Sept. 8, 1931. D. GRIMES 1,822,868

METHOD AND APPARATUS FOR MAKING GRAPHICAL REPRESENTATIONS AT A DISTANCE

Filed Dec. 22, 1928 2 Sheets-Sheet 1

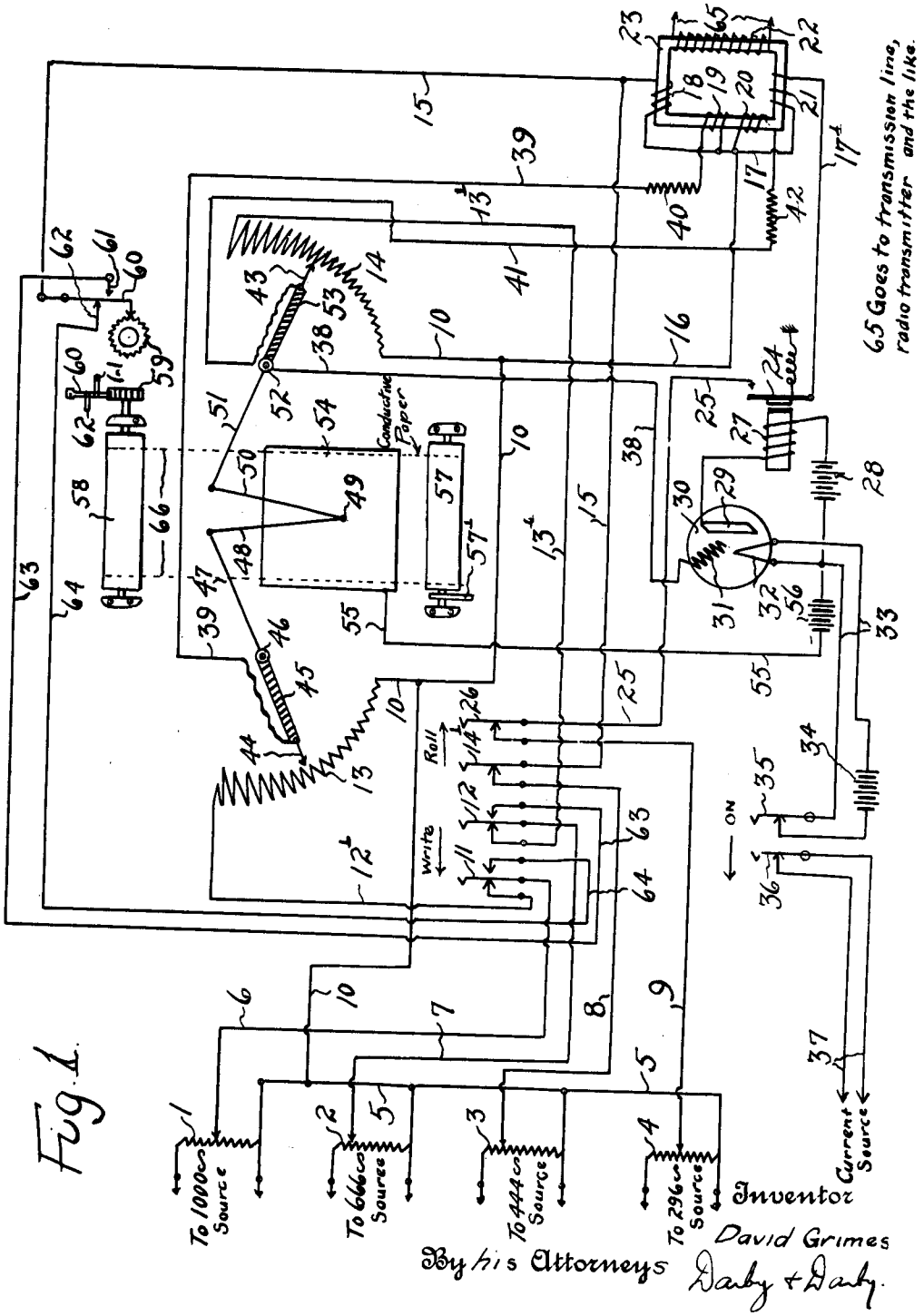

Fig. 1.

Inventor
David Grimes
By his Attorneys Darby & Darby.

