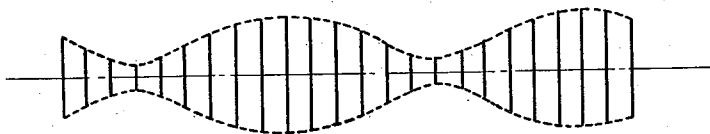
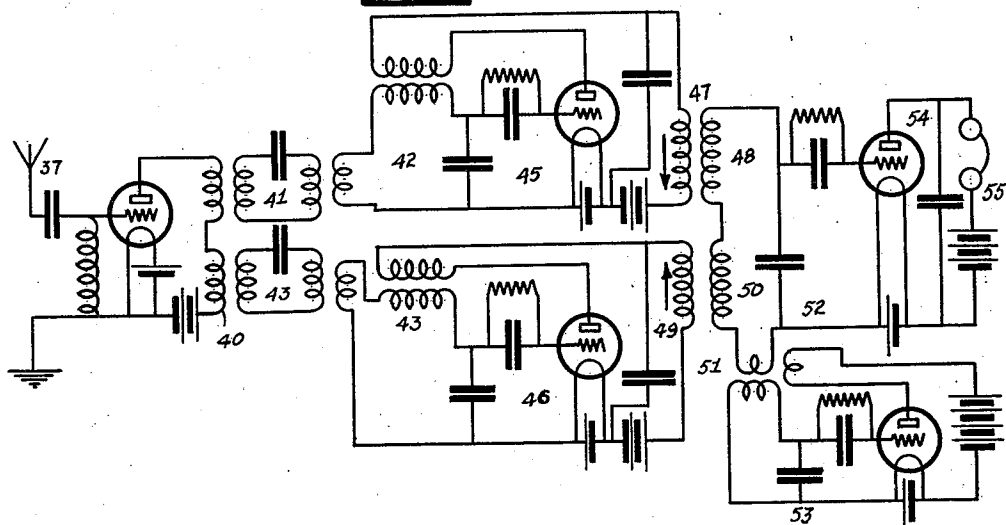


Fig 7



INVENTOR
JOHN HAYS HAMMOND JR.
BY *J. H. Grover*
ATTORNEY

Oct. 9, 1934.

