Feb. 15, 1927. 1,617,934

H. A. AFFEL

CARRIER TELEGRAPH SYSTEM

Filed Dec. 30, 1924 3 Sheets-Sheet 1

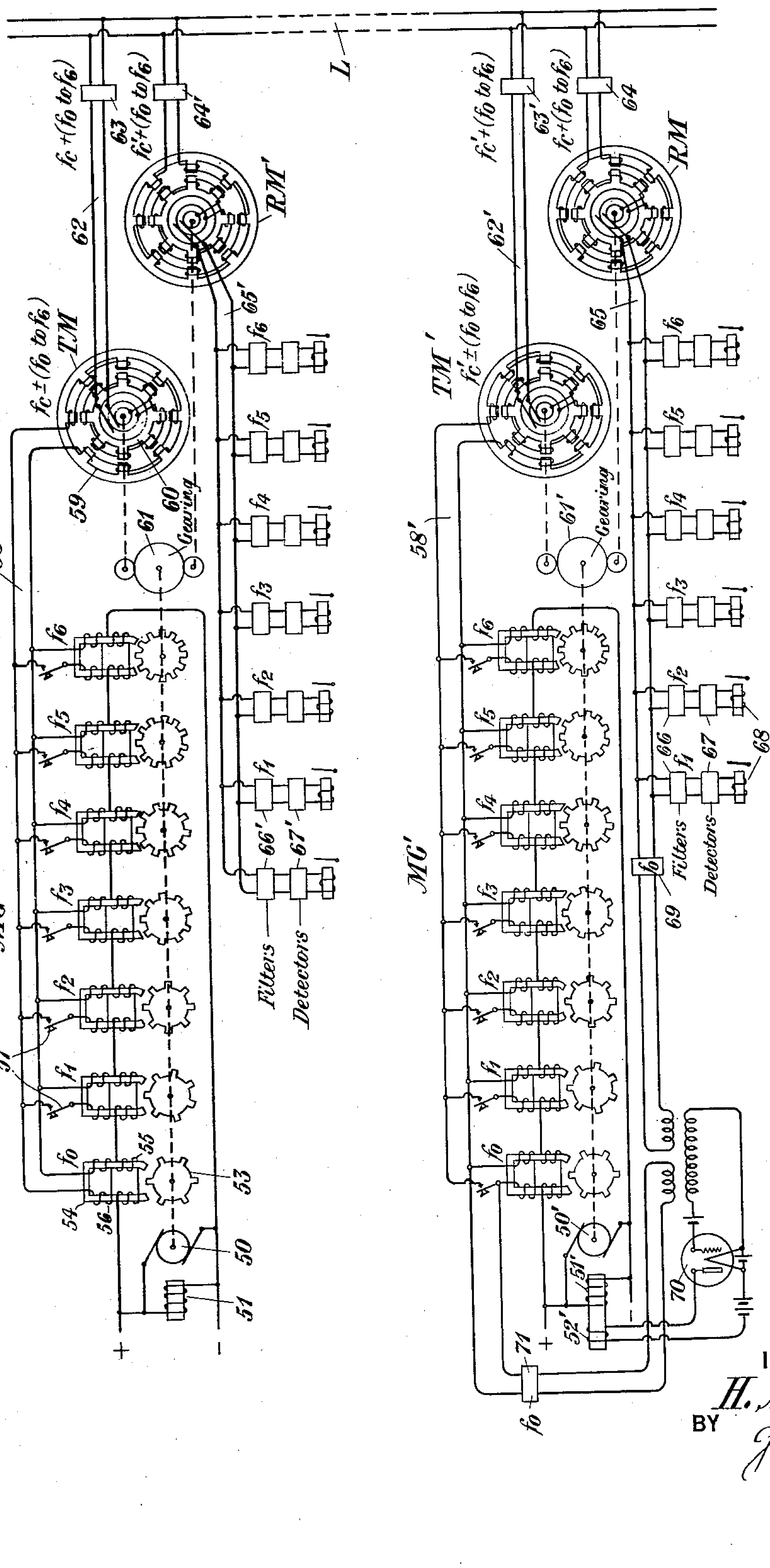

