Dec. 15, 1925. 1,565,521

J. S. STONE ET AL

SECRET COMMUNICATION SYSTEM

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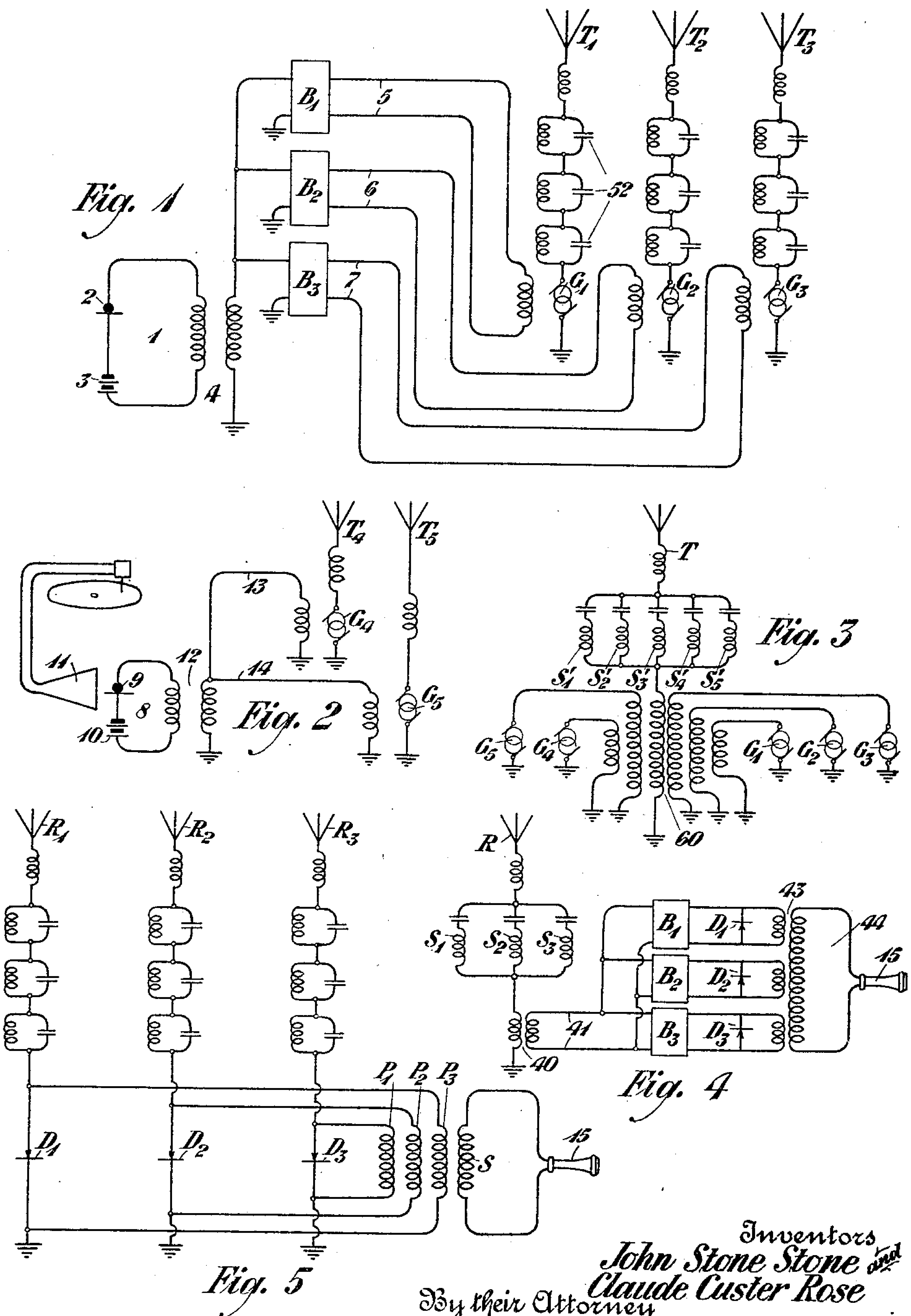

