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H. NYQUIST

REDUCTION OF DISTORTION IN MULTIPLEX REPEATERS

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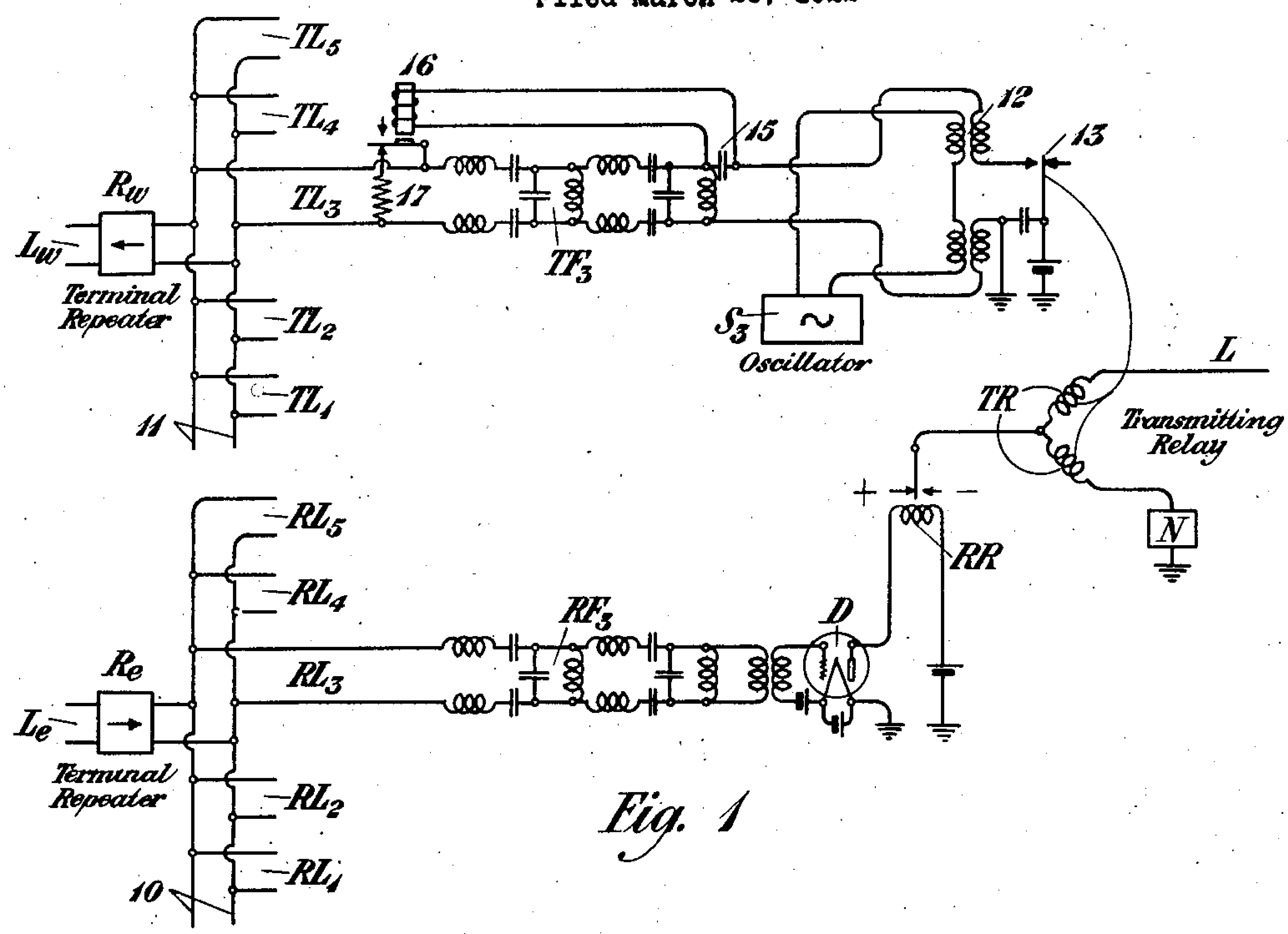

