July 29, 1924. 1,502,889

H. J. VAN DER BIJL

METHOD OF AND SYSTEM FOR RADIOSIGNALING

Original Filed Jan. 8, 1918 3 Sheets-Sheet 1

Fig. 1.

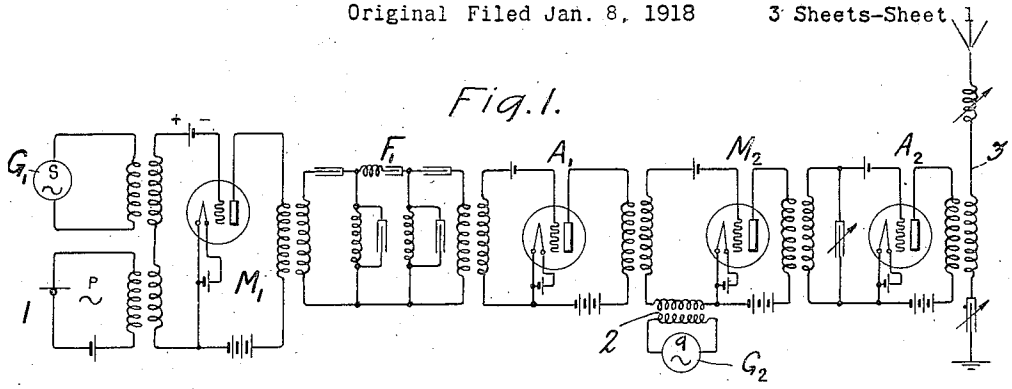


Fig. 2.

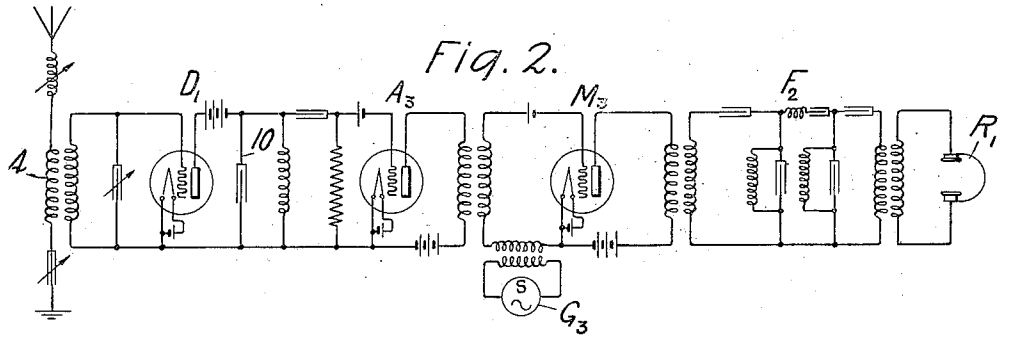


Fig. 3.

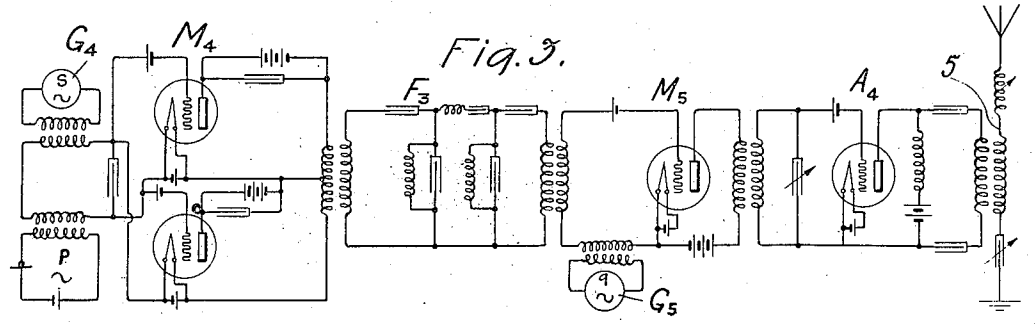
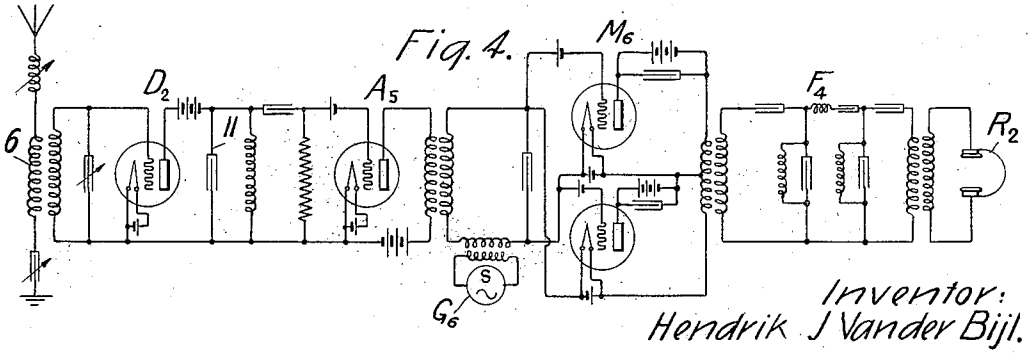


Fig. 4.



