

June 3, 1941.

H. NYQUIST

2,244,500

TELEPHONE SYSTEM

Filed Sept. 30, 1938

8 Sheets-Sheet 1

FIG. 10

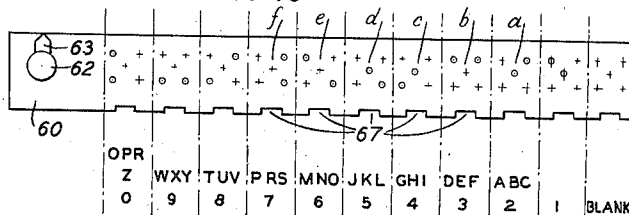


FIG. 11

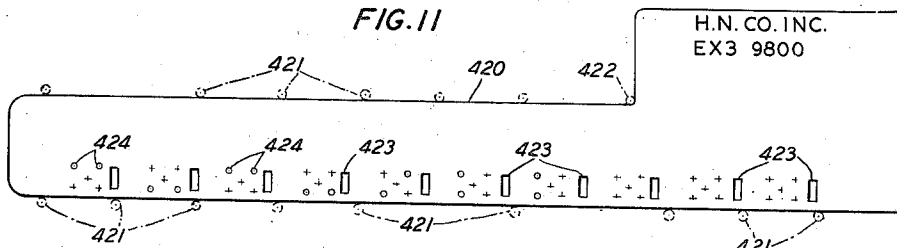


FIG. 5A

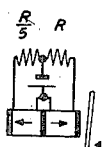


FIG. 5B

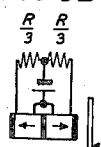


FIG. 5C

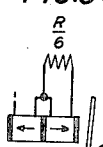
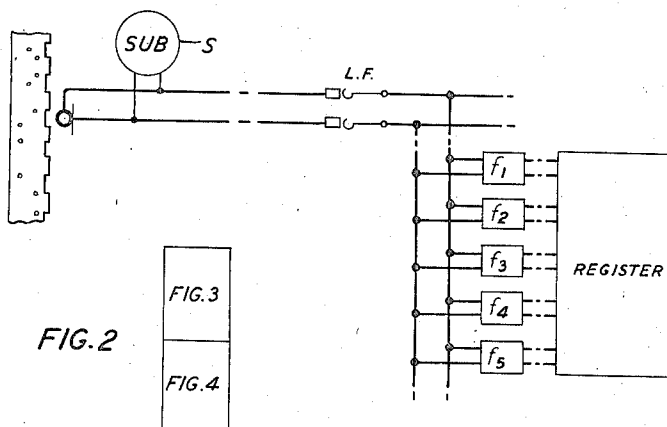


FIG. 1



INVENTOR
H. NYQUIST
BY
H. Nyquist
ATTORNEY

June 3, 1941.

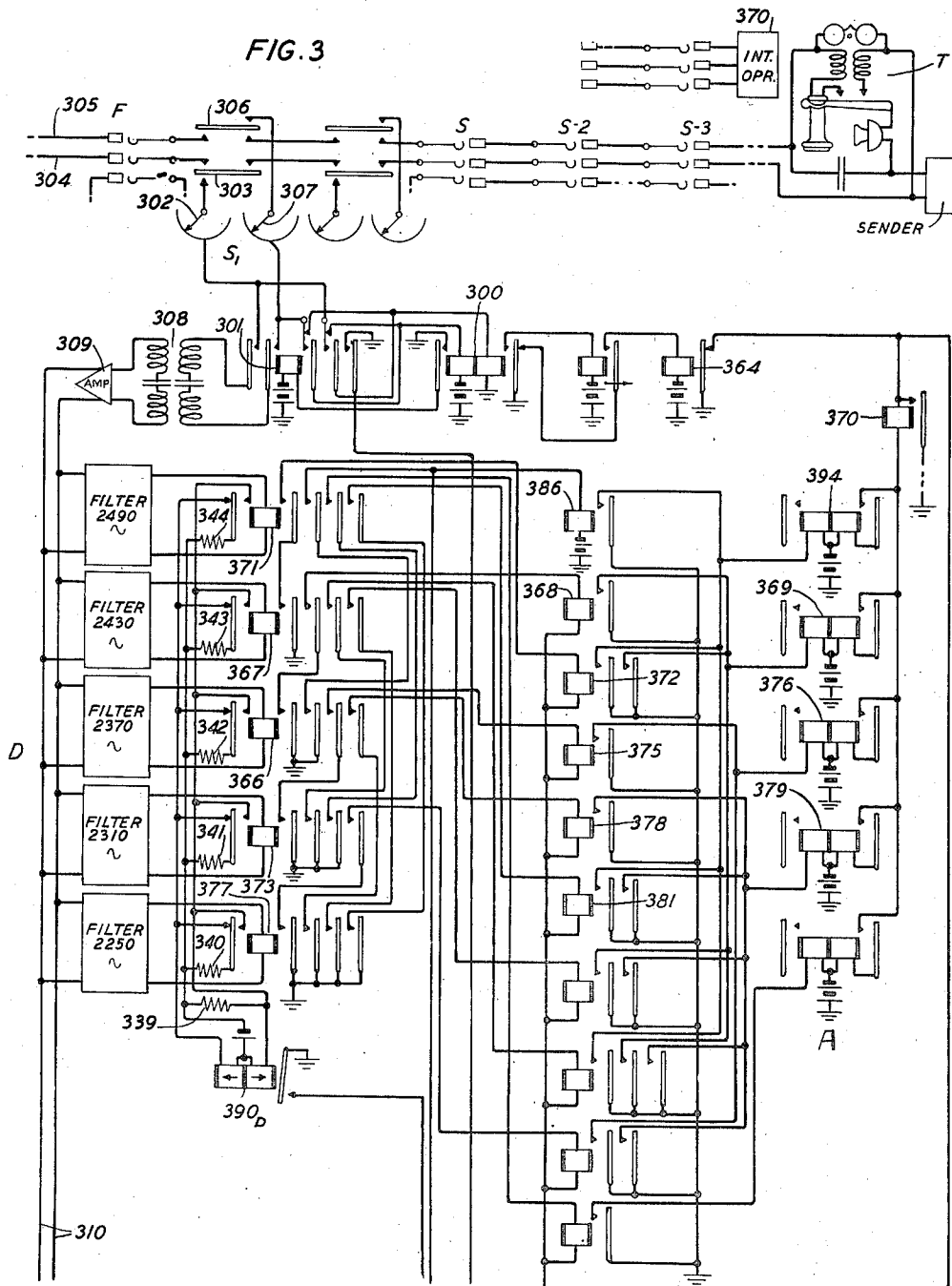
H. NYQUIST

2,244,500

TELEPHONE SYSTEM

Filed Sept. 30, 1938

8 Sheets-Sheet 2



INVENTOR
H. NYQUIST
BY

A. J. Krigman
ATTORNEY

June 3, 1941.

