Dec. 31, 1929. C. W. GREEN 1,741,767

CARRIER CURRENT SIGNALING SYSTEM

Filed June 22, 1927 3 Sheets-Sheet 1

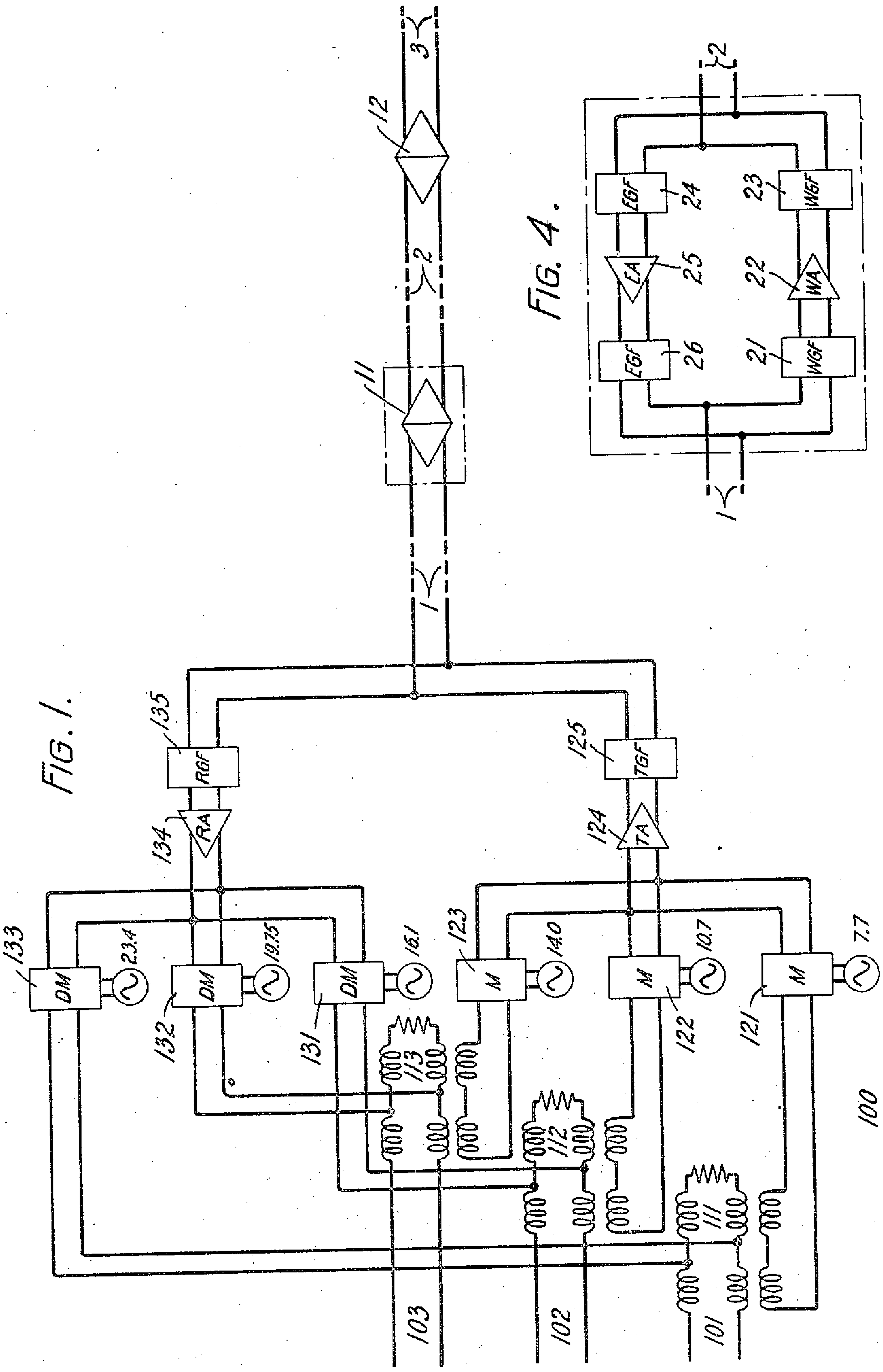


FIG. 1.

