April 19, 1927. 1,624,966

R. W. MORRIS

AMBULATORY REPEATING SYSTEM

Filed Aug. 25, 1923 3 Sheets-Sheet 1

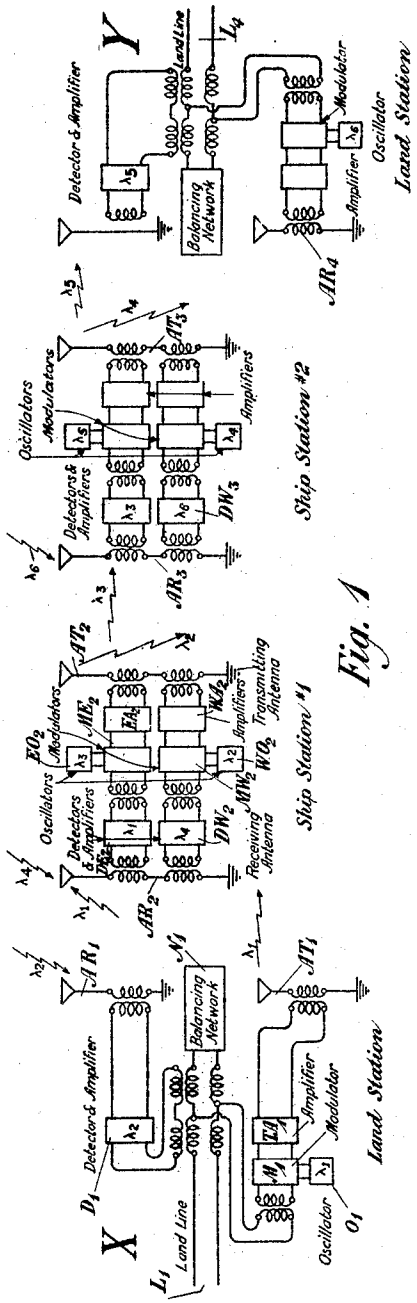


Fig. 1

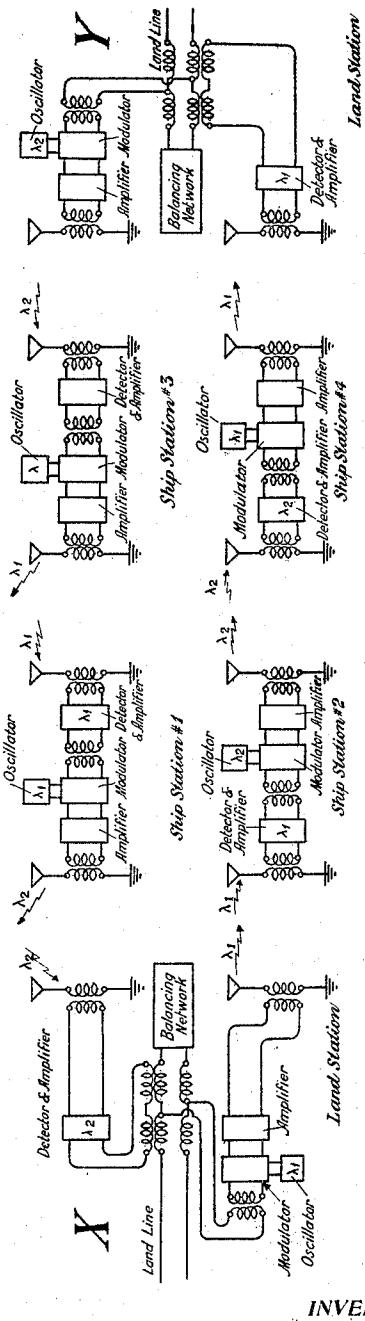


Fig. 2

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Filed Aug. 25, 1923 3 Sheets-Sheet 2