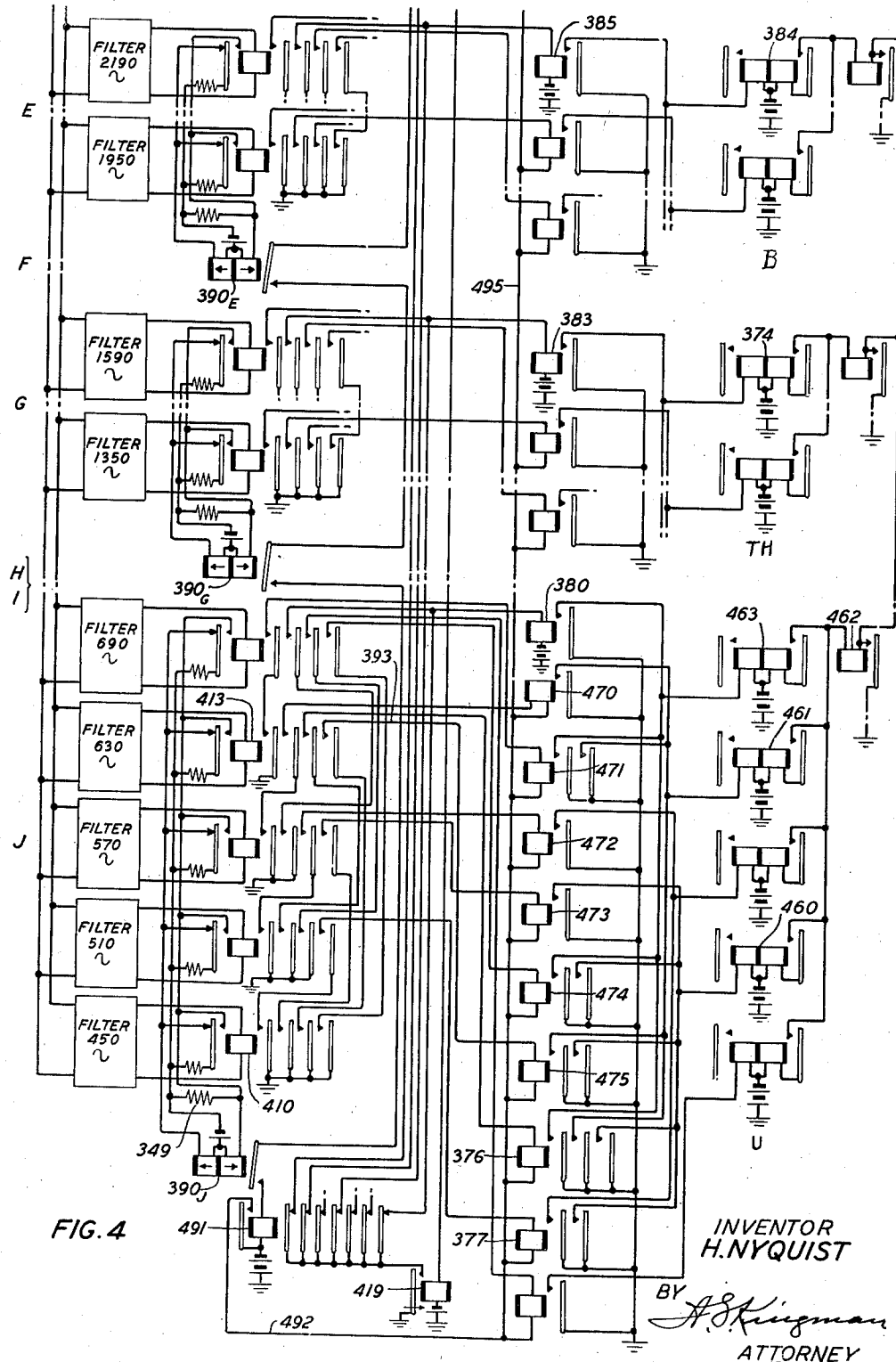
H. NYQUIST

2,244,500

TELEPHONE SYSTEM

Filed Sept. 30, 1938

8 Sheets-Sheet 3



June 3, 1941.

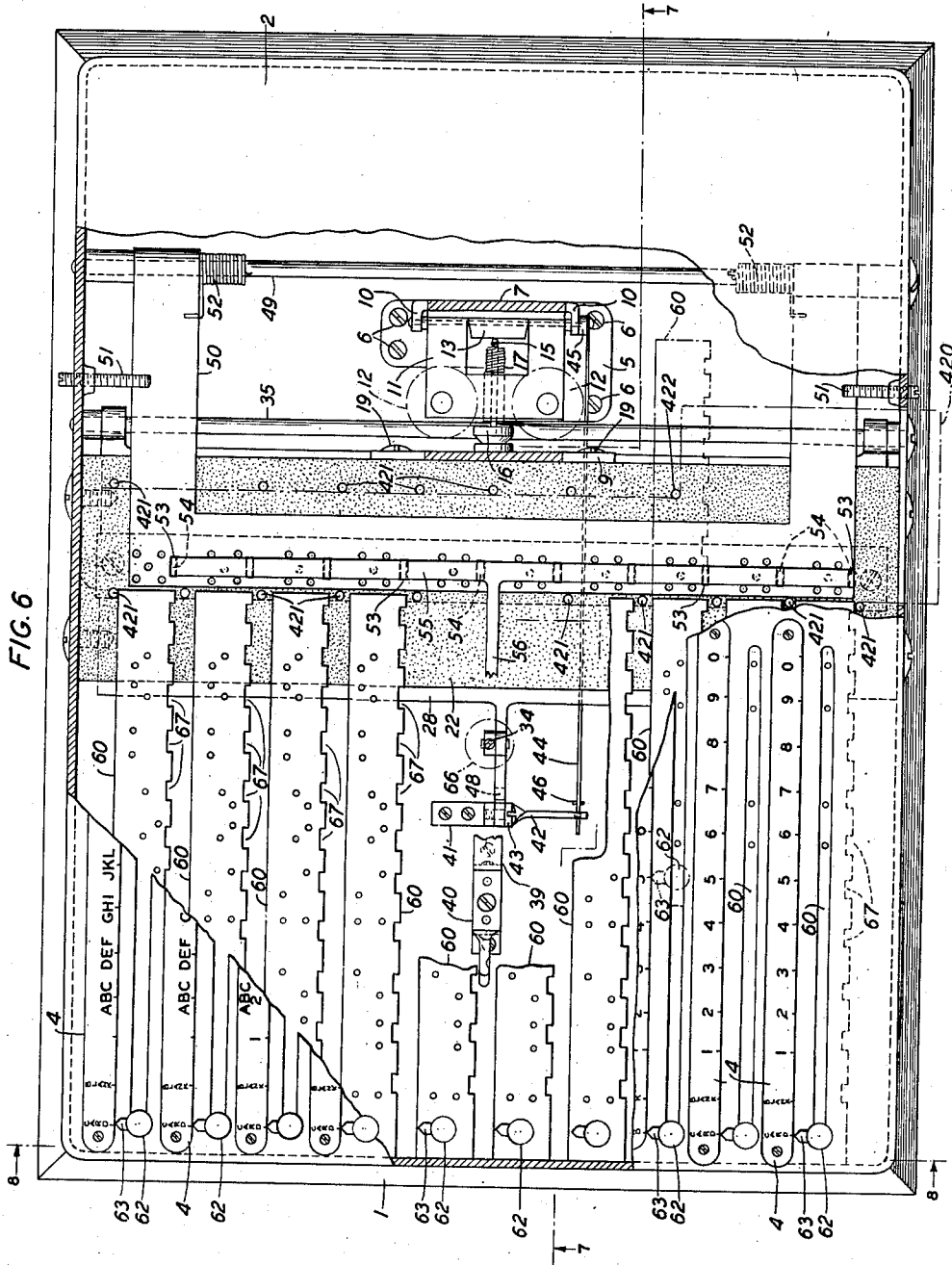
H. NYQUIST

2,244,500

TELEPHONE SYSTEM

Filed Sept. 30, 1938

8 Sheets-Sheet 4



INVENTOR
H. NYQUIST

H. J. Kingman
ATTORNEY

June 3, 1941.

H. NYQUIST

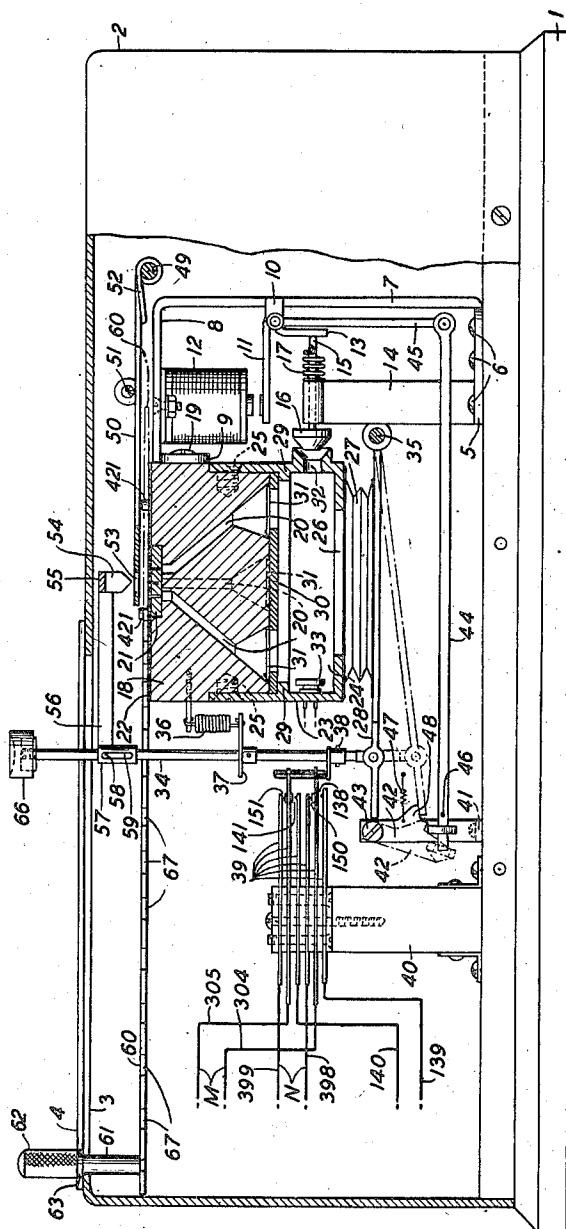
2,244,500

TELEPHONE SYSTEM

Filed Sept. 30, 1938

8 Sheets-Sheet 5

FIG. 7



INVENTOR
H. NYQUIST

BY

H. S. Krugman
ATTORNEY

June 3, 1941.