Fig. 1

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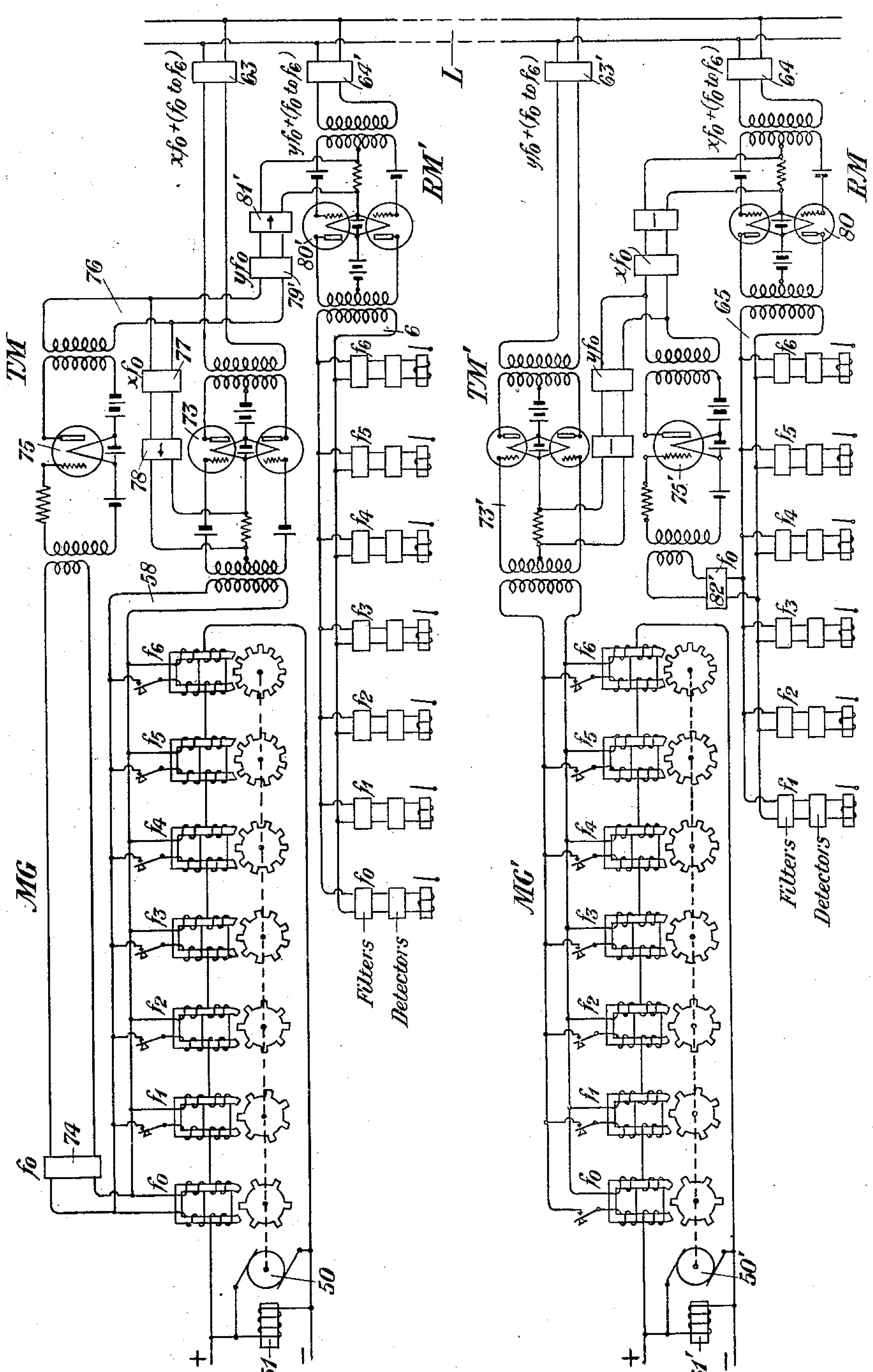