FIG. 4.

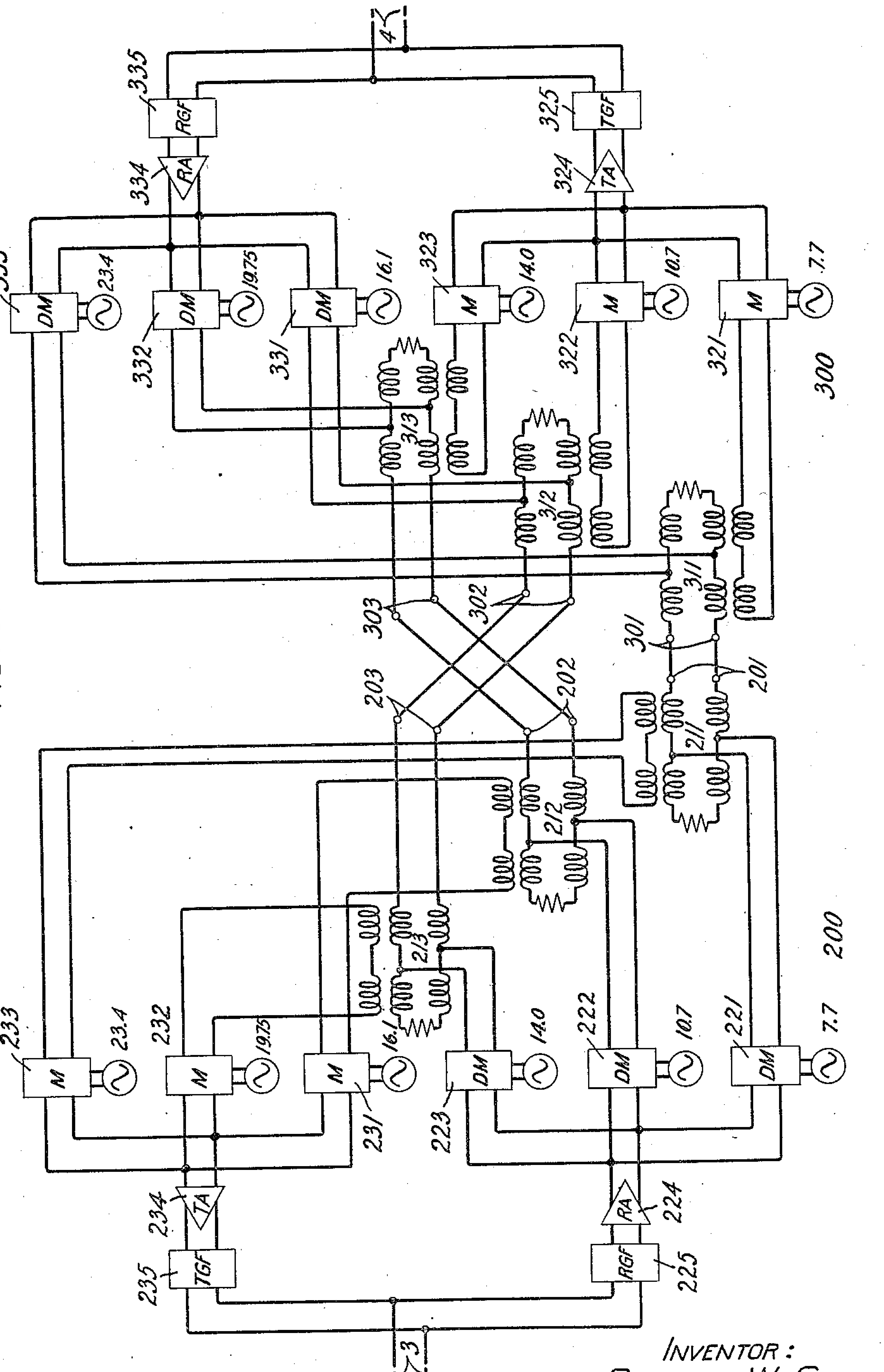
INVENTOR:
CHARLES W. GREEN
BY W. Griggs
ATTORNEY