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July 29, 1924. 1,502,889

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METHOD OF AND SYSTEM FOR RADIOSIGNALING

Original Filed Jan. 8, 1918 3 Sheets-Sheet 2

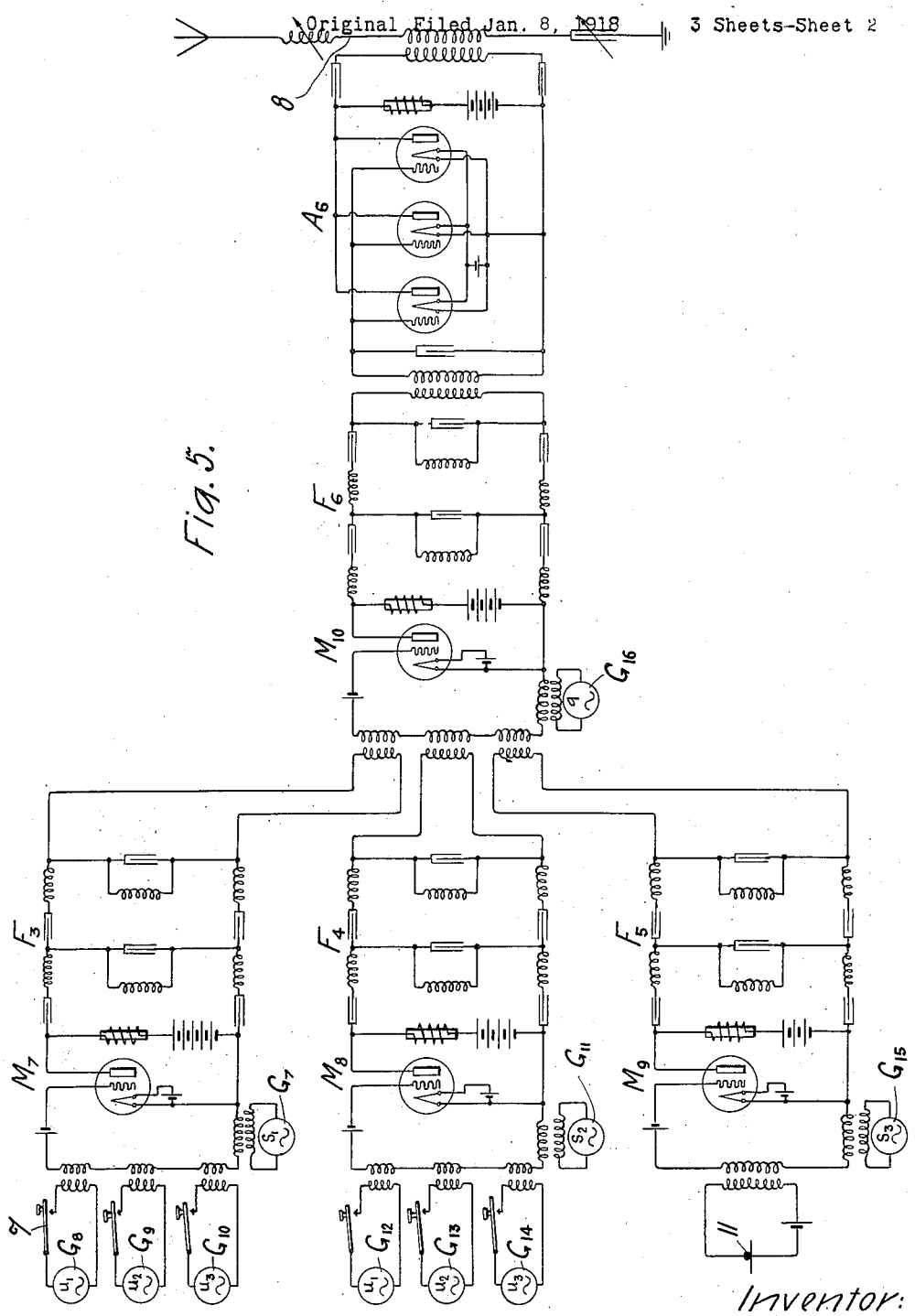

Fig. 5.

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METHOD OF AND SYSTEM FOR RADIOSIGNALING