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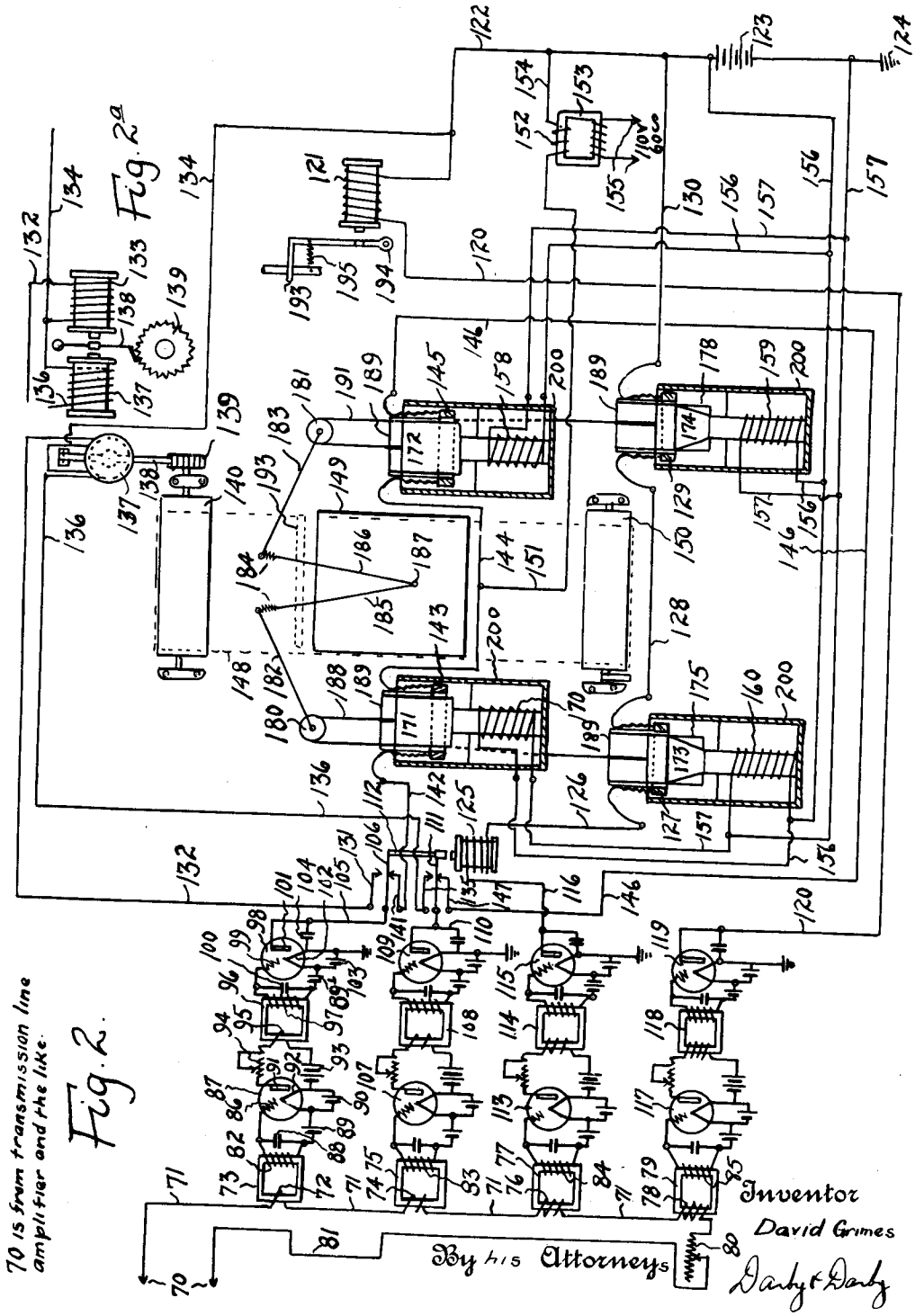

Fig. 2.

70 is from transmission line amplifier and the like.

Inventor
David Grimes

By his Attorneys
Darby & Darby

Patented Sept. 8, 1931

1,822,868

UNITED STATES PATENT OFFICE

DAVID GRIMES, OF GRASMERE, NEW YORK, ASSIGNOR TO GRIMES RADIO ENGINEERING COMPANY, INC., OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

METHOD AND APPARATUS FOR MAKING GRAPHICAL REPRESENTATIONS AT A DISTANCE

Application filed December 22, 1928. Serial No. 327,810.