Dec. 31, 1929. C. W. GREEN 1,741,767

CARRIER CURRENT SIGNALING SYSTEM

Filed June 22, 1927 3 Sheets-Sheet 2

FIG. 2.



INVENTOR:
CHARLES W. GREEN

BY E. W. Griggs ATTORNEY

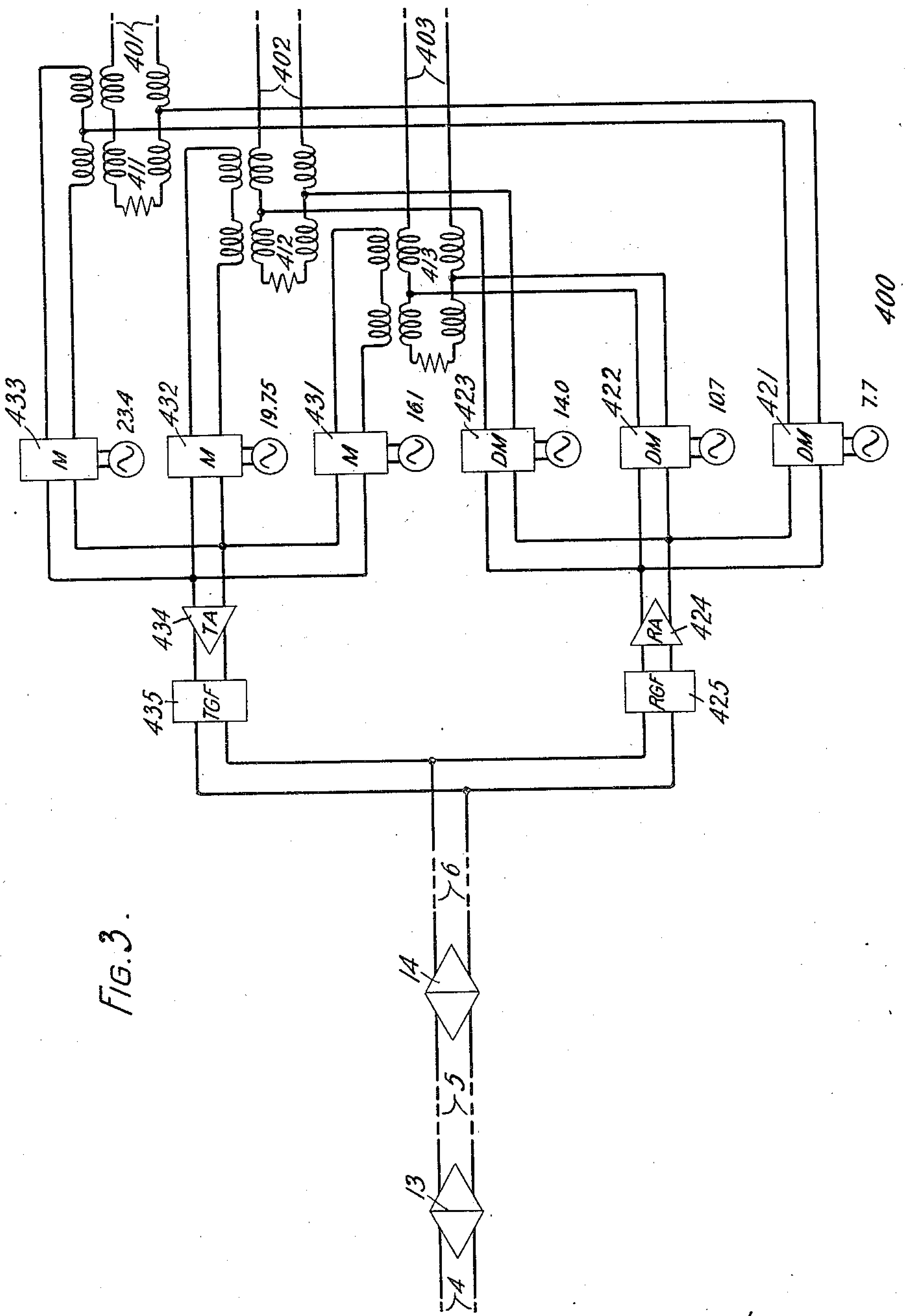


FIG. 3.

INVENTOR:
CHARLES W. GREEN
BY W. Griggs
ATTORNEY

Patented Dec. 31, 1929 1,741,767

UNITED STATES PATENT OFFICE

CHARLES W. GREEN, OF MILLBURN, NEW JERSEY, ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

CARRIER-CURRENT SIGNALING SYSTEM

Application filed June 22, 1927. Serial No. 200,545.

This invention relates to carrier current signaling systems and particularly to systems of that type in which messages of oppositely directed channels are separately grouped and transmitted over a line employing a large number of repeaters, and has for an object to reduce the distortion in such systems.

In one type of carrier current signaling system different carrier frequencies are employed for transmitting in the two directions and at repeater stations the waves used for transmitting in one direction are separated from those used for transmitting in the other direction by the use of so-called grouping filters. When the channels are arranged relatively close to one another in the frequency spectrum as is the usual commercial practice when it is desired to make use of the maximum capacity of a line, distortion will be produced in those channels which lie closest to the cut-off frequencies of the grouping filters. This is due to the fact that the attenuation produced by the filters is higher at frequencies near the cut-off than at other frequencies in the transmission band. In most systems in which only a few repeaters are required this distortion is not ordinarily large enough to be material or may be corrected by the use of attenuation equalizers without introducing a prohibitive loss into the system. However, since the distortion produced by successive filters is cumulative the overall quality of the system is often seriously affected by the use of a large number of repeaters.