Original Filed Jan. 8, 1918 3 Sheets-Sheet 3

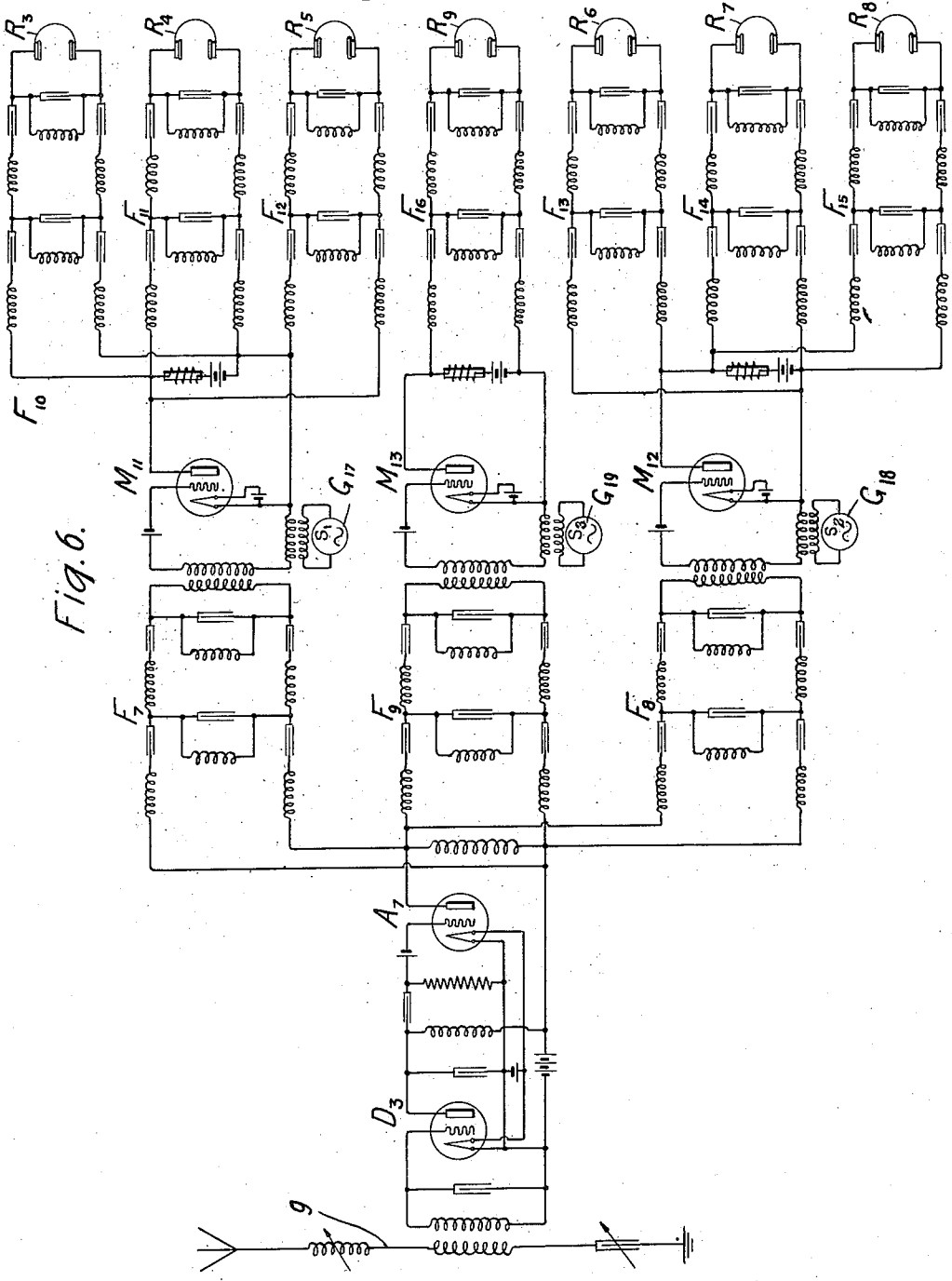

Fig. 6.

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Patented July 29, 1924. 1,502,889

UNITED STATES PATENT OFFICE.

HENDRIK J. VAN DER BIJL, OF PRETORIA, SOUTH AFRICA, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

METHOD OF AND SYSTEM FOR RADIOSIGNALING.

Application filed January 8, 1918, Serial No. 210,868. Renewed November 23, 1921. Serial No. 517,382.

To all whom it may concern:

Be it known that I, HENDRIK J. VAN DER BIJL, a subject of the King of Great Britain, residing at Pretoria, in the Union of South Africa, have invented certain new and useful Improvements in Methods of and Systems for Radiosignaling, of which the following is a full, clear, concise, and exact description.

This invention relates to methods of and systems for radio signaling whereby messages are transmitted as modulations of a high frequency carrier wave.

An object of the invention is to provide a signaling system which may be highly selective.

Another object of the invention is to enable the simultaneous transmission of a large number of messages without the use of a correspondingly large number of high frequency carrier waves.

In order to simultaneously transmit a number of non-interfering messages from a single station, it has been proposed to employ a different frequency carrier wave for each message. This method requires a large frequency interval between any two successive carrier waves and the number of simultaneous messages is accordingly limited. It has also been proposed to transmit several messages upon a single high frequency carrier wave. This may be done by modulating each of a number of auxiliary carrier frequency currents, in accordance with one of a corresponding number of signal currents, and then modulating a high frequency carrier in accordance with each of the modulated auxiliary carrier currents. The operation of modulating a carrier frequency wave by another wave which has been modulated in accordance with a third wave is termed double or successive modulation.

The present invention provides means whereby the auxiliary carrier currents employed to modulate the carrier current in a double modulation system, may each be modulated in accordance with a number of messages, each of which is impressed upon its modulator as a current of audio-frequency which may be selected from the remaining message currents in accordance with which the same auxiliary carrier frequency is modulated. The modulated auxiliary carrier wave is passed through a band filter or transmission net work, which permits only components corresponding in frequency to the range of the difference between the auxiliary carrier frequency and the audio or signaling frequency to pass. In other words, if the frequency of the auxiliary current be s and the frequency of the modulating or message current be p, which in telephony is a variable frequency, the band filter transmits only the component of the modulated auxiliary carrier current having a frequency $s-p$. Since the sum of the frequencies of this transmitted component and the message current is constant, either may be termed the frequency conjugate of the other. Since an ascending frequency signal or speech current gives rise to a descending conjugate frequency current, the signal current frequencies are inverted by the action of the modulator and filter. The high frequency carrier wave is then modulated in accordance with the current component transmitted by the filter or the frequency conjugate of the message or signal current. A number of auxiliary carrier frequencies may be used and each may be modulated in accordance with a number of signal currents of different frequencies.

At the receiving station the high carrier frequency component of the received waves is first eliminated and each of the modulated auxiliary carrier frequency components is transmitted to a modulator from which the various signaling components may be picked out by suitable band filters.

In the drawing, Fig. 1 represents a radio telephone transmitter set; Fig. 2, a corresponding receiving arrangement; Figs. 3 and 4 illustrate modifications of the circuits of Figs. 1 and 2, respectively; while Figs. 5 and 6 illustrate the application of my invention to multiplex radio telegraphy and radio telephony.

In Fig. 1 a generator G_1 and a microphone circuit 1, are inductively coupled to the input circuit of a modulator M_1, to

which they supply oscillations of frequency

$$\frac{s}{2\pi} \text{ and } \frac{p}{2\pi}$$

respectively. The modulator M_1 may be of the audion type and have a characteristic which is represented by

$$i=av+bv^2+cv^3+\ldots \quad (1)$$

where i represents instantaneous values of current in the output circuit, v represents instantaneous E.M.F.'s impressed between the cathode and the grid elements, and a, b, c, etc., are constants depending upon the external circuits and the design of the modulator tube. In general, the terms above the second degree are negligible and may be dropped. If the value of v, which is the sum of the electromotive forces set up in the modulator input circuit by generator G_1, and the microphone circuit 1, be written thus:

$$v=e \sin st+e_1 \sin pt \quad (2)$$

and be substituted in equation (1) the output current is represented by

$$i=ae \sin st+ae_1 \sin pt+be^2 \sin^2 st+2bee_1 \sin st \sin pt+be_1^2 \sin^2 pt \quad (3)$$