Fig. 2

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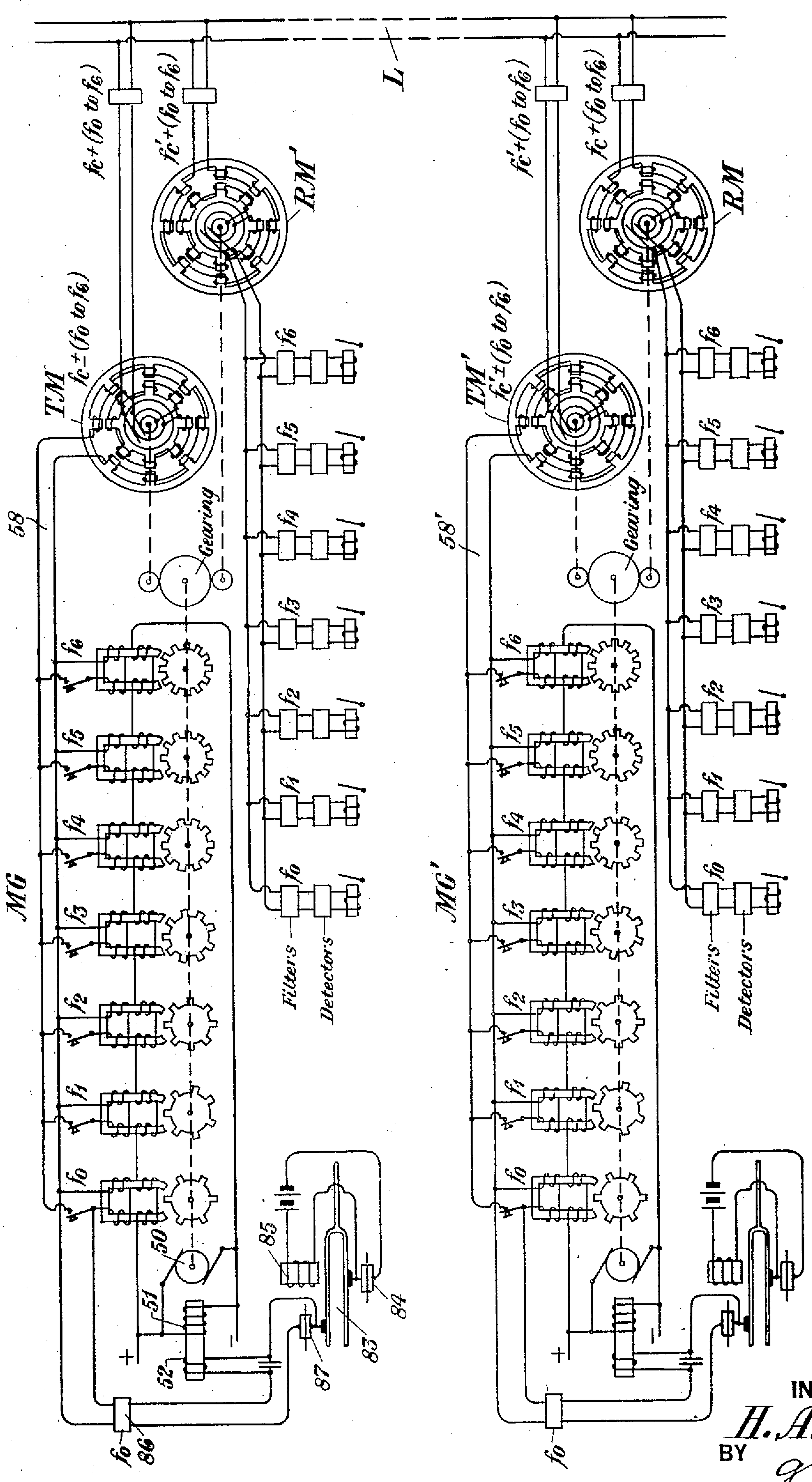

Fig. 3

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UNITED STATES PATENT OFFICE.

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CARRIER TELEGRAPH SYSTEM.

Application filed December 30, 1924. Serial No. 758,881.

This invention relates to carrier telegraph systems, and more particularly to arrangements for increasing the number of channels in a given frequency range.

Heretofore carrier telegraph systems have been of two types,—(*a*) systems employing carriers above the voice range so that the carrier channels may be superposed upon an ordinary telephone line without interference with ordinary voice transmission, and (*b*) systems employing carrier frequencies within the voice range, such systems being adapted for use on ordinary telephone transmission lines without changing the transmission characteristics of the lines. The latter type of system usually enables the employment of a greater number of carrier channels within the voice range than is possible in a band of equal width above the voice range where a system of the first type is employed. This follows from the fact that for a given spacing of the carrier frequencies employed, the frequency separation between any two adjacent frequencies will be a greater percentage of the absolute carrier frequency in the case of low frequency carriers, than in the case of high frequency carriers. With a selective circuit or given efficiency, it follows therefore that the low frequency carriers may be more closely spaced than the high frequency carriers.