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SECRET COMMUNICATION SYSTEM

Filed Dec. 8, 1920 4 Sheets-Sheet 2

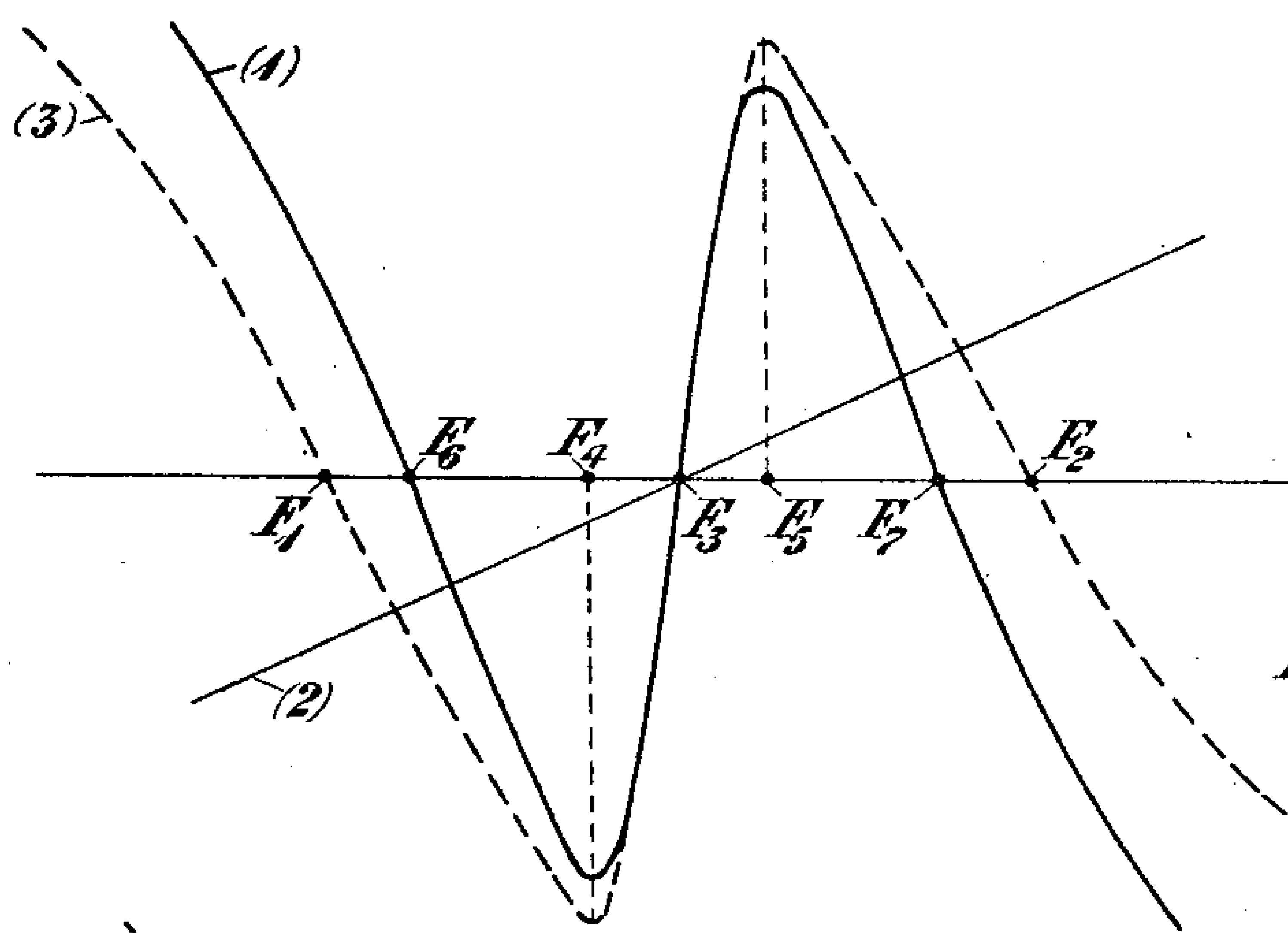

Fig. 6

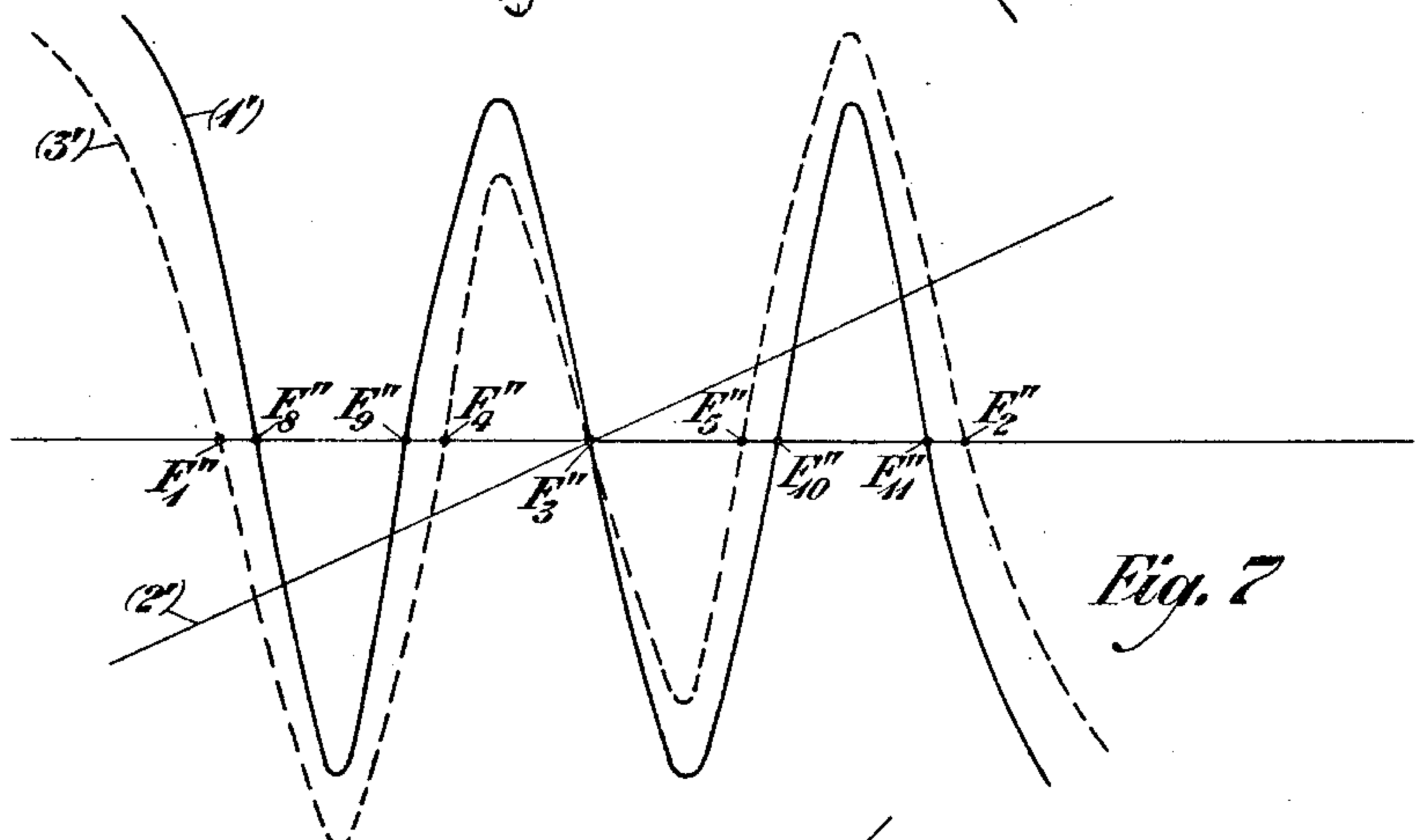

Fig. 7

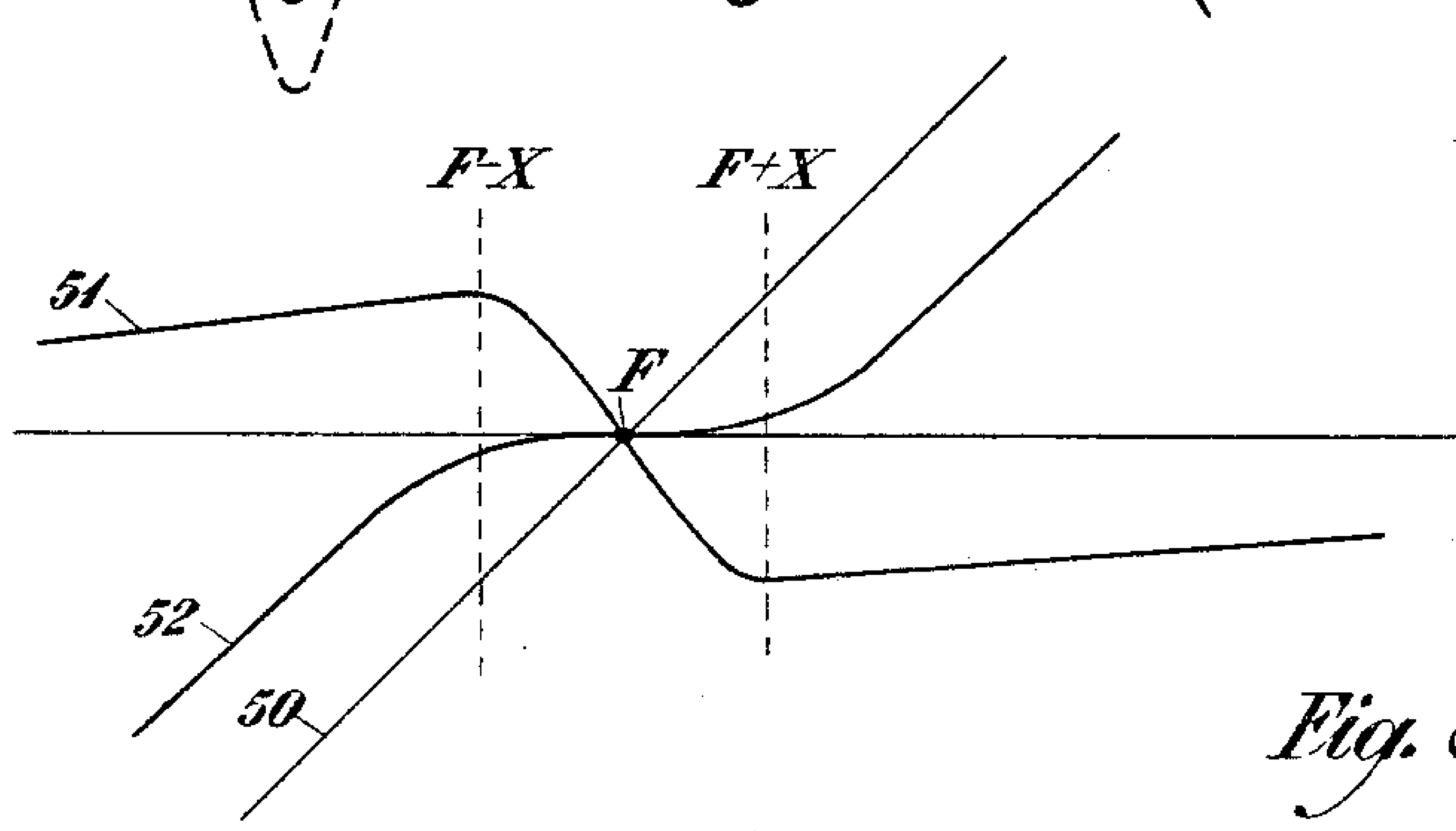