J. H. HAMMOND, JR

1,976,393

SIDE BAND REVERSAL TRANSMISSION SYSTEM

Original Filed May 18, 1929 4 Sheets-Sheet 3

Fig. 2

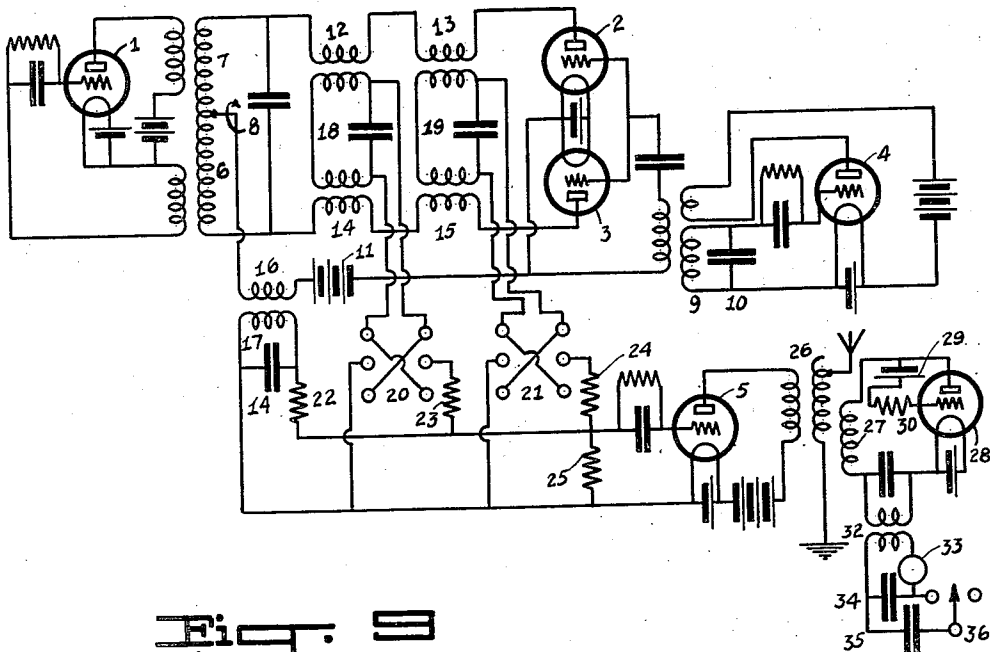
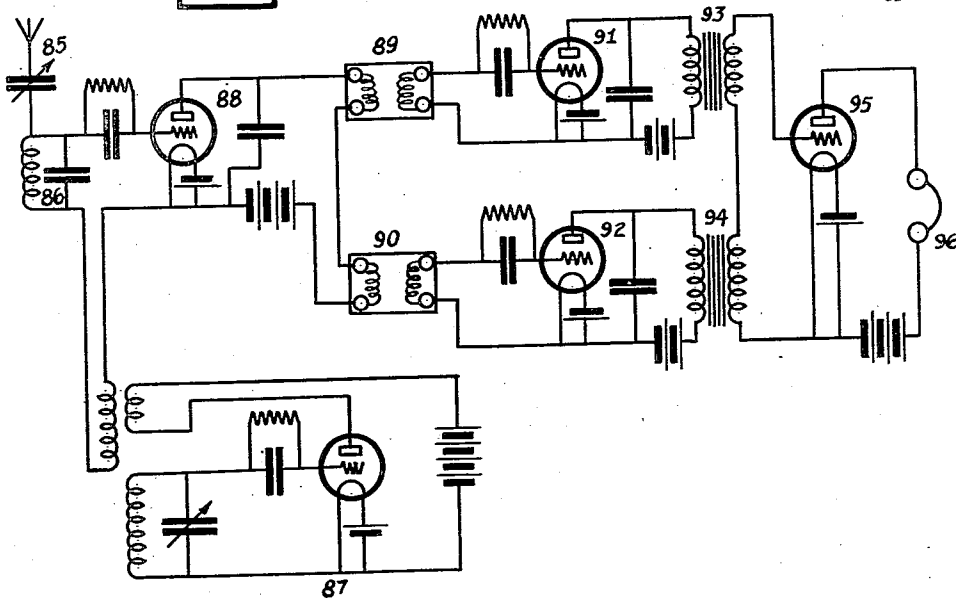


Fig. 3



INVENTOR
JOHN HAYS HAMMOND JR.
BY *J. H. Grover*
ATTORNEY

Oct. 9, 1934.

