March 2, 1943. A. A. LUNDSTROM 2,312,724

SIGNALING SYSTEM

Filed June 12, 1940 3 Sheets-Sheet 1

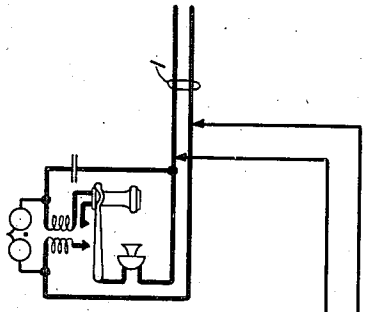


FIG. 1

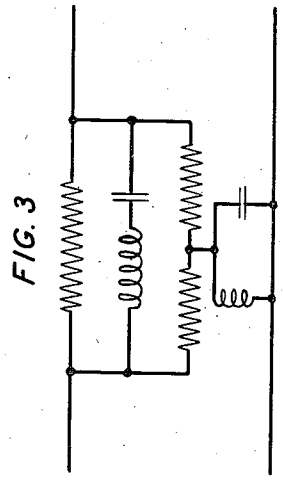
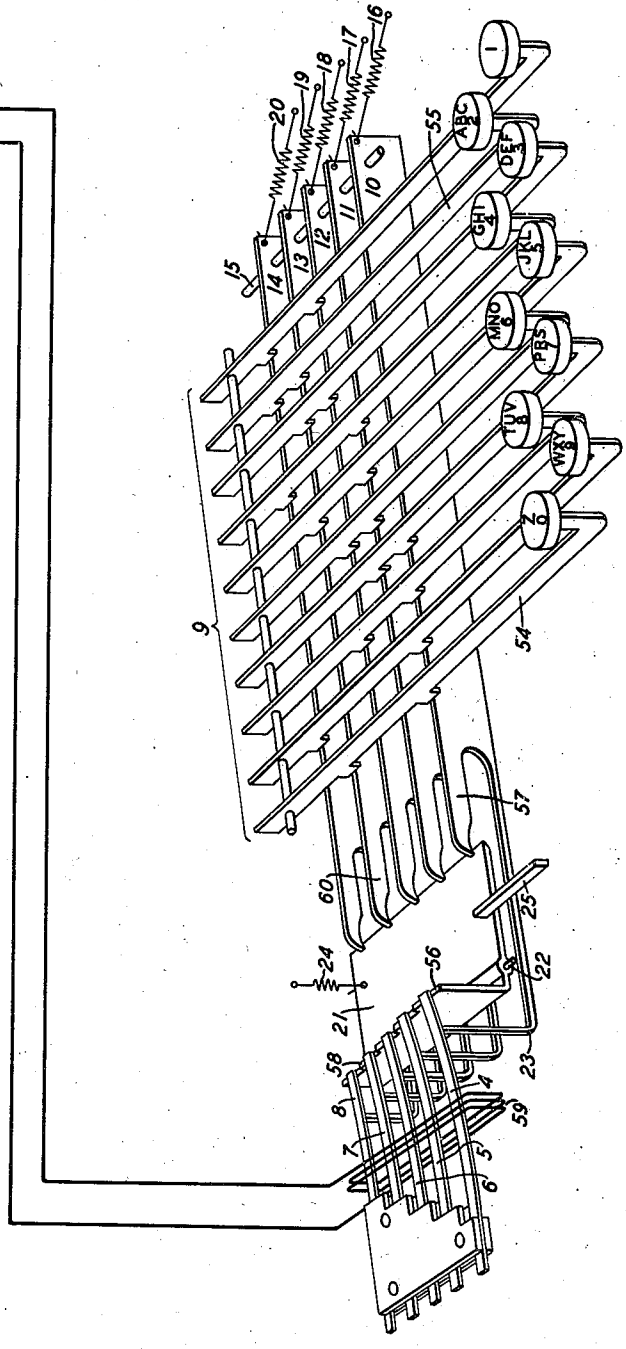