Fig. 1

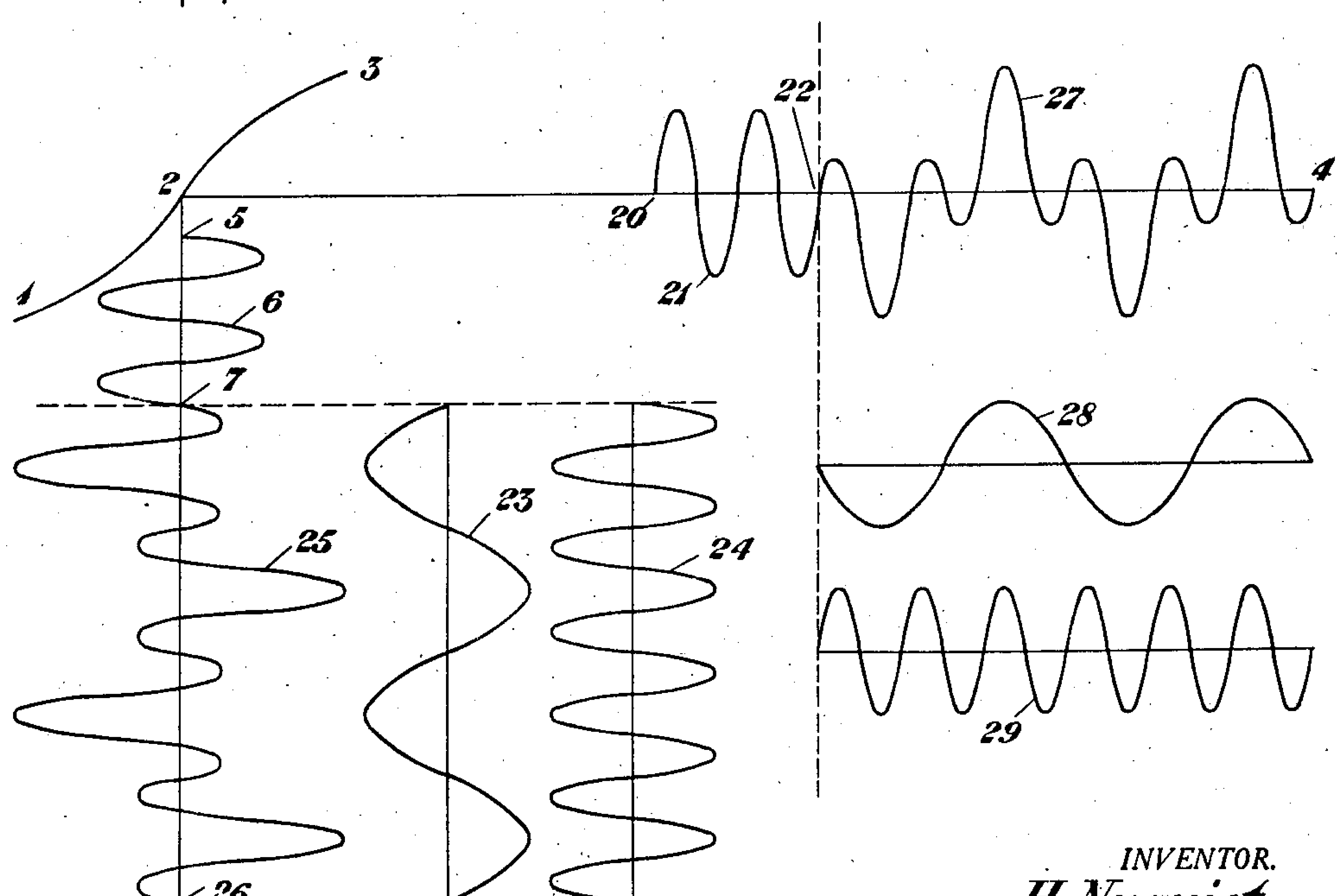

Fig. 2

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UNITED STATES PATENT OFFICE.

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REDUCTION OF DISTORTION IN MULTIPLEX REPEATERS.

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To all whom it may concern:

Be it known that I, HARRY NYQUIST, residing at Elmhurst, in the county of Queens and State of New York, have invented certain Improvements in the Reduction of Distortion in Multiplex Repeaters, of which the following is a specification.