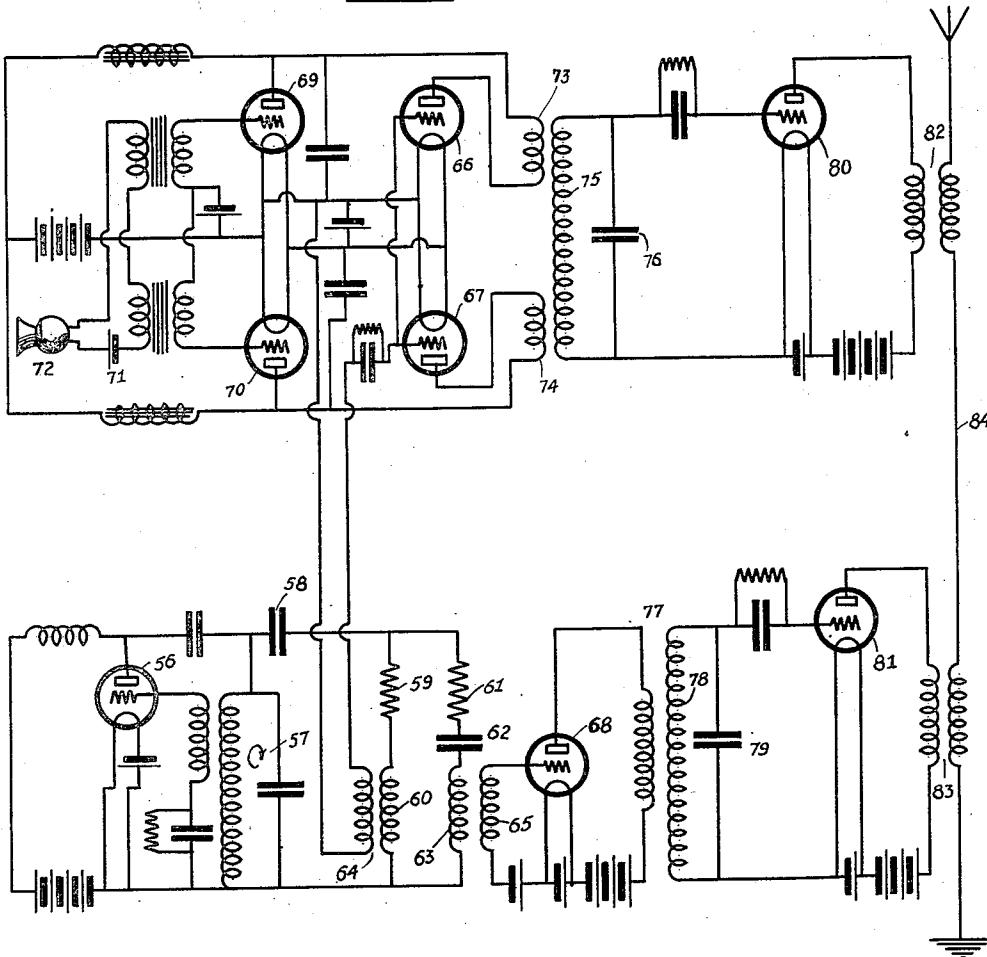
J. H. HAMMOND, JR

1,976,393

SIDE BAND REVERSAL TRANSMISSION SYSTEM

Original Filed May 18, 1929 4 Sheets-Sheet 4

Fig. 1



INVENTOR

JOHN HAYS HAMMOND JR.

BY

H. S. Gowan

ATTORNEY

UNITED STATES PATENT OFFICE

1,976,393

SIDE BAND REVERSAL TRANSMISSION
SYSTEM

John Hays Hammond, Jr., Gloucester, Mass.

Original application May 18, 1929, Serial No.
364,105. Patent No. 1,935,776. Divided and
this application December 12, 1931, Serial No.
580,520

4 Claims. (Cl. 250—17)

This invention is a division of my application Serial No. 364,105, filed May 18, 1929 entitled "Side band reversal transmission system" which has issued November 21, 1933 as Patent No. 1,935,776.

The object of this invention is to provide a system of radio communication by which intelligence can be transmitted subject to little or no interference from other radio signals or from atmospherics.

Another object of this invention is to provide a system of telegraphy and telephony which will produce a small amount of interference with respect to nearby receivers of the usual type, without, however, preventing strong signals from being received by special types of receivers.

It is also an object of this invention to provide a system of telegraphy and telephony which cannot be intelligently received by the ordinary type of receiver.

Other objects and uses of this invention will appear from the following description taken in connection with the accompanying drawings.

This invention relates to transmission by modulation methods or by a wave which may be compounded from a plurality of continuous waves. More particularly, this invention relates to the special feature that the signalling is accomplished by the reversal or other alteration of the phase of any of the constituents of the composite wave.

Having thus briefly described my invention, attention is invited to the accompanying drawings in which:

Figs. 1, 2, 3, 4 and 5 are each diagrams indicating the envelope of different synthetic waves.

Fig. 6 is a circuit diagram of a transmitter for carrying out the objects of my invention.

Fig. 7 is a circuit diagram of a receiver for cooperation with the transmitter of Fig. 6.

Fig. 8 is a circuit diagram of an alternative form of transmitter for carrying out the principles of my invention, and

Fig. 9 is a circuit diagram of an alternative form of receiver for cooperation with the transmitter of Fig. 8.

It is well known that a modulated sine wave is in all respects equivalent to a plurality of waves. In the present art, these waves are termed the carrier frequency and the side frequencies. A sinusoidally modulated wave of a carrier frequency of 1,000,000 cycles modulated by a frequency of 20,000 cycles behaves as far as tuning systems, beat systems, and all other physical tests are concerned, as though it were compounded of three sinusoidal waves, $S-$, the lower side frequency or

980,000 cycles, C , the carrier frequency of 1,000,000 cycles, and $S+$, the upper side frequency or 1,020,000 cycles. The envelope of such a modulated sine wave is represented in Fig. 1.