Fig. 8

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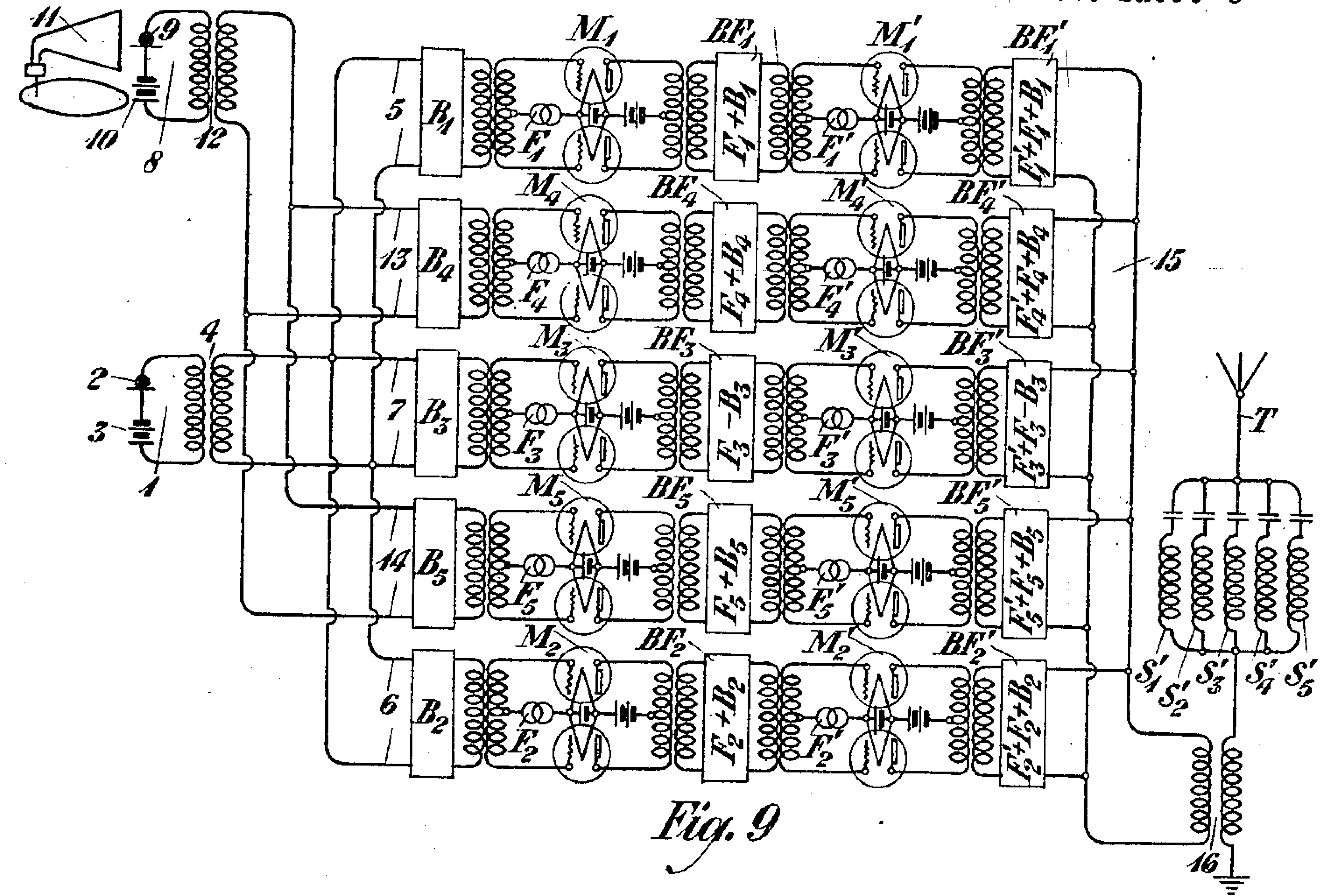

Fig. 9

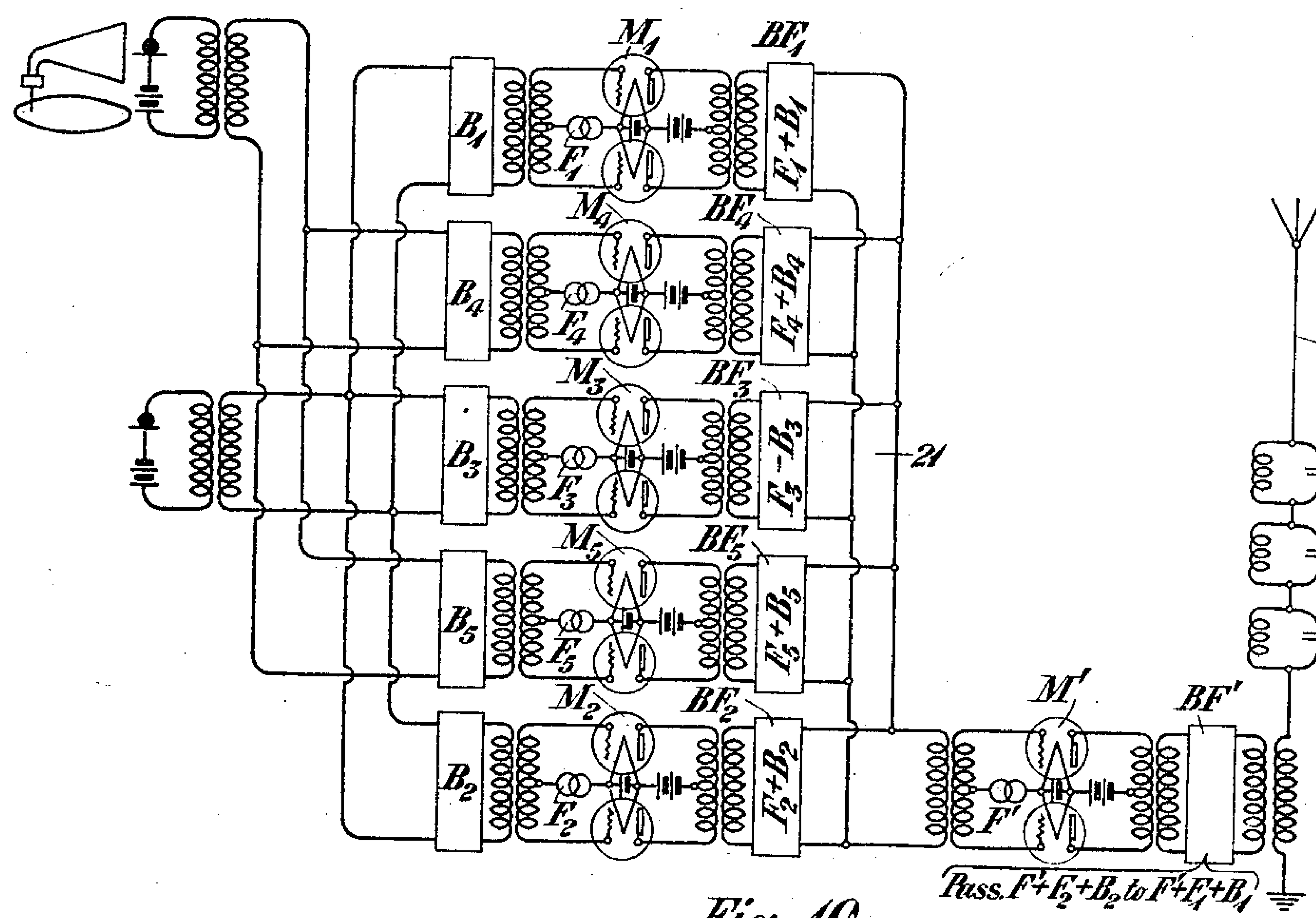

Fig. 10

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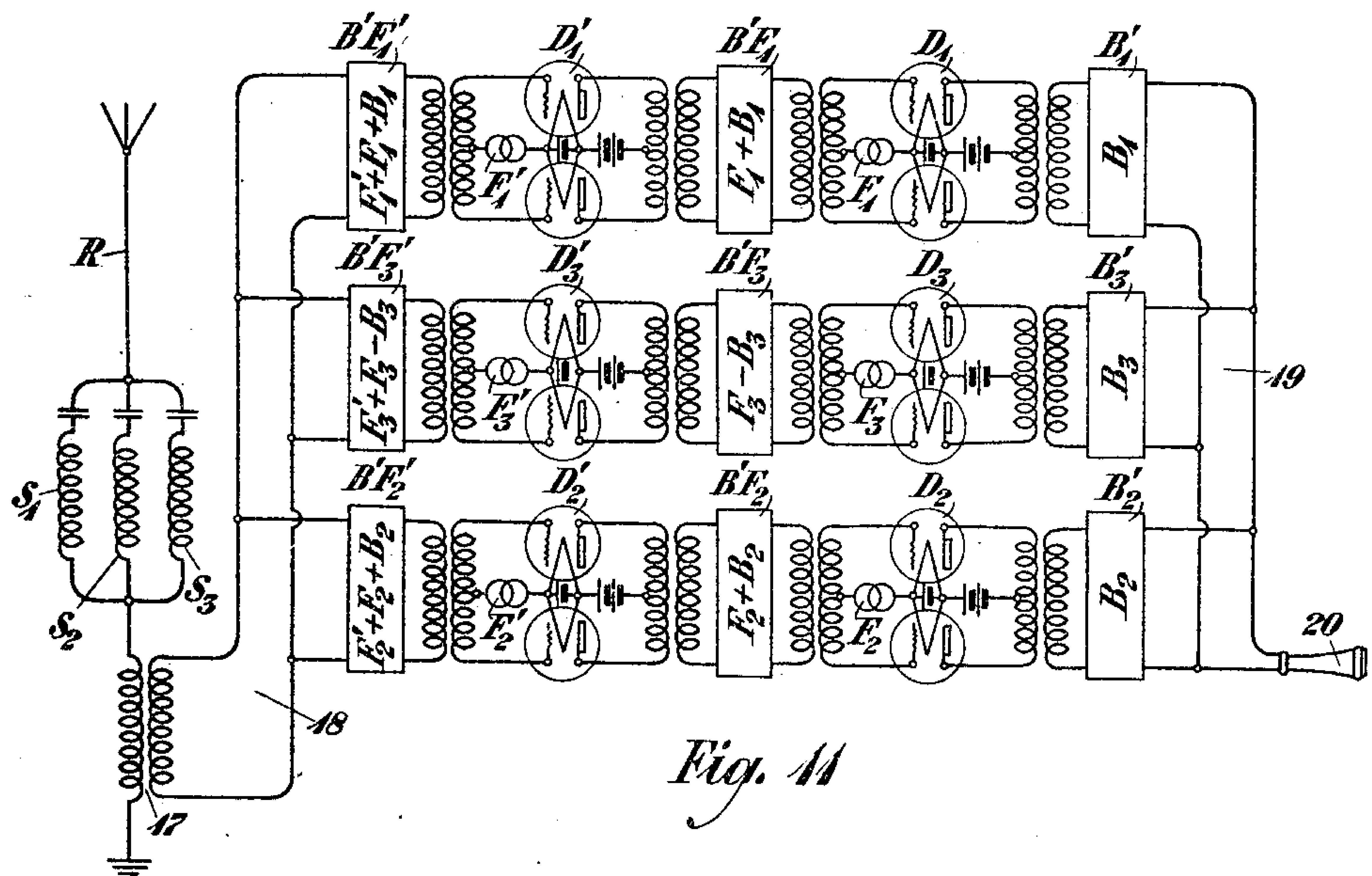