In a specific preferred embodiment, this invention comprises a carrier current telephone system in which different groups of channels are employed for transmitting in the two directions, at least two channels being used for transmitting in each direction. Approximately half way between the two terminals of the system the channel which is located closest to the cut-off frequency of each grouping filter is transposed to a different position in the frequency spectrum and the channel which previously occupied that position is transposed to the position nearest the cut-off frequency. This transposition is effected by demodulating the side bands and modulating a different carrier by the resulting wave. With this arrangement the distortion produced in any one channel is only a fraction of that which would be otherwise produced.

If at least three channels are employed for transmitting in each direction and the system is of sufficient length to require such precautions it may be divided into three sections and the channels twice transposed so that no one channel will occupy the position nearest the cut-off frequency of the grouping filters over more than one-third of the system.

This invention is illustrated in the accompanying drawing in which Figs. 1, 2 and 3 arranged end to end show diagrammatically one embodiment thereof in a carrier telephone system employing six one-way channels and Fig. 4 shows diagrammatically the arrangement of the carrier repeater apparatus at one of the repeater stations.

The west terminal 100 of the system shown at the left of Fig. 1 comprises three two-way low frequency lines 101, 102 and 103 which are connected through the corresponding hybrid coils or balance transformers 111, 112 and 113 to the respective one-way carrier circuits. For example, waves from the line 101 are modulated in the modulator 121 to be transmitted over the main transmission line while waves from the main line are demodulated in the demodulator 133 to be impressed on the line 101 through the hybrid coil 111. Similarly, the line 102 is associated with the modulator 122 and the demodulator 131 and line 103 is associated with the modulator 123 and the demodulator 131. The frequency of the carrier waves supplied to the respective modulators and demodulators are given in kilocycles by the figures associated with the oscillator of each modulator or demodulator. The particular distribution of channels with respect to the low frequency lines is the same as that disclosed and claimed in U. S. Patent 1,665,673, granted to W. B. Nottingham April 10, 1928, which arrangement is made for the purpose of reducing the crosstalk.