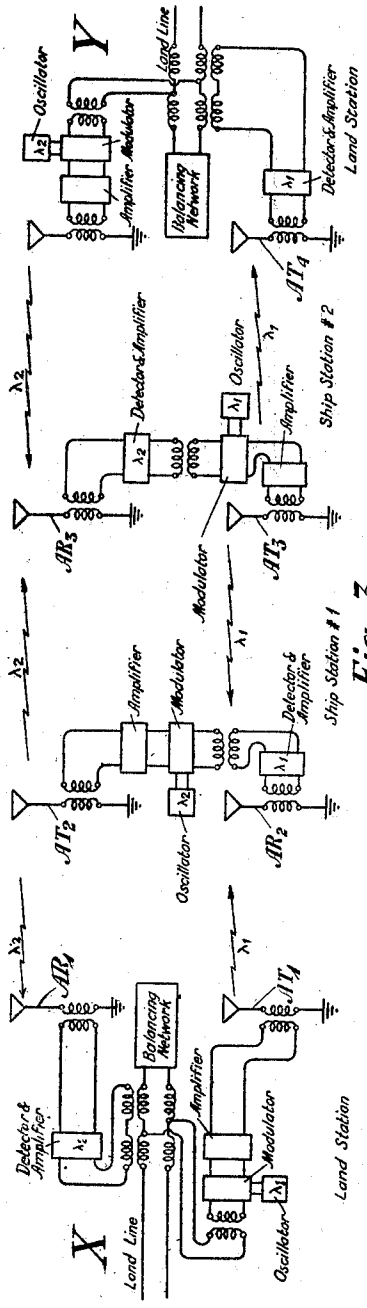


Fig. 3

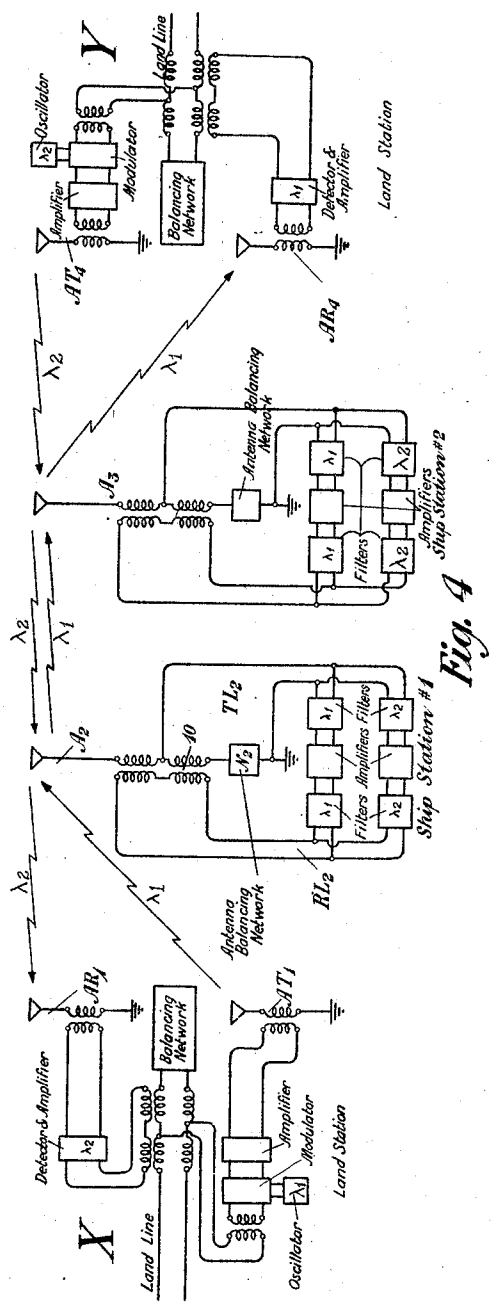


Fig. 4

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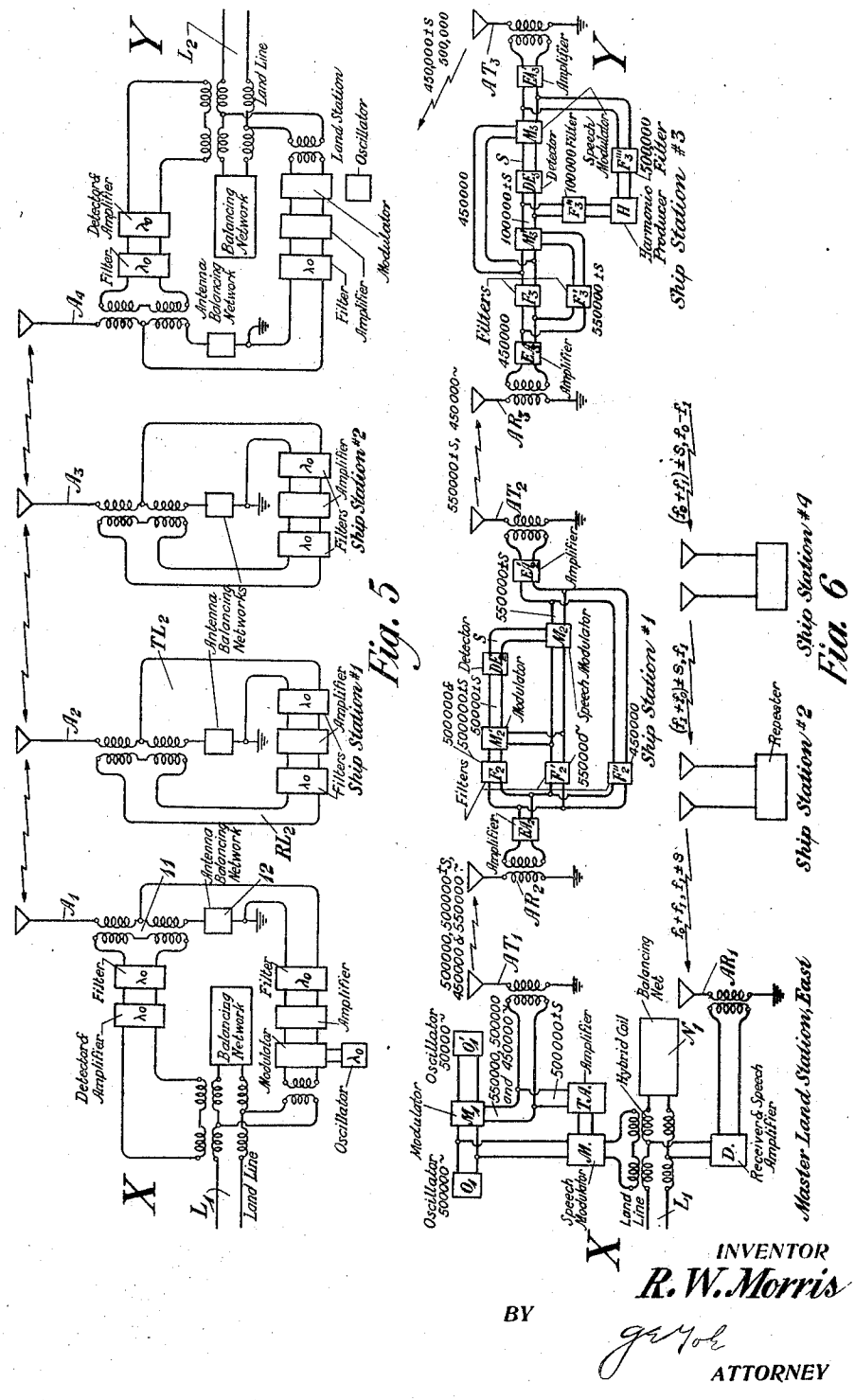
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AMBULATORY REPEATING SYSTEM

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UNITED STATES PATENT OFFICE.

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AMBULATORY REPEATING SYSTEM.

Application filed August 25, 1923. Serial No. 659,290.

This invention relates to radio repeating systems and more particularly to radio repeating systems employing stations having an ambulatory or mobile character as distinguished from fixed repeating stations.

In order to bridge across long distances in radio transmission it is necessary either to use high power radio transmitting apparatus or to adopt some system employing intermediate radio repeating systems. Such repeating stations in the past have been arranged at fixed points. Consequently, if it were desired to apply the repeating method to trans-oceanic communication difficulty would be encountered in establishing and maintaining suitable fixed repeating stations of the type ordinarily contemplated. It would be necessary to make use of small and inaccessible islands for this purpose and in some cases the method might fail altogether due to the absence of such islands along the route desired.