Carrier telegraph systems of the second type above referred to have the obvious disadvantage that they may only be used upon telephone circuits where the circuits are not necessary for ordinary telephone transmission. In accordance with the present invention it is proposed to utilize apparatus of the type heretofore employed for carrier telegraph transmission within the voice range for obtaining an equal number of carrier telegraph channels in a band of the same width above the voice range. This result may be obtained by first impressing signals on the low frequency carriers and then modulating the low frequency telegraph carriers with a carrier of high frequency, thereby producing side bands each containing individual bands corresponding to the low frequency carriers, and separated from each other by the same distance as the low frequency carriers, these bands, however, being elevated in the frequency spectrum with respect to the original telegraph bands. One of the resultant side bands will be suppressed leaving only one stepped up band for each original telegraph band. Preferably, the carrier component resulting from the second step of modulation will also be suppressed thereby reducing the energy transmitted over the circuits. At the receiving stations the stepped up telegraph channels will be restored to their original frequency range by a corresponding demodulating step. The telegraph signals may then be detected from the low frequency carriers in the usual manner.

The invention may now be more fully understood from the following description when read in connection with the accompanying drawing, Figures 1, 2 and 3 of which show circuit diagrams illustrating three different embodiments of the invention.

Referring to Fig. 1, a multi-frequency generator MG is illustrated for generating a plurality of carrier frequencies within the voice range. This generator comprises a driving motor having an armature 50 and a field winding 51. The motor is arranged to drive a shaft carrying a plurality of toothed rotor members 53. Each rotor member will have a different number of teeth, the teeth being arranged to rotate in the magnetic field of polar magnetic structures such as 54. Suitable coils 55 are wound about the pole pieces of the magnetic structures, and these coils are energized from a direct current source thereby producing a flux between the pole pieces which is varied as the teeth of the rotor members 53 rotate. Secondary windings 56 are also included in the magnetic structures. Alternating currents are induced in these secondary windings by the variations in flux produced in the magnetic circuits by the rotation of the rotor members.

The frequency of the alternating currents thus produced by any one of the magnetic circuits above described will depend upon the speed of the driving shaft and the number of teeth upon each rotor. In the case illustrated, the several frequencies generated are assumed to be frequencies f_0, f_1, f_2, f_3, f_4, f_5 and f_6. The currents of these several frequencies may be interrupted in accordance with a telegraph code by means of keys such as 57, and the currents may all be superposed upon a common transmission circuit 58.

So far the apparatus described is similar to that employed for multiplex carrier telegraph transmission within the voice range, the frequencies generated in the various magnetic circuits being relatively low frequencies. In order to step up the carrier channels to a point above the voice range, a modulating machine is provided, this machine comprising a relatively high frequency alternator having a toothed rotor member 60 and a toothed stator member 59. The rotor member is mounted upon a shaft geared by suitable gearing 61 to the shaft of the multi-frequency generator previously described. Coils are wound upon each of the teeth of the stator in order to provide the field windings of the machine, these coils being connected to the transmission circuit 58, carrying the superposed low frequency carriers. Similar coils are also wound upon the teeth of the rotor, these coils being connected through suitable slip rings to a circuit 62 connected through a filter 63 to the transmission line L. The machine TM, when its field winding is excited by carrier frequencies produced by the multi-frequency generator, operates as a modulating device, producing two side bands. The carrier component itself is suppressed, however, as the rotor windings are only energized when the low frequency modulated carriers are impressed upon the circuit 58 and the magnetic flux in the stator windings is at all times directly proportional to the amplitude of the energizing currents. The filter 63 is designed to suppress one of the side bands resulting from the modulating action of the machine TM.

At the distant station a similar multi-frequency generator MG′ is provided, this generator and its associated circuits being identical in all respects to the multi-frequency generator MG already described, except that the driving motor is provided with an auxiliary winding 52′ in addition to the field winding 51′, the auxiliary winding being provided for a purpose which will more fully appear hereinafter. A modulating machine TM′ similar to the machine TM already described is also provided at the distant station, this machine being geared through gearing 61′ to the shaft of the multi-frequency generator MG′. The gearing ratio is made different in this case, however, in order that the effective carrier frequency of the modulating machine will be such as to step up the low frequency bands to a range different from those transmitted by the modulating machine TM. The rotor windings of the modulating machine TM′ are connected by a circuit 62′ to the line L through a filter 63′ which is designed to suppress one of the side bands generated by the modulator.