This system is of the carrier suppression type in which only one side band is transmitted. The output side bands from the modulators 121, 122 and 123 are transmitted through the transmitting amplifier 124 and the transmitting grouping filter 125 to the first section of the main transmission line 1 while side bands transmitted from the other terminal and corresponding to the carrier frequencies 16,100, 19,750 and 23,400 cycles per second are selected by the receiving grouping filter 135 and transmitted through the receiving amplifier 134 where they are respectively selected by the input filters associated with the demodulators 131, 132 and 133.

Connecting the line sections 1 and 2 is a two-way repeater 11, the arrangement of which is shown in Fig. 4. The side bands employed for transmitting from west to east (namely those corresponding to the carrier frequencies 7,700, 10,700 and 14,000 cycles per second) are selected by the west grouping filter 21 and after being amplified in the west amplifier 22 are transmitted through the west grouping filter 23 to the line section 2. Similarly, the side bands employed for transmitting from east to west (namely those corresponding to the carrier frequencies 16,100, 19,750 and 23,400 cycles per second) are selected by the east grouping filter 24 and after being amplified in the east amplifier 25 are transmitted to the east grouping filter 26 to the line section 1. As is well understood in the art, when voice frequency and telegraph channels are employed they are separated out by means of low pass filters and transmitted around the carrier amplifiers through their amplifiers.

A second two-way carrier amplifier 12 connects the line section 2 with the line section 3 which terminates in the intermediate station 200—300.

Because of the intrinsic resistance of their elements wave filters tend to attenuate those frequencies nearest their cut-off to a greater extent than other frequencies in the transmission band, thus introducing distortion. While for a single filter this distortion can be kept below a point where it has a material effect on the transmitted band, in cases where the bands are transmitted through a large number of filters in succession, the distortion becomes material. Thus as heretofore explained, those side bands of each one-way group of channels which lie closest to the cut-off frequencies of the grouping filters will become materially distorted after being transmitted through several filters. For example, in the system shown the 14,000 cycle and the 16,100 cycle carrier channels are likely to become distorted so that in a system requiring the number of repeaters employed in the system shown in the drawing, it becomes necessary to transpose the channels at an intermediate point in order to obviate this difficulty. For this purpose the intermediate terminal equipment 200—300 shown in Fig. 2 is employed.

The arrangement of the apparatus in each of the terminal equipments 200—300 is similar to that of the apparatus in the east terminal 100 so that the group of west to east channels transmitted through the grouping filter 125 is selected by the receiving grouping filter 225, amplified in the receiving amplifier 224 and demodulated in the respective demodulators 221, 222 and 223 to be transmitted to the respective low frequency lines 201, 202 and 203 through the hybrid coils 211, 212 and 213, while waves from the low frequency lines 202, 203 and 201 are transmitted to the modulators 231, 232 and 233, respectively, where they are modulated to produce side bands which are transmitted to the transmitting amplifier 234 and transmitting grouping filter 235 to the line section 3.