Fig. 11

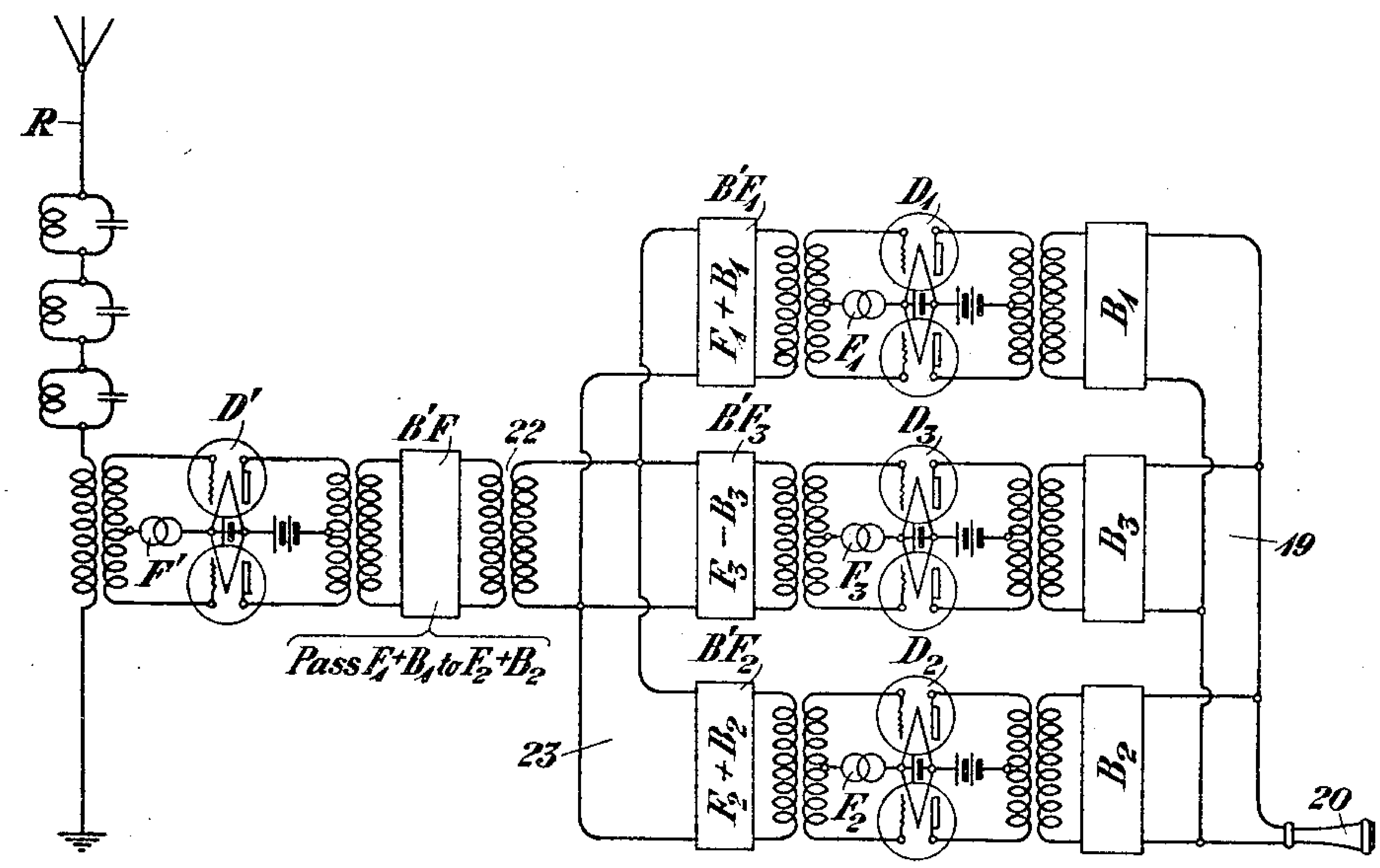

Fig. 12

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Patented Dec. 15, 1925. 1,565,521

UNITED STATES PATENT OFFICE.

JOHN STONE STONE, OF SAN DIEGO, CALIFORNIA, AND CLAUDE CUSTER ROSE, OF EAST ORANGE, NEW JERSEY, ASSIGNORS TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

SECRET-COMMUNICATION SYSTEM.

Application filed December 8, 1920. Serial No. 429,137.

To all whom it may concern:

Be it known that we, JOHN STONE STONE and CLAUDE CUSTER ROSE, residing at San Diego and East Orange, in the counties of San Diego and Essex, and States of California and New Jersey, respectively, have invented certain Improvements in Secret-Communication Systems, of which the following is a specification.

This invention relates to the transmission of signaling waves, especially the transmission of complex waves, such as voice current waves, and is particularly applicable to a system employing high-frequency carrier waves for conveying the voice waves.

It is one of the cardinal features of the invention that it may be utilized to transmit signals secretly and in such a manner that unauthorized persons, who may have access to the medium through or over which the waves are transmitted, will be unable to receive the message. In the arrangements of the invention this is accomplished by dividing the signal wave at the sending station into a plurality of bands or unintelligible fragments, transmitting each of these bands or fragments on a separate carrier, and recombining these bands or fragments at the receiving station in their original and intelligible relation. There may also be transmitted simultaneously with the message a plurality of disturbing or idle frequencies. These frequencies are preferably within the voice range and are transmitted on carrier currents having frequencies intermediate to or adjacent to frequencies utilized as carriers for the voice bands or fragments.

In transmitting the several bands into which the signal is divided, the carrier frequency, which is modulated by any given band, is suppressed and one of the modulated side bands is also eliminated, so that the band of frequencies actually radiated or transmitted, in order to convey a given fragment of the signal, will be no wider than the original portion of the signal. The transmission of a single side band of this character will not alone produce an intelligible signal at a receiver, since the effect of a detector will be to produce low frequencies corresponding to the differences between the individual frequencies comprising the band, instead of the differences between each of those frequencies and the carrier frequency. A further degree of secrecy may also be obtained by, in some instances, transmitting the upper side band for certain fragments of the signal and, in other instances, transmitting the lower side band for other fragments of the signal. As the frequencies in the lower side band will be transmitted in inverse order with respect to the original low frequencies, an attempt to detect and combine the several side bands will result in failure, unless the receiving station is suitably equipped with special apparatus for receiving purposes. In accordance with the invention, special provision is also made at the receiving station for eliminating the effect of the idle or disturbing frequencies transmitted along with the side bands representing the individual portions of the signal. In order to detect from each side band the original low frequencies from which the side bands were derived, each side band is caused to beat at the receiving station with a frequency corresponding to the carrier frequency which was modulated at the sending station to produce the side band. As each individual transmitted band must beat with the proper carrier frequency, in order to produce the original message fragment transmitted, it is apparent that only a station having information as to the carrier frequencies transmitted at the sending station will be able to detect the several bands making up the signal and to combine them in their proper relations. Inasmuch as it is possible, by modulating in successive steps, as will be more fully pointed out later, to transmit each side band as a band of frequencies quite remote from the carrier frequency used at the transmitting station, it will be apparent that, even if a receiving operator had a variable frequency source to beat with the received band, such an operator would be at a very serious disadvantage in adjusting the frequency of this source by reason of the fact that it would be impossible to determine from the band transmitted what frequency was used for the carrier at the transmitting station.