A demodulating machine RM is also provided at the distant station, this machine being similar in its construction to the modulating machine TM already received. The stator windings of this machine, however, are connected to the line L through a filter 64, this filter being designed to pass the same band of frequencies as the filter 63. The rotor windings of the machine RM are connected through suitable slip rings to a circuit 65. The action of the machine RM is to beat the received band of carrier frequencies with a frequency corresponding to the carrier frequency of the modulator TM thereby producing difference frequencies corresponding to the original low frequency carriers impressed upon the circuit 58. These stepped down frequencies are therefore impressed upon the circuit 65. A plurality of branch receiving circuits are connected with the circuit 65 through filters such as 66, these filters being arranged to select the original carrier frequencies, such as f_1, f_2, etc. Suitable detecting devices of a well known type are conventionally indicated at 67, these detecting devices being included in the individual branches for the purpose of detecting from the low frequency received carriers direct current impulses corresponding to the telegraph signals transmitted by the keys 57 at the transmitter. Receiving relays or sounders such as 68 are connected to the detectors to be actuated by the detected telegraph currents.

At the station where the multi-frequency generator MG is located, receiving equipment similar to that just described is also provided, this receiving equipment comprising a demodulating machine RM′ geared to the shaft of the multiple generator MG, the ratio of the gearing being such that the beating frequency of the demodulating machine RM′ will be the same as the carrier frequency of the modulating machine TM′, assuming, of course, that the driving shafts of the multi-frequency generators MG and MG′ are rotated at the same speed. The rest of the receiving equipment is identical with that already described and need not be further discussed.

For the proper functioning of the apparatus above disclosed, it is desirable that the motors driving the multi-frequency generators MG and MG′ rotate at the same speed. In order to accomplish this result, one of the frequencies generated by the multi-frequency generator MG, for example, the frequency f_0, is utilized as a synchronizing frequency. This frequency is stepped up by the transmitting modulator TM along with the other low frequency carriers, and upon being transmitted to the distant station is demodulated by the demodulating machine RM to restore it to its original frequency level. A filter 69 is connected in a branch leading from the circuit 65 to transmit the received synchronizing frequency to a suitable detector 70. The corresponding frequency f_0 generated by the multi-frequency generator MG′ is led off from the machine through a similar filter 71, so that this frequency is also impressed upon the input circuit of the detector 70. The output circuit of said detector includes the auxiliary winding 52′ previously referred to.

Whenever the motor driving the shaft of the machine MG′ tends to change its speed, the frequency f_0 generated by the machine will be different from the frequency f_0 generated by the machine MG and selected from the circuit 65 by the filter 69. The detected direct current component in the output circuit of the detector 70 will have a given amplitude when the local frequency f_0 and the received frequency f_0 are in synchronism, but as these two frequencies depart from synchronism the detected direct current component changes in amplitude. Consequently, when the motor driving the multi-frequency generator MG′ changes its speed with the result that the locally generated frequency f_0 departs from synchronism with the received frequency f_0, the energizing current in the auxiliary winding 52′ of the motor will change in value. The magnetic flux of the field of the motor will therefore be changed to restore the motor to its original speed. The motor driving the multi-frequency generator MG′ will therefore rotate at the same speed as the motor driving the multi-frequency generator MG, and consequently the carrier frequencies of the transmitting modulator TM and receiving demodulator RM will be the same. Likewise the carrier frequency of the transmitting modulator TM′ and the receiving modulator RM′ will be the same.

The various frequencies generated by the multi-frequency generator MG other than the frequency f_0, which is used for synchronizing, may be interrupted in accordance with the telegraph code by the keys 57 so that separate telegraph signals may be impressed upon each carrier. The resultant low frequency carriers are impressed upon the stator windings of the machine TM. The action of the machine TM is to produce in the rotor windings two side bands, each including components corresponding to the original low frequency carriers, these side bands being related to a carrier suppressed by the machine, the frequency of this carrier being determined by the number of teeth in the machine and the speed of rotation. This carrier is assumed to be a frequency f_c. One of the side bands, for example, the lower side band, is suppressed by the filter 63 which transmits the upper side band $f_c+(f_0$ to $f_6)$.

This side band, it will be noted, contains frequencies corresponding to each of the original frequencies f_0 to f_6, inclusive, and these frequencies are transmitted over the line L and passed through the filter 64 to the stator windings of the demodulating machine RM. The machine RM beats the received band with a frequency f_c to produce sum and difference frequencies. The difference frequencies corresponding to the original frequencies f_0 to f_c, inclusive, are impressed upon the circuit 65. The frequencies f_1 to f_6 carrying the telegraph signals are selected by the filters 66, and the telegraph signals are in turn detected by the detectors 67 to operate the individual receiving devices. The frequency f_0, which carries no signals, passes through the filter 69 to control the synchronizing arrangement, as already described.