An additional characteristic of these three constituent waves when arranged as in amplitude modulation, is shown by representing them in a vectorial sense, with one vector for each wave. At any instant of time, the angle between the vector representing the carrier C and the vector $S+$ representing the upper side frequency must be equal to the angle between the same carrier vector C and the vector $S-$ representing the lower side frequency. Thus, when the waves C and $S+$ are at their maximum positive value, the wave $S-$ must be at its maximum positive value. Consequently a sinusoidally amplitude modulated wave cannot be produced synthetically from three sinusoidal waves unless the following conditions are met.

1. The amplitudes of the side waves must be equal and not more than half the carrier wave.

2. The difference between the frequencies of the carrier wave and the upper side frequency must be exactly the same as the difference between the carrier frequency and the lower side frequency.

3. With two of the waves established, the phase of the third wave must be properly adjusted.

The envelope shown in Fig. 1 is that of composite wave made up of three waves suitably related to produce a sine modulated wave in accordance with the above rules. On the other hand, the envelope shown in Fig. 2 is that which would be produced, if, for example, the upper side wave were altered in phase by 180° from that which would be proper in conjunction with the other constituents to produce the sine modulated form of Fig. 1.

From this it is evident that the nature of a composite wave of three or more constituents is controllable by alterations of the phase of any one of the constituents. For example, if the composite form shown in Fig. 1 is an audio modulated form of 1,000 cycle modulation, then a non-oscillating detector operated by a voltage of such wave form will produce chiefly a 1,000 cycle tone, whereas if actuated by a wave as shown in Fig. 2, it will produce substantially a 2,000 cycle tone, or if by a wave as shown in Fig. 3, a resultant of both 1,000 cycle and 2,000 cycle tones.

From another point of view, if the three constituents are transmitted and impressed upon a detector, three audio signals result. The first is produced by the beat action between the carrier

and the upper side frequency. The second is produced by the beat action between the carrier and the lower side frequency. And the third is produced by the beat action between the upper and the lower side frequencies.

In the present case, the resultant 2,000 cycle current is the same, whether the form of envelope transmitted is that of Fig. 1, Fig. 2, or Fig. 3, since it arises from the beat action between the two side waves. The net 1,000 cycle current produced, however, depends upon how the individual 1,000 cycle detected currents, due to the carrier and the individual side frequency constituents are related as to phase. In the case they are in the phase relationship which would give the envelope as indicated in Fig. 1, they give the maximum net value. In the case they are in such phase relation as to give the form of envelope shown in Fig. 2, they are in phase opposition and give minimum net value, and in the case they are in such phase relation as to give the form of envelope shown in Fig. 3, they are in phase quadrature to give an intermediate value.

The common problem of transmitters constructed in accordance with this invention is to produce three or more waves, related in frequency and amplitude and to control the phase of one or more of the constituent waves. For telephony, it will be understood that the upper and lower side frequencies are to be replaced by upper and lower side bands, and that one band can be operated upon as a group to give 180° phase reversal to all of the constituent frequencies of the group.

A common feature of the receiver for cooperation with such a transmitter, however, as distinguished from receivers of the ordinary types, is the selective tuning circuits by which the energy of the carrier and of one side band may be directly or indirectly diverted to one detector, and energy of the carrier and of the other side band may be diverted to another detector. By these circuits the two detected currents can be separated. The ordinary type tuner, however, with but one detector, cannot segregate out the constituent waves and the constituent currents. Thus, if a wave, the envelope of which is represented in Fig. 2, were transmitted to a receiver of the ordinary type, which cannot separate out the three waves, as for example a single circuit tuner with a single detector, the net detected 1,000 cycle note will be zero and the only notes heard will be a relatively small 2,000 cycle note, due to beats between the two side frequencies. On the other hand, with selective receivers, by diverting part of the carrier and the upper side frequency only, to one detector, a 1,000 cycle note will be produced in the plate circuit of the detector and by diverting a part of the carrier and the lower side frequency current, to another detector, another 1,000 cycle current will be produced. These 1,000 cycle currents will be out of phase, but either current can be used by itself or the two detected currents can be combined by phase reversal to give an additive effect. Thus a wave form, the envelope of which is represented in Fig. 2, can be used in conjunction with special selective receivers to reproduce a good 1,000 cycle signal, whereas it will produce little or no 1,000 cycle signal in conjunction with the ordinary receiver.