The following trigonometric transformations may be made to simplify equation (3):

$$be^2 \sin^2 st=be^2\frac{(1-\cos 2st)}{2}$$

$$2bee_1 \sin st \sin pt=bee_1 \cos (s-p)t-bee_1 \cos (s+p)t$$

$$be_1^2 \sin^2 pt=be_1^2\frac{(1-\cos 2pt)}{2}$$

The output circuit of the modulator M_1 is coupled to a band filter F_1 of the type described in Patent No. 1,227,113 to G. A. Campbell and is designed to transmit the frequencies corresponding to the range of

$$\frac{s-p}{2\pi}.$$

For example, if the range of frequencies for effective speech be taken as 100 to 3,000 cycles and the auxiliary carrier frequency be chosen as 6,000 cycles, the band filter F_1 would be designed to pass frequencies between 5,900 and 3,000 cycles. Dropping constant terms and those of frequency outside the range of the band filter, equation (3) reduces to:

$$i=ae_1 \sin pt+bee_1 \cos (s-p)t-\frac{be_1^2 \cos 2pt}{2} \quad (4)$$

In general speech frequencies may be assumed to range from about 100 to 3,000 cycles, and the band of frequencies throughout this range may be termed the acoustic spectrum of speech. The center of energy of the acoustic spectrum of speech lies at about 900 cycles. The first term of the second member $ae_1 \sin pt$, may therefore be dropped. In general, this term represents frequencies which will be almost wholly eliminated if s is equal to or greater than the maximum value of $2p$ so as to make the lower limit of the range of the band filter,

$$\frac{s-p}{2\pi},$$

equal to or greater than $\frac{p}{2\pi}$. The last term of equation (4) represents a component of frequency $2pt$, the maxium energy of which will lie at about 1.800 cycles and this component will be largely eliminated by the band filter. Where s is chosen as larger than the maximum value of $2p$, the elimination of this term is still more complete. If e and e_1 are made equal, the coefficient of the last term will be half that of the middle term which will accordingly represent four times as much energy and if e is made greater than e_1 the last term will become relatively less. Considering these three factors, it will be evident that the last term will represent a very small portion of the energy passing the band filter and may therefore be neglected, leaving,

$$i=bee_1' \cos (s-p)t=k \cos rt \quad (5)$$

where $\frac{r}{2\pi}$ is the frequency conjugate of the speech current.

The band filter F_1 is coupled by means of an amplifier A_1 preferably of the audion type to the input circuit of a modulator M_2. A generator G_2 supplies high frequency carrier oscillations of frequency q to the

input of the modulator M_2 by means of a transformer coupling 2. The characteristic of modulator M_2 is like that of M_1 and may be represented by

$$i_1 = a_1 v_1 + b_1 v_1^2 + \cdots,$$

and since

$$v_1 = k \cos rt + e_2 \sin qt,$$

$$i_1 = a_1 k \cos rt + a_1 e_2 \sin qt + b_1 k^2 \cos^2 rt + b_1 e_2^2 \sin^2 qt + 2 b_1 k e_2 \cos rt \sin qt \quad (6)$$

Transforming the terms of the second member of equation (6) in accordance with the transformation used in connection with equation (3) and dropping constant terms and all terms not of radio frequency;

$$i_1 = a_1 e_2 \sin qt - \frac{b_1 e_2^2 \cos 2qt}{2} + b_1 k e_2 \sin (q+r)t + b_1 k e_2 \sin (q-r)t \quad (7)$$

Modulator M_2 is coupled by means of an amplifier A_2 preferably of the audion type, to an antenna 3 tuned fairly flat to a frequency

$$\frac{q}{2\pi} + \frac{r}{4\pi},$$

which is the mean of the carrier frequency and the frequency of the component represented by the term

$$b_1 k e_2 \sin (q+r)t.$$

If desired, a filter which will pass only currents of frequency lying between

$$\frac{q}{2\pi} \text{ and } \frac{q+r}{2\pi}$$

may be inserted between modulator M_2 and amplifier A_2.

The radiated wave is therefore proportional to:

$$a_1 e_2 \sin qt + b_1 k e_2 \sin (q+r)t.$$

Referring to Figure 2, a receiving antenna 4, also tuned as is antenna 3, to

$$\frac{q}{2\pi} + \frac{r}{4\pi},$$

is shown coupled to a detector D_1 of the audion type having a high frequency leak path 10.

Assuming a wave of form

$$k_2 \sin qt + k_3 \sin (q+r)t$$

supplied to the input circuit of detector D_1 having a characteristic of the form represented by equation (1), and dropping the radio frequency terms representing the energy dissipated in the leak circuit, the oscillations supplied to the input of the amplifier A_3 are proportional to

$$k_2 k_3 \cos rt \text{ or } k_4 \cos rt.$$

It may be noted that this is the frequency conjugate of speech current which would be received by parties attempting to pick up the message by means of an ordinary detector system. When s is not considerably greater than $2p$, this inverted frequency current is of audio frequency, and would give rise to an unintelligible noise in the receiver, thus effectively masking the talking signal. To this extent the system is secret.

In order to obtain intelligible signals from this conjugate signal frequency current, the output circuit of amplifier A_3 and the circuit of a generator G_3 supplying oscillations of auxiliary carrier frequency s, are both coupled to a modulator M_3, the output circuit of which is connected to the circuit of a receiver R_1 by means of a band filter F_2. The band filter F_2 is designed to pass all frequencies within the range of effective speech transmission, or, in the present case, frequencies between zero and the maximum value of $\frac{p}{2\pi}$.

The resultant modulated wave supplied to the band filter after modulating the auxiliary carrier wave $k_5 \sin st$, emanating from generator G_3, in accordance with the conjugate signaling frequency wave $k_4 \cos rt$ is filtered, and the resulting current in the receiver circuit is proportional to $k_4 k_5 \sin pt$.

