

H. S. OSBORNE.
PLURAL MODULATION SYSTEM.
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1,361,488.

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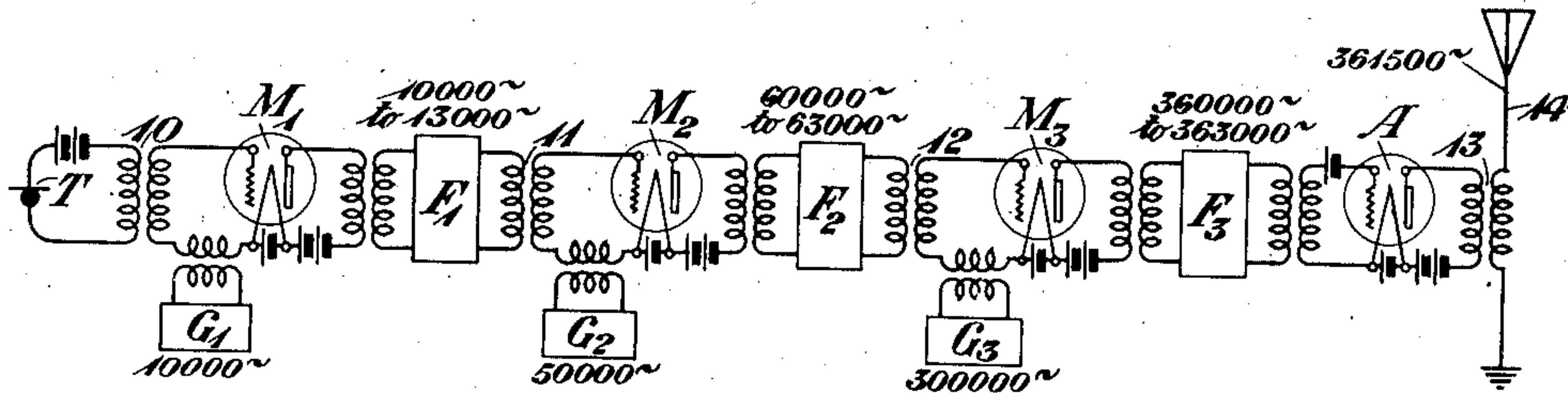