It is a further feature of the arrangements of the invention that they may be utilized to attain a higher degree of selectivity than any other arrangement of radio and carrier current signaling systems. It is well-known that where a signaling band is comparatively wide, as in the case of telephone transmission, it is impossible to tune the receiving circuit sharply to the carrier frequency, for the reason that the resonance curve will have a sharp peak which would seriously distort the signal. Accordingly, recourse has been had in the past to the use of a broadly selective antenna, rather than a sharply tuned antenna, so that the resonance curve will be sufficiently broad at the top to avoid undue distortion of the signal. This, of course, is very wasteful of the frequency range, as it necessitates a wider separation between adjacent channels, in order to avoid interference. While it might seem, at first thought, that the method herein disclosed of transmitting a signal as a plurality of individual bands separately modulating individual carriers would be wasteful of the frequency range because of the employment of a plurality of channels for the transmission of a signal, as a matter of fact, the method actually permits of a very economical use of the frequency range. This follows from the fact that, by narrowing the frequency band of the signal wave transmitted by each carrier frequency to a band much less in width than the voice range, the receiving apparatus may be very much more sharply selective for each band. Consequently, in accordance with the method of the present invention, the band of signaling frequencies, such as the voice band, may be subdivided into as many individual bands as desired, each subdivision producing a narrower individual signaling band. These bands are stepped up in frequency without any increase in the width of the band and are transmitted at high frequency without the accompaniment of a transmitted carrier. The bands may, therefore, be as closely spaced during transmission as is consistent with the selective possibilities of the receiving station. At the receiving station, each selective circuit would, as the subdivision increased, be capable of being more sharply tuned or, in other words, would become more highly selective. Therefore, in accordance with the present invention, the degree of selectivity at the receiving station might be determined by the number of subdivisions of the voice frequency band at the sending station.

Other features and purposes of the invention will appear more fully from the following description when read in connection with the accompanying drawing, in which the arrangements of the invention are illustrated.

In Figures 1, 2 and 3 are illustrated sending arrangements applicable to a radio telephone system embodying the invention, while in Figs. 4 and 5 are shown receiving arrangements for such a system. Figs. 6, 7 and 8 illustrate characteristic curves portraying the principles of operation of the selective transmitting and receiving circuits. Figs. 9 and 10 illustrate circuit arrangements embodying somewhat more elaborate modifications of the transmitting apparatus, while Figs. 11 and 12 disclose receiving arrangements to be used in connection therewith.

Referring to the drawing, Fig. 1 illustrates a transmitter of the type contemplated but reduced to its simplest form, for the purpose of making the description of its operation as free from ambiguity as possible. A transmitting circuit 1 is shown, comprising a telephone transmitter 2 in circuit with a battery 3, or other source of current, and the primary of a transformer 4, the secondary of which is included in a circuit having three branches 5, 6 and 7, said branches including band filters B_1, B_2 and B_3, respectively. The branches 5, 6 and 7 also include the individual field windings of high frequency generators G_1, G_2 and G_3, respectively, the armatures of which are included in the transmitting antenna arrangements T_1, T_2 and T_3. This arrangement of the generator circuits is such that the current in the field windings of each generator is determined by the portion of the telephone band which passes through the corresponding filter and, consequently, the high frequency generated by the generator will be modulated in accordance with the transmitted band. It will be understood, of course, that this arrangement of the generators G_1, G_2 and G_3 is symbolic of any known means whereby sources of current of high frequencies, for example, F_1, F_2 and F_3, respectively, may be modulated by currents passed through the filters B_1, B_2 and B_3. The radiating antenna arrangements T_1, T_2 and T_3 may be made selective of the carrier frequencies generated by the devices G_1, G_2 and G_3, by means well-known in the art, but these antennæ are preferably so constructed that instead of being resonant at the particular frequency of the generator, they will have zero reactance for a band of frequencies in the neighborhood of the carrier and wide enough to accommodate the band of frequencies due to modulation. The characteristic of each antenna may also be made such that the reactance for frequencies outside the band will be quite large. This will be clear from the curves of Fig. 8, in which the curve 50 may be taken as representing the reactance of an antenna at the frequency F. A network may be constructed having a reactance characteristic such as is indicated in the curve 51 of Fig. 8, by inserting in the antenna T_1, for example, a plurality of resonant circuits 52, each comprising a capacity in parallel with an inductance. In each case, the inductance is made relatively small and the capacity relatively large, so that the selectances of each circuit will be small as compared with that of the aerial alone. By selectance is meant the function which may be expressed thus:

$$S=\sqrt{\frac{L}{CR^2}}$$

where L is the inductance, C the capacity and R the resistance. As fully pointed out in the co-pending application, of John Stone Stone, filed November 30, 1920, Serial No. 427,392, entitled "Circuits for passing or stopping a frequency band of alternating currents," a proper proportioning of these elements will give a characteristic similar to that indicated by the curve 51. As will be seen from this curve, between frequencies F—X and F+X, the reactance introduced by the resonant elements will be substantially equal and opposite to that of the antennæ, so that the resulting reactance of the system as a whole will be as indicated by the curve 52. The reactance of the curve 52 is substantially zero over a range of frequencies between F—X and F+X, and this range may be made equal to that of the band produced by modulation. For frequencies beyond this band, the reactance increases rapidly. By constructing each of the antennæ T_1, T_2 and T_3 in this manner, the antennæ may be caused to produce a minimum degree of distortion for the band of frequencies each antenna is to transmit.

It will be seen that by the arrangement thus far described, the frequency band transmitted on each carrier is relatively narrow, so that it is possible, in the case of the relatively low frequency bands, to use at the receiving station, circuits selective of the transmitted carrier frequencies, which are very sharply tuned thereto, as compared with the tuning of a circuit adapted to receive a carrier modulated by an entire voice transmission band. The increased sharpness of tuning permits of a closer spacing of the carrier frequencies and, likewise, of a closer spacing of adjacent carriers used for other channels. The arrangement also renders the transmitted message unintelligible to an ordinary receiving station unprovided with special equipment for receiving from a sending station of this character, since, if the antenna of the ordinary receiving station be tuned to one of the carrier frequencies F_1, F_2 or F_3, it will only receive the portion of the voice band transmitted by that carrier and the other portions of the message will not be present.

A further refinement of the secrecy feature may be obtained by employing simultaneously at the sending station, in addition to the arrangments illustrated in Fig. 1, the arrangements illustrated in Fig. 2. In this figure, a transmitting circuit 8 is shown, comprising a telephone transmitter 9 in circuit with a battery 10 and the primary of a transformer 12, the secondary of which is in circuit with branches 13 and 14, including the individual field windings of generators G_4 and G_5, the armatures of which are included in transmitting antenna arrangements T_4 and T_5. As in the case of Fig. 1, the arrangements G_4 and G_5 are symbolic of any known devices whereby high frequency currents having frequencies, for example, F_4 and F_5, may be modulated by currents from the telephone transmitting apparatus 8. The radiating arrangements T_4 and T_5 may be tuned respectively to the frequencies F_4 and F_5, which are preferaby medial frequencies to the frequencies F_1, F_2 and F_2, F_3, respectively. The term medial, as here used, has reference to the approximate geometrical means as, for example, $\sqrt{F_1F_2}$ and $\sqrt{F_2F_3}$. It will be understood, however, that the invention is not limited to this arrangement of the frequencies. A phonographic apparatus 11 is arranged so that the sound of noise from a phonographic record may be spoken into the transmitter and radiated by the radiating devices T_4 and T_5, along with the message radiated by the radiators T_1, T_2 and T_3. The sound produced by the phonographic apparatus should be of a purely arbitrary character and, in this connection, it may be found useful to run the phonograph backwards, in order to make the noise more unintelligible.

As previously pointed out, the arrangement shown in Fig. 1, when used alone, has certain advantages from the standpoint of secrecy, and, consequently, requires specially arranged receiving apparatus in order to obtain an intelligible message. The message transmitted by the transmitter of Fig. 1 might, for example, be received by means of the arrangement illustrated in Fig. 5. In this figure, R_1, R_2 and R_3 designate receiving aerials which may be rendered selective of frequencies F_1, F_2 and F_3 by means well known in the art, but which are preferably constructed in a manner similar to the transmitting aerials T_1, T_2 and T_3 already described, so as to have a reactance characteristic such as that illustrated by the curves of Fig. 8. Each of these aerials will then be selective of a band of frequencies of the desired width and of the character radiated from the corresponding transmitting antennæ. For example, the aerial R_1 may be selective of the band of frequencies transmitted by the antenna T_1, etc. The receiving antenna will tend to discriminate against frequencies lying without its particular band. The devices D_1, D_2 and D_3 are symbolic of three detecting devices whose audio frequency circuits are connected respectively to the three primaries P_1, P_2 and P_3 of the telephone repeating coil, whose secondary S is included in circuit with the telephone receiver 15. As will be observed, the three portions of the telephone band which were separately transmitted will be separately detected and combined through the transformer, so that the entire band will be transmitted to the telephone receiver.