The purpose of this invention is to employ as repeating stations radio equipment installed upon vessels traveling across the ocean over which it is desired to transmit. As is well known, vessels of this character adhere very closely in their movements to fixed schedules and it would therefore be possible at all times to keep a desired number of repeating stations at fairly uniform distances apart between any two terminal stations by mounting the repeating apparatus upon certain vessels following a given schedule. In certain instances, the vessels traveling in one direction may be utilized as repeaters for transmission in one direction while those vessels which are returning may be utilized as repeaters for transmission in the opposite direction. In accordance with other embodiments of the invention, the repeating apparatus with which a ship is equipped may be of a two-way character so that the vessel will constitute a station for transmitting in either of two directions, regardless of its character. The invention also contemplates arranging the repeating apparatus so that the original currents to be amplified will be detected during the process of amplification, thereby enabling the receiving portion of the repeator equipment to be used for the purpose of receiving signals in the usual manner. Likewise, the sending equipment of the repeater may be used for transmitting. Obviously, a system of the type above described can be used on land under certain conditions, the ambulatory stations being located on railway trains or other mobile vehicles.

The invention may now be more fully understood from the following detailed description when read in connection with the accompanying drawing, Figures 1 to 6 inclusive of which illustrate a number of different typical methods by which the invention may be practiced.

Referring to Fig. 1, two land stations X and Y are shown working through two repeating stations designated ship station No. 1 and ship station No. 2 respectively, these stations being located on ships in the region between the land stations. The number of repeating stations may, of course, be increased as required. Communication in one direction is carried on by using wave lengths λ_1, λ_3 and λ_5 successively, while in the reverse direction wave lengths λ_2, λ_4 and λ_6 are so used.

The land station X comprises a land line L_1, this land line being either a telephone or telegraph line, a transmitting channel including a modulator M_1 and an amplifier TA_1 connects the line L_1 to a transmitting antenna AT_1. The modulator may be supplied with a carrier frequency λ_1 from any suitable source such as a vacuum tube oscillator O_1. It will be understood that the antenna and transmitting circuits may be tuned in accordance with the common practice in the art and that the modulator, amplifier and oscillator may be of any well known type. A receiving channel including a detecting and amplifying apparatus D_1 connects the land line L_1 to the receiving antenna AR_1. The detecting and amplifying apparatus may be of any type well known in the art and it will be understood that the receiving antenna and other receiving circuits may be tuned to the receiving frequency λ_2 in any well known manner. In order that the transmitting and receiving channels may be rendered conjugate the land line L_1 is balanced by a suitable network N_1.

Ship station No. 1 involves a receiving antenna AR_2 and a transmitting antenna AT_2 interconnected by two separate repeating channels. The one channel including detecting and amplifying apparatus DE_2 associated with the antenna AR_2, a modula-

tor ME_2 and an amplifier EA_2, the modulator being supplied with the carrier frequency λ_3 from an oscillator EO_2. The other channel includes the detecting and amplifying apparatus DW_2, modulator MW_2 and amplifier WA_2 the modulator being supplied with the carrier frequency λ_2 from the oscillator WO_2. It will be understood that the antenna AR_2 is merely conventionally indicated, the antenna as actually constructed being arranged so that it is resonant at either of two frequencies λ_1 or λ_4 in a manner well understood in the art. Likewise, the detecting and amplifying apparatus of the two channels may be rendered selective by tuning or other means well known in the art at frequencies λ_1 and λ_4 respectively. So, also, the transmitting portions of the channels may be rendered selective by tuning or other well known means and the transmitting antenna AT_2 may be resonant at either of two frequencies λ_3 and λ_2.

The apparatus at ship station No. 2 will be in all respects identical with that at ship station No. 1 except for the different frequencies involved and, similarly, the apparatus at land station Y will be identical in construction with that at land station X except for the different frequencies employed. At station Y the frequency λ_6 is used for transmission and the frequency λ_5 for reception. All of the elements conventionally indicated at all of the stations in Fig. 1 and also in the other figures may be of any type well known in the art except as otherwise indicated.

The operation is as follows: Telephonic or other signals incoming from land line L_1 are impressed upon the modulator M_1 and modulate the carrier frequency λ_1, the modulated carrier frequency being amplified by the amplifier TA_1 and radiated by the antenna AT_1. The modulated carrier frequency λ_1 is received at ship station No. 1 by the antenna AR_2, impressed upon the detector DE_2 and the signal detected therefrom. The detected signal may be heard in the local receiver in a manner well understood in the art but for purposes of repeating some of the detected energy is impressed upon the modulator EO_2 to modulate a carrier frequency λ_3, the modulated carrier being amplified by the amplifier EA_2 and radiated from the antenna AT_2. At ship station No. 2 the modulated carrier frequency λ_3 is received by the receiving antenna, detected, and the detected signal is used to modulate the carrier frequency λ_5, which in turn is radiated to the land station Y, where is is detected and impressed upon the outgoing land line L_4.