This invention relates in general to a method and apparatus for making graphical representations at a distance by transmitting energy at a plurality of frequencies which vary in strength in accordance with the graphical representations being transmitted.

This invention involves very broadly a system which I term a "radiograph" for transmitting intelligence over distance either by ether waves or by wire connections in the form of graphical representations.

One of the objects of this invention contemplates the control of a writing instrument at a distance by a local instrument through the agency of a plurality of varying currents produced at a sending point by movements of an originating writing instrument and received at a receiving point by the writing instrument thereat under the control of the writing instrument at the sending point.

A further object of this invention is the production of a transmitting apparatus by means of which electrical energy at two frequencies is varied in amplitude by and in accordance with the movements of a writing instrument and transmitted by ether waves or wire connections to a suitable receiving apparatus.

A further object of this invention is the transmission and control of electrical energy at another frequency by means of which the vertical impressions or contact motions of the writing instrument at the sending station are produced at a distance.

A further object of this invention is the control and transmission of energy at two frequencies for operating the magnetic control means for the writing instrument at the receiving end and energy at another frequency for opposing and counterbalancing the magnetic control means so that the magnetic control means depends upon the current ratio between the current at two frequencies and the current at the third frequency which ratio is not affected by disturbances occurring in the connecting media.

A still further object of this invention contemplates mechanism at the receiving station by means of which the energy at two frequencies which is varied in amplitude during the writing operation may also be employed to move at the receiving point the paper on which the writing instrument operates.

A further object of this invention is the provision of pantograph arms and variable resistance by means of which variations in amplitude of the energy at two frequencies is effected by movement of the writing instrument.

A further object involves the use of a three-electrode audion so connected with the apparatus that upon the contact of the writing instrument with the paper at the sending point a blocking action occurs in the vacuum tube to permit the operation of a relay to complete a circuit for the transmission of alternating current so as to operate at the receiving point a mechanism by means of which the writing instrument thereat contacts with the paper.

A further object of this invention contemplates the use at the transmitting point of a treated paper which is thereby rendered semi-conducting.

A still further object of this invention involves a switching mechanism controlled by the drum on which the paper at the transmitting point is rolled up, to send out current at two frequencies by means of which the paper at the receiving end is moved in synchronism with the paper at the transmitting point.

A further object of this invention contemplates means in which the electrical energy at the various frequencies transmitted is mixed or blended into a single composite current which may be transmitted directly over wires or may be employed to modulate the carrier wave for transmission to a distance either with or without wire connections.

A still further object of this invention contemplates circuit connections for all the above apparatus by means of which it is associated into the operative whole for the purpose of transmitting all forms of graphical representations to any distance with or without wire connections.

Another object of this invention involves at the receiving point a local circuit connected to an amplifying and filter system

comprising a plurality of channels at which the energy at the various frequencies transmitted is segregated, amplified, and delivered to the various instrumentalities comprising the complete receiving apparatus.

A further object of the invention relates to the provision of pantograph arms at the receiving point which are controlled from the sending point by alternating currents varying in amplitude in accordance with the graphical representations being transmitted.

Another object of the invention is the provision of electro-magnetic instrumentalities operatively connected to the pantograph arms which, when energized by the energy at two frequencies which is varying in amplitude in accordance with the movements of the writing instrument at the sending station, effect movement of the pantograph arms and the writing instrument at the receiving station to produce substantial duplication of the movements of the writing instrument at the sending point.

Another object of the invention is the provision of alternating current means operated by the impression movements of the writing instrument at the sending point for controlling the impression movements of the writing instrument at the receiving point.

Another object of the invention is the provision of means at the receiving point for substantially reducing the static friction of the moving parts of the receiving apparatus.

A still further object of the invention is the provision of switching means at the receiving point by means of which the energy at two frequencies normally received for controlling the pantograph arms may be switched, by operations at the sending point for use in effecting synchronous movement of the writing paper at the sending and receiving points.

A further object of this invention is the provision of electro-magnetic means for controlling the movement of the pantograph arms at the receiving station and electro-magnetic means operating in conjunction with the first electro-magnetic means and controlled from the sending point by means of which the forces operating the receiving pantograph arms produce motions directly proportional to the currents from the sending point, representing the movements of the pantograph arms thereat.

Another object of the invention is the provision of circuit connections for all of the apparatus at the receiving point by means of which the above instrumentalities are united into an electrically cooperating mechanism.