Fig. 1

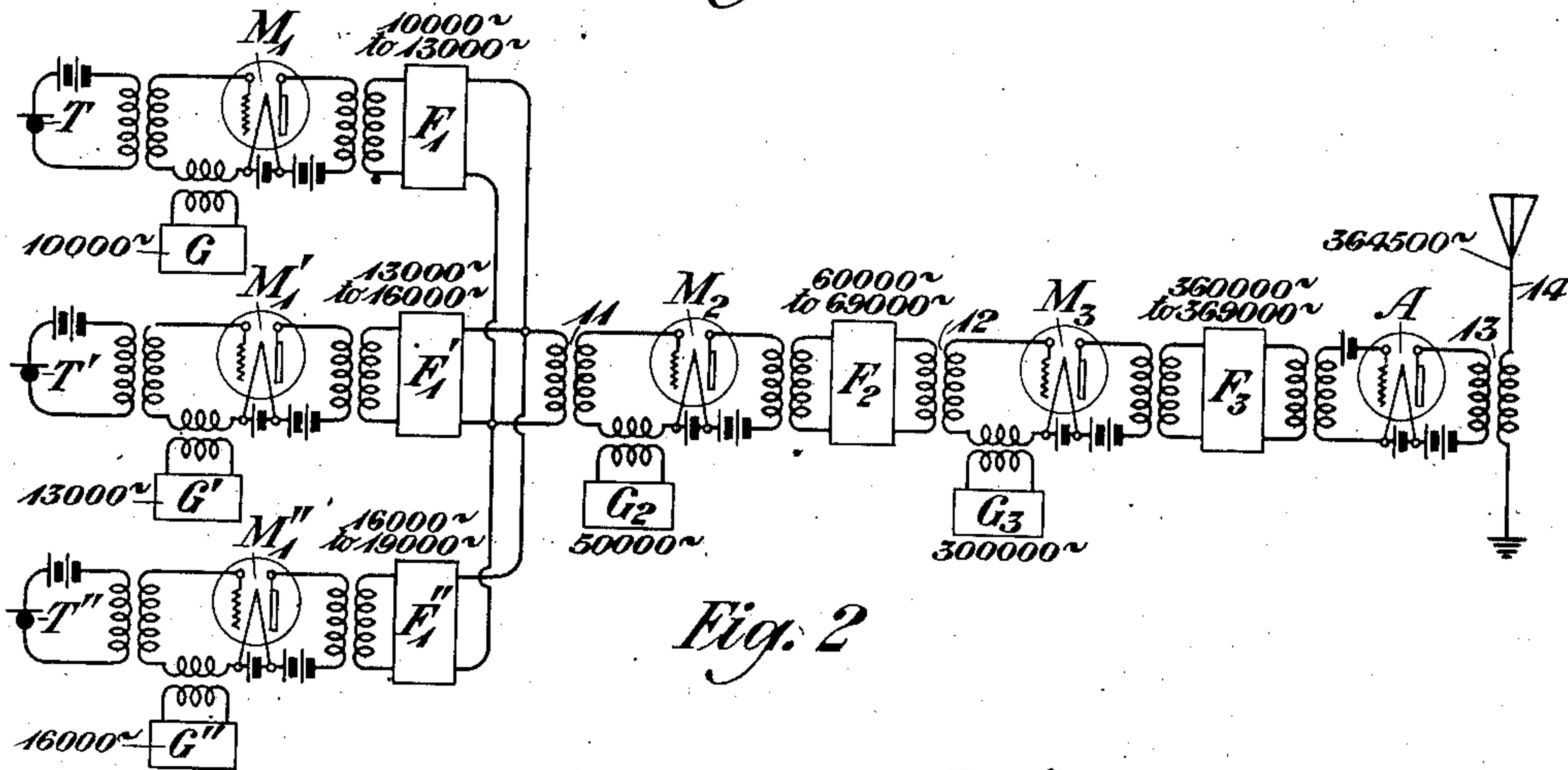


Fig. 2

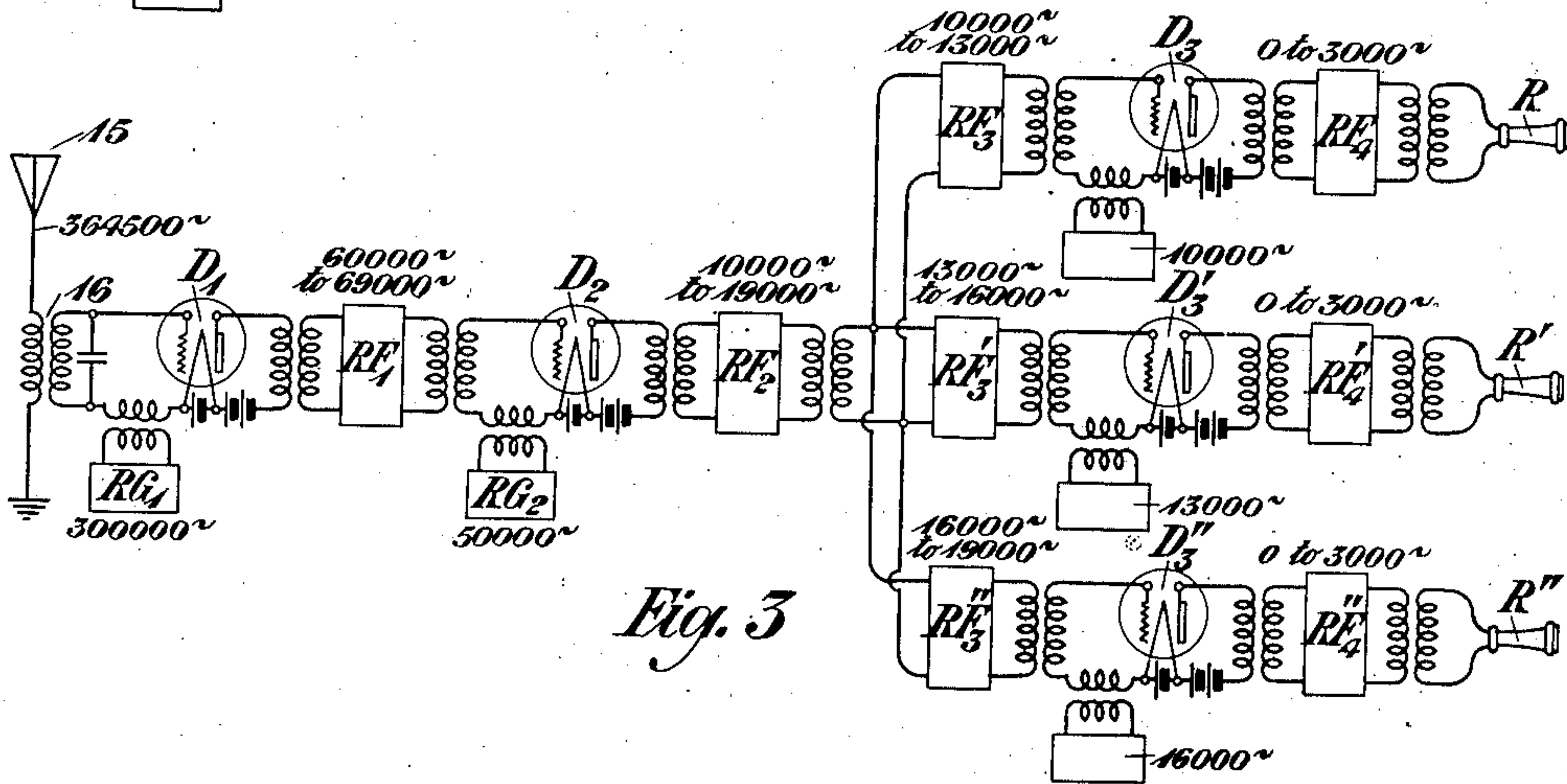


Fig. 3

INVENTOR.
H. S. Osborne
BY *g. v. 708*
ATTORNEY

UNITED STATES PATENT OFFICE.

HAROLD S. OSBORNE, OF NEW YORK, N. Y., ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

PLURAL MODULATION SYSTEM.

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Specification of Letters Patent.

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To all whom it may concern:

Be it known that I, HAROLD S. OSBORNE, residing at New York, in the county of New York and State of New York, have invented certain Improvements in Plural Modulation Systems, of which the following is a specification.

This invention relates to the transmission of signals, and more particularly to the transmission of signals by means of so-called carrier currents.

One of the objects of the invention is to provide a method of modulation whereby one of the resultant side bands may be separated from the other by means of ordinary selective apparatus even though the width of each side band is very small as compared with the carrier frequency involved.

A further object of the invention is to provide a modulating scheme whereby one of the resultant side bands may be selected to the exclusion of the other side band and the carrier involved, by the employment of ordinary selective apparatus, notwithstanding the fact that the width of the side band may be quite small as compared with the carrier frequency.

Another object of the invention is to provide a multiplex transmission system employing carrier currents in which the signaling bands of the several channels shall be as narrow as possible and as closely spaced together as possible while at the same time a very high degree of selectivity may be maintained between different channels with ordinary selective apparatus.

Other and further objects of the invention will more fully appear hereinafter as the description of the invention proceeds.

In the modulation of a carrier frequency by means of a band of signaling frequencies two side bands result, the width of each of which is coextensive with the width of the low frequency signaling band, so that the total band resulting from modulation is twice the width of that of the original signaling band. It is unnecessary for the transmission of signals, however, to transmit both side bands and by eliminating one of the side bands the transmitted band may be reduced to the same width as the original low frequency signaling band. Moreover, it is unnecessary to transmit the carrier frequency as this frequency may be supplied locally at the receiving station and the transmission

of this frequency therefore represents a large waste of power.

Where the carrier frequency is quite high as compared with the low signaling frequencies involved, it has heretofore been considered practically impossible to separate, by ordinary selective means, one side band from the other or either side band from the carrier.

Where multiplex carrier transmission is involved it is further desirable that not only should the transmitted bands be of the minimum width, as above outlined, but the bands corresponding to the several channels should be as closely spaced together as possible. This produces a further complication with ordinary selective apparatus over those above mentioned, due to the fact that it has heretofore been impossible commercially to closely space the several bands and yet maintain an accurate separation between them.