It will be noted that the term representing the receiver current contains the factor k_5 and the received signals are therefore increased in intensity by an amount which is dependent upon the amplitude of the auxiliary carrier oscillation component introduced at the receiving station. The current of the receiver corresponds in frequency and is proportional in amplitude to that in the microphone circuit 1 at the transmitter station. Speech may accordingly be transmitted by this system.

In the systems of Figs. 3 and 4, the modulators M_4 and M_6 corresponding respectively to M_1 and M_2 in the system previously described are of the balanced type described and claimed in the application of Carson, Serial No. 64,524, filed December 1, 1915. A modulator of this type has a characteristic that may be represented by

$$i = bv^2 + dv^4 + \text{etc.} \quad (8)$$

Dropping terms of higher than second degree and substituting the value of v from equation (2), the expression for the current in the output circuit of modulator M_4 is

$$i=be^2 \sin^2 st+be_1^2 \sin^2 pt+2bee_1 \sin st \sin pt \quad (9)$$

The expression obtained in this instance contains no term representing a current component of frequency st. The modulated auxiliary carrier current is supplied by modulator M_4 to the input circuit of a band filter F_3 which may be designed to pass frequencies corresponding to range of

$$\frac{s-p}{2\pi}.$$

The use of this type of modulator thus permits the band filter to have a greater range of transmitted frequencies and to be less sharply selective.

The generator G_4 produces oscillations of frequency s which are modulated as described in accordance with speech currents by the modulator M_4. The filter F_3 eliminates all components except those corresponding to the conjugate speech frequency and these remaining components are supplied to a modulator M_5, in order to modulate the high frequency carrier oscillations of frequency q impressed upon the modulator by a generator G_5. The resultant modulated high frequency carrier current is amplified by an amplifier A_4 preferably of the audion type, the output circuit of which is inductively coupled to antenna 5. Antenna 5 and the receiving antenna 6 of the system of Fig. 4 are both tuned fairly flat to the frequency

$$\frac{q}{2\pi}+\frac{r}{4\pi}.$$

If desired the other mean side frequency,

$$\frac{q}{2\pi}-\frac{r}{4\pi}$$

could be employed, in which case the transmitting and receiving antennæ would be tuned accordingly.

At the receiving station, signal oscillations are impressed upon a detector D_2 having a high frequency leak 11 in its output circuit which is coupled to an amplifier A_5. The conjugate speech frequency current component of the output current of detector D_2 is amplified and then employed to modulate auxiliary carrier frequency oscillations produced by generator G_6. The modulation is effected by a modulator M_6 of the balanced Carson type. The advantage of this form of modulator, as will be seen by reference to equation (8), is that it eliminates the first degree components which are difficult to weed out. This permits the use of a filter F_4 which is not as sharply selective as that required in the case of the single tube modulator. A receiver R_2 is coupled to the band filter F_4 and its operation is the same as that of receiver R_1.

Figs. 5 and 6 illustrate the application of my invention to multiplex radio telegraphy and telephony. In Fig. 5, a generator G_7 is arranged to supply auxiliary carrier oscillations of frequency s_1 to a modulator M_7 of the audion type. The auxiliary carrier frequency is modulated in accordance with signaling currents of frequencies u_1, u_2 and u_3, supplied by generators G_8, G_9 and G_{10} respectively. Each of these signaling currents may be employed to transmit a message which is determined in accordance with the operation of a signaling device such as an ordinary telegraph key 7, in the circuit of its individual generator.

The modulated auxiliary carrier current is passed through a band filter F_3 which transmits the range of frequencies corresponding to

$$\frac{s_1-u_n}{2\pi}.$$

The components which pass the filter may be represented by

$$\Sigma\alpha n \cos (s_1-u_n)t=\Sigma\alpha n \cos r_n t.$$

The generator G_{11} produces an auxiliary carrier frequency current of frequency

$$\frac{s_2}{2\pi}$$

which is impressed upon modulator M_8 together with the signaling frequencies of u_1, u_2 and u_3 which are set up in their respective circuits by generators G_{12}, G_{13} and G_{14}. A band filter F_4 passing a range of frequencies between

$$\frac{s_2}{2\pi} \text{ and } \frac{s_2-u_n}{2\pi}$$

is coupled to the output circuit of M_8 and transmits a set of current components which may be represented by

$$\Sigma\beta n \cos (s_2-u_n)t=\Sigma\beta n \cos r'_n t.$$

Filters F_3 and F_4 are coupled to the input circuit of modulator M_{10} upon which a generator G_{16} impresses oscillations of the high carrier frequency q. Oscillations of the resultant frequencies are impressed through a band filter F_6 and an amplifying set A_6 upon the antenna 8 which is tuned flat to a mean frequency:

$$\frac{(N+1)q+r_n+r'_n+\text{etc.}}{2\pi(N+1)}$$

where N represents the number of signal

current sources. Each auxiliary carrier frequency modulating the high carrier frequency produces two side frequencies, one of which is the sum of the carrier and auxiliary carrier frequencies and the other of which is their difference. The frequency to which the antenna is tuned is determined by taking the average of the carrier frequency and one side frequency produced by each of the auxiliary carrier frequencies. The receiving antenna is similarly tuned.

Filter F_6 may be designed to pass only currents of frequencies ranging from the high carrier frequency $\frac{q}{2\pi}$ to the sum of this frequency and the highest conjugate signaling frequency, thus eliminating the side frequencies less than $\frac{q}{2\pi}$ and the higher radio frequencies.

An auxiliary carrier frequency generator G_{15} and a microphone circuit 11 are associated with a modulator M_9 which is connected to a band filter F_5. Filter F_5 transmits a conjugate speech frequency current to modulator M_{10}. Each of these elements corresponds in every way to the similar elements in the transmitting system of Fig. 1, and the frequency of the auxiliary carrier current generator and the range of the band filter are preferably about the same as in the previously described system. It may be noted that as many telephone circuits as may be desired could be employed with this system, each operating upon its own auxiliary carrier frequency. The conjugate speech frequency current would, however, not be audible except in cases where the auxiliary carrier frequency is comparatively low.