This invention relates to multiplex signaling, and more particularly to means for reducing the effect of distortion in repeaters or other translating devices used in connection with such a system.

Heretofore, in the operation of multiplex carrier systems, it has been found that the repeater tubes employed at points along the line for transmitting carrier frequencies produce certain undesirable effects where the same tube is used to transmit the frequencies of a number of channels. This is for the reason that the tubes do not have a straight line characteristic, and hence produce a certain amount of distortion which causes what might be termed mutual "crowding" of the channels. By this is meant that where one frequency exists in a repeater or other form of translating circuit along with other frequencies, it decreases the amplitude of all of the other frequencies by a certain amount, as compared with the amplitudes the frequencies would have if each were on the circuit alone. This effect at the receiving end of the circuit is very similar to the effect which would be produced by the introduction of a loss in the circuit by any other means, such, for example, as a resistance shunted across the circuit. This effect is very undesirable in a carrier telegraph system involving a large number of channels employing carrier frequencies within the usual voice range, for in such a system it is almost essential to economic working of the system that the channels be narrow and closely spaced, so that all the channels may be amplified by the same repeater tube.

In accordance with the present invention, it is proposed to overcome this difficulty by so arranging each carrier channel that when the carrier frequency is applied to the channel, the normal impedance of the circuit will be reduced by an amount sufficient to compensate for the reduction in amplitude to which the frequencies then existing on the circuit would be subjected.

The invention may now be more fully understood by reference to the following description, when read in connection with the accompanying drawing, Figure 1 of which illustrates in simplified form the circuit arrangement of a carrier system embodying the present invention, and Fig. 2 of which shows a number of curves illustrating the principles of the invention.

Referring to Fig. 1, L_e and L_w designate two transmision lines forming a four-wire circuit for the transmission of carrier frequencies, the line L_w being used for transmission from east to west and the line L_e for transmission from west to east. R_e and R_w designate one-way repeaters which may be included in the line at terminal or other points, these one-way repeaters being of any well known type, such, for example, as vacuum tube repeaters. The output side of the repeater R_e is connected to bus-bars 10 from which a plurality of receiving channels RL_1, RL_2, RL_3, RL_4, RL_5, etc., may be branched. Each receiving channel, such as, for example, the channel RL_3 includes a selective device or filter RF_3, a detector D and a receiving relay RR.

The filter RF_3 may be of the well known Campbell type and is illustrated as consisting of two sections, each having a series resonant element and a shunt anti-resonant element. The filter at the side adjacent the bus-bars terminates in a full series element in order to present the greatest impedance to frequencies lying without the range of free transmission. The detector D may be of any well known type, such, for example, as a vacuum tube detector. It will be understood that each of the receiving channels includes apparatus similar to that illustrated in connection with the channel RL_3, and that the filters of each channel will be so designed as to freely transmit a range of frequencies differing from the other channels.

The receiving relay RR is arranged to transmit the direct current impulses detected by the detector D to an ordinary telegraph line L, which is balanced by means of a network N, the transmitted impulses being connected to a neutral point between the line L and the network N in order not to operate the transmitting relay TR associated with the telegraph line L.

The input side of the repeater R_w is connected to bus-bars 11, from which transmitting channels TL_1, TL_2, TL_3, TL_4, TL_5, etc., are branched. Each channel, such as the channel TL_3, includes a filter TF_3 which may be of the well known Campbell type. As illustrated, it, like the filters associated with the receiving channels, consists of two sections each comprising a series resonant element and a shunt anti-resonant element. The section adjacent the bus-bars terminates in a full series element in order to present the greatest impedance to frequencies lying outside of the range of free transmission of the filter. The filters for the different channels, of course, will transmit different ranges of frequencies.

A source of carrier frequency characteristic of each channel, such as the source S_3, will be associated with the channel for transmitting carrier oscillations. The source S_3 for the channel TL_3 is associated therewith through a transformer 12, the secondary circuit of which is included in the channel TL_3 and may be opened or closed under the control of the armature 13 of the transmitting relay TR. Direct current impulses from the line L will, therefore, be translated into groups of carrier oscillations from the source S_3, which may be transmitted through the channel TL_3 to the line L_w. The transmitting apparatus associated with each channel will be similar to that illustrated in connection with the channel TL_3.