H. NYQUIST

2,244,500

TELEPHONE SYSTEM

Filed Sept. 30, 1938

8 Sheets-Sheet 6

FIG. 8

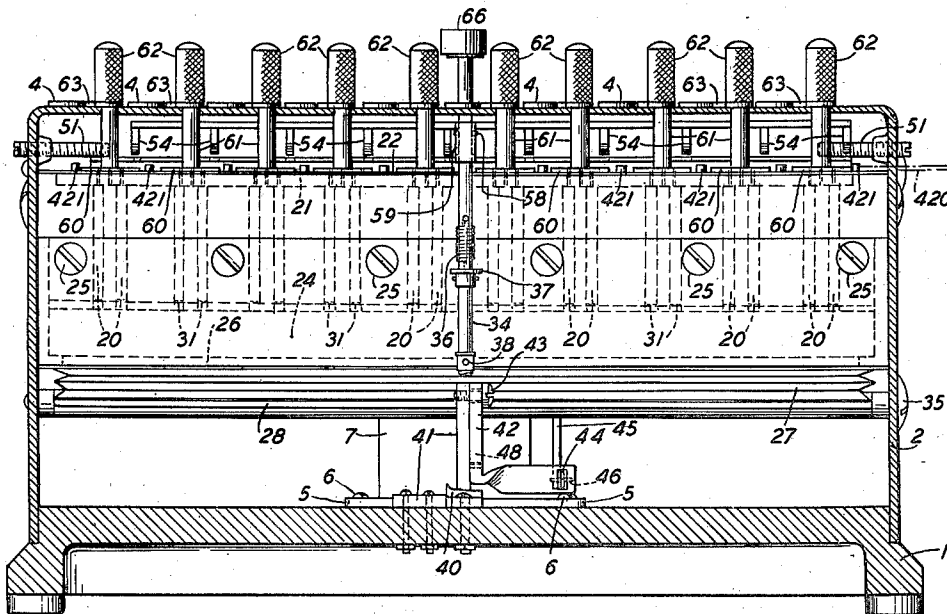
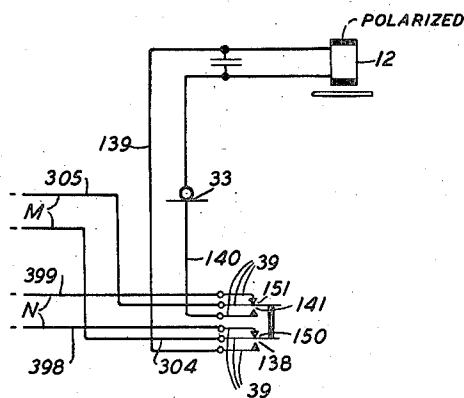


FIG. 9



INVENTOR
H. NYQUIST
BY

H. S. Krigman
ATTORNEY

June 3, 1941.

H. NYQUIST

2,244,500

TELEPHONE SYSTEM

Filed Sept. 30, 1938

8 Sheets-Sheet 7

FIG. 12

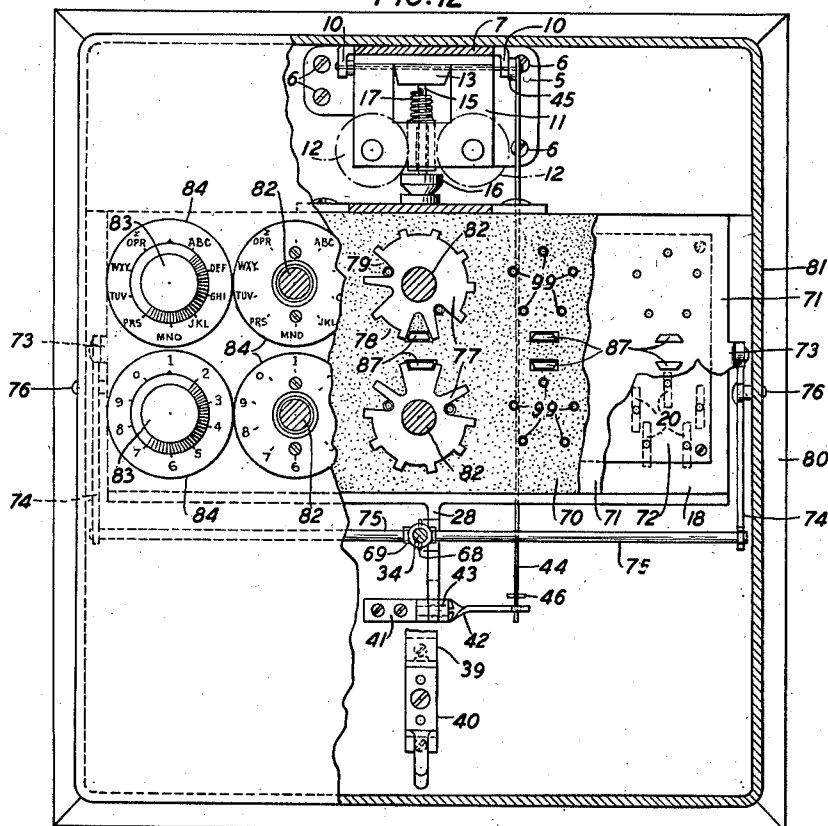
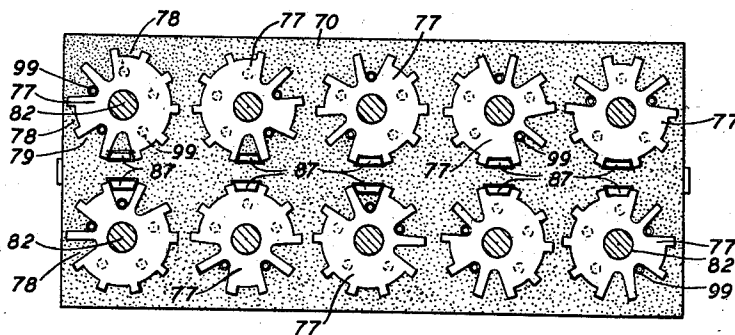


FIG. 14



INVENTOR
H. NYQUIST
BY
H. B. Klingman
ATTORNEY

June 3, 1941.

H. NYQUIST

2,244,500

TELEPHONE SYSTEM

Filed Sept. 30, 1938

8 Sheets-Sheet 8

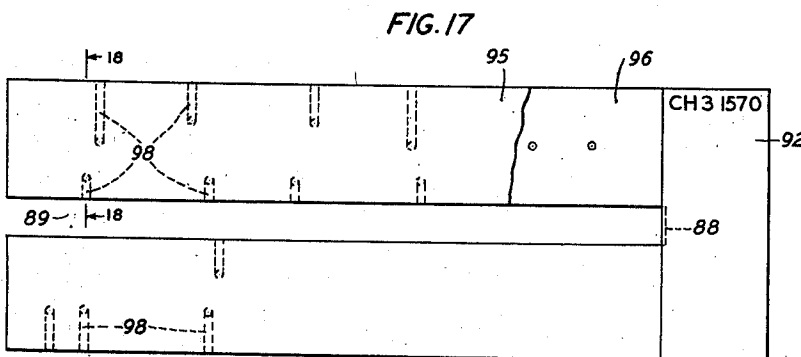
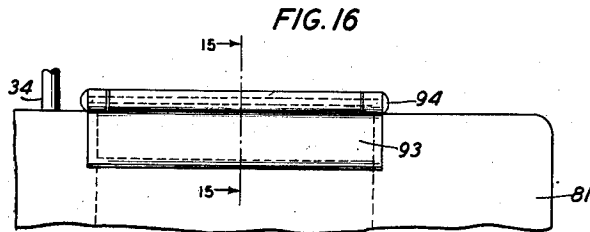
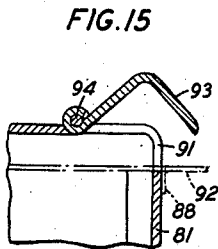
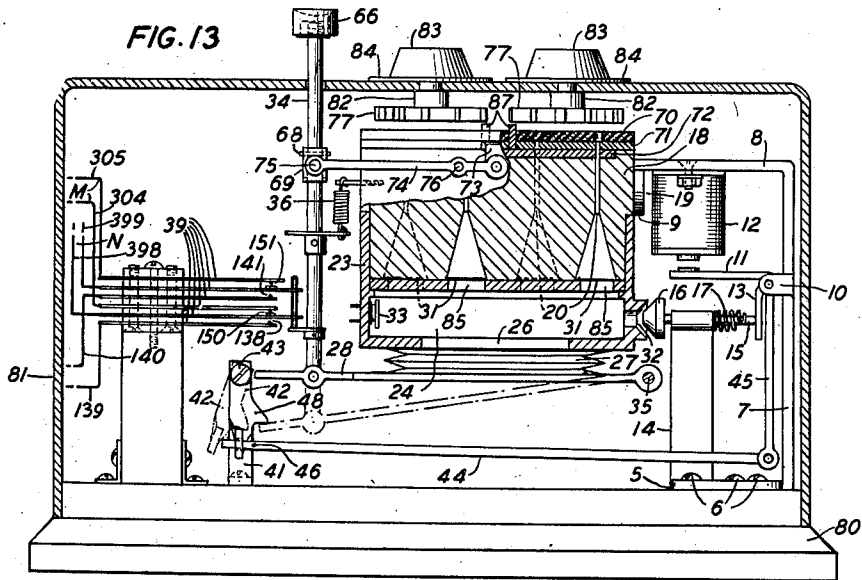
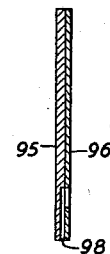


FIG. 18



INVENTOR
BY H. NYQUIST

H. Nyquist
ATTORNEY

UNITED STATES PATENT OFFICE

2,244,500

TELEPHONE SYSTEM

Harry Nyquist, Millburn, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application September 30, 1938, Serial No. 232,519

14 Claims. (Cl. 179—18)

This invention relates to telephone systems and particularly to telephone systems of the type in which automatic switches at a central office are controlled by means of alternating currents generated at a subscriber's station.

The objects of the invention are to reduce the efforts required of subscribers and operators in transmitting telephone designations; to decrease the time consumed in transmitting the designations; to lessen the possibility of "wrong numbers" and to otherwise improve automatic telephone systems.