The three aerials T_1, T_2 and T_3 may be so adjusted as to their radiation and the three generators may be so adjusted as to their power and modulation, that the three bands of frequencies passed respectively by the filters B_1, B_2 and B_3 are transmitted proportionately.

Thus, if ρ_1, ρ_2 and ρ_3 be the radiation resistance, respectively, of the three radiators at the frequencies F_1, F_2 and F_3, respectively, and if I_1, I_2, I_3 be the amplitudes of the modulation of these frequencies, respectively, then we may have

$$I_1^2\rho_1 : I_2^2\rho_2 : I_3^2\rho_3 :: W_1 : W_2 : W_3$$

where W_1, W_2 and W_3 are the energies of the telephone currents passed by the filters B_1, B_2 and B_3, respectively. These adjustments, however, are not to be made by calculation and must be made through symmetry of the apparatus and by extremely simple adjustments which present little difficulty.

Similarly, at the receiving station, through symmetry of the apparatus and simple adjustments, the three frequencies may be received in such proportionality to that in which they are transmitted, that the audio frequencies developed in the audio frequency circuit of each detector will correspond, in quantity as well as quality, to the bands passed by the filters B_1, B_2 and B_3, respectively, at the transmitter.

It may, under some circumstances, however, be desirable to depart from such a symmetrical adjustment, and to transmit the frequencies F_1, F_2 and F_3 at very different intensities, so as to render the reception of the message still more difficult at a receiver to which the message was not addressed. Thus, it may be desired to transmit the bands passed by filters B_1, B_2 and B_3, respectively, on carrier frequencies F_1, F_2 and F_3, at amplitudes m_1, m_2 and m_3, respectively. In this case, the receiver must be so adjusted that the coupling coefficients γ_1, γ_2, and γ_3 of the detectors r_1, r_2 and r_3 to the aerial, are in the proportion

$$\gamma_1 : \gamma_2 : \gamma_3 :: \frac{1}{m_1} : \frac{1}{m_2} : \frac{1}{m_3}$$

or the coupling of the audio frequency circuits of these detectors to the telephone T, may be in such proportion.

It is readily apparent from the preceding discussion, that there is a remote possibility that a message of the character transmitted by the station of Fig. 1 might be received by a station for which it was not intended. If such a station were provided with a plurality of receiving antennæ, a receiving operator might, by the exercise of considerable patience, tune the several antennæ to the different carriers transmitted by the station of Fig. 1 and by painstaking adjustments, combine the individually detected portions of the telephone band in such proportions as to magnitude or intensity of the corresponding currents as to reproduce the telephonic signal transmitted from the distant station. Where, however, the signal is further confused by the employment of the transmitting apparatus in Fig. 2, the reproduction at a receiving station of the actual signal intended to be transmitted may be rendered practically impossible, even by the employment of receiving apparatus illustrated in Fig. 5, since the carrier frequencies F_4 and F_5, upon which the disturbing noise is transmitted, may be very closely spaced with respect to the frequencies F_1, F_2 and F_3, upon which the message is transmitted. Consequently, the receiving antennæ R_1, R_2 and R_3, even though they are sharply tuned, will receive very considerable interference from the intermediate frequencies F_4 and F_5 and the detected message will be mingled with unintelligible noise.

In order to receive an intelligible message when transmitted by the arrangements of Figs. 1 and 2, under the aforesaid conditions, the apparatus illustrated in Fig. 4 may be employed. As it is not essential or indeed desirable that there be separate aerials for each of the frequencies F_1, F_2 and F_3 at the receiver, the receiving device in Fig. 4 is provided with but a single aerial but includes a network of tuned branch circuits, so that the antennæ, as a whole, will have a plurality of degrees of freedom. As illustrated, the receiving antenna R is provided with three branches S_1, S_2 and S_3, each including inductance and capacity, so that each branch may be rendered selective to a particular frequency by tuning. If, in accordance with this arrangement, the branches S_1, S_2 and S_3 have equal selectances

$$S=\frac{1}{R}\sqrt{\frac{L}{C}}=\sqrt{\frac{L}{CR^2}};$$

if, in addition, they are resonant respectively at frequencies F_3, F_6 and F_7 and if the aerial per se be made resonant at frequency F_3, then the three resonant branches S_1, S_2 and S_3 will give a reactance frequency function curve corresponding to the curve 1 of Fig. 6. If, now, the aerial per se as tuned to the frequency F_3 has a lesser selectivity and its reactance be represented by the curve

2 of Fig. 6, the resulting reactance of the system will be represented by the dotted line curve 3, which is obtained by adding the reactances indicated by the curves 1 and 2. An examination of this curve shows that points of zero reactance correspond to frequencies F_1, F_3 and F_2 while points of very great reactance correspond to the intermediate frequencies F_4 and F_5. Consequently, if the antenna arrangement is so designed that the frequencies F_1, F_2 and F_3 correspond to the three carrier frequencies used at the transmitting station of Fig. 1 and that the frequencies F_4 and F_5 correspond to the carrier frequencies employed by the transmitting arrangement of Fig. 2, it will be apparent that the receiving antennæ will have such a characteristic as to be sharply selective of frequencies in the neighborhood of F_1, F_2 and F_3 but will offer very considerable impedance of frequencies in the neighborhood of F_4 and F_5. As a consequence, the receiving antennæ system will discriminate against the carrier frequencies carrying the disturbing noise, while it will readily receive the three frequencies carrying the divided message. Such a receiver will, therefore, enable the operator to receive the intelligible message to the exclusion of the unintelligible noise superposed upon it and stations not so arranged as to receive from the transmitting apparatus of Figs. 1 and 2, will be unable to receive an intelligible message. In order to detect the low frequency signaling bands from the radiated bands received by the antenna arrangement R, the antennæ may be coupled through a transformer 40 and a circuit 41 having branches including band filters B_1, B_2 and B_3. These band filters will select the bands radiated by the antennæ T_1, T_2 and T_3 and will discriminate against the bands radiated by the antennæ T_4 and T_5. The selected bands will be impressed upon detectors D_1, D_2 and D_3 of any well known type, which may be included in the branch circuits. The detected low frequency currents may be impressed upon a common circuit 44 through a transformer arrangement 43 and thus combined in intelligible relation at the receiver 15.

While, as illustrated in Figs. 1 and 2, a plurality of radio antennæ are employed for transmitting the several fragments of the signal, it is not necessary and, in general, is not desirable to employ a plurality of antennæ, but a transmitting antenna may be employed, which is provided with a single aerial having a plurality of degrees of freedom corresponding to the frequency bands to be transmitted. An antenna of this character is illustrated in Fig. 3, in which T is a transmitting aerial having branches S_1', S_2', S_3', S_4' and S_5', each tuned to a different frequency by means of a suitable arrangement of inductance and capacity. If the individual branches are arranged to have equal selectances and if they are resonant respectively at frequencies F_8'', F_9'', F_3'', F_{10}'' and F_{11}'', respectively, then, if the aerial per se be made resonant at frequency F_3'', the several resonant branches S_1' to S_5' inclusive will give a reactance frequency function curve corresponding to the curve 1′ of Fig. 7. If, now, the aerial per se as tuned to the frequency F_3'' has a lesser selectivity and its reactance be represented by the curve 2′ of Fig. 7, the resulting reactance of the system will be represented by the dotted line curve 3′. An examination of this curve shows that points of zero reactance correspond to frequencies F_1'', F_4'', F_3'', F_5'' and F_2''. If these frequencies be so chosen as to correspond to the medial frequencies of the bands to be transmitted, as hereinafter described, it will be apparent that the transmitting aerial T will have large radiating capacity at frequencies in the neighborhood of the points of zero reactance but will discriminate against frequencies remote therefrom. The antenna T may be coupled through a multiple transformer arrangement 60 to a plurality of circuits including the generating and modulating arrangements G_1, G_2, G_3, G_4 and G_5, these modulating arrangements being similar to those illustrated in Figs. 1 and 2, and having modulating bands impressed upon them in the same way, as illustrated in said figures.