Before describing the arrangements of the invention designed to overcome the condition known as "crowding", it will be explained how this condition arises in connection with a repeater, for example. Referring to Fig. 2, 1—2—3 is a curve illustrating the characteristic of a vacuum tube repeater. It will be noted that the curve is not a straight line and that its angle with the axis 2—4 becomes less as the curve recedes from said axis. The condition represented by the curve 1—2—3 is, of course, exaggerated in order to more clearly show what takes place, and in practice it will be understood that the characteristic curve of a vacuum tube repeater will more nearly approach a straight line. However the phenomenon known as "crowding" will exist, though to a lesser degree than illustrated in connection with the curve 1—2—3.

Let us suppose a simple sine wave such as is illustrated at 5—6—7 and having a definite frequency and constant amplitude is impressed upon the repeater. The wave appearing in the output circuit will take the form indicated at 20—21—22 and as seen, the amplitude of the wave in the output circuit will be proportional to that of the input wave and the frequency will be the same. For the sake of simplicity, the amplitude of the output wave is made equal to that of the input wave which would correspond to a condition in which no actual amplification takes place. This, however, has no effect upon the principle about to be explained.

Assume now that in addition to the wave having the same frequency and amplitude as the wave 5—6—7, another wave of the same amplitude but of different frequency be impressed upon the amplifier. The two waves now impressed upon the amplifier will take the form indicated at 23—24. The two waves, when combined in the same circuit, however, produce a combined wave having the form illustrated at 7—25—26. Owing to the non-linear characteristic illustrated at 1—2—3, the output wave will take the form 22—27—4. This wave, it will be noted, is substantially of the form of the wave 7—25—26, but its amplitude is less than that of the wave 7—25—26. If the wave 22—27—4 be resolved into its components, it will be found to comprise two waves 28 and 29, corresponding in frequency to the waves 23 and 24, respectively, but each being of smaller amplitude than the original waves impressed upon the amplifier. Thus it will be seen that while the wave 24, if impressed upon the amplifier alone will produce a wave of the same amplitude in the output circuit, when another wave, such as 23, is impressed upon the amplifier at the same time, the wave 29 in the output circuit corresponding to the applied wave 24, will have an amplitude less than it would have if the wave 23 were not applied.

In order to overcome this difficulty, a condenser 15 is included in the transmitting channel TL and a high impedance alternating current relay 16 is shunted about the condenser. The contacts of the relay 16 control a resistance 17 shunted across the channel TL_3 in parallel with the side of the filter TF_3 adjacent the bus-bars 11. Whenever the carrier frequency is applied to the channel, the relay 16 disconnects the resistance 17 shunted across the channel, and when the carrier frequency is no longer applied to the circuit, the shunt resistance 17 is again bridged across the channel. The condenser 15 acts as a shunt for the high impedance relay 16, so that the inclusion of this relay in the circuit does not materially affect the impedance of the filter as viewed from the source of carrier oscillations S_3. An arrangement similar to that just described in connection with the channel TL_3 is associated with each of the transmitting channels.

If we consider the action of the transmitting channels on the assumption that the shunt resistances, such as 17, are not provided, it will be seen that when a frequency is applied to a single one of the channels, the impedances of the filters in the other channels will be so large that very little of the energy transmitted from the active channel will be diverted from the line L_w into the other transmitting channels. When, however, shunt resistances such as 17 are provided, as illustrated, and but one channel is active, a certain percentage of the energy from the channel will be diverted from the line L_w into each of the other channels, owing to the reduced impedance of the channel due to shunting the resistance 17 across the terminal of the filter. This reduces the amplitude of the carrier frequency supplied from the active channel to the line L_w by an amount which may be made by proper proportioning of the resistance 17 just equal to the reduction in amplitude due to crowding.