These objects are attained in accordance with a feature of the invention by replacing the rotating dial, commonly used in automatic telephone systems, by a reed-type designation sender of the preset variety, which functions to selectively generate groups of alternating current frequencies, which characterize the digits of a designation, and to cause all the generated frequencies to be transmitted simultaneously to a central office to selectively control automatic switches thereat.

Another feature of the invention resides in the provision of means which precludes the possibility of the designation sender functioning to transmit the designation characterizing frequencies before the central office equipment is ready to receive them. This feature is obtained by causing the sender, after having been set by the subscriber, to lock under the control of a polarized relay at the subscriber's station which relay functions upon a current reversal effected when the receiving equipment at the central office is connected to the established connection, to release the frequency transmitting mechanism at the subscriber's station.

A further feature of the invention resides in the use of a signaling code which is self-proving. To this end a signaling code of permutations of an invariable number of opposed conditions is employed. In the present invention the term "opposed conditions" has particular reference to a signaling condition, characterized by the use of two frequencies, and a non-signaling condition characterized by three frequencies. Each element of the signaling code, or telephone designation, is characterized by the transmission of two of five frequencies allotted to each digital position of the designation. For example, the "units" position of a designation may have assigned thereto frequencies f^1 , f^2 , f^3 , f^4 and f^5 and each digit capable of occupying such position is characterized by an invariable proportion of these frequencies arranged in various combina-

tions or as permutations. The digit "1," for example, may be characterized by frequencies f^1 and f^2 representing the signaling condition and frequencies f^3 , f^4 and f^5 representing the non-signaling condition. The digit "1" therefore, is characterized by opposed conditions (signaling and non-signaling) in the proportion of two to three. Similarly, the digit "2" may be characterized by frequencies f^1 and f^3 , the signaling condition, and frequencies f^2 , f^4 and f^5 , the non-signaling condition, so that this digit is also characterized by opposed conditions in the same proportion of two to three. The signaling code, or telephone designation, therefore, may be accurately described as consisting of permutations of opposed conditions in an invariable proportion. Such a code may be termed self-proving since the receipt of an invariable number of signaling impulses or frequencies is practical proof of correctness and any deviation from the invariable number of signaling frequencies, or from the invariable proportion of opposed conditions, may readily be detected to indicate mutilation of the signaling code or telephone designation.

These and other features of the invention will be described more fully in the following description made with reference to the accompanying drawings, in which:

Fig. 1 constitutes a diagrammatic representation in skeletonized form of some of the essential equipment employed at a subscriber's station and at the central office and illustrates the general operation of the system embodying the features of the invention. In this figure, a portion of a tape-type frequency selecting device, which is capable of being moved into ten operating positions by a calling subscriber, is shown to the left of a carbon button which functions to convert the vibrations effected by the vibrated reeds into electric currents of corresponding frequencies, which are then transmitted to the central office and received by groups of frequency selecting circuits diagrammatically shown at the right of the figure;

Fig. 2 is a block diagram illustrating the manner in which the drawings disclosing the circuits involved in the completion of a connection from a calling subscriber to a called subscriber are to be assembled to effect a complete workable system;

Figs. 3 and 4 are circuit diagrams illustrating schematically the central office switches, the frequency receiving equipment and the central office registers into which the frequency receiving cir-

cuits work and which serve to register the designations transmitted from the subscriber's station by the designation sender located thereat;

Figs. 5A, 5B and 5C illustrate several of the circuit conditions which may be encountered by the code proving circuit;

Fig. 6 is a top plan view, with certain parts broken away, of a designation transmitter which functions with the system disclosed;

Fig. 7 is a vertical cross-sectional view of the transmitter of Fig. 6 taken along the line 7—7 of Fig. 6 and looking in the direction of the arrows;

Fig. 8 is a section taken along the line 8—8 of Fig. 6 looking in the direction indicated by the arrows;

Fig. 9 is a circuit schematic illustrating the electrical equipment involved in the designation sender and the switching mechanism for connecting the same to the central office line;

Fig. 10 is a plan view of one of the frequency selecting tapes employed in the designation sender of Fig. 6;

Fig. 11 is a plan view of an alternative form of frequency selecting device which may be employed in the designation sender of Fig. 6;

Fig. 12 is a top plan view, with certain parts broken away, of another form of designation sender;

Fig. 13 is a sectional view of the sender shown in Fig. 12;

Fig. 14 is a plan view of the sender shown in Fig. 12 with the top removed;

Figs. 15 and 16 are fragmentary views illustrating certain structural details of the sender of Fig. 12;

Fig. 17 is a plan view of an alternative form of frequency selecting device which may be employed in the sender of Fig. 12; and

Fig. 18 is an enlarged section taken along the line 18—18 of Fig. 17 looking in the direction of the arrows.

The designation sender illustrated in Figs. 6, 7 and 8 is housed in a box-like structure consisting chiefly of a base 1 and a cover 2, the latter being removably secured to the base by means of screws as shown. The cover 2 is solid except for ten longitudinally extending slots 3 which extend substantially half way up the length thereof. These slots are clearly seen in Fig. 7. Running parallel to the slots 3 and located to the left of each thereof is located a designation strip 4 secured to the cover by means of screws. The first two strips to the left bear letters of the alphabet grouped in a manner to correspond to the letter groupings on the number plate of the rotating type of dial in common usage today; the third strip may include both letters and numerals whereas the remaining strips bear numerals only. Each strip has also a "Blank" and a "Card" designation, the former identifying the normal position of the selecting devices to be described hereinafter and the latter corresponding to the position to which the selecting devices are moved when a card-type selector is used as will appear from a later description. The "Blank" position is not an essential requirement since the central office equipment would be made to disregard any superfluous information transmitted by the sender.

Upon the base 1 there is secured an irregularly shaped bracket member clearly indicated in Fig. 7. This bracket consists of a lower horizontal flange 5 secured to the base 1 by screws 6, an elongated vertical portion 7 which is bent at

right angles near its top to form a horizontal portion 8. Extending at right angles in either direction from the end of the bracket portion 8 is an elongated horizontal portion 9. The portions 8 and 9 of the bracket form a T. At about one-third the way down from the top of portion 7 there are provided two ear-like projections 10 which serve as supports for the armature 11 of electromagnet 12. The magnet 12 is secured to the bracket piece 8 by means of bolts and nuts, as shown. The center portion of armature 11 is cut away and bent downwardly to form the element 13. Also extending vertically from the bracket base 5 is a member 14 which is curled at its upper end to form a bearing for shaft 15 which carries at one end a valve 16 and whose other end abuts against the member 13 and is held in this position by the action of coil spring 17.

Secured to the elongated bracket piece 9 is a substantially rectangular mold 18 which may be made of any suitable material which can be readily molded or drilled. The mold 18 extends substantially the entire width of the cover 2 and is secured to the bracket piece 9 by means of screws 19. The mold 18 is provided with ten sets of air passages or conduits 20, each set consisting of five ducts converging at their upper ends and terminating in enlarged openings at their lower ends. The conduit or duct outlets are so arranged as to identify the four corners and center of a square. Embedded in the mold and extending over the ten sets of conduit outlets is a metal strip 21 having ten sets of five perforations which are in alignment with the conduit outlets and therefore serve, in effect, as continuations of the conduits 20. Secured to the upper face of the mold 18 and strip 21 is a rubber gasket 22 which is apertured in the same manner as the strip 21 and whose apertures coincide with the apertures therein.

A metal framework 23 defining an air chamber 24 is fitted over the lower portion of the mold 18 and secured thereto by means of screws 25. The lower wall of the chamber 24 is cut away at 26 to provide a communication passage between the chamber 24 and a bellows 27, one end of which is secured in any suitable manner to the outside of the lower wall of chamber 24 and the other end of which is carried by the actuating member 28. The upper wall of chamber 24 is also cut away to form the shelf-like projections 29 upon which rests a metal plate 30 having fifty slots in it, each of which is located opposite or contiguously with the enlarged lower ends of the conduits 20. Over each slot there is fixed a reed 31, after the fashion of musical reed instruments, such as mouth organs. Each reed is dimensioned to vibrate at an odd harmonic of 30 cycles beginning, for example, at 450 cycles and continuing until a required number is obtained.

Midway along one side of one of the side walls of the chamber 24 is a vent 32 which terminates in a seat for the valve 16. Secured to the opposite wall of the chamber 24 is a carbon button 33.

The means for actuating the bellows 27 consists of a plunger rod 34 which protrudes through an opening in the cover 2 and has its lower end pivotally connected to the bellows support 28. The bellows support is rotatably mounted on a shaft 35 which extends substantially the width of the cover 2. The plunger rod 34 is held in its normal position (illustrated) by means of retractile spring 36 which has one end anchored to a pin projecting from the mold 18 and the other

end to the member 37 mounted on the rod 34. Just above its pivot connection with the bellows support 28 there is mounted on the rod 34 a contact operating member 38 which functions to control the operation of the spring pile-up 39 when the plunger rod 34 is actuated. The spring pile-up 39 is suitably mounted on the insulating block 40 which in turn is made fast to the base 1.