FIG. 3



INVENTOR
A. A. LUNDSTROM
BY M. T. McEnney
ATTORNEY

March 2, 1943. A. A. LUNDSTROM 2,312,724

SIGNALING SYSTEM

Filed June 12, 1940 3 Sheets-Sheet 2

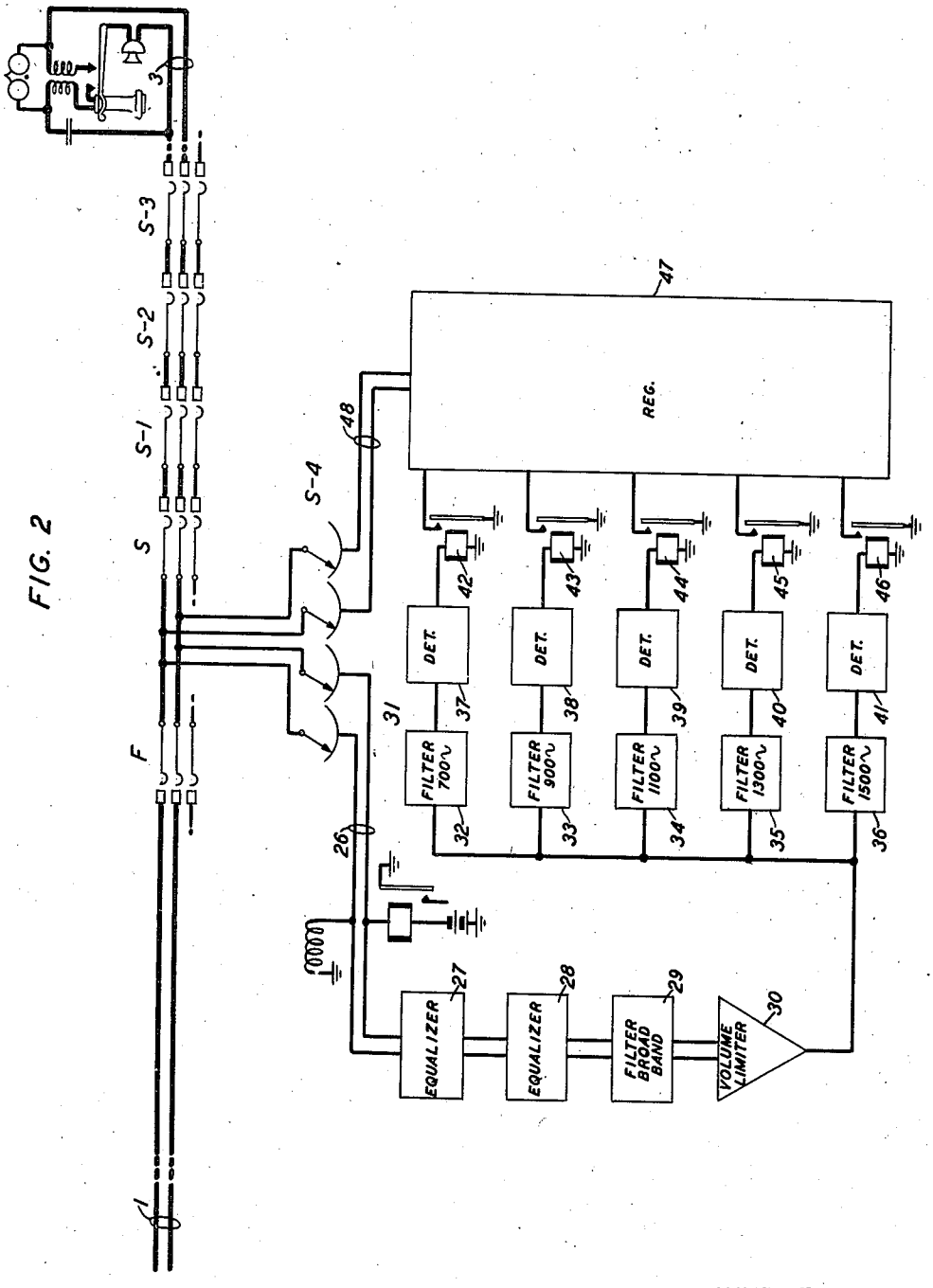


FIG. 2

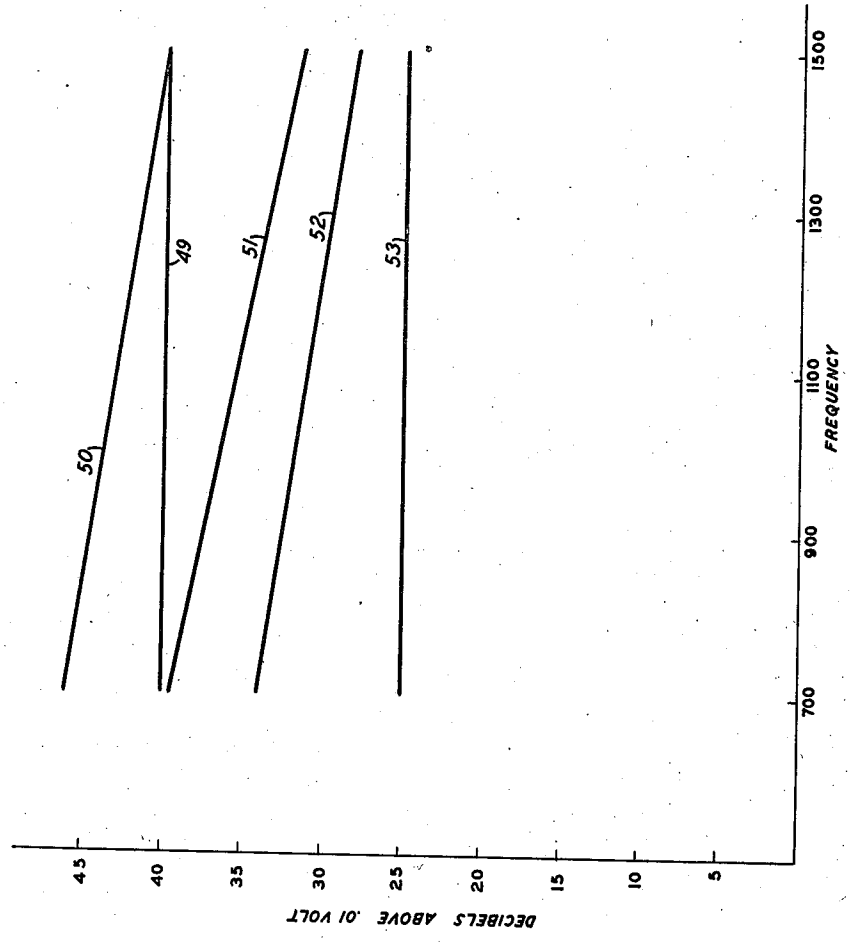
INVENTOR
A. A. LUNDSTROM
BY M. P. McInerney
ATTORNEY

March 2, 1943. A. A. LUNDSTROM 2,312,724

SIGNALING SYSTEM

Filed June 12, 1940 3 Sheets-Sheet 3

FIG. 4



INVENTOR
A. A. LUNDSTROM
BY
M. W. McKenney
ATTORNEY

Patented Mar. 2, 1943 2,312,724

UNITED STATES PATENT OFFICE

2,312,724

SIGNALING SYSTEM

Alexis A. Lundstrom, East Orange, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application June 12, 1940, Serial No. 340,042

8 Claims. (Cl. 179—90)

This invention relates to the transmission of signals and particularly to the transmission of call designations in telephone systems.

The objects of the invention are to obtain greater speed and simplicity in the sending of designations; to facilitate the use of signal currents at relatively high energy levels; to make use of these high energy levels to reduce the liability of false operation of the signal responsive devices; and to obtain other improvements in these systems.

It has been proposed heretofore to utilize alternating currents of a plurality of different frequencies for sending telephone designations from a subscriber's station to the central office. For this purpose keys are provided for plucking reeds which vibrate at the desired frequencies and produce corresponding currents for transmission over the line. At the central office these currents are distinguished by selective means, such as filters, and used to operate registers, which in turn control the switches to establish the desired connection.