Referring to the receiving system of Fig. 6, the oscillations received from antenna 8 are impressed by the antenna 9 upon detector D_3 having a high frequency leak path in its output circuit. An amplifier A_7, preferably of the audion type, conductively connects the detector D_3 to a series of band filters F_7, F_8 and F_9 each of which supplies a conjugate signal frequency current to its own modulator.

From previous considerations it will be evident that the oscillations set up in the output circuit of amplifier A_7 will consist of a number of components, one series of which will represent the conjugate signal frequencies. Another series will consist of all the interference combinations of the modulated auxiliary carrier frequencies. The waves passed will therefore be proportional to

$$\Sigma g_n \cos r_n t + \cdots \Sigma h_n \cos r'_n t + \cdots + k\Sigma_{2n} C_2 \cos (r_n - r'_n)t + \cdots \quad (10)$$

where Σg_n and Σh_n signify the summation of the various conjugate signal frequencies of their respective auxiliary carrier frequencies and $\Sigma_{2n} C_2$ represents the summation of all the possible combinations of the auxiliary carriers. If, for example, the auxiliary carrier frequencies $s_1, s_2 \ldots s_n$ used for telegraphy are chosen so that

$$s_2 = 2s_1 + 2mu_n$$

and

$$s_n = s_{n-1} + s_{n-2} + 2mu_n$$

where m is any integer, there will be no combination which will have the same frequency as one of the modulated auxiliary carrier currents. This will permit the band filters F_7, F_8, etc., to eliminate these combination frequency currents and the series represented by the last term in expression (10) will disappear.

Band filters F_7 and F_8 each select the conjugate signal frequencies set upon a single corresponding auxiliary carrier frequency, and supply them to the input circuits of their respective modulators M_{11} and M_{12}. For this purpose, filter F_7 is designed to pass a range of frequencies

$$\frac{s_1 - u_1}{2\pi} \text{ to } \frac{s_1 - u_n}{2\pi}$$

and filter F_8 has a corresponding range of

$$\frac{s_2 - u_1}{2\pi} \text{ to } \frac{s_2 - u_n}{2\pi}.$$

A generator G_{17} in a circuit coupled to the input of modulator M_{11} supplies oscillations of the auxiliary carrier frequency s_1 which are modulated by the conjugate signal frequencies, thus giving rise to a complex wave in the modulator output having components of frequencies

$$\frac{u_1}{2\pi}, \frac{u_2}{2\pi}, \frac{u_3}{2\pi}, \ldots$$

A series of band filters F_{10}, F_{11} and F_{12} select these and supply each to its respective receiver R_3, R_4 or R_5.

The filter F_8 and generator G_{18} are both coupled to a modulator M_{12} which is connected to receivers R_6, R_7 and R_8 through filters F_{13}, F_{14} and F_{15} respectively. The operation of each of these devices is similar to that of the corresponding elements in the train of devices connected to filter F_7 and hence needs no further explanation.

Filter F_9 selects the components derived from the talking circuit 11 and impresses them upon the input of a modulator M_{13} which is connected to receiver R_9 by a band filter F_{16}. A generator G_{19} supplies auxil-

iary carrier oscillations of the frequency s_3 to the input of modulator M_{13}.

The receivers R_3, R_4 and R_5 will therefore serve to receive telegraph messages from the transmitters giving signals of frequency u_1, u_2 and u_3 respectively, operating with an auxiliary carrier frequency s_1. Receivers R_6, R_7 and R_8 will be affected by their respective signals transmitted by auxiliary carrier currents of frequency s_2, while speech current will be received by receiver R_9 as determined by microphone circuit 11.

It may be noted that while I have illustrated only two auxiliary carrier frequency generators at the transmitting station for telegraphic signaling, each operating in conjunction with three signaling frequency generators, and a single auxiliary carrier frequency for telephonic signaling, this system is capable of operation with a large number of auxiliary carrier frequency generators. Each auxiliary carrier frequency generator employed for telegraphic purposes may be associated with any number of signaling frequency generators. As an example, let us take the simple case illustrated in Figs. 5 and 6 in which only two auxiliary carrier frequencies are employed for telegraphy and each is modulated in accordance with three signaling frequencies. If

$$\frac{s_1}{2\pi}=10{,}000,$$

$$\frac{s_2}{2\pi}=22{,}000,$$

$$\frac{u_1}{2\pi}=500,$$

$$\frac{u_2}{2\pi}=600,$$

$$\frac{u_3}{2\pi}=700,$$

six code messages may be transmitted simultaneously The frequencies

$$\frac{s_1-u_1}{2\pi} \text{ to } \frac{s_1-u_3}{2\pi}$$

will range from 9,500 to 9,300 and filter F_7 will be designed to pass frequencies of this range. The output circuit current of modulator M_{11} will have components of frequencies 500, 600 and 700, and filters F_{10}, F_{11} and F_{12} are each designed to pass one of these frequencies. Obviously, with the frequency ranges given, each of the filters F_{10}, F_{11}, etc., ten audio frequencies might be used to modulate a single auxiliary carrier frequency. By choosing more auxiliary carrier frequencies and choosing the signaling frequencies more closely, an indefinite number of noninterfering messages may be simultaneously transmitted.

A single receiving station might have a generator of auxiliary carrier frequency s_1, another receiving station, a generator of frequency s_2, etc., and in this manner multiplex signaling may be carried on with a number of stations without interference.

In its general aspects, the invention is as applicable to transmission of signals by means of waves guided on wires as to transmission by unguided waves. It is also applicable to electrical selective systems of any type as well as to signaling systems.