An L-shaped bracket 41 is secured to the base 1 by means of screws and provides a support for the latch 42 which is rotatably secured to the upper end of the bracket by means of a screw 43. The latch 42 is bent at right angles at substantially its mid-point and the portion extending at right angles from the vertical portion thereof is given a right angle twist, and the twisted end is provided with a hole which slidably accommodates one end of the link or rod 44. The rod 44 is pivotally connected to the extension 45 of armature 11, so that any motion of the armature is transmitted to the rod 44. When the electromagnet 12 operates and the armature 11 is attracted, the rod 44 is thrust forward, its free end traveling in the hole in the latch member 42 until the pin 46 abuts against the latch and causes it to swing about its pivot against the restraining influence of spring 47. The latch 42 is provided with a lip 48 under which the bellows support 23 is locked when the plunger rod 34 is depressed.

Rotatably mounted on screw shaft 49 is a U-shaped clamp 50 which is normally held against the stop screws 51 by coil spring 52. The bridging portion of the U-shaped clamp is provided with ten sets of apertures, five apertures in each set relatively disposed in the same manner as the apertures in the plate 21 and gasket 22. Intermediate each set of five apertures is located a slot or opening 53, each of which accommodates a centering wedge 54. The centering wedges 54, there being ten in number, are formed as integral projections of a T-shaped frame consisting of the elongated portion 55 and the arm 56 which is provided with a slotted sleeve 57 slidably associated with the plunger rod 34. A pin 58 secured to the rod 34 rides in the slot 59 of the sleeve 57, so that when the plunger is depressed the centering wedges 54 are not moved until the pin 58 engages the lower end of the slot 59. The purpose of this lost motion effect will be explained hereinafter.

The frequency selecting device consists of one tape 60 for each digital position of a designation, or ten tapes, assuming a ten digit sender. Near one end of each tape 60 there is secured a pin 61 which protrudes through a slot 3 in the cover 2 and is furnished with a knurled grip or handle 62. The other ends of the tapes 60 rest upon the rubber gasket 22 so that when the grip or handle 62 is pushed forward, the associated tape rides over the gasket and under the clamp 50. Each tape is provided with ten sets of two perforations, the two perforations in each set being so located as to occupy two of the five square-identifying points hereinbefore mentioned, that is, each set consists of two apertures, each aperture being located at either one of the four corners or center of a square. This arrangement of apertures is clearly illustrated in Fig. 10. It is apparent that ten different combinations of two perforations may be had from the five perforations located as shown in Fig. 10. Each combination of two perforations corresponds to a particular digit of a telephone designation as shown on the drawing. Each grip or handle 62 is provided with an indicator or pointer 63 to assist the subscriber in ac-

curately setting the tapes 60. The pointers 63 register with the symbols on the designation strips 4 when the tapes are being set.

The operation of the designation sender disclosed in Figs. 6, 7 and 8 is as follows:

Assuming the calling subscriber at whose station the designation sender is located desires to converse with a subscriber whose station designation is AB-3-4567 for example, the calling subscriber would grasp the first (left-hand) grip 62 and push it forward until the associated indicator 63 registers with the symbols ABC located on the corresponding designation strip 4; the second grip 62 would then be pushed forward until its associated indicator 63 also registered with the symbols ABC on the adjacent strip 4; the next five handles would be manipulated in the same manner until their associated pointers registered with the numerals 3, 4, 5, 6 and 7, respectively, on corresponding designation strips 4. The subscriber may check the number he has set up by reading the characters adjacent to the operated pointers and may also preserve the setting until he is connected with the called party. Being assured that the desired designation has been correctly set up on the sender, the subscriber depresses the plunger rod 34 by pressing down on the button 56 associated therewith. This operation, following the setting operation, is all that is required of the subscriber except for the removal of the receiver from its switchhook for conversational purposes.

When the plunger 34 starts its downward movement the first function performed is the connection of the designation sender to the central office loop by the operation of the spring pile-up 39 as will be more fully described hereinafter. It will be noted that the springs of the pile-up 39 are normally held under tension so that as the spring actuator 38 moves downwardly with the plunger rod 34, the tension is relieved and the springs are actuated. As the plunger rod continues its downward travel the pin 58 associated therewith eventually engages the lower end of the slot 59 in sleeve 57 whereupon the centering arm 56 is lowered. The centering wedges 54 partially pass through their respective slots 53 in the clamp 50 and enter the centering notches 67 located on one edge of each of the frequency selecting tapes 60. The tapes are thus correctly positioned to insure a perfect alignment of the apertures in the tapes with those in the gasket 22 and strip 21. Just as the centering operation is performed, the wedges 54 engage the clamp and force it tightly against the tapes so that there is no possibility for air to escape from any place other than through the apertures now in alignment.

As the plunger rod 34 is depressed, the bellows 27 is opened due to the association of the bellows support 28 with the plunger, and air is drawn into the chamber 24 by way of the vent 32. During its downward movement, the free end of bellows support 23 rides upon the periphery of the latch lip 48 causing the latch to swing to the left. When the support 23 clears the lip 48 the spring 47 functions to restore the latch to its normal position so that the plunger rod and bellows 27 are locked in their operated positions.

As will hereinafter appear more fully, a current reversal in the central office loop is effected when the receiving equipment thereat is ready to receive the designation set up by the subscriber. This reversal causes polarized magnet 12 to operate and attract its armature which

causes the armature extension 13 to act upon the valve shaft 15 and actuate the valve 16 whereupon the vent 32 is closed. The rod 44 also experiences a thrust due to the operation of armature 11 so that it advances through the hole in the latch 42 until the pin 46 engages and moves the latch to the left, releasing the plunger rod 34. The plunger 34 returns to normal under the action of spring 36 and in so doing closes the bellows 27, thus causing the air in the chamber 24 to be driven over the selected reeds and through those air passages or conduits 20 whose outlets are in alignment with the holes in the frequency selecting tapes 60. The selected reeds 31 are accordingly vibrated at their natural periods of vibration. These vibrations act upon the carbon button 33 and are thereby converted into electric currents of corresponding frequencies. These frequencies are accordingly impressed simultaneously upon the central office loop and are received by the frequency receiving circuits at the central office. During the greater part of the return movement of the plunger rod 34, the centering wedges are held in their operated positions thereby maintaining the clamp 50 tightly against the set tapes 60 during the closure of the bellows 27. It will also be noted that near the end of its return travel the plunger 34 causes the springs of pile-up 39 to be returned to normal whereupon the designation sender is disconnected from the central office loop and the subscriber's line circuit connected thereto. Magnet 12 accordingly releases its armature causing the opening of valve 16 and the restoration to normal position of the latch member 42.

The designation sender described above, as well as the alternative form to be described hereinafter, are capable of transmitting telephone designations having as many as ten digits though it is understood that in present practice only a maximum of seven or eight digits is required.

It will now be described how a call originated at station S (Fig. 1), at which the designation sender of Figs. 6, 7 and 8 is located, is extended to a called subscriber's station T (Fig. 3) whose designation is assumed to be AB-3-4567.

As shown in Fig. 1 and Fig. 7 the central office line circuit M indicated by the numerals 304 and 305 is normally connected to the subscriber's line circuit N indicated by the numerals 398 and 399, by the normally closed contacts 150 and 151 of the spring pile-up 39, whereas the circuit to the designation sender is normally open at the contacts 138 and 141. In setting up the desired designation, the subscriber at station S grasps each of the first seven handles 62 starting from the left in Fig. 6 and moves them forward individually until the desired designation is indicated by a reading of the symbols appearing to the left of the pointers 63 associated with the handles 62 as hereinbefore described. These operations cause the apertures *a* (Fig. 10) in the first frequency selecting tape 60 to be moved into alignment with corresponding apertures in the first group of five apertures in the gasket 22, the apertures *b* (Fig. 10) of the third tape 60 to be aligned with corresponding apertures in the second group of five apertures in the gasket 22, the apertures *c*, *d*, *e* and *f* of the fourth, fifth, sixth and seventh groups are brought into alignment with corresponding apertures of the corresponding

groups of five apertures appearing in the gasket 22. The plunger rod 34 is then actuated and locked in a manner previously described and the set tapes are centered and clamped by the action of the centering wedges 54, also described in detail hereinbefore. As the plunger rod moves downwardly, the tension on the springs of spring pile-up 39 is relieved and contacts 150 and 151 are opened and contacts 138 and 141 are closed. The closure of the second set of contacts completes the connection of the subscriber's designation sender with the central office loop M. The closure of this loop, as is well known in the art of automatic telephony, causes a line finder F (Fig. 3) to function and seize the calling line. At the same time, the sender selector S-1 becomes effective to extend the calling line through to an idle sender. When these operations have been completed a circuit exists which may be traced from grounded battery, left winding of relay 300, back contact and right make-before-break contacts of relay 301, sender brush 302, contact of spring 303 on a controlling sequence switch, thence over the lower brush and contact of finder F, conductor 304, contact 138 of spring pile-up 39, conductor 139, windings of polarized magnet 12, carbon button 33, conductor 140, contact 141 of spring pile-up 39, conductor 305, contact and upper brush of finder F and sequence switch contacts 306, brush 307 of sender selector S-1, left-make-before-break contacts of relay 301 to ground through the right winding of relay 300. The magnet 12, being polarized, does not operate in this circuit. Relay 300 does operate, however, and at its left armature establishes an obvious energizing circuit for relay 301.