Fig. 4 shows the envelope of the composite wave, composed of half the energy of the carrier and all of the energy of the lower side frequency of the composite wave, the envelope of which is shown in Fig. 2, and Fig. 5 shows the envelope of the composite wave composed of half the energy

of the carrier and all of the energy of the upper side frequency of the same wave. It will be noticed that there is no difference in the shape of the envelope produced in these two cases, but there is a difference of 180° in the phase with respect to the 1,000 cycle modulation. It will also be noted, that as explained above, the resulting detected currents will be in opposition, in the plate circuit of the individual detectors.

In one method of using the principle of this invention, the difference between the carrier frequency and the side frequency will be a high frequency, say of the order of 20,000 cycles. The transmitter arrangement for producing the composite waves in case the ratio of the carrier frequency to difference frequency is not too high, for example is shown in Fig. 6.

In this arrangement the difference frequency between the carrier frequency and the side frequency is produced and determined by the frequency of the tube 1 and its associated circuits. The frequency of the oscillation circuits is determined principally by the values of the inductances 6 and 7 and the condenser 8.

The carrier frequency is produced and its frequency determined by the thermionic device 4 and its associated circuits, the frequency of the oscillations produced being principally determined by the value of the inductance 9 and the capacity 10. The method of and circuit for producing these oscillations is well known in the art and need not be described here in detail.

Tubes 2 and 3 are high frequency amplifiers. The plate power for these amplifiers is supplied in part by the battery 11 and in part by the voltage developed across the inductances 6 and 7 of the difference frequency oscillator circuit.

Since substantially the same current flows through both coils 6 and 7, it is apparent that when the plate voltage supplied to the tube 2 by the inductive coupling of coil 7 is positive the plate voltage supplied to tube 3 by inductive coupling of coil 6 is negative. In other words, the tubes are actuated 180° out of phase in the low frequency cycle.

The grid circuits of the tubes 2 and 3 are actuated in phase by their parallel coupling to the high frequency circuit of tube 4. In consequence high frequency modulated currents appear in the plate circuits of tubes 2 and 3.

The modulation thus caused will be nearly sinusoidal if the proper relation exists between the direct voltage and the alternating low frequency voltage. Moreover, the modulations will be out of phase with the result, which can readily be shown that with a symmetrical arrangement, the carrier currents are in phase but the side frequencies are out of phase in the two plate circuits. This is indicated by the arrows C, S+, and S- in each plate circuit which show the instantaneous directions of carrier and side frequency currents.

Accordingly, energy of the carrier and side frequencies may be separated out by circuits 17, 18, and 19, which are tuned to the frequencies C, S+, and S-, respectively, and suitably coupled to the plate circuits of 2 and 3 by couplings 16, 12 and 14, 13 and 15, respectively. The coupling coil 16 is substantially free of currents of the side frequencies so that a pure carrier frequency current is developed in the tuned circuit 17. Furthermore, due to the phase difference of the side frequencies in coils 12 and 14, a reversed coupling winding used on one side will cause the carrier frequency to be substantially balanced

out with respect to circuit 18, whereas it will cause the frequency desired to be accepted. This circuit need be sharp enough only to discriminate against the lower side band frequencies. Similarly, the carrier frequency is substantially balanced out from circuit 19 which would be tuned only to discriminate against the upper side band.

This process, therefore, provides a means for separating out the three constituent frequencies arising by modulation of the carrier by the difference frequency. The three constituent frequencies are combined in the grid circuit of the tube 5 by means of the resistance couplings 22, 23, 24 and 25 and means are provided by switches 20 and 21 for reversing the phase of either side frequency current for the purposes of keying. The tube 5 is a radio frequency power amplifier tube delivering its output plate power into an antenna 26 or any other appropriate radiating system.