While I have illustrated and described a number of specific circuit arrangements, it is to be understood that these circuits may be variously modified by those skilled in the art, and that my invention is therefore to be limited only by the scope of the appended claims.

What is claimed is:

1. The method of signaling which comprises inverting the frequencies of a talking signal so as to produce an unintelligible noise current of audio frequency and modifying oscillations in accordance with said noise current.

2. The method of signaling which comprises modulating a carrier wave in accordance with a wave of inverted signal frequencies.

3. The method of signaling comprising modulating a carrier wave in accordance with the frequency conjugate of a signal wave, and suppressing one of the components of the modulated carrier frequency wave.

4. The method of masking talking signals comprising disproportionally changing the frequency of each of the different frequency components of the talking signals and modifying oscillations in accordance with said components of changed frequencies.

5. The method of signaling which comprises transmitting a carrier wave modulated in accordance with the frequency conjugate of a signaling wave.

6. The method of signaling comprising modulating an auxiliary carrier wave in accordance with a signal wave so as to obtain the frequency conjugate of said signal wave, and modulating a carrier wave in accordance with said frequency conjugate.

7. The method of signaling comprising modulating an oscillation current in accordance with speech current selecting the components of the resultant modulated oscillation current lying within the frequency range of the difference in frequencies of said oscillation current and said speech current, and modulating a carrier wave in accordance with said components of changed frequencies.

8. The method of masking a talking signal which comprises modulating an oscillation current in accordance with speech cur-

rent in order to obtain a noise current and modulating a carrier wave in accordance with said noise current.

9. The method of signaling comprising modulating an auxiliary carrier wave in accordance with a signaling wave, selecting the components of the modulated auxiliary carrier wave within a given band of frequencies, and modulating a carrier wave in accordance with said selected auxiliary carrier wave components.

10. The method of receiving signals transmitted as doubly modulated carrier waves which comprises detecting the carrier waves and employing a component of the detected waves to modulate oscillations corresponding in frequency to one of the waves by which the carrier waves were modulated.

11. The method of secret signaling comprising distorting signaling currents to produce noise currents, modulating carrier frequency currents in accordance with said noise currents, transmitting energy of said modulated carrier frequency current to produce noise currents at a receiving station, and distorting said last mentioned noise currents to reproduce the signaling currents.

12. The method of signaling comprising simultaneously varying each of a plurality of auxiliary carrier frequency waves in accordance with a plurality of independent energy variations and simultaneously varying a carrier frequency wave in accordance with each of said varied auxiliary carrier waves.

13. A transmitting station comprising a source of talking current, a source of oscillating current, means for modulating said oscillating current in accordance with said talking current, means for selecting the components of said modulated oscillating current within a desired range of frequencies and means for modulating a carrier wave by said selected components.

14. A signaling system comprising a modulator having input and output circuits, a source of talking current and a source of oscillating current operatively related to said input circuit, a network coupled to said output circuit for selectively transmitting currents within a limited range of frequencies and means associated with said network for modulating carrier waves in accordance with the selectively transmitted currents.

15. A transmitting station comprising a signaling circuit and a source of alternating current, a modulator operatively related to said signaling circuit and said source, a wave filter connected to said modulator for transmitting with uniformly negligible attenuation a band of frequencies terminated by definite cut-off limits and highly attenuating frequencies without said limits, a source of carrier frequency current, and a second modulator having an input circuit operatively related to said wave filter and said source of carrier frequency current.

16. A receiving station comprising a conductor, a detector connected thereto, a source of alternating current, a modulator having its input circuit operatively connected to said detector and said source of alternating current, and a wave filter connected to the output circuit of said modulator, said filter having a transmission band of uniformly negligible attenuation terminated by definite cut-off limits beyond which the attenuation is large.

17. A signaling system comprising a generator of carrier waves, means including a transmitter device for doubly modulating said carrier waves, and means for impressing said doubly modulated waves first upon a detector to eliminate the carrier frequency component and then upon a modulator and wave filter to eliminate one of the modulation components, said filter transmitting with uniformly negligible attenuation a band of frequencies terminated by sharply defined cut-off limits beyond which the attenuation is large.

18. A multiplex signaling system, comprising a generator of carrier frequency waves, a generator of auxiliary carrier frequency waves associated therewith, means for modulating said carrier frequency waves in accordance with said auxiliary carrier frequency waves and a plurality of signaling devices for simultaneously transmitting a corresponding plurality of signals associated with said last named generator for varying the waves generated thereby.

19. A multiplex signaling system comprising a source of carrier frequency waves, an auxiliary source of oscillations for modulating said carrier frequency waves, and means for simultaneously modulating said oscillations in accordance with a plurality of independent messages.

20. A receiving system for signals transmitted as doubly modulated carrier waves comprising means for selecting components corresponding to the frequency conjugate of the signals, and means for employing said selected components to combine with oscillations of the frequency of one of the components used to modulate the carrier frequency.

21. A receiving system comprising a receiving conductor, a detector connected thereto, a band filter connecting said detector to a modulator for transmitting thereto with uniformly negligible attenuation a band of frequencies terminated by sharply defined cut-off limits and highly attenuating waves beyond said limits, and a source of oscillations associated with said modulator.

22. In combination, a source of carrier frequency waves, means for simultaneously varying said carrier frequency waves in ac-

cordance with a plurality of auxiliary carrier frequency waves, and means for simultaneously varying each of said auxiliary carrier frequency waves in accordance with a plurality of independent energy variations.

23. A radio receiving system comprising means for receiving high frequency oscillations and converting the oscillations into lower frequency inaudible oscillations, a detector, and means for supplying said lower frequency oscillations to said detector, said last mentioned means comprising a band pass filter.

24. In a signaling system, means for generating a high frequency carrier wave, means for generating an intermediate frequency current, means for producing a signal current, means for modulating the intermediate frequency current by the signal current, means for modulating the high frequency wave by the modulated intermediate frequency current, and a band filter to prevent the modulation of the high frequency wave by the signal current.