Likewise, the terminal equipment 300 comprises low frequency lines 301, 302 and 303 connected through hybrid coils 311, 312 and 313 which are associated with the modulators 321, 322 and 323 and the demodulators 333, 331 and 332 in the same manner as in the west terminal 100. The output of the modulators is transmitted through the transmitting amplifier 324 and the transmitting grouping filter 325 to the line section 4, while waves therefrom are transmitted through the receiving grouping filter 335 and the receiving amplifier 334 to the demodulators 331, 332 and 333. In order that the bands which occupy the positions closest to the cut-off frequencies of the grouping filters through the first carrier section (i. e. over line sections 1, 2 and 3) should occupy different positions in the frequency spectrum in the second carrier section, the low frequency line 203 is connected to the low frequency line 302, while the line 202 is connected to the line 303. Thus, the band which was transmitted over the 14,000 cycle channel in the first section will be transmitted over the 10,700 cycle channel in the second section and vice versa, and the band which was transmitted over the 16,100 cycle channel in the first section will be transmitted over the 19,750 cycle channel in the second section and vice versa.

The line section 4 is connected to the line section 5 through the two-way repeater 13 and the line section 5 is connected to the line section 6 through the two-way repeater 14. Line section 6 is terminated in the east terminal 400, the apparatus of which is arranged in a similar manner to that in the other terminal equipments. The side bands transmitted by the modulators 321, 322 and 323 being selected by the grouping filter 425 and after being amplified in the receiving amplifier 424 are demodulated in the demodulators

421, 422 and 423 and transmitted to the low frequency lines 401, 403 and 402, respectively, through the hybrid coils 411, 413 and 412, while waves from the low frequency lines 401, 402 and 403 are modulated in the modulators 433, 432 and 431, respectively, to produce side bands which are transmitted through the amplifier 434 and the transmitting grouping filter 435 to the line 6.

Obviously it is not necessary to employ the hybrid coil arrangement in the intermediate terminal equipment 200—300 but instead to connect the corresponding modulators and demodulators directly. However, the use of the hybrid coil arrangement increases the flexibility of the system making it possible to employ part or all of the carrier channels for transmission only from the east or west terminals to the intermediate terminal 200—300 if traffic conditions so require.

What is claimed is:

1. In a multiplex carrier signaling system comprising a line having such a characteristic as to distort waves lying in one portion of the frequency spectrum, and means for transmitting waves over a plurality of channels, the method of limiting the distortion produced in any one channel, which comprises transposing the positions with respect to one another of at least a portion of said channels while keeping the relative positions of the frequencies in each channel the same at an intermediate point on said line so that no one channel will occupy the distorted porton of the frequency spectrum over more than a fraction of the line.

2. In a multiplex carrier signaling system comprising a line, separate groups of channels for transmitting in each direction thereover and a plurality of repeaters distributed along said line and employing filters for separating said groups of channels, each of said filters tending to distort the channels lying closest to its cut-off frequency, the method of limiting the distortion produced in any one channel which comprises transposing the channels in their positions in the frequency spectrum at an intermediate point on said line so that no one channel in either group will occupy the portion of the spectrum closest to the cut-off frequency of the filter over more than a fraction of the line.

3. A carrier signaling system comprising a line tending to distort waves lying in one portion of the frequency spectrum, means for transmitting waves over a plurality of carrier channels, and means located at an intermediate point on said line for transposing at least a portion of said channels in their positions with respect to one another in the frequency spectrum while keeping the relative positions of the frequencies in each channel the same so that no one channel will occupy the distorted portion of the spectrum over more than a fraction of the line.

4. A carrier signaling system according to the next preceding claim in which the means for transposing the channels comprises demodulator and modulator circuits.

5. A multiplex carrier signaling system comprising a line, means for transmitting waves in each direction over separate groups of channels, a plurality of repeaters distributed along said line and each employing filters for separating the group of channels used for transmitting in one direction from the group of channels used for transmitting in the other direction, said filters tending to distort the channel occupying the position closest to its cut-off frequency, and means located at an intermediate point on said line for transposing the channels in each group in their positions in the frequency spectrum so that no one channel of either group will lie in the position closest to the cut-off frequency of the respective filters over more than a fraction of the line.

In witness whereof, I hereunto subscribe my name this 21 day of June A. D., 1927.

CHARLES W. GREEN.