In a similar manner, signaling currents received from the line L_4 modulate a carrier frequency λ_6 at station Y, are radiated to ship station No. 2, where they are detected in the other channel by detector DW_3, the detected oscillations modulating a carrier frequency λ_4, which is then amplified and radiated from the antenna AT_3 to ship station No. 1. The modulated carrier λ_4 is detected at ship station No. 1 by the detector DW_2, the detected signaling current being used to modulate a carrier frequency λ_2 which in turn is radiated to the receiving antenna AR_1 at station X. The detector D_1 of the receiving channel detects the signal from the frequency λ_2 and transmits it to the land line L_4.

The system above described is so arranged that any interference between stations is avoided, this result being accomplished, however, by the employment of somewhat complex equipment and the use of a number of different wave lengths. It will be understood, of course, that as the ship stations shown approach land the ship which is landing may be dropped out of the chain of radio repeaters and a new ship starting out from the distant shore may take its place. Whenever this occurs the frequencies will be readjusted at the various repeater stations so that the translation in frequency occurs in the same order at the different repeater stations. In order to maintain suitable energy levels for good transmission it will be possible to have the operators of the various ships whose radio stations are to function as repeater stations adjust the energy transmitted with reference to their geographical location or with reference to the positions of the repeater stations on ships either side of them with which they are to work. The energy level adjustments may be made by the use of potentiometers in connection with the amplifiers or by any other means well known in the prior art. Where a regular lane for shipping exists it will readily be possible to arrange a simple and easily followed routine for adjusting the transmission level and wave lengths employed at any repeating station so that a minimum of attention by the ship's operator will be required to insure satisfactory transmission.

A second method is illustrated in Fig. 2. In accordance with this method separate stations are used for traffic in each direction, each station being arranged to receive on a wave length λ_1 and transmit on a wave length λ_2 or vice versa, depending upon its position in the chain of repeaters. As a result the wave lengths used from one land station to the other are alternately λ_1 and λ_2 in either direction and no station receives and transmits simultaneously on the same wave length even though but two wave lengths are employed throughout. The nature of the apparatus employed will be obvious from the description of Fig. 1 and

the coordination of the apparatus will be clear from a statement of the operation. Signals incoming from the land line at land station X will modulate a radio frequency λ_1, which is transmitted to ship station No. 2, where is is detected and the detected signal used to modulate the radio frequency λ_2. The modulated frequency λ_2 in turn is radiated to ship station No. 4, where it is detected and the detected signal used to modulate a radio frequency λ_1. The radio frequency λ_1 in turn is radiated to the land station Y where it is detected and transmitted to the land line. Transmission in the opposite direction from the land line at station Y takes place at a radio frequency λ_2 between the land station and ship station No. 3. Between ship station No. 3 and ship station No. 1 transmission takes place at frequency λ_1 and finally transmission between ship station No. 1 and land station X takes place at radio frequency λ_2, the modulated radio frequency being detected at station X and the detected signals transmitted to the land line thereat.

While this arrangement has the advantage of employing only two carrier frequencies, a certain amount of interference between traffic in the two directions may result in the form of an echo or side tone unless the stations carrying traffic in one direction follow paths well separated from those carrying traffic in the other direction. For example, should ship station No. 1 and ship station No. 3 approach too close together an echo path may be traced from land station X to ship station No. 2 at carrier frequency λ_1 and from ship station No. 2 to ship station No. 3 at carrier frequency λ_2 and then from the latter station back to land station X through ship station No. 1. This is a matter which may be readily overcome, however, by keeping the lanes of the ships traveling in the two directions well apart from each other. Adjustments of the transmission level and the wave lengths employed may be made as described in connection with Fig. 1.