Transmission in the opposite direction by means of the frequencies generated by the multi-frequency generator MG′ is similar to that already described herein. It should be noted, however, that the frequency f_0 generated by the machine MG′ is not used for synchronizing purposes when received at the distant end, and consequently this frequency may be interrupted by means of a suitable key to transmit telegraph signals. It follows therefore that the arrangement above described involves one less telegraph channel for transmission in one direction than in the case of transmission in the other direction, the omitted channel being used for synchronizing purposes.

A modified arrangement is illustrated in Fig. 2, this arrangement employing vacuum tube modulators and demodulators for the stepping up and stepping down operation. The carrier frequencies for the modulators and demodulators are supplied by a harmonic producer and by employing one of the low frequency carriers, as, for example, f_0, as the base frequency of the harmonic producer at both stations, synchronism may be obtained. The step-up apparatus TM comprises a balanced modulator 73 of the vacuum tube type, having its input circuit associated with the common circuit 58 leading to the multi-frequency generator MG. In order to provide the carrier frequency for energizing the modulator, the frequency f_0 generated by the machine MG is taken off through a filter 74 and impressed upon the vacuum tube distorting device 75 which produces harmonics of the beating frequency f_0. These harmonics are impressed upon circuits 76. A filter 77 selects one of the harmonics, for example, the harmonic xf_0 which is to be used as the carrier for the modulator 73. An amplifying device 78 is provided for amplifying the selected harmonic and impressing it upon the modulator. A second filter 79′ is provided for selecting another harmonic, for example, yf_0 to be used as the carrier for supplying the receiving demodulator at the same station. This demodulator comprises a balanced vacuum tube arrangement 80′ having its input circuit connected through the filter 64′ to the line L. The harmonic which is selected by the filter 79′ is amplified by a suitable amplifier 81′ and impressed upon the common branch of the input circuit of the demodulator.

The modulator 73′ and the demodulator 80 at the distant station are similar to the corresponding devices already described. The base frequency from which the carriers are to be generated is in this instance obtained from the circuit 65 by means of a filter 82′. This frequency is impressed upon a distorting device 75 thereby producing harmonics corresponding to xf_0 and yf_0, the former being impressed upon the detector 80 and the latter upon the modulator 73′.

The various low frequency carriers f_0 to f_6, inclusive, are impressed through the circuit 58 upon the modulator 73. The frequency f_0 is also impressed upon the distorting tube 75, as already described, thereby producing the harmonic xf_0 for supplying the carrier to the modulator 73. The modulator produces upper and lower side bands containing frequencies corresponding to the frequencies generated by the multi-frequency generator MG. The carrier frequency xf_0 is suppressed, however, by the balanced arrangement of the modulator 73. The filter 63 suppresses one of the side bands, say the lower side band, and the upper side band is transmitted over the line L and through the filter 64 to the demodulator 80. The harmonic xf_0 supplied to the demodulator 80 by the distorting device 75′ beats with the received band to produce difference frequencies corresponding to the original frequencies f_0 to f_6, inclusive. The frequencies f_1 to f_6, inclusive, carrying signals, are detected to operate the receiving devices in the manner already described. The controlling frequency f_0 is selected by the filter 82′ to control the harmonics generated by the harmonic generator 75′.

Transmission in the opposite direction will be similar to that already described except that in this case the frequency f_0 generated by the machine MG′ is used for signaling, this frequency not being necessary as a controlling frequency for transmission in this direction.

Fig. 3 shows an arrangement in which all of the frequencies generated by the multi-frequency generators MG and MG′ may be utilized for transmitting signals. This is accomplished by arranging the motors driving the multi-frequency generators so that the speed of each motor is controlled locally by a constant frequency device, such, for example, as a tuning fork of great frequency stability. It is therefore unnecessary to transmit the frequency f_0 uninterrupted by signals to the distant station to control the motor thereat.

The synchronizing apparatus in detail comprises a tuning fork 83 having one of its vibrating tines arranged to operate a current changing device, such, for example, as a microphone 84, included in the local circuit with a magnet 85. The magnet 85, as the current therethrough is varied at a frequency determined by the natural period of the tuning fork, acts upon the tuning fork to keep it continually in vibration at its natural frequency. Part of the energy of the frequency f_0 generated by the multi-frequency generator MG is passed through a filter 86, and this frequency flows through a second microphone device 87 which is also operated by the tuning fork. The auxiliary winding 52 of the motor is connected in circuit with the microphone 87 which acts as a modulator so that a direct current component is supplied to the auxiliary winding 52 depending on the synchronization of the frequency f_0 transmitted through the filter 86 with the frequency of vibration of the microphone 87. Any tendency of the motor 50 to vary its speed is therefore counteracted by the compensating current supplied to the winding 52.