The difficulties above mentioned are overcome in accordance with the present invention by taking advantage of the fact that it is comparatively simple to separate one side band from the other or from the carrier frequency when the total frequency spacing of the side band from the carrier is not too small in comparison with the carrier frequency. For instance, if selective apparatus having 5% selectivity is available and the frequency spacing between side bands is greater than one twentieth of the band extending from zero up to the carrier frequency it is apparent that one side band may be selected from the other. It will be further apparent that if several channels are involved, each employing carriers of the order of frequency magnitude just mentioned, the selected side bands for each channel may be closely spaced, by combining channels at a lower frequency stage, and the two sets of side bands, each representing a plurality of channels may be separated by apparatus having a selectivity of the order above mentioned.

In accordance with the present invention where it is desired to employ a high frequency carrier as the final transmitting medium, the principles above outlined may be employed as follows:

Individual carrier frequencies are chosen for each channel, these frequencies being sufficiently low so that the side bands resulting from modulation may be separated

one from another by ordinary commercial selective apparatus. Carriers are also so chosen that their frequency differences will be as small as possible consistent with selectivity by the use of ordinary selective apparatus. These frequency differences, while considerable when compared with the carrier frequencies chosen for the channels, will be relatively small as compared with the final carrier frequency employed for transmission in the manner hereinafter described.

The relatively low carrier frequency of each channel is modulated in accordance with the low frequency signal to be transmitted over each channel, thereby producing in each channel two side bands, each having a width corresponding to the width of the band of frequencies involved in the low frequency signals to be transmitted. One side band is selected to the exclusion of the other for each channel and the selected bands are collected into a common circuit where they appear as a band of frequencies whose width may approximate that of an individual side band multiplied by the number of channels. This larger band is then used to modulate a higher carrier frequency, thereby producing two side bands each having the same width as the composite modulating band referred to but spaced from the higher carrier frequency by an amount comparable to the frequencies originally employed as carriers in the separate channels. If the higher carrier employed is not too high it will be at once seen that ordinary selective apparatus may be used to select one of these side bands to the exclusion of the higher carrier frequency and the other side band. In this manner not only will the higher carrier frequency be suppressed but the transmitted band will be narrowed to a band of frequencies no wider than the composite band formed from the side bands selected in the individual channels, plus the necessary frequency spacing between channels.

If the frequency of the band selected as just described is not sufficiently high for the contemplated character of transmission, the selected band may be used to modulate a still higher frequency, and one side band may be selected to the exclusion of the other side band and the carrier frequency involved by means of ordinary selective apparatus. This process of stepping up and selecting may be continued as many times as is necessary to elevate the band to be transmitted to the desired position in the frequency spectrum.

The invention may now be more fully understood from the following detailed description thereof when read in connection with the accompanying drawing, Figure 1 of which is a circuit diagram of one form

of transmitting apparatus in accordance with the invention, Fig. 2 of which is a circuit diagram of another form of transmitting apparatus, and Fig. 3 of which is a circuit diagram of a receiving arrangement which may be employed with either transmitting arrangement illustrated.

In the embodiment of the invention illustrated in Fig. 1, T designates a telephone transmitter associated through a transformer 10 with modulator M_1 , which may be of any well known type but as illustrated is a modulator of the vacuum tube type. The modulator M_1 is supplied with carrier currents from a source, G_1 , which may have, for example, a frequency of 10,000 cycles per second, a filter, F_1 , is associated with the output circuit of the modulator for the purpose of selecting one side band. This filter may be of any well known construction, but is preferably a band filter such as is illustrated and described in the United States patents to George A. Campbell, Nos. 1,227,113 and 1,227,114 issued May 22, 1917. As indicated in this drawing, this filter may be so designed as to transmit frequencies lying between 10,000 and 13,000 cycles. The band frequencies transmitted by this filter may be impressed through a transformer 11, upon a modulator M_2 , which is similar to the modulator M_1 already described and is supplied with carrier currents from a source G_2 , the frequency of which may be, for instance, 50,000 cycles per second. The output circuit of the modulator M_2 is provided with a filter F_2 , similar to filter F_1 already described, and this filter may be designed to transmit frequencies between 60,000 and 63,000 cycles.