25. In a carrier wave transmission system in which a portion only of the components of a given modulated carrier wave are employed for transmission, the combination of a modulator, a band filter having a transmission band of uniformly negligible attenuation terminated by sharply defined cut-off limits beyond which the attenuation is large for restricting transmission to a portion only of the frequency components of the modulated carrier wave, an amplifier for said portion of the components, and a transmission circuit for the output of the amplifier, in the order named.

26. In combination, a wave modulator, an amplifier for the modulated wave, and a filter having a transmission band of uniformly negligible attenuation terminated by a sharply defined cut-off limit with large attenuation beyond said limit between the modulator and the amplifier for transmitting to the amplifier one side band of the modulated current and for suppressing transmission of the other modulator output components.

27. In combination, a source of modulating waves, a source of waves of higher frequency to be modulated, a modulator, the output circuit thereof having connected thereto a band filter of which the transmission band is of uniformly negligible attenuation and terminated by sharply defined cut-off limits beyond which the attenuation is high for suppressing components having the frequency of one of said waves and one combination frequency produced by the interaction of said waves, and an amplifier for amplifying the unsuppressed components.

28. A signaling system comprising means for varying the amplitude of one wave in accordance with a plurality of other waves each representing a signal, and means for suppressing all components of the resultant waves of which the frequencies lie on one side of the frequency of said one wave.

29. The method of signaling which comprises varying the amplitude of one wave in accordance with a plurality of other waves each of different frequency ranges and suppressing all components of the resultant waves having frequencies lying on one side of the frequency of said one wave.

30. A modulation system comprising means for varying the amplitude of one wave in accordance with a plurality of other waves of different frequency ranges and suppressing from the modulated output the component having the frequency of said one wave and all components having frequencies on one side thereof.

31. A transmission system comprising means for modulating the amplitude of one wave in accordance with a plurality of frequencies of distinct and different ranges, and means for suppressing from the resultant modulated output components having the frequency of said one wave and of all of said modulating frequencies.

32. A sending system comprising means at one station for modifying one wave by another, means for suppressing all components of the resultant modulated wave except one combination frequency, and means at said station whereby the unsuppressed component modulates another wave.

33. A radio transmitting system comprising at one station means for modulating one wave in accordance with another, means for suppressing all components of the resultant wave except one side frequency, means for modulating another wave in accordance with the unsuppressed side frequency, and means at said station for radiating energy controlled in accordance with said last-mentioned modulation output.

34. A radio telephone transmission system comprising a station having means for modulating one wave in accordance with speech, means for suppressing all components of the resultant wave except one side band of a width approximately equal to the width of the speech, means for modulating another wave in accordance with the unsuppressed band, and means at said station for amplifying and radiating the output of said last-mentioned modulating means.

35. In a successive detection signalling system, the combination of the following means arranged in tandem in one channel; a receiving conductor, a detector, amplifying and selecting means, a second detector supplied by currents traversing said amplifying and selecting means, and an in-

dicating device energized by current supplied by said second detector, said amplifying means producing amplification in addition to any incidental amplification in said detectors.

36. In a double detection receiving system comprising a channel for transferring waves having inherent characteristics to be reproduced, the combination of successive detectors between which are located amplifying means and a band filter comprising a plurality of sections.

37. In a multiplex transmission system, means in tandem for performing a plurality of steps of modulation successively, and means in each channel associated with one of said means in tandem for suppressing the unmodulated carrier component of the modulated wave before further utilizing said wave in the system.

38. In a multiplex transmission system, means in tandem for performing a plurality of steps of modulation successively, and means in each channel associated with one of said means in tandem for suppressing the unmodulated carrier component and one side frequency of the modulated wave before further utilizing said wave in the system.

39. The method of radio signaling, which consists in modulating a plurality of closely spaced carrier frequencies in accordance with low frequency signals, suppressing one side band of each of the resultant modulated bands, so as to prevent interference with the unsuppressed band of the adjacent channel, modulating another frequency with each of the unsuppressed bands, suppressing the lower side band of the resulting band and transmitting the unsuppressed band.

40. A radio signaling system comprising a plurality of low frequency signaling circuits, modulators associated therewith for modulating a plurality of carrier frequencies in accordance with low frequency currents transmitted over said circuits, means for suppressing one of the resultant side bands, a common modulator, means for impressing the unsuppressed bands upon said common modulator in order to modulate another frequency, means for suppressing the lower band produced by the common modulator, and means to radiate the unsuppressed band.

41. A signaling system comprising a plurality of low frequency signaling circuits, modulators associated therewith for modulating a plurality of carrier frequencies in accordance with low frequency currents transmitted over said circuits, means for suppressing one of the resultant side bands, a common modulator, means for impressing the unsuppressed bands on said common modulator in order to modulate current of another frequency, and means for suppressing waves of all currents having frequencies lying to one side of the other frequency.

42. In a channel for selecting waves from interfering waves, the combination in the order named of the following elements; a detector, a band filter, a second detector, and a second band filter.

43. In a multiplex signaling system, a common demodulator for a plurality of channels, a plurality of demodulators each for a plurality of channels supplied by said common demodulator, means for supplying continuous waves to each of said plurality of demodulators, and a plurality of outgoing channels supplied by each of said common demodulators.

44. The method of signaling which comprises producing a wave having a band of frequencies including at least a portion of the frequencies of a speech wave, inverting the frequencies of said produced wave, and modulating a carrier wave in accordance with said wave of inverted frequencies.

45. A signaling system comprising means for producing a wave of inverted frequencies comprising at least a portion of a band of speech frequencies, and means for modulating a carrier wave in accordance with said produced wave.

In witness whereof, I hereunto subscribe my name this 31st day of December, A. D. 1917.

HENDRIK J. VAN DER BIJL.