Experience with sending systems of this character shows that the signal energy produced by the reeds, when plucked with a given force, decreases as the natural frequency of vibration increases. In other words the high frequency reeds produce signals of the least energy, and the low frequency reeds produce signals of greatest energy in response to a given plucking force. However, it is also found that the signal receiving mechanism at the central office functions best when the incoming signals are substantially uniform in their energy levels. Accordingly it has been necessary to graduate the plucking forces applied to the reeds, the reed of highest frequency being plucked with the greatest force and the remaining reeds being plucked with correspondingly reduced forces. But this method of plucking the reeds may be considered as having a disadvantage from the standpoint of the subscriber or operator in that different degrees of pressure are required to manipulate the different keys of the keyboard.

Another difficulty in these prior sending systems is that of false operation by spurious currents having frequencies in the signaling range. These are sometimes known as noise currents and are often caused by contact disturbance somewhere in the signaling circuit. The detrimental effect of these noise currents is not uniform over the entire signal frequency range. It is most pronounced at the lower frequencies, and the result is that the low frequency channels of the signal receiving mechanism are falsely operated when the energy of the noise current reaches a certain level relative to the energy level of the true signals.

According to a feature of the present invention these disadvantages are overcome by means of a signaling system in which the sending reeds are plucked with forces that are equal for all reeds and of such magnitude that the energy of the signal produced when the reed of highest frequency is plucked is sufficient to operate the signal receiving mechanism at the central office. Hence the energy produced by each of the remaining reeds is greater than required by the receiving mechanism, the energy values of the successive signals varying upward as the frequency decreases. The effect of thus increasing the energy of the low frequency signals is to increase correspondingly the ratio of signal energy to noise energy at the low frequencies. This desirable effect makes it possible to attenuate the noise signals at the receiving end of the line below the levels at which it is possible for them to cause false operation. This final step is accomplished by means of an equalizer which is designed to receive all signals coming over the line and to attenuate their energies in larger amounts for the lower frequencies, such that all signals passing from the equalizer to the receiving mechanism are of substantially the same energy value. At the same time the noise currents, which are usually smaller in magnitude than the reed signals of corresponding frequencies, are reduced by the equalizer to minimize the possibility of false operation of the receiver by these noise currents.

Another feature of the invention is a designation transmission system in which the party operating the transmitter applies equal manual forces to pluck the vibratory reeds, and in which the signals of different frequencies produced by these reeds are delivered at a uniform energy level to the receiving mechanism.

Another feature of the invention is the novel method of transmitting signals whereby the foregoing objects are realized.

These and other features of the invention will be explained more fully in the following detailed specification.

In the drawings accompanying the specification:

Fig. 1 illustrates a subscriber's substation and shows the structure of the designation transmitter thereat;

Fig. 2 illustrates the switches and control mechanism in the central office;

Fig. 3 illustrates an equalizer for attenuating the signals produced by the substation transmitter; and

Fig. 4 is a graph showing the signal energy in different parts of the system.

The system chosen to illustrate the invention is one in which the central office is equipped with automatic line-finder switches, such as the finder F, and with selector switches, such as the selectors S, S—1, S—2 and S—3, for establishing connections between calling subscribers' lines and called subscribers' lines. The calling subscriber's line 1, for example, appears in the line-finder switch F and is provided at the substation with a keyboard designation transmitter of the vibratory reed type. The central office is equipped with a plurality of common register senders for receiving and registering wanted designations transmitted over the calling subscribers' lines and for controlling the selective operation of switches S, S—1, S—2 and S—3 to complete the connections to the called subscribers' lines, such as the line 3. These common register senders, one of which is illustrated, are selected automatically by a sender selector switch S—4 associated with the link interconnecting the finder F and the first or district selector switch S.

The subscriber's designation transmitter comprises a plurality of vibratory reeds, 4, 5, 6, 7 and 8, having graduated natural periods of vibration. For instance, reed 4 may be chosen with a frequency of 700 cycles and the succeeding reeds 5, 6, 7 and 8 with frequencies of 900, 1100, 1300 and 1500 cycles, respectively. A plurality of keys 9, preferably ten in number, are provided for plucking the vibratory reeds to generate in the line 1 currents of corresponding frequencies. Each key may be arranged to pluck two different reeds, each pair of reeds representing a digital character of the designation. The plucking operation is performed by the code bars 10, 11, 12, 13 and 14. These bars are pivoted on the rod 15 and are normally held in the upward position by individual retractile springs 16, 17, 18, 19 and 20. Each of these bars cooperates with a common latch plate 21 which is rotatable about its pivot pin 22 to pluck any reed that is released at the moment. Normally the reeds are held in a flexed position by damping fingers on the extreme ends of the code bars. For instance, the damping finger 23 individual to the bar 10 rests against the under surface of the reed 4 and tensions it to a predetermined extent. Similarly each of the other code bars is provided with an individual damping finger for tensioning the respective reeds 5, 6, 7 and 8.