Another object of the invention contemplates apparatus of the above type comprising the receiving equipment which is not subject to static and fading influences when operating without the use of connecting wires between the transmitting and receiving apparatus and is not subject to attenuation effects and induction interference when the transmitting and receiving apparatus is wire connected.

There are many other objects of this invention, such as simplicity, ruggedness, absence of distortion effects, substantial indifference to distance over which the energy is transmitted, secrecy, simplicity of operation, adaptability for speed of operation, indifference to variations in the received energy caused by the intervening transmitting medium, indifference to variations in power supply at the receiving end, the use of fixed platens over which the writing paper moves, and many other features as will appear from the following disclosure.

A still further object of the invention is the provision of a novel method of operation of apparatus of this type in which the movements of a tracing point or writing instrument are translated into electrical energy at several frequencies varying in amplitude in accordance with the movements thereof, transmission to a distance and actuation of another tracing point or writing instrument in accordance with the varying amplitudes of the electrical energy transmitted.

This invention resides substantially in the combination, construction, arrangement, relative location of parts, circuital connections, steps and series of steps, all as will be more fully set forth hereinafter.

Referring to the drawings—

Figure 1 is a diagrammatic illustration of the apparatus and circuit connections comprising the transmitting apparatus of this invention;

Fig. 2 is a diagrammatic illustration of the receiving apparatus and circuit connections thereof; and

Fig. 2A is a diagrammatic illustration of the apparatus for operating the paper roll at the receiving point.

There are at the present time many well known systems for the transmission of intelligence in various forms from point to point either with or without wire connections. For example, it is now common to electrically transmit intelligence by code or by articulate sounds directly over wires or by means of the radiant energy from point to point either by ether waves or by wire connections. There are also known methods for transmitting both still and moving pictures by radiant energy or by wire connections. There are also systems by means of which graphical representations are now sent over small distances by wire connections.

This invention is directed in general to that portion of the field of intelligence transmission by electrical currents in which the transmission of graphical representations is effect-

ed. All systems now known for the transmission of graphical representations electrically are limited to apparatus employing wire connections. Apparatus operating in accordance with the principles of these systems is seriously limited in many respects and most particularly with respect to the effective distance over which the apparatus will operate. It is the general purpose of this invention to provide apparatus for making graphical representations at any distance, either with or without wire connections.

A better understanding of the theory and method of operation of the apparatus of this invention will be had if the description of the apparatus and connections is given first. This procedure will, therefore, be followed and the operation of the apparatus will be given in greater detail below.

Referring to the drawings, there are shown in Fig. 1 four circuits which are energized from alternating current sources of different frequencies. Thus the four circuits or channels shown are operated by alternating currents of 1,000, 666, 444, and 296 cycles. The generators of these currents have not been shown in the drawings because the invention does not involve them specifically. There are many ways now known for generating alternating currents of these frequencies of which alternating current generators, electrical tuning forks, and three-electrode vacuum tube oscillators are examples. Across the output circuit of each generator is connected a high non-inductive resistance, as shown at 1, 2, 3 and 4. One terminal of this resistance from each source is united by the wire 5. A wire 6 having a variable contacting connection with resistance 1 connects to the movable switch arm of switch 11 and a wire 7, which has a variable contact connection with resistance 2, is connected to the movable arm of switch 12. Wire 8, having variable contact with resistance 3, is connected to the fixed contact of switch 14′ and wire 9, having variable contact with resistance 4, is connected to the fixed contact of switch 26. These resistances 1, 2, 3 and 4 are potentiometers and represent one form of apparatus for varying the amplitude of the current supplied from the source so that the average current strength in each channel is substantially the same. Wire 5 is connected by wire 10 to one end of resistances 13 and 14. The left hand contact of switch 11 is connected by wire 12′ to the other end of resistance 13. The left hand contact of switch 12 is connected by wire 13′ to the other end of resistance 14. The arm of switch 14′ is connected by wire 15 to one terminal of the winding 18 of the transformer 23. Wire 10 is connected by means of wire 16 to wire 17 which units one terminal of each winding 18, 19, 20 and 21 of the transformer 23. The winding 22, having leads 65, represents the output side of transformer 23.

Transformer 23 provides what I term a mixing circuit and is merely an illustrative example of one form of apparatus by means of which the various alternating currents from the four sources shown as modified are mixed together to form a composite current which may be transmitted directly over wires or may be employed to modulate the carrier wave of a carrier current telephone system or a radio transmitter.