The band transmitted by this filter may be impressed through a transformer 12, upon a modulator M_3 , which is similar to those already described and is supplied with carrier oscillations from a higher frequency source G_3 . The frequency of this source may be, for example, 300,000 cycles. A filter F_3 , in the output circuit of this modulator is provided for the purpose of selecting one of the side bands. This filter is of the type already referred to and, as illustrated, is designed to transmit the side band lying between 360,000 and 363,000 cycles. The band transmitted by this filter may be impressed upon a power amplifier A, which may be any well known type such as a vacuum tube amplifier, and operates to amplify the transmitted band and impresses it through a transformer 13, upon a transmitting antenna 14. This antenna may be tuned to a medium frequency of the band of frequencies transmitted by the filter F_3 ; for example, in the case illustrated the antenna is tuned to 361,500 cycles. The antenna tuning is not so sharp but that the entire band will be efficiently transmitted.

The operation is as follows:

Carrier currents having a frequency of 10,000 cycles are supplied from a generator G_1 , to the modulator M^1 and are modulated in accordance with the low frequency telephone currents generated by the telephone transmitter T. The frequencies ordinarily involved in telephonic transmission lie between 200 cycles and a higher limit in the neighborhood of 2,000 or 2,500 cycles. At any rate the band of telephonic frequencies may be considered to be well within the limits of zero and 3,000 cycles. As a result of the modulating operation two side bands are produced on either side of the normal carrier frequency of 10,000, each side band corresponding to the telephonic band. These side bands may be considered to lie between 10,000 and 13,000 cycles on one side and between 10,000 and 7,000 cycles on the other side. The filter F_1 operates to suppress the latter side band and transmit the side band lying between the frequencies of 10,000 and 13,000 cycles. This discrimination between side bands is rendered possible because of the relatively low frequencies involved and the fact that there is actually an unoccupied space of 10,000 to 200 cycles separating the two side bands. If the carrier had been 300,000 cycles the side bands would have extended from 300,000 to 303,000 cycles, and from 300,000 cycles to 297,000 cycles. Obviously it would be practically impossible to discriminate between two side bands thus closely related, but it is relatively easy by means of ordinary selective apparatus to discriminate between two bands of the same width at frequencies in the neighborhood of 10,000 cycles.

The side band selected by the filter F_1 is impressed upon the modulator M_2 and modulates an intermediate carrier frequency of 50,000 cycles supplied by the source G_2 . As a result of this modulating operation an unmodulated carrier component of 50,000 cycles appears in the output circuit together with side bands extending from 60,000 to 63,000 cycles and from 40,000 to 37,000 cycles. It will be noted that these side bands, while of the same width as those appearing in the output circuit of the modulator M_1 , are now spaced from the carrier frequency of 50,000 cycles by about 10,000 cycles. Therefore, even though the frequency is now higher the filter F_2 may readily select the upper side band to the exclusion not only of the lower side band which is distant at least 20,000 cycles, but also to the exclusion of the carrier frequency which is 10,000 cycles distant from the selected band. The carrier frequency and one side band may therefore be suppressed by means of ordinary selective apparatus without any special refinement of the circuit.

If the frequency of the band supplied by

the filter is not as high as desired for radio transmission, for example, the frequency may be still further stepped up by additional steps of modulation. In the case illustrated the band transmitted by the filter F_2 is impressed upon the modulator M_3 to modulate a still higher carrier frequency of, for example, 300,000 cycles. The side bands now lie between 360,000 and 363,000 cycles and between 237,000 and 240,000 cycles respectively. It will be noted that these bands are spaced from the carrier frequency by about 60,000 cycles so that the upper side band may again be selected by the filter F_3 and the unmodulated carrier component, and the lower side band may be suppressed. The band selected by the filter F_3 is impressed upon the power amplifier A, and after being amplified is transmitted to the antenna 14 for radiation. This antenna being tuned to the mid-frequency of the band selected by the filter F_3 will efficiently radiate frequencies lying within this band but will still further discriminate against the carrier frequency of 300,000 cycles and the lower side band.