By means of this arrangement, a composite wave form may be radiated from the antenna, the envelope of which wave is as shown in either Figs. 1 or 2 depending upon the throw of the reversing switches.

The condition of the current in the antenna may be examined for purposes of making adjustment of the coils and condensers, and for monitoring purposes by means of an aperiodic detector circuit including the tube 28 and its associated circuits. The tube 28 is preferably of the three electrode type and has its grid connected through the resistance 30 and battery 29 to the plate, in order to give it very nearly a straight line rectification characteristic. In consequence, when radio voltage is induced upon the tube circuit through the coil 27, there will appear in the coil 31 a direct current and also a current of the frequency determined by the envelope of the composite wave being radiated by the antenna 26. This current may be investigated by the tuned circuit comprising the coil 32, the meter 33, condensers 34 and 35, and the switch 36. With the switch 36 to the left, the system is tuned to the difference frequency, but with the switch to the right, the system is tuned to twice the difference frequency. When the circuits are adjusted so as to be in the signaling condition, that is, when the composite wave emitted would have the envelope as indicated in Fig. 2, the meter will indicate with the switch to the right and not to the left. If there is an indication with the switch 36 in each position, the transmitter requires adjustment.

To receive the energy of the transmitted wave form, a receiver may be employed as shown in Fig. 7. This comprises a receiving antenna or other receiving system 37, a radio frequency amplifier 38, carrying in its plate circuit a pair of coils 39 and 40. In the plate circuit of the amplifier tube will be reproduced the wave form similar to that radiated by the transmitter antenna, say of Fig. 2 when in signalling condition. By means of coupled circuit systems 41 and 42, associated with detector tube 45, and coupled circuits 43 and 44, associated with detector tube 46, the energy delivered from the plate circuit is divided, with half of the carrier and all of the lower side frequency energy diverted to detector 45, and half of the carrier and all of the higher side frequency energy diverted to detector 46. The wave forms of envelopes across grids of detectors 45 and 46, in consequence, are shown in Figs. 4 and 5, respectively.

These modulations being out of phase, the de-

tected currents in the plate circuits will also be out of phase. In consequence, the output detected currents are to be combined by a differential transformer, with windings 47 and 48 differently related than 49 and 50. In consequence, the opposingly phased currents in plate circuits of tubes 45 and 46 will produce an additive effect in the tuned system 48, 50, 51 and 52 which is tuned to the difference frequency employed. The current of difference frequency then may be detected by means of a separate heterodyne oscillator 53, and detector 54, and indicated by telephones 55. Amplifiers may be inserted wherever desired for building up the difference frequency which may be of audio frequency tone. It is understood, of course, that in case the difference frequency is of audio frequency, no second detection will be required.

This arrangement of the receiver will therefore be responsive when the modulated wave emitted from the antenna is as shown in Fig. 2. But when the modulated wave is as shown in Fig. 1, the two wave forms in the detectors 45 and 46 will be similar, and the plate currents will produce no effect in the tuned circuit 48, 50, 51 and 52, and consequently no signals in the receiver telephones.

Stray disturbances, it is readily seen, produce much less effect with this double arrangement of detectors. Thus modulated signals due to radio telephone transmitters, for example, forcing the tuned circuits, produce substantially identical wave forms in the plate circuits of detectors 45 and 46, but due to the reversal of couplings will produce no forced oscillations in succeeding circuits. Also shock disturbances, producing oscillations in the tuned systems 41, 42, 43 and 44, to a great extent are lessened over what would get through with but one detector operating.

In another application of this principle, the side frequencies may be so close to the carrier wave that it is not feasible to separate them out by filtering. For example, it is not considered feasible to separate out by filtering the upper side band from the carrier and lower side band of a signal produced by modulating a carrier wave, say 800,000 cycles by voice frequencies. In that case the same effect can be produced by another type of transmitter. The transmitter of Fig. 6 is constructed on the principle of changing the phase of one side frequency by 180°. It is obvious that the same result may be obtained by changing the phase of the carrier by 90°, since this will increase the phase of modulation with respect to one side frequency by 90°, but decrease the phase of modulation with respect to the other side frequency by 90°, giving a total phase displacement by the two channels of 180°.