The other terminal of winding 21 is connected by wire 17′ to the pivoted arm 24. The contact controlled by the pivot arm 24 is connected by wire 25 to the arm of switch 26. The movable arm 24 is controlled by the electro-magnet, having the winding 27, one terminal of which is connected to the current source 28, whose other terminal is connected to one lead of the cathode 32 of audion 30. The other terminal of winding 27 is connected to the plate electrode 29 of audion 30.

The grid electrode 31 of the audion is connected by wire 38 to lever 51. The wires 33 connect the current source 34 through switch 35 to the cathode 32. Switch 36 controls the current supplied through wires 37. The circuit which includes wires 37 controls the current input to the oscillators which supply the alternating current for the four channels.

The pantograph system comprises the two levers 47 and 51 pivotally supported at 46 and 52, respectively. Pivotally attached to the levers 47 and 51, respectively, are the levers 48 and 50 which are pivotally united at their other ends to the writing instrument indicated at 49. The levers 47 and 51 extend beyond their pivot points and comprise the insulating portions 45 and 53, having the movable contacts 44 and 43 supported thereby. In each case a complete lever, comprising the parts 44, 45 and 47 and the parts 51, 53 and 43, is pivotally supported at 46 and 52, respectively. The wire 38 connects to the lever 51 and is insulated from the contact 43. Contact 44 is connected by wire 39 through non-inductive resistance 40 to the other terminal of winding 19. Contact 43 is connected through wire 41 and non-inductive resistance 42 to the other terminal of winding 20. The resistances 13 and 14 are arcuate in form and mounted with respect to the pivot points 46 and 52 so that contacts 44 and 43, respectively, may move thereover and contact therewith. The resistances 40 and 42 are provided so that windings 19 and 20 will not be short-circuited when contacts 44 and 43 are at the lower end of resistances 13 and 14.

The fixed conducting metal platen 54 is provided, over which the paper 66 moves. The platen is connected by wire 55 to the

negative terminal of the potential source 56, the positive terminal of which is connected to one terminal of the cathode 32. 57 is a roll or drum on which the fresh paper is mounted. The paper feeds from drum 57 over the top of platen 54 and onto the receiving drum 58. These two drums are mounted for rotation; drum 57 being provided with any suitable form of spring 57' for exerting a drag thereon. Mounted on the shaft of drum 58 is a toothed wheel 59 in contact with which is the contact arm 60. Mounted on opposite sides of the contact arm 60 are contacts 62 and 61. An edge and side view have been given of the toothed wheel 59, arm 60, and contacts 61 and 62 to more clearly bring out the idea involved. The arm 60 is connected by wire 15 to one terminal of winding 18. Contact 61 is connected by wire 63 to the right hand contact of switch 12. Contact 62 is connected by wire 64 to the right hand contact of switch 11.

A description of this apparatus which comprises the transmitting equipment will be given at this point. The paper 66, which is impregnated with a conducting solution, such as salt water, dilute sulphuric acid, and the like to render it semi-conducting, is placed over platen 54 from roll 57 and secured to roll 58 so that as this roll is revolved by hand, the paper is fed from roll 57. Switches 35 and 36 are moved to the left to close them. This causes cathode 32 to be energized and completes the circuit to the alternating current generators so that alternating current is supplied at the frequencies indicated to the four channels. Switches 11 and 12 are moved to the left to the position indicated by the legend "Write" and switches 14 and 26 are permitted to be closed, as shown in the drawings. The result of placing switches 11, 12, 14 and 26 in the position shown in the drawings is to impress the 1,000 cycle current across resistance 13 and the 666 cycle current across resistance 14. The 444 cycle current is impressed across winding 18 and the 296 cycle current flows through wire 25 to the fixed contact adjacent arm 24. The current flowing through the audion 30 energizes winding 27 and holds switch arm 24 away from the fixed contact so that the 296 cycle current is not impressed upon the winding 21 at this time.