In attracting its outermost right armature relay 301 establishes an obvious energizing circuit for relay 419 (Fig. 4). This relay is slow to operate and performs no useful function at this time since relay 491 will have operated before it, as will appear presently. The function performed by relay 419 will be set forth in greater detail in a subsequent description to be made covering a condition wherein an incorrect number of frequencies are transmitted from the subscriber's station. At its two left armatures relay 301 connects one side of the transformer 308 to the established connection. The other winding of the transformer 308 is connected to a common channel 310 by way of the amplifier 309. The frequency receiving circuits are now connected to the station designation sender for the receipt of the designation set up thereon. At its first and second right armatures, relay 301 reverses the connections to the windings of relay 300, thereby causing a reversal of current in the loop M which now includes the windings of polarized magnet 12.

Magnet 12 operates upon the reversal of line current causing the plunger rod 34 of the designation sender to be unlatched with the result that the bellows 27 closes under the action of coil spring 36. The valve 16 is also operated by the magnet 12 causing the closure of the vent 32. The air expelled by the action of the bellows 27 is driven over the reeds 31 through the selected conduits 20 in the mold 18 and thence out through the outlets of the selected conduits which are now in alignment with the apertures *a*, *b*, *c*, *d*, *e* and *f* of the set tapes 60 and through corresponding apertures in the clamp 50. The reeds associated with the conduits whose outlets are open accordingly vibrate at their natural periods of vibration. These vibrations are con-

verted into electric currents of corresponding frequencies by the action of the carbon button 33 which, as shown in Fig. 9, is included in the circuit now connected to the central office loop M. A group of fourteen frequencies, or perhaps, seven groups of two frequencies, are accordingly transmitted over the established connection to the common circuit 310.

Seven groups of frequency receiving circuits, each group consisting of five distinct channels, are connected to the common circuit 310. These groups are indicated on the drawings by the letters D, E, F, G, H, I and J, the groups D and J being shown complete, groups E and G in part and groups F, H and I represented only by the broken lines in the common circuit 310. Each channel is equipped with a distinctively tuned filter which is indicated on the drawings by the frequency which it selectively passes.

It may be well at this time to describe, somewhat generally, the code proving circuits illustrated at the right of each group of filters. This circuit comprises a group of five neutral relays for each digital position of a designation and a differential relay for each group of five neutral relays. Under normal conditions there are five equal resistances connected across the left winding of each differential relay and a single resistance, having a value equal to one of the other five resistances, connected across the right winding. This connection is schematically illustrated by Fig. 5A. Under this condition there exists an unbalance between the currents in the two windings so that the differential relay of each group is normally operated. Upon the receipt of two frequencies by each group of frequency receiving circuits, two of the neutral relays operate to transfer two of the five resistances from across the left winding of the differential relay to the circuit including the right winding. There are then three equal resistances connected across each winding of the differential relay which produces a condition of current balance. The differential relays accordingly release their armatures. This condition is illustrated by Fig. 5B. Any deviation from the correct number of frequencies, that is two frequencies, preserves the normal condition of unbalance and the differential relays remain operated. Such a condition is illustrated in Fig. 5C. This figure shows the condition which prevails when five frequencies have been received by a group of frequency receiving circuits.

Resuming the description of the circuit operation of the system disclosed, it will be assumed that the correct number of two frequencies per digital position are received at the central office. Under this condition two of the neutral relays in each of the code proving circuits operate thereby causing the release of all the differential relays. An obvious operating circuit is thereupon established for relay 491 (Fig. 4). Relay 491 operates under this condition before relay 419 thereby rendering ineffective, at this time, the ground potential connected to the right armatures of relay 491 by the operation of relay 419. As hereinbefore stated, relay 419 is slow to operate.

For descriptive purpose only, it will be assumed that the character A of the desired telephone designation is characterized by the two frequencies 2430 and 2370 cycles and that these frequencies result from the alignment of the apertures *a* (Fig. 10) with the first group of five apertures in the plate 21 and the associated gas-

ket 22. The filters so indicated in group D selectively pass the two frequencies 2430 and 2370 cycles causing relay 367 and 366, which are tuned to these frequencies, to operate. A circuit is thereupon established extending from grounded battery, left armature and front contact of relay 491, conductors 492 and 495, winding of chain relay 368, front contact and second right armature of relay 367, front contact and first right armature of relay 366 to ground. Relay 368 operates in this circuit and at its armature and front contact establishes an obvious operating circuit for register relay 369 of the register A. Register relay 369 in attracting its right armature locks to ground at the armature and back contact of relay 364 in a circuit including the winding of relay 370. Relay 370 operates in this circuit and, inclosing its armature contacts, locks with relay 394 to ground independent of the ground at the armature of relay 364. The designation digit "A" is accordingly stored by relay 394 in register A for subsequent use in controlling the automatic switches employed in extending the desired connection.

The character "B" of the assumed designation is characterized by the frequencies 2190 and 2130 cycles which are selectively received by correspondingly tuned filters in the group E. Only one of these filters 2190 cycles is shown. The other filter, 2130 cycles, occupies the same position in group E as does the 2430 cycle filter of group D. Correspondingly tuned relays in the code proving circuit of group E thereupon operate and cause the operation of a chain relay controlling the register relays of register B which corresponds to relay 368 in the preceding chain. This relay in turn causes the operation of a relay, corresponding to relay 369, in the register B. Such relay locks in the same manner as does relay 369 to store the second designation character "B" for subsequent use.

The digit "3" of the assumed designation is characterized by the frequencies 1170 and 1140 cycles which are received by filters located in group F (not shown) in positions corresponding to the 2490-cycle and 2430-cycle filters of group D. Similarly tuned relays, corresponding to relays 371 and 367 of group D, in group F operate to cause the operation of a chain relay corresponding to relay 372 of the relay chain of group D. This relay, in turn, causes relays in the C register (not shown), corresponding to relays 394 and 369 of the A register, to operate and lock, thus storing the digit "3" for subsequent use.

The thousands digit "4" is characterized by the frequencies 1470 and 1410 cycles which are received by filters in group G corresponding in position to the 2370-cycle and 2310-cycle filters in group D with the result that tuned relays in the code proving circuit of group G corresponding to relays 365 and 373 operate to cause a chain relay, corresponding to relay 375 of the relay chain of group D to be energized. Such relay operates and, in turn, causes a register relay in register TH, corresponding to relay 376 of register A to operate. This relay locks in the same manner as all previously operated register relays and thus the digit "4" of the desired designation is stored for subsequent use.

The hundreds digit "5" is characterized by frequencies 1170 and 1050 cycles which are received by filters in group H (not shown) which correspond, in position, to the 2370-cycle and 2350-cycle filters of group D causing the opera-

tion of tuned relays in the code proving circuit of group H which correspond to relays 366 and 377 of group D. These relays, in turn, cause a chain relay, corresponding to relay 378 in the relay chain of group D, to operate, as a consequence of which, a register relay in the hundreds register corresponding to relay 379 of the A register operates and locks, thus storing the hundreds digit "5" for subsequent use.

The tens digit "6" of the desired designation is characterized by frequencies 990 and 750 cycles which are selectively received by correspondingly tuned filters in group I (not shown), which filters occupy positions corresponding to those of the 2490 and 2250 filters of group D. Code proving relays of group I corresponding to relays 371 and 377 of group D thereupon operate to cause the operation of a chain relay corresponding to the chain relay 381 of group D. This relay functions to operate two relays in the tens register corresponding to relays 394 and 379 of register A, which relays lock in a manner now well understood. The tens digit "6" of the desired designation is accordingly stored for subsequent use.

The units digit "7" of the called number is characterized by the frequencies 630 and 450 cycles which are received by correspondingly tuned filters of group J. Tuned relays 413 and 410 accordingly operate and establish an obvious operating circuit for chain relay 475. Relay 475, operated, establishes obvious operating circuits for relays 460 and 461 of register U which relays thereupon operate and lock to ground under control of relay 462. Thus the units digit "7" is stored for subsequent use.

The description thus far advanced covers the setting of the designation sender at the calling subscriber's station, the operation of the designation sender in transmitting the correct frequency code, corresponding to the telephone designation AB-3-4567, to the central office and the consequent operation and locking of the various register relays in storing the designation for subsequent use in extending the call to a called station.

As hereinbefore mentioned, each designation digit is characterized by two of five frequencies. In other words, each digit is characterized by an invariable proportion of a group of frequencies allotted to each digital position of a designation and to insure the correct code being registered at the central office it is necessary that there be no deviation from the said invariable proportion without detection. The following description covers the transmission of a code in which one or more of the designation digits, through faulty operation of the designation sender or for some other reason, is made up of a single frequency or a combination of frequencies greater in number than two.

It will be assumed that in the transmission of the character "A" occupying the first digital position in the designation, the frequency 2430 cycles has been suppressed and only the 2370-cycle frequency is received at the central office. Under this condition only relay 366 of the code proving circuit of group D would be operated and no relays in the register A would be operated. With only relay 366 operated there would be connected across the right winding of differential relay 390D only resistances 342 and 339 whereas the left winding would be shunted by the four resistances 340, 341, 343 and 344. The relay 390D would accordingly remain operated

due to the current unbalance in its windings. Even though each of the remaining digits of the designation was characterized by the correct number of frequencies, the circuit to relay 491 (Fig. 4) would be open at the contacts of relay 390D. Relay 491 would, therefore, remain unoperated and when slow-to-operate relay 419 operated, ground potential would be connected to the windings of relays 380, 383, 385 and 386 of groups J, G, E and D, respectively, and to the windings of corresponding relays in groups I, H and F, it being noted that the battery supply circuit to all other chain relays, such as 470, 471, etc., in each group is open at the left armature of relay 491. It follows, therefore, that the first register relay, such as 463, 374, 384, 394, etc., in each register, operates to register the fact that an incorrect code has been transmitted. These relays lock in a manner now well known and subsequently function to route the originated call to an intercepting operator's position indicated at 370. Upon the receipt of such a call, the operator would request the calling subscriber for the number desired and proceed to complete the connection in a well-known manner.