The depression of any one of the keys 9 forces a particular pair of code bars down against the tension of their springs. As the code bars move downwardly a projection thereon engages the latch plate 21 and rotates it about the pin 22. At the same time the damping fingers on the depressed code bars recede from the under surfaces of the corresponding reeds, allowing these reeds to rest solely on the plucking edge of the latch plate 21. A moment thereafter the rotating latch plate moves out from under all of the reeds, whereupon the two released ones are set in vibration. The remaining three reeds are still held by their damping fingers and are not permitted to vibrate. When the depressed key is released, the individual springs withdraw the code bars to their normal positions, permitting the retractile spring 24 to return the latch plate 21 to its normal position against the stop member 25. As the depressed code bars return to their normal positions, the damping fingers reengage the vibrating springs and flex them upwardly to the point where the returning latch plate 21 moves in under their free ends.

It will be noted that the forces required to flex the reeds to their normal pretensioned condition are stored in the springs 16 to 20 by the keys under the pressure applied thereto by the subscriber's finger. It is desirable that the manual pressure required to operate the keys shall not be excessive and especially that the pressure required shall be uniform for all keys. This desirable condition is obtained in the present structure by designing the latching mechanism so that the force needed to pretension one spring is the same as that required of the other springs. This special latching mechanism is formed with a series of steps, one for each of the five reeds 4, 5, 6, 7 and 8. The low frequency reed 4, being the longest and most easily flexed, is associated with the highest step on the latching plate 21. Hence the same amount of force is required to flex the reed 4 to its normal position above the highest step on the latching plate as is required to flex the next shorter reed 5 to its position above the next and somewhat lower step on the latching plate. And the same force is required to flex the succeeding reeds 6, 7 and 8 to their respective latched positions above the associated lower steps on the plate. Hence the same pressure on any one of the keys 9 serves to store the same amount of energy in the corresponding pair of springs 16 to 20, and the energy stored in these two springs is sufficient to return the released reeds to their normal flexed position ready for the next vibratory action.

Thus the subscriber's transmitter is designed to pluck the reeds with equal forces and at amplitudes which increase to larger magnitudes for each successively lower frequency reeds, the long reed 4 having an amplitude of vibration to generate more energy than the short reed 8. Correspondingly the intermediate reeds will generate signals the energy of which is larger for each reed having a lower frequency of vibration. The advantages of this method of generating the designation signals will be explained more fully hereinafter.

The designation transmitter has been illustrated to a large extent in diagrammatic fashion to simplify the understanding of its operation. Some parts have been omitted and others have been simplified for this purpose. For a general understanding of the full mechanism of a device of this kind reference may be made to Mallina Patent 2,147,710 of February 21, 1939.

Although the finder and selector switches used in the central office for establishing the connections may be of any suitable type, it will be assumed that switches of the panel type are used and that these switches are controlled in the well-known manner by common register senders.

Each of the register senders in the central office includes signal receiving mechanisms comprising equalizers, volume limiters, channel filters and detectors, digit registers, and the usual controlling relays and circuits necessary to the performance of the various functions of the sender. The signal circuit 26 incoming to the sender from the subscriber's line leads first to an equalizer 27. The purpose of this equalizer is to correct for the unequal attenuation effects produced