The apparatus as above described is used for telephone transmission. The same principles may be employed however, for telegraph transmission by merely substituting a telegraph transmitter for the telephone transmitter T. In this instance, however, the band of frequencies will be much narrower, since the higher frequencies employed for ordinary Morse telegraphy may be in the neighborhood of 50 cycles. In order to discriminate between two side bands as narrow as these in the first step of modulation it may be necessary to modulate a much lower carrier frequency than 10,000 cycles for the first step of modulation, such as 150 cycles, and it may be necessary to employ additional steps of modulation in order to sufficiently step up the frequency, since for each step of modulation it is necessary to keep the carrier currents low enough in frequency so that the separation of the side bands will represent a considerable fraction of the frequency represented by the carrier.

For multiplex operation separate antennae may be used for each channel and each antenna will then have associated therewith transmitting apparatus similar to that illustrated in Fig. 1. The apparatus of each channel and the frequencies involved in each channel may be the same up to the last step of modulation. It is necessary, however, before impressing the bands from the different channels upon the common transmitting medium, *i. e.*, the ether, to separate the bands in frequency so that they do not overlap. This may be accomplished in the last stage of modulation by supplying slightly separated carrier frequencies to the modulator corresponding to M_3 ; for instance, the carrier

frequency for one channel may be 300,000 cycles; for a second channel, 303,000 cycles, and for a third channel, 306,000 cycles. The three bands from three such channels will then lie between 360,000 and 363,000 cycles, between 363,000 and 366,000 cycles, and between 366,000 and 369,000 cycles respectively, thus comprising a band in the ether between 360,000 and 369,000 cycles. This separation between the bands may, of course, take place at any other stage of the modulation.

In Fig. 2 the spacing of the bands for different channels is illustrated as taking place during the first step of modulation. In this form of the invention the several channels are also illustrated as being combined after the first step of modulation and the succeeding modulation operations are performed in common for all the channels and all the channels are likewise associated with a common antenna.

Low frequency signals to be transmitted from the several channels are supplied by transmitters T , T' and T'' , which are associated with modulators M_1 , M_1' , M_1'' . These modulators are supplied with low frequency carrier currents of 10,000 cycles, 13,000 cycles and 16,000 cycles from generators G , G' and G'' respectively. Filters F_1 , F_1' , and F_1'' are provided in the output circuits of these modulators, the output circuits from the filters being joined together and associated through a transformer 11 with the input circuit of the modulator M_2 . The filter F_1 may transmit a band of frequencies between 10,000 and 13,000 cycles; the filter F_1' may transmit a band of frequencies from 13,000 to 16,000 cycles, while the filter F_1'' may transmit a band between 16,000 and 19,000 cycles.

In the operation of the apparatus shown in Fig. 2 the filters F_1 , F_1' and F_1'' select the upper side band resulting from the first step of modulation in each of the channels, the lower side band being suppressed. As a consequence, the three bands when merged in the incoming circuit of the modulator M_2 comprise a band extending from 10,000 cycles to 19,000 cycles. This band modulates the carrier frequency of 50,000 cycles through the medium of the modulator M_2 , the upper side band extending from 60,000 to 69,000 cycles being selected by the filter F_2 . This band is then impressed upon the modulator M_3 modulating the carrier frequency of 300,000 cycles, the upper side band extending from 360,000 to 369,000 cycles being selected by the filter F_3 . This band, it will be noted, is the same as that described as being impressed upon the ether from three channels of the type illustrated in Fig. 1. After amplification by the amplifier A the band is then impressed upon the antenna 14 through the transformer 13. In this instance the antenna may be tuned to 364,500

cycles which is the mid-frequency of the band to be transmitted.

The receiving apparatus to be employed in connection with the transmitting arrangements of either Fig. 1 or Fig. 2 may be of the general type illustrated in Fig. 3. In this figure, 15 is the receiving antenna, which is tuned to the mid-frequency of the band to be received. The transformer 16 serves to couple the antenna to a receiving detector or demodulator D_1 , which is supplied with a demodulating frequency from a source RG_1 whose frequency may be, for instance, 300,000 cycles. A band filter RF_1 of the general type already described, may be provided in the output circuit of the demodulator for the purpose of selecting one of the resultant side bands. The second demodulator D_2 , similar to the demodulator D_1 , may be provided, this demodulator being supplied with a demodulating frequency of say 50,000 cycles from the generator RG_2 . A filter RF_2 is provided for selecting one of the resultant side bands. The several bands making up the side band selected by the filter RF_2 may be separated into different channels by means of filters RF_3 , RF_3' and RF_3'' . Each channel may be provided with an additional demodulator as illustrated at D_3 , D_3' and D_3'' . Filters RF_4 , RF_4' and RF_4'' may be provided in the output circuits of each of the detectors of the several channels. These filters may be low pass filters of the Campbell type designed to suppress frequencies higher than the actual signal frequencies to be received. These three filters may be identical in construction. Receiving devices, R , R' and R'' may be associated with the filters.