Fig. 9 illustrates arrangements for eliminating from the transmitted frequencies not only the carrier frequencies involved, but also one side band of each pair of side bands, thereby increasing the selective possibilities and also providing for additional secrecy. Referring to Fig. 9, T is a transmitting aerial similar to that already described in connection with Fig. 3 and having similar characteristics. The modulating arrangements employed in Fig. 9 are somewhat different from those illustrated in Figs. 1 and 2. In this instance, the circuit of the transmitter 1 is associated with branches 5, 6 and 7 leading through band filters B_1, B_2 and B_3 to modulating devices M_1, M_2 and M_3, respectively. These modulating devices are preferably of the balanced vacuum tube type disclosed in the U. S. patent to John R. Carson, No. 1,343,307, dated June 15, 1920. This type of modulator is arranged to suppress the carrier frequency involved and transmit only the side bands. It is desirable, in order to provide for greater economy in the use of the frequency range, to transmit only one side band and, consequently, the carrier frequencies F_1, F_2 and F_3 supplied to the common branch of the input circuit of each modulator are so chosen as to be relatively low, so that it will be possible to effectively discriminate between the two side bands by means of suitable filtering apparatus. For the purpose of thus discriminating, band filters BF_1, BF_2 and BF_3 are associated with the output circuits of the modulators. The filter BF_1 may be arranged to transmit a band of frequencies F_1+B_1, where B_1 represents a narrow band of frequencies corresponding to a portion of the signal and F_1 is the carrier frequency involved. It will be seen that this represents a band whose width is the same as that of B_1 and that the various frequencies in this band are all above the carrier frequency F_1. Similarly, the band filter BF_2 may be arranged to transmit the side band F_2+B_2. While it is possible to arrange the filter BF_3 to also transmit the upper side band produced in the output circuit of the modulator M_3, it might be, in some instances, desirable to transmit the lower side band F_3-B_3, as this inverts the order of the frequencies involved in the transmitted band and produces further confusion in the signal, which can only be eliminated at the receiving station by special arrangements. The bands transmitted from the filters BF_1 and BF_3 may be impressed upon modulators M_1', M_2' and M_3', similar in construction and arrangement to the modulators M_1, M_2 and M_3, already described. These modulators are supplied with carrier frequencies F_1', F_2' and F_3', which may be of the order of radio frequencies and these frequencies are modulated by the bands transmitted from the band filters to produce side bands, each having a width corresponding to the original bands transmitted through the filters B_1, B_2 and B_3, respectively but spaced a considerable distance in frequency from the carriers F_1', F_2' and F_3', since the frequencies in each band are commensurate with the lower carrier frequencies F_1, F_2 and F_3 employed in the first step of modulation. Band filters BF_1', BF_2' and BF_3' are provided in the output circuits of these modulators for the purpose of transmitting one side band and suppressing the other. By designing these filters so that the transmitted band has a width substantially no greater than the one side band to be transmitted, the filters will also serve to suppress the carrier frequencies, although these frequencies are, in the case illustrated, suppressed by the balanced arrangement of the modulator circuit. The band filters are arranged, in the case illustrated, to transmit the upper side band although, in practice, the lower side band may be transmitted, if desired. Accordingly, the filter BF_1' is arranged to transmit a band $F_1'+F_1+B_1$, these having a width equal to B_1 and representing a band of frequencies in the neighborhood of $F_1'+F_1$. Similarly, the filter BF_2' will transmit a band $F_2'+F_2+B_2$, while the filter BF_3' will transmit a band $F_3'+F_3-B_3$. The three bands transmitted may be impressed upon a common circuit 15 for transmission to the radiating antenna and it will be readily apparent that the carrier frequencies may be so chosen as to bring the several bands as closely together in the frequency range, as is desired.

In order to transmit unintelligible noise along with the three signal bands previously described, the phonographic transmitting apparatus 8—11 is connected to the circuit having branches 13 and 14, including band filters B_4 and B_5. These band filters transmit the disturbing noise currents to modulators M_4 and M_5, similar to the modulators already described, and these modulators are supplied with carrier frequencies F_4 and F_5, which frequencies may preferably be intermediate or adjacent to the frequencies F_1, F_3 and F_3, F_2. Filters BF_4 and BF_5 are associated with the output circuits of the modulators M_4 and M_5 for transmitting side bands F_4+B_4 and F_5+B_5, respectively. These side bands are impressed upon modulators M_4' and M_5' supplied with carrier frequencies F_4' and F_5'. Filters BF_4' and BF_5', associated with the output circuits of these modulators, may be arranged to select one of the resultant side bands and discriminate against the other side band and the carrier frequency involved in each case. For purposes of illustration, the filter BF_4' is indicated as transmitting a band $F_4'+F_4+B_4$ and the filter BF_5' is illustrated as transmitting a band $F_5'+F_5+B_5$. These bands, like the bands transmitted by the filters BF_1', BF_2' and BF_3' will be of relatively narrower width and preferably will be somewhat remote from the carrier frequencies supplied to the modulators and the carrier frequencies will not be transmitted along with the bands. All five bands may be impressed upon the common circuit 15, which is associated through a transformer 16 with the transmitting antenna T. Referring again to the curve 3' of Fig. 6, which represents the transmission characteristic of the transmitting antenna, the frequencies F_1'', F_4'', F_5'' and F_2'', corresponding to points of zero reactance, should be so chosen as to be medial frequencies for the bands transmitted by the filters BF_1', BF_4', BF_3', BF_5' and BF_2', respectively.

An advantage which is inherent in the arrangement of Fig. 9 resides in the possibilities which it affords of so choosing the frequencies supplied to the various modulators that the bands ultimately radiated from the radiating apparatus T may be arbitrarily and widely spaced in the frequency spectrum. It is also possible to shift the relative positions of the bands in the frequency spectrum. For example, the band passed by the filter B_3 may be intermediate in the voice range, between the band passed by the filter B_1 and that passed by the filter B_2. By a proper choice of the carrier frequencies, however, the high frequency bands corresponding to these bands may be transposed so that the band representing the signal passed through the filter B_3 will be higher than that representing the signals passed through the filters B_1 and B_2. Other bands from other transmitting stations may be so arranged as to be intermediate between the several bands radiated by the transmitting apparatus of Fig. 9 and in this way, the entire available frequency range may be utilized and a further degree of secrecy attained, owing to the fact that a receiver, tuned to receive one of the bands radiated by the transmitter of Fig. 9, for example, would also receive adjacent bands on either side of it which originated as parts of signals transmitted from other transmitting stations. Such an arrangement of the bands of the frequency spectrum would permit, therefore, of using bands from other radiating stations as the idle frequencies for rendering the signals transmitted from the station of Fig. 9 unintelligible so that it would not be necessary to provide the idle frequencies from the transmitting apparatus 8, although this apparatus may be provided as an additional precaution, if desired.

A receiving apparatus adapted to receive intelligible signals from the transmitting arrangement disclosed in Fig. 9 is illustrated in Fig. 11. This receiving arrangement comprises a receiving antenna R, having a transmission characteristic similar to that indicated in Fig. 4, said antenna being associated through a transformer 17 with a circuit 18 having branches leading through filters $B'F_1'$, $B'F_3'$ and $B'F_2'$. By proper design of the antenna, the points of zero reactance may be made to correspond to medial frequencies of the bands transmitted by the filters BF_1', BF_3' and BF_2' at the transmitting station, while discriminating against the bands transmitted by the filters BF_4' and BF_5'. The bands to which the antenna arrangement is approximately selective are individually selected by the band filters $B'F_1'$, $B'F_3'$ and $B'F_2'$, respectively, at the receiving station and impressed upon demodulators D_1', D_3' and D_2'. These demodulating devices may be of the balanced vacuum tube type described in the U. S. patent to John R. Carson, No. 1,343,308 issued June 15, 1920 and are supplied with locally generated carrier frequencies F_1', F_3' and F_2', respectively, corresponding to the carrier frequencies used in the last step of modulation at the transmitting station. As a result of the detecting action of the demodulators, frequencies F_1', F_3' and F_2' are added to and subtracted from the bands transmitted by the filters $B'F_1'$, $B'F_3'$ and $B'F_2'$, respectively. By providing band filters $B'F_1$, $B'F_3$ and $B'F_2$ for the output circuits of the demodulators, the lower side bands corresponding to F_1+B_1, F_3-B_3 and F_2+B_2 will be selected in each case to the exclusion of the upper side bands and the bands thus reduced in frequency will be applied to similar demodulating devices D_1, D_3 and D_2, respectively. These demodulating devices are supplied with locally generated carrier frequencies F_1, F_3 and F_2, corresponding to the frequencies used in the first step of modulation at the transmitting station. The demodulator D_3 functions to subtract the band F_3-B_3 from the carrier frequency F_3 and the demodulators D_1 and D_2 function to subtract the carrier frequencies from the corresponding bands applied to the demodulators. The bands resulting from the subtraction of the carrier frequency from the band applied to the demodulator will, in each case, correspond to the corresponding portions of the signal band at the transmitting station and this low frequency band may, in each case, be selected from the upper band by means of filters B_1', B_3' and B_2', which are connected to a common receiving circuit 19, so that the component bands of the signal may be combined in the receiver 20.