A similar apparatus is provided at the distant station for controlling the motor thereat. In each case the frequency f_0 of the multi-frequency generator is used locally for controlling the speed of the motor. Consequently this frequency may in both cases be used for telegraph signals by providing a suitable key to interrupt the transmission of the frequency to the circuit 58 or 58′, as the case may be. The modulating and demodulating apparatus TM, RM′, etc., for stepping up and stepping down the frequencies is of the type illustrated in Fig. 1, and the operation during transmission in either direction will be clear without further description.

It will be obvious that the general principles herein described 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 carrier telegraph system, means to generate a plurality of closely spaced carrier frequencies within the voice range, means to impress separate telegraph signals upon the various carrier frequencies, a modulator having an effective carrier frequency whose ratio is defined with respect to one of said first mentioned carrier frequencies, means to determine said ratio, means to impress the various bands resulting from signaling upon said modulator to produce side bands at least one of which is above the voice range, means to transmit a side band above the voice range, the transmitted band comprising sub-bands corresponding to the original bands and having the same frequency separation.

2. In a carrier telegraph system, means to generate a plurality of closely spaced carrier frequencies within the voice range, means to impress separate telegraph signals upon the various carrier frequencies, a modulator having an effective carrier frequency whose ratio is defined with respect to one of said first mentioned carrier frequencies, means to determine said ratio, means to impress the various bands resulting from signaling upon said modulator to produce side bands at least one of which is above the voice range, means to transmit a side band above the voice range, the transmitted band comprising sub-bands corresponding to the original bands and having the same frequency separation, a demodulating apparatus at the receiving station for effectively beating the received transmitted band with an effective carrier frequency bearing a definite ratio to one of the originally generated carrier frequencies, means to determine said last mentioned ratio, means to select from said demodulating apparatus bands within the voice range corresponding to the original bands, and means to separately detect signals from said bands.

3. In a carrier signaling system, a multi-frequency alternator for generating a plurality of closely spaced carrier frequencies within the voice range, one of said frequencies being a controlling frequency, means to impress signals upon the carrier frequencies, a modulator having an effective carrier frequency bearing a defined ratio to said controlling frequency, means controlled by said controlling frequency to determine said ratio, means to apply said controlling frequency together with other frequencies generated by said multi-frequency alternator upon said modulator to produce side bands at least one of which is above the voice range, and means to transmit one of said side bands, said transmitted side band containing carrier frequencies corresponding to frequencies generated by said multi-frequency generator and having the same frequency spacing.

4. In a carrier signaling system, a multi-frequency alternator for generating a plurality of closely spaced carrier frequencies within the voice range, one of said frequencies being a controlling frequency, means to impress signals upon the carrier frequencies, a modulator having an effective carrier frequency bearing a definite ratio to said controlling frequency, means controlled by said controlling frequency to determine said ratio, means to apply said controlling frequency together with other frequencies generated by said multi-frequency alternator upon said modulator to produce side bands one of which is above the voice range, means to transmit one of said side bands, said transmitted side band containing carrier frequencies corresponding to the frequencies generated by said multi-frequency generator and having the same frequency spacing, a demodulating apparatus at the receiving station for effectively beating the received transmitted band with an effective carrier frequency bearing a definite ratio to said controlling frequency, means to detect from said demodulating apparatus said controlling frequency and bands within the voice range corresponding to the original bands, means to separately detect signals from said bands, and means controlled by said detected controlling frequency to determine said last mentioned ratio.

5. In a carrier signaling system, a multi-frequency alternator for generating a plurality of closely spaced carrier frequencies within the voice range, one of said frequencies being a controlling frequency, means to impress signals upon the carrier frequencies, a modulator having an effective carrier frequency bearing a fixed ratio to said controlling frequency, means to apply said controlling frequency together with other frequencies generated by said multi-frequency alternator upon said modulator to produce side bands at least one of which is above the voice range, means to suppress the carrier frequency component and one of said side bands while transmitting the other side band, said other side band containing carrier frequencies corresponding to frequencies generated by said multi-frequency generator and having the same frequency spacing, a modulating arrangement at a receiving station for beating the received transmitted band with an effective carrier frequency, means controlled by the component of the received band corresponding to the controlling frequency for maintaining said effective carrier frequency the same as the effective carrier frequency of the modulator, means to select from the demodulator fre-

quencies within the voice range corresponding to the frequencies generated by said multi-frequency generator, and means to detect signals from said frequencies.