The detectors or demodulators above referred to may be of any well known type but are illustrated as being vacuum tube detectors. The detectors as illustrated operate as demodulators functioning to step down the received frequency, each detector being supplied with a local source of carrier. As in the case of modulation for transmitting, each demodulating action yields two side bands, the sum and difference terms of modulation, the frequency step down action being obtained by selecting each time the lower side band.

The operation is as follows:

Assuming that a band lying between 360,000 cycles and 369,000 cycles is received by the antenna 15 from the transmitting apparatus of either Fig. 1 or Fig. 2, said band will be readily absorbed by the antenna 15 due to the fact that it is tuned to the mid-frequency of the band. The band is then impressed through a transformer 16 upon the demodulator D_1 , where it is modulated with a frequency of 300,000 cycles from the source RG_1 . This results in the appearance in the output circuit of an unmodulated

component of 300,000 cycles, an upper side band lying between 660,000 and 669,000 cycles and a lower side band lying between 60,000 and 69,000. Filter RF_1 selects the lower side band to the exclusion of the unmodulated frequency and the upper side band, the selected band being impressed upon the detector D_2 , where it is modulated with the frequency of 50,000 cycles from the source RG_2 . Upper and lower side bands again appear and the filter RF_2 selects the lower side band which lies between 10,000 and 19,000 cycles, to the exclusion of the upper side band and the unmodulated frequency of 50,000 cycles. From this band the filter RF_3 selects the band between 10,000 and 13,000 cycles, the filter RF_3' selects the band from 13,000 to 16,000 cycles, and the filter RF_3'' selects the band from 16,000 to 19,000 cycles. These three bands are separately modulated with frequencies of 10,000, 13,000 and 16,000 cycles respectively by means of the detectors D_3 , D_3' and D_3'' . This results in the formation of lower side bands in each channel lying between zero and 3,000 cycles, these lower side bands comprising the low frequencies supplied by the transmitters of the separate channels at the distant transmitting station. The upper side bands and the unmodulated beating frequencies are suppressed by the filters RF_4 , RF_4' and RF_4'' , and the selected frequencies are impressed upon the receivers R , R' and R'' , thereby resulting in signals corresponding to the signals originally transmitted.

It will be noted that in the operation of reception demodulation takes place in separate steps corresponding somewhat to the separate steps of modulation at the transmitter. It is not necessary, however, that the same number of steps be employed in receiving as in transmitting, and it is not necessary that the same frequency translations take place in the separate steps. In general the frequencies illustrated are by way of example only and it is to be understood that the frequencies may be varied as the exigencies of a particular situation may necessitate.

The apparatus disclosed is intended merely to illustrate the principles of the invention and it will be obvious that these general principles may be embodied in many other organizations widely different from those illustrated without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. The method of transmission which consists in producing currents of signaling frequencies lying within a predetermined range; modulating by said signaling frequency currents a carrier frequency displaced in the frequency spectrum from said

modulating frequencies by an amount sufficiently small so that the resultant side bands due to modulation will encompass a relatively large portion of the total range of frequencies extending from zero up to the upper limit of the upper band; selecting one of said side bands; and then stepping up the frequency of the selected band to the desired transmission range by a plurality of steps.

2. The method of transmission which consists in producing currents of signaling frequencies lying within a predetermined range; modulating by said signaling frequency currents a carrier frequency displaced in the frequency spectrum from said modulating frequencies by an amount sufficiently small so that the resultant side bands due to modulation will encompass a relatively large portion of the total range of frequencies extending from zero up to the upper limit of the upper band; selecting one of said side bands; modulating an intermediate carrier frequency by the selected band; selecting one of the resultant side bands, and modulating a still higher carrier frequency by said last mentioned selected band.