A somewhat similar arrangement embodying the same principles is illustrated in Figs. 10 and 12, the former illustrating the transmitting apparatus and the latter the receiving apparatus. Referring to Fig. 10, it will be seen that the apparatus involved in the first step of modulation may be identical with that of Fig. 9, but in this instance the output circuits BF_1 to BF_5, inclusive, are connected to a common circuit 21, which is associated with the input circuit of a modulator M′ of the general type already described. This modulator may be supplied with a carrier frequency F′ of radio character. As a result of the action of the modulator M′, the five relatively narrow bands appearing in the circuit 21 are added to and subtracted from the frequency F′, thus producing two sets of bands on either side of carrier frequency F_1 and considerably spaced therefrom. A filter BF′ is provided in the output circuit of the modulator M′ and this filter is designed to suppress the bands on one side of the carrier and transmit those on the other. In the case assumed, the filter is designed to transmit the upper set of bands and suppress the carrier frequency and the lower set of bands. The upper set of bands in this case comprises band frequencies $F'+F_1+B_1$, $F'+F_4+B_4$, $F'+F_3-B_3$, $F'+$

F_5+B_5 and $F'+F_2+B_2$. The transmitting antenna T in this case may be constructed in accordance with the principles illustrated in Fig. 8 to have zero reactance over a band of frequencies of sufficient width to accommodate the several bands impressed upon it through the band filter BF′, and, therefore, will readily transmit the particular frequencies desired while tending to discriminate against other frequencies.

The frequencies transmitted may be all closely spaced, owing to the highly selective character of the receiving apparatus employed at the receiving station, which is illustrated in Fig. 12 and will now be described. In this case, the receiving antenna R may be given the characteristics indicated in Fig. 8 so as to have zero reactance over a band of frequencies corresponding to the band radiated by the antenna T of Fig. 1. It will, therefore, readily receive the frequencies included in the five bands of frequencies transmitted in the assumed case but will discriminate against other frequencies. The receiving antenna R is associated with the input circuit of a demodulator D′, which is supplied with the carrier frequency F′, corresponding to the carrier frequency used in the last step of modulation at the transmitting station of Fig. 10. As the result of the action of the demodulator D′, the frequency F′ is added to and subtracted from the frequencies in each of the bands radiated by the transmitting antenna T. A band filter B′F is associated with the output circuit of the demodulator, however, and this filter is so designed as to eliminate the upper set of frequencies and pass the lower set of frequencies, which will comprise the bands F_1+B_1 and F_2+B_2, as well as the intermediate bands. It will be seen that these bands include the disturbing bands, and in order to eliminate these disturbing bands and to select the desired bands, the frequencies represented by all five bands are impressed upon the common circuit 23 having branches leading through filters $B'F_1$, $B'F_3$ and $B'F_2$. These filters function to suppress the two undesired bands and to select and separate the three desired bands into separate circuits and impress them upon the demodulators D_1, D_3 and D_2, which function in a manner identical with the corresponding elements in Fig. 9 to detect the component bands of the signal and combine them in the receiver 20.

It will be observed that in this case the received bands are all stepped down in frequency before any selecting action takes place, so that the degree of separation between the bands becomes relatively large, as compared with the actual frequencies then involved, so that it is much easier to discriminate between the bands desired and those which are undesired. This makes it possible to space the transmitted bands much more closely together than has heretofore been the practice.

While the invention has been disclosed as particularly applicable to a radio system it is understood that the principles of the invention are equally well applicable to a system utilizing wire lines. It will be obvious that the general principles herein disclosed 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. In a radio transmission system, a sending station, means at said sending station for dividing the message frequency band into sub-bands and for radiating each of said sub-bands on a separate carrier frequency, means at said sending station for producing a disturbing low frequency band, and means for radiating said low frequency band on carrier frequencies intermediate in the frequency scale to said first mentioned carrier frequencies.

2. In a radio telephone system, a sending station, means thereat for dividing the voice frequency band into unintelligible fragments and for transmitting each of said fragments on separate carrier frequencies, means for producing a low frequency band within the voice range of frequencies, and means for transmitting said last mentioned band simultaneously with said first mentioned carrier frequencies on carrier frequencies intermediate in the frequency scale to said first mentioned carrier frequencies.

3. In a radio transmission system a sending station including means for dividing the message frequency band into sub-bands and for radiating each of said sub-bands on a separate carrier frequency, means for producing an additional low frequency band, means for radiating said additional low frequency band on a carrier frequency intermediate in the frequency scale to said first mentioned carrier frequencies, and a receiving station including means adapted to receive only the carrier frequencies transmitting the sub-bands of the message frequency band, and means for combining said sub-bands in their original relation.

4. In a radio transmitting system a sending station including means for dividing the message frequency band into sub-bands and for radiating each of said sub-bands on a separate carrier frequency, means for producing an additional low frequency band, means for radiating said additional low frequency band on a carrier frequency intermediate in the frequency scale to said first

mentioned carrier frequencies and a receiving station including an arrangement of circuits so tuned that only said first mentioned carrier frequencies will be detected.

5. The method of radio transmission which consists in dividing the message frequency band at the sending station into sub-bands, radiating each of said sub-bands on a separate carrier frequency, producing at the sending station a disturbing low frequency band, and radiating said low frequency band on carrier frequencies adjacent in the frequency scale to said first mentioned carrier frequencies.

6. In a radio transmission system, a sending station, means at said sending station for dividing the message frequency band into sub-bands, means for translating each sub-band into a band of radio frequencies having a width no greater than that of the corresponding sub-band, whereby each band when transmitted may be received to the exclusion of other bands by ordinary sharply tuned selective apparatus, without appreciable distortion due to the width of the band.

7. In a radio transmission system, a sending station, means at said sending station for dividing the message frequency band into sub-bands, means for translating each sub-band into a band of radio frequencies having a width no greater than that of the corresponding sub-band, whereby each band when transmitted may be received to the exclusion of other bands by ordinary sharply tuned selective apparatus without appreciable distortion due to the width of the band, and means at a receiving station for selecting the individual bands thus radiated to the exclusion of other bands, and means for detecting therefrom the original sub-bands and for combining the sub-bands together to form a signal.

8. In a radio transmission system, a sending station, means at said sending station for dividing the message frequency band into sub-bands, means for translating each sub-band into a band of radio frequencies having a width no greater than that of the corresponding sub-band, and means for transmitting certain of the translated bands with their frequency relations inverted with respect to the original sub-band, whereby each band when transmitted may be received to the exclusion of other bands by ordinary sharply tuned selective apparatus, without appreciable distortion due to the width of the band.

9. In a radio transmission system, a sending station, means at said sending station for dividing the message frequency band into sub-bands, means for modulating separate carrier frequencies in accordance with the sub-bands, and means for radiating one only of the side bands involved in each separate modulation to the exclusion of the other side band and the carrier frequency, whereby each band may be detected without distortion by a receiving station sharply tuned in the neighborhood of one of the bands and the detected signal will be unintelligible.

10. In a radio transmission system, a sending station, means at said sending station for dividing the message frequency band into sub-bands, means for translating each sub-band into a band of radio frequencies having a width no greater than that of the corresponding sub-bands, means for simultaneously radiating the several translated bands, and means for simultaneously transmitting other bands lying in frequency ranges intermediate to the radiated bands corresponding to the signal.

11. In a radio transmission system, a plurality of sending stations, means at each sending station for dividing a message to be transmitted from said station into sub-bands, means at each station for translating the various sub-bands into radio bands of corresponding width, said means being arranged so that the several bands radiated from each station will be separated from each other, and means to transmit disturbing bands which will lie intermediate between said bands of a given station, thereby producing disturbing frequencies at receiving stations which are not arranged to discriminate against undesired bands.

12. The method of obtaining secrecy in the transmission of intelligence, which consists in dividing each of a plurality of message frequency bands into sub-bands, translating each sub-band into corresponding radio frequency bands, the radio frequency bands being so arranged that sub-bands of different messages will be intermingled in the frequency spectrum.

13. The method of secret multiplex transmission, which consists in producing a number of message frequency bands, dividing each message frequency band into a plurality of sub-bands, translating each sub-band into a corresponding radio frequency band, the radio frequency sub-bands corresponding to each signal being so related to each other and to the sub-bands of other signals that sub-bands of different signals will lie adjacent to each other in the frequency spectrum.

In testimony whereof, we have signed our names to this specification this 18th day of November, 1920.

JOHN STONE STONE.
CLAUDE CUSTER ROSE.