6. In a carrier signaling system, a motor-driven multi-frequency alternator for generating a plurality of closely spaced carrier frequencies within the voice range, means to impress signals on said carrier frequencies, a modulating alternator for producing an effective carrier frequency to which the modulated bands corresponding to the modulated carriers of the multi-frequency generator may be applied, said modulating alternator being driven by the motor which drives said multi-frequency alternator so that the effective carrier frequency of the modulating alternator will bear a fixed ratio to at least one of the frequencies generated by the multi-frequency alternator, means to select from the output of said modulating alternator a band comprising a plurality of sub-bands corresponding to the originally modulated band impressed upon the modulating alternator.

7. In a carrier signaling system, a motor-driven multi-frequency alternator for generating a plurality of closely spaced carrier frequencies within the voice range, means to impress signals on said carrier frequencies, a modulating alternator for producing an effective carrier frequency to which the modulated bands corresponding to the modulated carriers of the multi-frequency generator may be applied, said modulating alternator being driven by the motor which drives said multi-frequency alternator so that the effective carrier frequency of the modulating alternator will bear a fixed ratio to at least one of the frequencies generated by the multi-frequency alternator, means to select from the output of said modulating alternator a band comprising a plurality of sub-bands corresponding to the original modulated bands impressed upon the modulating alternator, a demodulating alternator at the receiving station, means to drive said demodulating alternator so as to produce an effective beating frequency corresponding to the effective carrier frequency of said modulating alternator, means to select from the output of said demodulating alternator frequencies corresponding to the frequencies originally generated by said multi-frequency generator, and means to detect signals from said selected frequencies.

8. In a carrier telegraph system, a multi-frequency alternator for generating a controlling frequency and a plurality of carrier frequencies within the voice range, a motor for driving said alternator, means for impressing signals upon said carrier frequencies, a modulating alternator upon which the resultant signaling bands may be impressed, means whereby said motor for driving said multi-frequency generator will drive said modulating alternator to produce an effective carrier frequency bearing a constant ratio to said controlling frequency, and means to select from the output of said modulating alternator a band of frequencies comprising a plurality of sub-bands corresponding to the original carrier bands.

9. In a carrier telegraph system, a multi-frequency alternator for generating a controlling frequency and a plurality of carrier frequencies within the voice range, a motor for driving said alternator, means for impressing signals upon said carrier frequencies, a modulating alternator upon which the resultant signaling bands may be impressed, means whereby said motor for driving said multi-frequency generator will drive said modulating alternator to produce an effective carrier frequency bearing a constant ratio to said controlling frequency, means to select from the output of said modulating alternator a band of frequencies comprising a plurality of sub-bands corresponding to the original carrier bands, a demodulating alternator at the receiving station, a motor for driving said demodulating alternator to produce an effective beating frequency corresponding to the effective carrier frequency of said modulating alternator, means to select from the output of said demodulating alternator frequencies coresponding to the original frequencies modulated by the multi-frequency generator, means to detect signals from said frequencies, and means to control the speed of said last mentioned motor in accordance with a component selected from the output of said demodulating alternator and corresponding to said controlling frequency.

10. In a carrier telegraph system, a multi-frequency generator for generating a plurality of closely spaced carrier frequencies within the voice range, a motor for driving said generator, means to impress signals upon said carrier frequencies, a modulating alternator, means to impress the signaling band resulting from said signals upon said modulating alternator, means whereby said alternator may be driven by the motor for driving said multi-frequency generator so as to produce an effective carrier frequency so chosen as to produce side bands at least one of which is above the voice range, means to select and transmit one of said side bands above the voice range, apparatus similar to that above described at a distant station but differing therefrom in that the modulating alternator at the distant station is driven by the motor at such a speed as to produce an effective carrier frequency which will result in the production of a side band lying in a different range from the side band transmitted from the first station, demodulating alternators at each station, said de-

modulating alternators being driven by the motors for driving the multi-frequency generators at each station at speeds such that each demodulating alternator will produce an effective beating frequency corresponding to the effective carrier frequency of the modulating alternator at the other station, means to select from each demodulating alternator frequencies corresponding to the frequencies generated by the multi-frequency generator at the other station, and means to detect signals from the selected frequencies.

In testimony whereof, I have signed my name to this specification this 29th day of December, 1924.

HERMAN A. AFFEL.