A third method of transmitting with the aid of radio repeating stations of the mobile type is illustrated in Fig. 3, where each repeating station receives one wave length λ_1 and transmits with wave length λ_2 or vice versa. For example, transmission takes place from land station X to ship station No. 1 at frequency λ_1. At ship station No. 1 this frequency is received by the antenna AR_2 and is then detected and the detected frequency used to modulate a frequency λ_2, which is radiated from the antenna AT_2. This frequency is transmitted to ship station No. 2, where it is received by the receiving antenna AR_3 and detected. The detected signal is then used to modulate the carrier frequency λ_1, which is radiated from the antenna AT_3 to the receiving antenna AT_4. For transmission in the opposite direction a frequency λ_2 is employed in transmitting from land station Y to ship station No. 2, the latter frequency being received by receiving antenna AR_3 at the latter point. This is translated to a frequency λ_1 for radiation from antenna AT_3 to receiving antenna AR_2 of ship station No. 1 where the frequency is again translated to λ_2 for transmission from antenna AT_2 to the receiving antenna AR_1 of land station X. This arrangement has the advantage of great simplification of the apparatus involved in addition to the use of only two frequencies, but, here again, side tone may result in certain cases. For example, if ship stations No. 1 and No. 2 approach each other too closely a side tone path may be traced from antenna AT_2 at ship station No. 1 to antenna AR_3 at ship station No. 2 at a frequency of λ_2, being translated at the latter station to a frequency of λ_1, which is transmitted back from antenna AT_3 to receiving antenna AR_2 at ship station No. 1. This difficulty may, of course, be avoided by taking care that the stations are properly separated.

Where it is found practicable to balance the transmitter against the receiver, transmission may take place from land station to land station through the intermediate repeater stations without translation in wave length, one wave length being employed for transmission in one direction throughout and one wave length being employed for transmission in the other direction throughout. Figure 4 illustrates a system of this type. In this system a single antenna may be used both for transmitting and receiving at the repeater station. For example, a ship station No. 1 a single antenna A_2 is shown, the antenna being coupled to a receiving channel RL_2 through a hybrid coil arrangement 10. An outgoing channel TL_2 is connected to the midpoint of the hybrid coil and the two channels are rendered conjugate by balancing the antenna A_2 by means of a suitable network N_2, in a manner well known in the art. The two channels are interconnected by selective paths, each including high frequency amplifying apparatus with suitable filters on either side of the amplifiers for rendering the paths selective to frequencies λ_1 and λ_2 respectively. Ship station No. 2 may be in all respects identical with that described in connection with ship station No. 1.

The operation is as follows: Signals from the land line at land station X modulate a carrier frequency λ_1 which is radiated from the antenna AT_1 and received by the antenna AT_2 (which may be arranged so as to be selective at either of two frequencies or else made aperiodic so as not to discriminate

between the frequencies); and then transmitted to the receiving channel RL_2. From this channel it will be selected into the upper path by means of the filter selective to frequency λ_1, the modulated carrier being amplified and transmitted through the transmitting path TL_2 to the antenna A_2. The modulated amplified frequency λ_1 will then be radiated and transmitted to station No. 2, where a similar operation will take place, the amplified radio frequency λ_1 being then radiated to station Y and received by antenna AR_4. Transmission in the opposite direction will take place at frequency λ_2. This frequency is received by the antenna A_3 of station No. 2 and passed into the receiving channel where it is selected by the filters of the lower path for amplification and transmission to the receiving channel. From the receiving channel the frequency λ_2 is transmitted back to the antenna A_3 for radiation to ship station No. 1, where a similar operation takes place. The amplified frequency λ_2 is finally radiated from antenna A_2 to the receiving antenna AR_1 of land station X. The arrangement described in connection with Fig. 4 will be free from any echo or side tone effect, due to proximity of repeater stations, although it requires a very high degree of balance to prevent singing or side tone in the individual circuits of each repeater station.

Fig. 5 illustrates a system of a similar type in which reception and transmission take place in both directions at all stations at the same wave length. At land station X, the transmitting and receiving antennae AT_1 and AR_1 of the preceding figures are replaced by a single antenna A, which is coupled to the local receiving and transmitting channel by means of a hybrid coil 11 and balancing network 12 in a manner well understood in the art. The apparatus at the ship stations No. 1 and No. 2 will be similar to that illustrated in Fig. 4, except that the receiving and transmitting channels associated with the common antenna at each ship station will be interconnected by a single path containing an amplifier and suitable selective apparatus.