A transmitter for voice modulation in accordance with this plan may be constructed as indicated in Fig. 8. In this circuit, tube 56 and its associated circuits, particularly the circuit 57 produce and determine the frequency of the carrier frequency oscillations. The output of this tube is capacitively coupled by the condenser 58 to a phase shifting circuit, comprising resistance 59 and coil 60 in series, parallel by resistance 61, condenser 62 and coil 63 in series. Constants of these impedances are so chosen that the phase of the current in coil 60 differs from that in coil 63 by 90°. Coils 60 and 63 are the primaries of two transformers, the secondaries of which are coils 64 and 65 respectively. The coil 64 supplies power for exciting the grid circuit of tubes 66 and 67, which in conjunction with other apparatus

produces the radiated side band energy, and coil 65 supplies power to radio amplifier tube 68 which in conjunction with other apparatus amplifies and radiates the carrier frequency energy.

5 Tubes 69 and 70 are push-pull modulators of the plate modulation type, arranged in a balanced manner, with both grids actuated from a common speech or other audio frequency source, as indicated, by the microphone circuit, 71, 72. The grid
10 of the tube 69 becomes most positive when the grid of tube 70 becomes most negative, and consequently the speech or other audio power is maximum for tube 66 when it is minimum for tube 67. The output circuits of these tubes have op-
15 posite couplings, 73 and 74, to the common output circuit.

In consequence, since the currents impressed upon the grids of tubes 66 and 67 are in phase, the carrier currents in the plate circuit are in
20 phase and therefore produce no current in circuit 75—76. But because of the opposition of phase of plate voltage impressed from modulators 69 and 70 upon radio amplifiers 66 and 67, the side band currents in the plate circuit of 66 are in
25 phase opposition to the side band currents in the plate circuit of 67. On account of the opposite couplings from the plate circuits upon the circuit 75—76, the side frequency energy from both circuits are additive in their effects on circuit 75 and
30 76. Therefore circuit 75—76, tuned to a frequency intermediate between the two side bands, has currents of only the side band frequencies and no carrier frequency current.

On the other hand, voltage from coil 65 impressed upon amplifier tube 68, produces carrier frequency energy only in the plate circuit which is transferred by coupling 77 into circuit 78—79 which is tuned to the carrier frequency.

From the foregoing it is evident that only carrier frequency current exists in coil 78, and only
40 energy of the side frequencies exists in the coil 75. Moreover, the phase of the carrier current in coil 78 differs by 90° from the current which would need to be combined with currents in coil 75 to constitute the usual modulated wave form.

The voltage due to the side frequency currents in coil 75 supply the grid of the radio frequency amplifier 80, and the amplified signals are im-
50 pressed through coupling 82 upon the antenna circuit 84. Similarly, the voltage due to the carrier frequency current in coil 78 is impressed upon the grid of the amplifier tube 81, and the amplified signals are impressed upon the antenna circuit through coupling 83.

In consequence, the antenna current of 84 has the same components and is the same as would have been produced by the usual type modulation, except that the phase of the carrier has been
10 changed by 90°. The effect of this alteration of carrier is precisely the same as if the phase of one of the side bands of the ordinarily modulated signal had been altered by 180°, or completely reversed.

As indicated above, this type of transmission has the especial property of producing little effect upon ordinary type receivers, because the detected
15 currents produced by the carrier and one side band are neutralized by the detected currents produced by the carrier and the other side band. The noise produced by beating between side bands themselves is small and of poor quality, and often unintelligible.

With the proper type of receiver, however, signals may be received of equally good quality, at
20 equally great distances, as compared with usual

type transmission. Also, the reception of such a signal is subject to much less interference than the reception of the usual type receivers.

A receiver for reception of signals produced by the transmitter of Fig. 8 is shown in Fig. 9. This
80 receiver is of the superheterodyne type, employing two detectors in the intermediate frequency. This circuit is preferred for audio modulated signals, since it permits the reconstruction of the audio wave by circuits of a comparatively low fre-
85 quency and by fixed filter systems, rather than by variable high frequency circuits as shown in the receiver of Fig. 7. It is to be understood that this receiver will receive the signals transmitted by the transmitter of Fig. 6.