It will be noted that regardless in which digital position the false code appears, the same group of register relays operate to extend the connection to the intercepting operator. It will also be understood that regardless of the number of frequencies, other than two, which are transmitted in characterizing a digit, an unbalance in the current in the windings of the differential relays will result which causes relay 491 to remain unoperated so that under all conditions, except that in which the correct number of frequencies is transmitted, the register relays 463, 374, 384 and 394, as well as corresponding relays in the other registers, operate to subsequently route the call to the intercepting operator. The code proving arrangement just described precludes the possibility of "wrong numbers" being obtained by a calling subscriber as the result of faulty operation of the designation sender or of the frequency receiving equipment at the central office.

The designation sender of Figs. 6, 7 and 8 lends itself to operation as a repertory "dialing" device, that is, a device which may be supplied with plates or cards which are so perforated as to characterize an entire designation. Such a device finds utility in any establishment wherein it is customary for a particular number or numbers to be called at frequent intervals. Fig. 11 illustrates a frequency selector of the repertory type in the form of a card. The apertures in this card are arranged so as to correspond to the telephone designation EX-3-9800. This card 420 may be of cardboard, metal or any other suitable material. The card, when used, is inserted in a slot in the side of the cover having a dimension such as to accommodate the narrow end thereof. The card is pushed inwardly, riding between suitable guide pins 421. The guide pin 422 limits the extent to which the card may be pushed inwardly and determines its correct position. When the card is to be used, all the tapes are pulled back until their corresponding indicators 63 register with the word "Card" on the strips 4. The card is provided with ten slots 423 which correspond to the centering notches of the frequency selecting tapes 60 and accommodate the centering wedges 54 when the plunger rod 34 is operated. In this manner the card is correctly centered so that the apertures 424

therein are accurately aligned with corresponding apertures in the gasket 22 which terminate the conduits or air ducts 20 of the designation sender. It is believed unnecessary to enter into any detailed operation of the sender when used with a card type selector, such operation being now apparent. Suffice it to say, however, that the card selector distinguishes from the tape selector in that the former comprises seven sets of apertures 424, (assuming a seven digit number), each characterizing a particular digit in each digital position of a designation whereas each tape consists of ten sets of apertures which characterize all the characters of a designation which may occupy a particular digital position. The tapes are set by being pushed longitudinally of the sender whereas the card is set by being pushed in a transverse direction.

The designation sender of Figs. 12, 13 and 14 is an alternative form in which small rotatable wheels are employed as frequency selecting devices in place of the tapes of the sender hereinbefore described. This sender is housed in a container comprising a base 80 and a cover 81. It will be noted from an inspection of Figs. 7 and 13 that, in general, the two senders are similar in design and it is believed that a description of only those details in which the sender of Figs. 12, 13 and 14 distinguishes from that of Figs. 6, 7 and 8 will suffice for a complete understanding of the construction of the alternative form. In order to indicate more clearly the similarities in the two designs of designation senders, those elements which are identical are identified on the drawings by the same numerals.

The molds 18 are similar in general design except that in the alternative form it is of shorter length and instead of their being a single row of ten groups of conduits 20, five in each group, there are two rows of five groups each. On the upper end of the mold 18 there are situated three plates, a rubber plate 70, and two metal plates 71 and 72 secured together in any suitable manner. The plates 70 and 71 are substantially of the same width whereas the lower plate 72 is not as wide, being recessed in the mold as shown. The center plate is provided at each end with an integral ear-like depending projection 73, which together serve to associate with the plate 72 a pair of links 74 whose other ends are pivotally secured to shaft 75. The shaft 75 consists of two equal sections, the inner ends of which are secured to the fitting 69 which is loosely fitted upon the plunger rod 34. This fitting is comparable to the sleeve 57 shown in Fig. 7, and is provided with a pair of slots through which the pin 68 integrally associated with rod 34, extends. This fitting provides a lost motion connection between the rod 34 and the links 74 so that the latter do not respond to the movement of the rod 34 until the rod pin 68 reaches the bottom of the slots 69. The links 74 are rotatably mounted on pins 76 located in the sides of the cover 81. It is apparent from the description so far advanced that when the plunger rod 34 is operated, the links 75, after a short delay, rotate about their respective pins 76 so that the three plates 70, 71 and 72 are raised as a unit. The extent to which the plates are raised is less than that to which the plate 72 is recessed in the mold 20 so that, though there is effected a small chamber between the upper face of the mold and the undersurface of the plate 72, there is no passage for the leakage of air except through

those holes in the selecting wheels 77, as will appear presently.

The selecting wheels, ten in number, are identical in design, consisting of a circular metal plate whose periphery is cut away in such a manner as to form ten notches having equal peripheral lengths. There are six notches 78 of equal depth and four notches 79 of greater depths. The arrangement is such that five of the notches 78 are grouped on one half of the wheel with the sixth notch 78 separated therefrom on either side by two of the deeper notches 79. The wheels 77 are each carried on a shaft 82 to the other end of which is secured a knob 83. The knob-supporting end of shaft 82 is of smaller diameter than the end to which the selecting wheel 77 is secured so that the upper face of the wheel-supporting portion constitutes a shoulder which abuts against the undersurface of the cover 82. Encircling each knob-supporting shaft portion is a circular dial or designation plate 84 which bears the same symbols that are displayed on the tapes of the designation sender hereinbefore described. The knob 83 is rotatable relative to the designation plate 84 and carries with it a pointer which may be set opposite any group of characters on the designation plate. The wheel 77 rotates with the knob 83.

The three plates 70, 71 and 72 are provided with ten groups of apertures, the corresponding apertures in each plate being in alignment with each other and with the upper end of the corresponding conduits 20. The conduits 20 are tapered outwardly at their lower ends to provide for the accommodation of reeds 31. A metal frame 23 defining an air chamber 24 is fitted over the lower portion of the mold 18 and is secured thereto in any suitable manner. The lower wall of chamber 24 is cut away at 25 to provide a communication passage between the chamber and the bellows 27, one end of which is secured in any suitable manner to the outside of the lower wall of chamber 24 and the other end of which is carried by the actuating member 28. The upper wall of the chamber 24 is provided with fifty slots 35 over each of which a reed 31 is secured after the fashion of musical reed instruments, such as mouth organs. Each reed is dimensioned to vibrate at an odd harmonic of 30 cycles beginning, for example, at 450 cycles and continuing until a required number is obtained.

Midway along one of the side walls of the chamber 24 is a vent 32 which terminates in a seat for the valve 16. Secured to the opposite wall of the chamber 24 is a carbon button 33. The bellows actuating means as well as the means for operating the valve 16 are the same as illustrated in Figs. 6, 7 and 8 and no further description thereof is believed necessary.

The operation of the designation sender disclosed in Figs. 12, 13 and 14 is as follows:

Assuming the calling subscriber at whose station the designation sender is located desires to converse with a subscriber whose station designation is for example, AB-3-4567, the calling subscriber rotates the first upper left knob until the indicator associated therewith registers with the group of characters on its associated designation plate, in which the character A appears; the next knob to the right is then similarly rotated until its associated pointer registers with the group of characters in which the character "B" appears and so on until seven of the knobs

have been set to the positions which determine the designation digits desired. As each knob is rotated, the corresponding wheels 77 are rotated and assume positions in which two of the deeper notches 79 in each wheel are located immediately above and in alignment with two of the five apertures 99 in a corresponding group of apertures in the rubber plate 70. Each selecting wheel is capable of assuming any of the ten positions illustrated in Fig. 14. In each position it will be noted that three apertures 99 in each of five are masked by the solid portion of the wheel whereas two in each group of five are open due to their alignment with the deeper notches 79 in the wheels. Fig. 14 is comparable to Fig. 10 and illustrates the ten possible settings of the wheels 77. The first upper left setting corresponds to the designation digit "1," the next right setting corresponds to the designation characters 2ABC; the next setting, to the designation characters 3DEF; and so on.

Having set the several selecting wheels 77 in accordance with the desired designation by rotating the knobs 83, the subscriber pushes the plunger rod 34 downwardly by pressing on the button 66. When the pin 68 associated with the fitting 69 reaches the bottom of its slots, the unit, comprising plates 70, 71 and 72, is forced upwardly against the set wheels 77 by the action of the links 74 which are associated with the plunger rod through the fitting 69. It will be noted that there are ten centering wedges 87 integrally associated with the plate 71 (see Fig. 12) so that as the unit, comprising the three plates 70, 71 and 72, is raised, each of the centering wedges enters one of the centering notches 79 in the wheels 77 or one of the deeper notches 79, depending upon the position of the wheels when the plunger rod is actuated. The wheels are accordingly accurately set and the unmasked apertures in the rubber plate 70 accurately aligned with the deeper notches 79. As the unit, comprising the plates 70, 71 and 72, is raised into position, the uppermost plate 70 being of rubber, is compressed, thereby insuring against the escape of air except through the conduits 20 which are now aligned with the unmasked apertures in the plate 70. As in the designation sender hereinbefore described, the plunger rod 34 is locked in its operated position and remains so locked until the electromagnet 12 operates. The operation of magnet 12 and the results produced thereby are the same as those produced by the similarly identified magnet in Figs. 6 and 7 and no further description thereof is necessary.