by the subscriber's line on the signaling currents of different frequencies. Following the equalizer 27 is a second equalizer 28, the purpose of which is to eliminate the differences in signal energy, purposely introduced by the transmitter at the substation, by attenuating the signals by amounts varying in ascending values for decreasing frequencies. Following the equalizer 28 is a broad-band filter 29 designed to pass all of the signaling frequencies and to exclude other frequencies. A volume limiter 30, connected between the filter 29 and the signal receiver 31, serves to limit the energy of the signals delivered to the receiver. The receiver 31 includes five channels, each including a selective filter and a detector. These filters 32, 33, 34, 35 and 36 are tuned to pass currents of frequencies of 700, 900, 1100, 1300 and 1500 cycles, respectively, these frequencies corresponding to those produced by the transmitter reeds at the subscriber's station. The output energy of the associated detectors 37, 38, 39, 40 and 41 is applied to the respective relays 42, 43, 44, 45 and 46. These relays serve to set the registers 47 to register the designation transmitted by the calling subscriber. After the registers 47 have been positioned, the sender controls the selective operation of switches S, S—1, S—2 and S—3 to complete the desired connection, this control being performed over the circuit 48.

For a more complete disclosure of a system utilizing switches of the type herein illustrated and register senders for controlling them, reference is made to the patent to Stearn et al. 1,395,977 of November 1, 1921, and to Kopp 1,589,402 of June 22, 1926.

It has been previously mentioned herein that the presence of noise currents in the transmission circuit may result in the false operation of the receiver provided the frequency of these currents fall within the signaling range. These noise currents usually occur at the switch contacts and relay contacts included in the circuit over which the signals are sent. The subscriber's line and the substation circuit are substantially free of noise-producing contacts, but there are necessarily a number of contacts in the line finder F, in the associated relays and in the sender selector switch S—4 at the central office. Furthermore, experience shows that the noise currents are more numerous in the lower frequencies of the signaling range. That is to say, the liability of false operation of the signal receiver 31 by noise currents is much greater in the low-frequency channel 32 than it is in the high frequency channel 36. Notwithstanding this relation between noise currents and frequency it is highly desirable that the signaling currents of all frequencies shall be applied to the receiver at the same energy level. To meet this requirement it has been proposed heretofore to design the substation transmitter such that all reeds produce signals of the same amplitude. As mentioned hereinbefore, such a transmitter is shown in the Patent to Mallina, No. 2,147,710. In Fig. 4 the graph 49 illustrates this relation between frequency and signal energy at a subscriber's station equipped with such a transmitter. After these signals have reached the central office, where the noise currents also are in the transmission circuit, they may be represented by a similar graph (not shown) which is parallel to the graph 49 except for the effect of line attenuation on the higher frequencies. Since the amplitudes of the signals thus reaching the central office are substantially equal for all frequencies it follows that the margin between the signal current energy and noise current energy is no greater in the low frequency range than it is in the high frequency range. Yet the exposure to interference from these noise currents is, as above noted, much greater in the low frequency region of the graph.

This exposure to false operation by noise currents in the lower frequency range is reduced in the present system by designing the substation transmitter such that the reeds 4, 5, 6, 7 and 8 are plucked with equal forces to produce in the line signal currents having intensities which are of larger magnitude for signals of lower frequency. In other words the low frequency reed 4 produces a signal of greater energy than the signal produced by the high frequency reed 8. This inverse relation is also illustrated in Fig. 4 where the graph 50 represents the signal energy produced by the transmitter at the substation of line 1 and before transmission to the central office. For convenience the abscissae of the graphs in Fig. 4 express frequency and the ordinates express energy in terms of decibels above .01 volt. During the transmission of these signals over the line they undergo attenuation, the high frequency currents usually suffering a greater loss than the currents in the low frequency range. Hence the signals arriving at the central office may be expressed by the graph 51. Since the graph 51 slopes upward toward the low frequency end of the scale the ratio of signal energy to noise energy is considerably improved in this range.

At the central office the signal currents, represented by the graph 51, and the noise currents generated by the contacts or otherwise enter the equalizer 27. The equalizer 27 is designed in such a manner that it attenuates the currents according to frequency by amounts which bear an inverse relation to the attenuation produced upon these currents by transmission over the line. Hence the signal currents passing the equalizer 27 may be represented by the graph 52, which has been restored to parallel relation with the original graph 50. At the same time the equalizer 27 reduces the noise currents by equal amounts for corresponding frequencies. For example, signal current of 700 cycles is attenuated between 5 and 6 decibels as indicated by the graphs 51 and 52, and noise currents undergo an equal reduction in the intensity.