3. The method of transmission which consists in producing currents of signaling frequencies lying within a predetermined range; modulating by said signaling frequency currents a carrier frequency displaced in the frequency spectrum from said modulating frequencies by an amount sufficiently small so that the resultant side bands due to modulation will encompass a relatively large portion of the total range of frequencies extending from zero up to the upper limit of the upper band; selecting one of said side bands; modulating an intermediate carrier frequency by the selected band; selecting one of the resultant side bands; modulating a still higher carrier frequency by said last mentioned selected band; and selecting for transmission one of the side bands resulting from the last modulating step.

4. The method of transmitting a modulated band of frequencies corresponding to one side band resulting from modulation, to the exclusion of the carrier frequency and the other side band, which consists in modulating a low frequency carrier in accordance with the signals to be transmitted, thereby producing side bands which may be readily separated; selecting one of said side bands; modulating a higher carrier frequency by the selected band, thereby producing side bands displaced from said higher carrier frequency by an amount comparable to said first mentioned carrier frequency; passing the frequencies corresponding to said side bands and said second carrier through frequency selecting apparatus which will freely

transmit frequencies in the neighborhood of one of said side bands but will not freely transmit frequencies remote therefrom, thereby suppressing one of the side bands and the carrier.

5. The method of signal transmission which consists in modulating a relatively low carrier frequency in accordance with signals; modulating a higher carrier frequency in accordance with the modulated current resulting from the first step of modulation, producing thereby side bands on either side of the second carrier frequency and corresponding to the original signaling frequency, said side bands being displaced in frequency from said second mentioned carrier frequency by an amount comparable to said first mentioned carrier frequency; selecting one of said side bands; and suppressing the other side band and the second carrier.

6. The method of signal transmission which consists in modulating a relatively low carrier frequency in accordance with signals; modulating an intermediate carrier frequency by the current resulting from the first step of modulation; modulating a higher carrier frequency in accordance with frequencies resulting from the last mentioned step of modulation, producing thereby side bands corresponding to signals to be transmitted and displaced from said higher carrier frequency by an amount comparable to said intermediate frequency; and selecting one of said side bands to the exclusion of said higher carrier frequency and the other side band.

7. In a multiplex signaling system a plurality of sources of low frequency carrier current, each source having a different frequency; means to modulate the carrier frequency from each source in accordance with a different signal; means to impress frequencies corresponding to each of said modulating operations upon a common modulator together with a higher carrier frequency, thereby producing side bands of modulated frequencies each of which bands is displaced from said higher frequency by an amount comparable to said lower frequency carriers; and means to select one of said bands to the exclusion of the other band and said higher carrier frequency.

8. In a multiplex signaling system a plurality of sources of carrier current of

relatively low frequency; means to separately modulate the carrier frequencies from each of said sources in accordance with different signals; means to select one of the resultant side bands of each modulation to the exclusion of the other, the frequencies of said sources being such that the selected side bands will lie closely together in the frequency spectrum; means to impress the selected bands together with a higher carrier frequency upon a common modulator, thereby producing two side bands, each practically coextensive in width with the combined range of the previously selected side bands, said side bands resulting from said second step of modulation being also displaced in frequency from said higher carrier frequency by an amount comparable to the carrier frequencies used in the first step of modulation; and means to select one of the side bands resulting from the second step of modulation to the exclusion of the other side band and the carrier frequency involved in the second step of modulation.

9. In a multiplex signaling system a plurality of sources of low frequency carrier current, each source having a different frequency; means to modulate a carrier frequency from each source in accordance with a different signal; means to impress frequencies corresponding to each of said modulating operations together with an intermediate carrier frequency upon a common modulator, thereby producing side bands corresponding to the original signals, said side bands being displaced in frequency from the intermediate carrier frequency by an amount comparable to the carrier frequencies used in the original modulating operations; means to select one of said side bands to the exclusion of the intermediate carrier and the other side band; means to modulate a higher carrier frequency in accordance with the band thus selected, producing thereby side bands displaced in frequency from said higher carrier by an amount comparable to said intermediate carrier frequency; and means to select one of said last mentioned side bands to the exclusion of the other side band and said higher carrier frequency.

In testimony whereof I have signed my name to this specification this 29th day of March, 1920.

HAROLD S. OSBORNE.