The designation sender shown in Figs. 12, 13 and 14 also is capable of use as a repertory "dialing" device. To this end the cover 81 is apertured as at 91 to permit a card 92 to be inserted and moved transversely into position. A door 93, hinged at 94 is normally in its closed position and may be opened to admit the card 92. The card 92 as shown in Figs. 17 and 18 consists of two superposed sheets 95 and 96 secured together in any suitable manner. The upper sheet 96 is provided with irregularly spaced apertures 97 which communicate with corresponding ducts 98 formed in the lower sheet. The card is arranged with a central slot 89 whose edges ride against the centering wedges when the card is slid into position. A stop 88 is provided for the purpose of limiting the extent to which the card may be pushed inwardly. Each card is provided with seven groups (assum-

ing seven digit numbers) of apertures, two apertures to a group. When the card is inserted in the sender, it is pushed inwardly until the stop 88 engages the side of the cover 81. In this position the seven groups of apertures in the card are in alignment with corresponding apertures in the rubber plate 70, the remaining apertures in the plate 70 being masked by the solid portion of the card. Operation of the plunger rod 34 forces the unit consisting of plates 70, 71 and 72 and with it the card 92 upward against the wheels 77 which now serve no purpose other than to limit the upward movement of the unit elements and card. When the bellows is operated as a consequence of the operation of magnet 12 the air is expelled through the unmasked conduits 20 and permitted to escape through the apertures 97 in the card and their associated ducts 98. The selected reeds are accordingly vibrated and the vibrations converted into electric currents of corresponding frequencies as in the case of the senders hereinbefore described. Each card is provided with an extended portion or tab upon which may be printed the telephone designation to which the card corresponds.

What is claimed is:

1. The method of making a selection at a distant point which consists of simultaneously transmitting to such point intelligence signals in a signaling code in which each signal is characterized by an invariable proportion of the same number of different frequencies.

2. The method of insuring the correctness of a selection made at a distant point which consists of simultaneously transmitting to such point intelligence signals in a signaling code in which each signal is characterized by an invariable proportion of the same number of different frequencies, measuring said proportion at such distant point and detecting any deviation from said proportion.

3. The method of transmitting a multi-digit telephone designation from one point to another which comprises generating at one point a different group of frequencies for each digital position of the designation, preselecting an invariable proportion of the frequencies of each group of frequencies to characterize the digit occupying the corresponding digital position of the designation and simultaneously transmitting to the other point the preselected proportion of each group of frequencies.

4. The method of transmitting a multi-digit telephone designation from one point to another and insuring the correctness of the transmitted designation which comprises generating at one point a different group of frequencies for each digital position of the designation, preselecting an invariable proportion of each group of frequencies to characterize the digit occupying the corresponding digital position of the designation, simultaneously transmitting to the other point the preselected proportion of each group of frequencies, measuring the said proportion and detecting any deviation from the said proportion.

5. In a signaling system, a line, a sender at one end of said line arranged for simultaneously transmitting intelligence signals in a signaling code in which each signal is characterized by an invariable proportion of the same number of different frequencies, means at the other end of said line responsive to said signals and means responsive to any deviation from said proportion for indicating mutilation of said intelligence signals.

6. In a signaling system, a central office, a line

extending to said central office from a subscriber's station, code signal receiving equipment at said central office, a designation sender at said subscriber's station arranged to set up code signals each of which consists of an invariable proportion of a predetermined number of different frequencies, said code signals characterizing a telephone designation, means at said station for setting said designation sender and connecting it and said code signal receiving equipment to said line and means responsive to the connection of said code receiving equipment to said line for operating said designation sender to cause said code signals to be simultaneously transmitted to said central office.

7. In a signaling system, a central office, a line extending to said central office from a subscriber's station, code signal receiving equipment at said central office, a designation sender at said subscriber's station arranged to set up code signals each of which consists of an invariable proportion of a predetermined number of different frequencies, said code signals characterizing a telephone designation, means at said station for setting said designation sender and connecting it and said code signal receiving equipment to said line, means responsive to the connection of said code receiving equipment to said line for operating said designation sender to cause said code signals to be simultaneously transmitted to said central office, and means included in said code signal receiving equipment for indicating any deviation from said invariable proportion to indicate mutilation of the transmitted designation.

8. In a signaling system, the combination of a central office, a line extending thereto from a subscriber's station, frequency receiving equipment at said central office, a designation transmitter at the subscriber's station normally disconnected from said line comprising means for generating alternating current frequencies for use in characterizing the digits of a designation, means for preparing said designation transmitter for operation, said means also functioning to connect said transmitter and said frequency receiving equipment to said line, and means responsive to the connection of said frequency receiving equipment to said line for operating said transmitter to cause the designation digit characterizing frequencies to be transmitted to said central office.

9. In a signaling system, the combination of a central office, a line extending thereto from a subscriber's station, frequency receiving equipment at said central office, a designation transmitter at the subscriber's station normally disconnected from said line comprising means for generating alternating current frequencies and selecting a predetermined number thereof to characterize each of the particular digits of a designation, means for preparing said designation transmitter for operation, said means also functioning to connect said transmitter and said frequency receiving equipment to said line, means responsive to the connection of said frequency receiving equipment to said line for operating said transmitter to cause the designation digit characterizing frequencies to be transmitted to said central office and means included in said frequency receiving equipment for detecting the characterization of any designation digit by any other than said predetermined number of frequencies.

10. In a signaling system, the combination of

a line circuit, a designation transmitter comprising a wind generating device, a plurality of air passages extending from said wind generating device and each terminating in an outlet, a vibrating element mounted within each of said air passages, means for selectively closing the outlets of certain of said air passages, means for operating said wind generating device to cause air to traverse the unclosed air passages and the vibrating elements mounted therein to produce sound tones of different frequencies, means normally disconnected from said line circuit for receiving said sound tones and converting them into electric currents of corresponding frequencies when connected to said line, and means controlled by the operating means for said wind generating device for connecting said sound receiving and converting means to said line whereby said corresponding frequencies are simultaneously applied to said line circuit.

11. In a signaling system, the combination of a line circuit, a central office, a designation transmitter comprising a wind generating device, a plurality of air passages extending from said wind generating device and each terminating in an outlet, a vibrating element mounted within each of said air passages, means for selectively closing the outlets of certain of said air passages, means for setting said wind generating device for operation, frequency receiving circuits at said central office adapted to be connected to said line circuit upon the operation of said setting means, means responsive to the connection of said frequency receiving circuits to said line circuit for effectively operating said wind generating device to cause the vibratory elements mounted within the unclosed air passages to produce sound tones of different frequencies, means for receiving said sound tones and converting them into electric currents of corresponding frequencies, and means for simultaneously applying said corresponding frequencies to said line circuit for transmission to said frequency receiving circuits at said central office.

12. In a signaling system, the combination of a central office, a line circuit extending thereto, frequency receiving equipment at said central office, a designation transmitter comprising a wind generating device, a plurality of air passages extending from said wind generating device and each terminating in an outlet, a vibratory element located in each of said air passages, a selector tape having a group of perforations lesser in number than the number of said air passages, means for moving said tape so as to align the perforations therein with a corresponding number of air passage outlets and to effectively close the remainder thereof, means for preparing said wind generating device for operation, said means functioning to also connect said designation sender and said frequency receiving equipment to said line circuit, means responsive to the connection of said frequency receiving equipment to said line for operating said wind generating device to force air through the air passages aligned with the tape perforations and to cause the vibratory elements in said air passages to produce sound tones of different frequencies, means for receiving and converting said sound tones into electric currents of corresponding frequencies, and means for simultaneously applying said corresponding frequencies to said line circuit for transmission to said frequency receiving equipment at said central office.

13. In a system for transmitting a telephone designation, each digital position of which is characterized by a group of frequencies, each group containing the same number of different frequencies and each digit of which is characterized by a definite proportion of the frequencies characterizing the digital positions, a line circuit, a designation sender comprising means for generating each group of digital position characterizing frequencies, means for causing said generating means to selectively generate said definite proportion of each group of digital position characterizing frequencies, and means for applying the selectively generated frequencies to said line circuit for simultaneous transmission thereover.

14. In a system for transmitting a telephone

designation, each digital position of which is characterized by a group of frequencies, each group containing the same number of different frequencies and each digit of which is characterized by a definite proportion of the frequencies characterizing the digital positions, a line circuit, a designation sender comprising means for generating each group of digital position characterizing frequencies, means for causing said generating means to selectively generate said definite proportion of each group of digital position characterizing frequencies, means for applying the selectively generated frequencies to said line circuit for simultaneous transmission thereover, and means for detecting any deviation from said definite proportion.

HARRY NYQUIST.