The currents represented by the graph 52 are next applied to the second equalizer 28, which is designed to attenuate them inversely as their frequency and by amounts such that they are all brought to equal amplitudes as they emerge from the equalizer. This relation is illustrated by the graph 53. It may be assumed that the energy level of the signals represented by this graph is sufficient to operate the receiver 31. Since, however, the noise currents have undergone an equal attenuation, frequency for frequency, by the equalizer 28, these noise currents have been depressed, in amplitude, thus minimizing the likelihood of false operation of the receiver.

After emerging from the equalizer the signal currents are passed by the filter 29 and undergo any reduction required by the limiter 30 and are then delivered to the selective filters 32 to 36, inclusive, of the receiver 31.

Since the details of the signal receiver are not essential to an understanding of the inven-

tion, this mechanism has been illustrated to a large extent in diagrammatic manner. For a better understanding of a mechanism of this general type reference may be had to the patent to A. A. Lundstrom, No. 2,237,742 of April 8, 1941.

While the invention is not limited to any particular form of equalizer for attenuating the signal and noise currents one specific equalizer circuit suitable for use in the present system is illustrated in Fig. 3.

To explain briefly the operation of the system in the transmission of a designation, assume that the subscriber of line 1 wishes to converse with the subscriber of line 3 and that the designation of line 3 contains two code digits and four numerical digits. The calling subscriber at the substation of line 1, having initiated the call and caused the operation of the finder switch and the selector S—4 to seize an idle sender, depresses in succession the two keys representing the office code and the four keys representing the number of the line. Assuming that the two office code digits are represented, respectively by keys 54 and 55, the subscriber first depresses the key 54 to move the select bars 10 and 13 downwardly against the tension of their springs 16 and 19. As the bar 10 moves downwardly the damper 23 disengages the reed 4 allowing the reed to be supported solely by the step 56 of the latch plate 21. As the bar 10 moves further in its downward direction the finger 57 engages the edge of the latch plate 21 and rotates it about the pivot pin 22. In the meantime the other bar 13 has likewise withdrawn its damper from the reed 7, allowing the reed to be supported solely by the step 58 of the latch plate. The latch plate 21 rotates about its pivot pin 22 until it clears the ends of all five reeds. When this happens the reeds 4 and 7 are free to vibrate whereas the other three reeds are held by the individual dampers on the select bars 11, 12 and 14. The vibration of these reeds generates currents of corresponding frequencies in the coil 59, and these currents are transmitted over the line 1. When the key 54 is again released by the subscriber, tensioned springs 16 and 19 restore bars 10 and 13, and the dampers on the ends of these bars engage and flex the reeds 4 and 7 back to their normal positions. At the same time the latch plate 21, being released by the fingers 57 and 60, rotates back to its normal position under the reeds.

In this manner the remaining digits of the code and number are transmitted successively by the depression of the corresponding keys.

The signals are received at the central office in the manner above described, the switches are operated to complete the connection, and the sender is released. At the end of conversation the subscribers replace their receivers whereupon the switches are restored to normal in the well-known manner.

What is claimed is:

1. In a signal transmission system, a line, a plurality of reeds having different periods of vibration, means for applying equal forces to all of said reeds to set them in vibration to produce in said line signals having differing energy levels and frequencies equal to the frequencies of the corresponding reeds, a receiving mechanism operable in response to signals of uniform energy levels, and means for equalizing the energy of the signals transmitted over said line and for delivering them to said receiving mechanism.

2. In a signal transmission system, a line, a plurality of vibratory reeds having different natural periods of oscillation, means for applying equal forces to all of said reeds to set them in vibration to cause the transmission over said line of signals having the frequencies of the corresponding vibratory reeds, the energy values of said signals increasing in magnitude as the frequency decreases, a receiving mechanism operable in response to signals of uniform energy levels, and means for equalizing the energy of the signals transmitted over said line and for delivering them to said receiving mechanism.