The operation is as follows: Signals incoming from land line L_1 modulate the radio frequency λ_0 and after amplification and selection the modulated frequency is radiated from the antenna A_1 to the antenna A_2 of ship station No. 1. The modulated frequency is then passed into the receiving channel RL_2, amplified by the amplifier in the common path and then passed into the transmitting channel TL_2 for radiation from the antenna A_2 to ship station No. 2. At this station a similar operation takes place and the same wave length is finally radiated to the receiving antenna A_4 at land station Y. Transmission in the opposite direction will obviously take place in a similar manner. This arrangement is subject to the disadvantage that it will require a very perfect degree of balance to prevent echoes or howling between adjacent stations. It is ideal, however, in that it employs only one wave length and, aside from the balancing apparatus, a very simple and inexpensive amplifying arrangement.

Many other combinations of frequencies in repeating stations might be devised but the systems above described may be considered illustrative. It is not, however, intended to limit this system employing mobile or ambulatory repeating devices to any particular system of wave length distribution among the various stations. In this connection, it is pointed out that the use of a frequency control system similar to that disclosed in United States patent to O. B. Blackwell, Serial No. 1,403,835, of January 17, 1922, or United States patent to J. R. Carson, Serial No. 1,403,841, of January 17, 1922, may be used in connection with the repeater arrangements of the present invention. Fig. 6 illustrates a circuit arrangement embodying this feature. At the land station X, which may be treated as a master station in accordance with the scheme disclosed in the Carson and Blackwell patents, above referred to, two oscillators O_1 and O'_1 are provided, one of which may generate a frequency of 500,000 cycles, for example, and the other a frequency of 550,000 cycles, for example. These two frequencies are impressed upon a modulator M'_1, thereby producing in the output circuit components having frequencies of 450,000, 500,000 and 550,000 cycles. A certain amount of energy from the oscillator O'_1 is led to the speech modulator M_1, which is also associated with the land line L_1, so that the frequency 500,000 cycles may be modulated in accordance with the signals incoming from said line and after being amplified by the amplifier TA_1 may be impressed upon the transmitting antenna AT_1. Obviously, there would be radiated from the antenna AT_1 an unmodulated component of 500,000 cycles, components corresponding to 500,000 cycles $\pm s$, the signaling frequency, and frequencies of 450,000 and 550,000 cycles.

At ship station No. 1, these frequencies may be received by the antenna AR_2. An amplifier EA_2 is associated with the antenna for amplifying the frequencies and on the output side of the amplifier three branches are arranged including filters F_2, F'_2 and F''_2 respectively. Filter F_2 passes a band corresponding to 500,000 cycles $\pm s$. Filter F'_2 passes 550,000 cycles and filter F''_2 450,000 cycles. A modulator M'_2 is provided and is so associated with the branches including filters F_2 and F'_2 that the band of frequencies corresponding to 500,000 cycles $\pm$

s will beat with the frequency of 550,000 cycles to produce a lower band corresponding to 50,000 cycles $\pm s$ in the ouput side of the modulator. This band may be selected and detected by the detecting arrangement DE_2, thereby producing the signal s in its output. A speech modulator M_2 is provided, the signal s being impressed upon said modulator together with the frequency 550,000 cycles so that the latter frequency will be modulated in accordance with the signal and a band corresponding to 550,000 cycles $\pm s$ will appear upon the output side of the modulator. An amplifier EA'_2 may be provided for impressing the energy upon the transmitting antenna AT_2. The band corresponding to 550,000 cycles $\pm s$ is impressed upon this modulator and the unmodulated frequency of 450,000 cycles is also impressed upon this modulator so that these frequencies are radiated from the antenna AT_2 in amplified form.