Referring now more particularly to Fig. 9, as in the usual type of superheterodyne, the incoming signals are picked up and tuned in by circuit 86 and combined on the input side of the first
90 detector 88 with a local heterodyne frequency supplied by the oscillator 87. As a result, in the plate circuit of the first detector there appears an intermediate frequency determined by the difference between the incoming carrier frequency and the local frequency. This intermediate fre-
95 quency, of say 30 kc. is modulated with the side bands in the same relation as they exist in the incoming signal, so that the result of first detection is merely to reduce the frequency of the modulated signals without changing their general
100 nature. The energy of this reduced frequency modulated wave is segregated out by means of filters 89 and 90, such that half the energy of the intermediate carrier and the upper side band is diverted to tube 91, while half the energy of the
105 intermediate carrier and the lower side band is diverted to tube 92. The voltages impressed on grid circuits of tubes 91 and 92 are different in phase of amplitude variation by 180 degrees. Consequently, on detection by these tubes, the
110 audio current in the plate circuit of tube 91 is out of phase with respect to the audio current in the plate circuit of tube 92. To use both detected currents, the audio energy of both tubes is transferred to a common circuit, say the grid circuit
115 of tube 95, by means of transformers 93 and 94, with the relation between primary and secondary windings in an opposite sense for 94 than for 93. As a result the effects of the audio currents become additive, and the correct signal is produced
120 in the telephone receiver 96 in the plate circuit of the tube.

It is to be noted, however, that all currents or pulses in the plate circuit of tube 88 which pass
125 through the filters 89 and 90 in equal manner, will produce effects in phase in the plate circuit of tubes 91 and 92, and therefore will produce opposite and neutralizing effects in the tube 95. For this reason, this system of transmission and
130 reception is much more selective against general interference than a receiver system similar to Fig. 9 for ordinary telephony, but with transformers 93 and 94 similarly wound instead of oppositely wound.

Having thus described several embodiments of
140 my invention, it is to be understood that I am not to be restricted to the forms herein set forth for the purpose of illustration, but by the scope of my invention as determined by the appended claims.

1. A method of signalling which includes the
145 steps of producing a carrier frequency dividing the carrier frequency into at least two portions, shifting the phase of one of said portions with respect to another portion so that the two portions are 90 degrees out of phase with respect to each
150

other, modulating one of said portions of the carrier frequency by the signal energy desired to be transmitted, suppressing the carrier frequency component from the products of said modulation while retaining the side band components resulting from said modulation, and transmitting the retained side band components together with the other of said two portions of the carrier frequency.

2. Apparatus for the transmission of radiant energy which comprises, means including a thermionic oscillation generator for producing a carrier frequency, means for producing an audio frequency, a push-pull modulator for modulating a portion of said carrier frequency by the audio frequency, the carrier frequency being applied to the push-pull modulator so that said portion of the carrier frequency is eliminated from the output of the modulator, means for radiating the side bands produced by said modulation, means for altering the phase of another portion of the carrier frequency 90 electrical degrees with respect to the first mentioned portion thereof and means for radiating the carrier frequency the phase of which has thus been altered together with said side bands.

3. The steps in a method of signal transmission which comprise producing a carrier frequency wave, producing a modulating wave, combining a portion of the carrier frequency wave and the modulating wave and producing from said combination two side bands, and transmitting the remaining portion of the carrier wave, and the two sidebands, one of the transmissions having its phase altered from its normal phase relationship with respect to the other transmissions.

4. In a transmission system, means for producing a carrier frequency wave, means for producing a modulating frequency wave means for combining said modulating wave and a portion of the carrier wave and producing from said combination two side-bands, said last named means comprising a balanced modulator adapted to eliminate the carrier from its output, means for transmitting the two side bands and at least part of the remaining carrier wave and means prior to said transmission for altering the phase of one of the transmissions as respects the other transmissions.

JOHN HAYS HAMMOND, JR.

30

105

35

110

40

115

45

120

50

125

55

130

60

135

65

140

70

145

75

150