Consequently, when a second channel becomes active and a carrier frequency is transmitted therethrough the opening of the shunt through the resistance in the second channel increases the impedance of the second channel to the frequency transmitted from the first active channel, so that a greater proportion of the energy from the first channel is transmitted to the line L_w. The increased amplitude of the current transmitted to the input side of the repeater in the line will, if the shunt resistance is properly proportioned, be sufficient to make up for the reduction in the output of the repeater due to crowding, and consequently, the amplitude of the frequency from the first channel appearing in the output circuit of the repeater will be substantially the same whether any other channel is active or not. It will be at once apparent that any desired combination of channels may be transmitting without substantial variation in the amplitude of the frequency transmitted from each channel as it appears at the receiving end. The reduction in amplitude which this principle necessarily involves is not of consequence inasmuch as the repeaters used in a system of this type may be utilized to make up for the loss introduced by the use of the element 17.

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 multiplex signaling system in which a plurality of frequencies from a plurality of channels may be transmitted over a circuit including a common repeater, the method of overcoming the effects of crowding of the channels in the repeater when more than one frequency is transmitted at the same time, which consists in increasing the transmission of the circuit for the frequencies of the other channels when a given channel is transmitting.

2. In a multiplex signaling system in which a plurality of frequencies from a plurality of channels may be transmitted through a common repeater, the method of overcoming the effects of crowding of the channels in the repeater when more than one frequency is transmitted at the same time, which consists in diverting a certain amount of the energy transmitted by a given channel for each of the other channels which are not then active, and reducing the amount of energy thus diverted for any of said other channels when they become active.

3. In a multiplex signaling system in which a plurality of frequencies from a plurality of channels may be transmitted through a common repeater, the method of overcoming the effects of crowding of the channels in the repeater when more than one frequency is transmitted at the same time, which consists in diverting a certain amount of the energy from a channel which is actively transmitting into each of the inactive channels, and increasing the impedance of the inactive channels to frequencies outside the range of the particular inactive channel when the inactive channel actively transmits.

4. In a multiplex signaling system in which a plurality of channels may be transmitted through a common repeater, the method of overcoming the effects of crowding of the channels in the repeater when more than one frequency is transmitted at the same time, which consists in diverting from the repeater a certain amount of the energy from a channel which is actively transmitting, controlling the amount diverted by impedances in shunt with the other channels, and reducing the amount thus diverted as other channels become active.

5. In a signaling system, a transmission line including a repeater, a plurality of channels transmitting at different frequencies through said repeater, means operating when a given channel is actively transmitting to divert from the repeater a portion of the energy from the transmitting channel, and means controlled by the other channels as they become active in transmitting for reducing the amount of energy which is diverted from the repeater.

6. In a signaling system, a transmission line, a repeater therein, a plurality of channels transmitting at different frequencies through said repeater, terminal apparatus for the transmitting channels, said terminal apparatus including means operating when a given channel is transmitting to partially divert the energy from said channel into an impedance associated with the inactive transmitting channels, and means to reduce the energy thus diverted into the impedance associated with an inactive channel when it becomes active.

7. In a signaling system, a transmission line, a repeater therefor, a plurality of transmitting channels for transmitting through said repeater at different frequencies, and means controlled by each channel for increasing the transmission of the repeater circuit for frequencies of the other channels when said channel is transmitting.

8. In a signaling system, a transmission line, a repeater therefor, a plurality of transmitting channels for transmitting through said repeater at different frequencies, and means associated with each channel for controlling an impedance associated with that channel as regards frequencies transmitted by the other channels when that channel is transmitting.

9. In a signaling system, a transmission line, a repeater therefor, a plurality of terminal transmitting channels connected in multiple to transmit through said repeater, the impedance of the channels being such that when any channel is transmitting a portion of its energy will be diverted from the line to the parallel channels, and means associated with each channel to decrease the amount of energy of other channels diverted thereto when the particular channel is transmitting.

10. In a multiplex signaling system involving transmission loss due to mutual crowding of the channels, means to produce a variable transmission loss, and means for varying the transmission loss produced by said means in a manner complemental to the variation in transmission loss due to crowding, so that the total transmission loss shall be substantially constant.

In testimony whereof, I have signed my name to this specification this 18th day of March, 1922.

HARRY NYQUIST.