At ship station No. 3 a somewhat similar arrangement is provided. Here the received frequencies are amplified by the amplifier EA_3. The modulated band of 550,000 cycles $\pm s$ is selected by a filter F'_3, while the unmodulated frequency of 450,000 cycles is selected by a filter F_3 and impressed upon the same modulator. As a result, a lower side band corresponding to 100,000 cycles $\pm s$ is produced in the output of modulator M'_3. From this band the signal s is selected and detected by the detector DE_3 so that the signal s is produced upon the output side of the detector. A speech modulator M_3 is provided upon which the signal s is impressed, together with the unmodulated frequency of 450,000 cycles from the filter F_3. As a result, the signal is modulated upon a carrier frequency of 450,000 cycles and impressed upon the amplifier EA'_3. At the same time, the unmodulated component of 100,000 cycles is selected from the output of modulator M'_3 by the filter F''_3 and impressed upon a harmonic producer H. The harmonic producer H may be of any type well known in the art such, for example, as a distorting tube. By the action of this harmonic producer, harmonics of 100,000 cycles are produced, of which the harmonic corresponding to 500,000 cycles is selected by the filter F'''_3 and impressed upon the amplifier EA'_3. Consequently, the transmitting antenna radiates an unmodulated frequency of 500,000 cycles and a signaling band comprising 450,000 cycles $\pm s$.

The above illustrations are sufficient to indicate the manner in which the frequency may be transmitted from station to station by successive changes in frequency, all of the frequencies being controlled from a master station X. The transmission in the opposite direction may take place in a similar manner and it has not been considered necessary, therefore, to illustrate the details of the repeaters at ship station No. 1 and ship station No. 4. It will be understood, of course, that the distant land station (not shown) will act as a master staton for transmission in the opposite direction. It may be considered, for example, as transmitting three frequencies f_1, f_1+f_0 and f_1-f_0. One of these three frequencies is modulated and at the first repeater point the signal is detected and by re-modulation and re-amplification, retransmitted on another of the three frequencies. Each time the signal is transmitted to a repeater staton it will be detected and modulated upon a different carrier in a manner similar to that described in connection with ship stations No. 1 and No. 3.

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. A radio repeating system comprising terminal receiving and transmitting stations and a plurality of intermediate stations shifting in position with respect to the terminal stations along routes of travel between said terminal stations, means at each intermediate station for receiving and amplifying signals transmitted from the nearest adjacent station on one side and means responsive to the received signals for transmitting the amplified signals to the nearest station on the other side.

2. A radio repeating system comprising terminal receiving and transmitting stations and a plurality of intermediate stations shifting in position with respect to each other along routes of travel between said terminal stations, means at each intermediate station for receiving and amplifying signals transmitted from the nearest adjacent station on one side and means responsive to the received signals for transmitting the amplified signals to the nearest station on the other side.

3. A radio repeating system comprising terminal stations, each arranged for transmission and reception, and a plurality of intermediate repeating stations arranged to move in a continuous chain from one terminal station to the other, each intermediate station comprising means for receiving and amplifying signals transmitted from the nearest adjacent station on one side and means responsive to the received signals for transmitting the amplified signals to the nearest adjacent station on the other side.

4. A radio repeating station comprising terminal stations, each including means for transmitting and receiving signals, a plurality of movable repeating stations intermediate between the terminal stations, said

repeating stations moving in an endless chain in the space between the terminal stations so that a given number of the stations will always be moving between the terminal stations in one direction while other repeating stations will be moving between the terminal stations in the opposite direction, means at each repeating station for receiving and amplifying signals transmitted from the nearest station on one side moving in the same direction and means responsive to the received signals for transmitting the amplified signals to the nearest station on the other side moving in the same direction.

5. A radio repeating system comprising terminal stations, each arranged to transmit and receive signals at different frequencies, a plurality of intermediate repeating stations movable with respect to said terminal stations along routes of travel between said terminal stations, means at each repeating station to receive signals transmitted from the nearest adjacent station on one side, means responsive to the received signals to translate the signals in frequency and means to transmit the signals thus translated in frequency to the nearest adjacent station on the other side.

6. A radio repeating system comprising terminal stations, each arranged to transmit and receive signals at different frequencies, a plurality of intermediate repeating stations movable with respect to each other along routes of travel between said terminal stations, means at each repeating station to receive signals transmitted from the nearest adjacent station on one side, means responsive to the received signals to translate the signals in frequency and means to transmit the signals thus translated in frequency to the nearest adjacent station on the other side.

In testimony whereof, I have signed my name to this specification this 7th day of August, 1923.

ROBERT W. MORRIS.