3. The combination in a telephone system of a line having a station thereon, a plurality of vibratory reeds at said station having different periods of oscillation, manual means for plucking said reeds selectively and with equal forces to set them in vibration, means responsive to the vibration of said reeds for producing in said line signal currents having frequencies corresponding to the respective reeds, the energy values of said signals increasing in magnitude as the frequency decreases, a receiving mechanism operable in response to signals of substantially equal energy values, means for attenuating the energy of the tranmitted signals by varying amounts depending on the frequency, and circuit means for delivering the attenuated signals to said receiving mechanism.

4. In a telephone system, a telephone line subject to the presence of noise currents, a station for said line, a designation transmitter at said station comprising a plurality of vibratory reeds having different natural periods of vibration, manual means for applying equal forces to selected reeds to set them in vibration, means responsive to the vibration of said reeds for transmitting over said line signal currents of corresponding frequencies and of relative energy levels which increase in magnitude as the signal frequency decreases, a receiving mechanism operable in response to signals of substantially equal energy values, an equalizing device at the distant end of said line for attenuating the signal and noise currents transmitted over said line, said equalizer serving to reduce the signal currents to substantially equal energy values, and circuit means for delivering the equalized signal currents to said receiving mechanism for registering the designation represented by said currents.

5. In a telephone system, a central office, a telephone line extending to said central office, said line being subject to the presence of noise currents, a subscriber's station on said line, a designation transmitter at said station comprising a plurality of vibratory reeds having graduated periods of vibration, manual means for selectively operating different combinations of said reeds to represent a desired telephone designation, said manual means serving to pluck the respective reeds with equal forces to set them in vibration, means responsive to the vibration of said reeds for transmitting over said line current signals of corresponding frequencies and of varying energy values, a receiving mechanism operable in response to signals of substantially equal energy values, attenuating means at the central office for reducing by varying amounts depending upon the frequency the energy of all designation and noise signals transmitted over said line, said attenuating means serving to reduce the energy of the designation signals to a substantially uniform value, and

automatic switches in said central office for extending said line in accordance with the transmitted designation, said receiving mechanism being responsive to the designation signals after passing through said attenuating means for registering the desired telephone designation and for controlling said automatic switches in accordance therewith.

6. In a telephone system, a central office, a subscriber's line terminating therein, a substation on said line, a designation transmitter at said substation comprising means for transmitting over said line a plurality of designation signals of different frequencies and of different energy values, said transmitter including a plurality of keys for selecting a desired combination of said frequencies to represent a wanted telephone designation, all of said keys being responsive to a uniform operating pressure, said line being subject to noise currents, a signal receiver in the central office operable in response to signals of equal energy values, means at the central office for attenuating all designation and noise signals to reduce the designation signals of all frequencies to a single energy value and to reduce the noise signals below said energy value, and circuit means for delivering the designation signals after passing through said attenuating means to said signal receiver for registering the wanted telephone designation.

7. In a telephone system, a central office, a subscriber's line terminating therein, a substation on said line, a designation transmitter at said substation comprising means for transmitting over said line a plurality of designation signals of different frequencies and of different energy values, a signal receiver at the central office designed to respond most efficiently to signals of uniform energy values, means at the central office for attenuating said signal currents by amounts corresponding inversely to the attenuation produced upon said signals by transmission over said line, and means at the central office for further attenuating said signals to reduce them to a single energy value for all frequencies, said signal receiver being responsive to the designation signals after passing through said attenuating means for registering the telephone designation represented by said signals.

8. In a telephone system, a telephone line subject to the presence of noise currents, a station for said line, a designation transmitter at said station comprising a plurality of vibratory reeds having different natural periods of vibration, means for applying equal forces to said reeds to flex them by varying amounts, means for holding said reeds normally in their flexed condition, means for withdrawing said holding means to set said reeds in vibration, means responsive to the vibration of said reeds for transmitting over said line signal currents of corresponding frequencies and of energy levels which vary with the frequencies of the signals, an equalizing device at the distant end of said line for attenuating the signal and noise currents transmitted over said line, said equalizing device serving to reduce the signal currents to substantially equal energy values, and a receiving mechanism responsive to the equalized signal currents for registering the designation represented by said currents.

ALEXIS A. LUNDSTROM.