Before going further in the description of the operation of this apparatus the reason for selecting the frequencies of the four channels will be given. It may be first pointed out that I term the 1,000 cycle current the left hand actuation channel; the 666 cycle current the right hand actuation channel; the 444 cycle current the repulsion channel; and the 296 cycle current the impression channel. The left hand actuation channel is so called because the left hand pantograph link controls the amplitude or volume of the current flowing through this channel. The right hand actuation channel is so called because the right hand pantograph link controls the amplitude or volume of the currents flowing through this channel. The repulsion channel is so called because the current which flows through it controls the electro-magnetic counterbalancing means which operates the pantograph arms at the receiving station. The operation of this apparatus will be described in considerable detail later. The impression channel is so called because the current which flows therethrough is controlled by the vertical movements of the pantograph arms at the transmitting station to provide the impressions or vertical movements of the writing instrument at the receiving station.

The particular frequencies of 1,000 and 666 were selected to give a frequency difference of about 50%, which is sufficient to permit complete separation of the two component electrical channels at the receiving end with only simple electrical filter arrangements. This frequency separation is one common in the science of music and is called a fifth. It is the same separation which is found between middle C and the first G above. It is, of course, apparent that other separations can be chosen providing certain precautions are exercised. Any narrowing of this separation increases the stringency of the receiving filters and also serves to complicate the receiving apparatus. Any greater separation results either in a discordant tone or a distortion in the writing caused by interfering harmonics, as will be described later. Frequency discrimination in associated electrical apparatus is also a limiting factor to greater separation. This same separation theory applies to the other channels as well and the frequencies have been chosen accordingly.

Assuming now, as set forth, that the paper 66 has been fed to roller 58 over platen 54 and all the parts are in the position indicated in the drawings as pointed out above, the next operation is for the writer to grasp the writing instrument indicated at 49. This writing instrument can, of course, assume many forms. In best form it consists of a pencil having a lead for writing and a member for securing it to the pantograph arms to provide universal movement. The handle or body portion of the pencil is insulated so that the writer will not have electrical contact therewith. The structure of the pantograph arms and pencil are well known in this art and need not be described in detail. When the writer first contacts the pencil with the impregnated paper 66 a circuit is completed through potential source 56, wire 55, platen 54, impregnated paper 66, writing instrument 49, lever 50, lever 51, wire 38, and grid 31 to place a large negative bias thereon.

This results in a blocking action in the audion to prevent any further flow of current from cathode 32 to plate 29. As a result winding 27 is deenergized. The spring operated lever 24 moves to the right to contact with the fixed contact completing a circuit as follows: From resistance 4, through wire 9, switch 26, wire 25, lever 24, wire 17', winding 21, wire 17, wire 16, wire 10, wire 5, and back to the other terminal of resistance 4. Thus, immediately the writing instrument 49 contacts with the paper 66, the 296 cycle impression current flows through switch 24, and winding 21 to be impressed across the secondary 22 of transformer 23. The operation of the apparatus at the transmitting point will be followed up to the terminals 65 of transformer 23 and will be left there until the receiving apparatus is described.

The writer now begins to make on the paper 66 the graphical representations which he desires to transmit. They, of course, may be pencil marks of any form, such as words, numbers, maps, sketches, shorthand writing, codes, and in fact any form of intelligence which may be made by pencil markings on a paper. I wish to point out here one of the highly advantageous features of this system over any known system of this type. These features reside in the contact of the writing instrument with paper 66 at the transmitting end so as to actually record on the paper 66 the intelligence in the form of graphical representations which it is desired to transmit. Thus the writer not only secures a permanent record of what he has done but has immediately before him as he produces it his work so that he may, for instance if he is drawing a map, be able to complete it intelligently. In general in systems of this type now known the writer merely moves his tracing instrument over a non-recording platen so that he must picture mentally the marks which he has made, or look elsewhere for the record reproduced by a special local receiving device. Thus the present systems are limited to simple writings and diagrams since it is apparent that one cannot remember where in space he has already made movements of the writing instrument indicating the representations he desired to send.

Thus, in drawing a map it is quite essential to go back many times to a previous point which cannot be done if the movements of the writing instrument leave no record of their own. In the present system actual marks are made on the paper by the tracing point itself, giving a permanent record so that in drawing a map, for instance, it can be completed correctly. The writer now proceeds to mark on the paper 66 representations which he wishes to transmit. The movement of the writing instrument 49 is resolved by the right and left hand pantograph arms into right and left hand components. These components are converted into right and left hand circular components by the pivoted pantograph arms and cause the contacts 43 and 44 to move over the resistances 14 and 13, respectively, in an amount proportional to these components. The final result is a proportionate variation in the amplitude of the currents in the right and left hand actuation channels in the proper sequence. Thus the magnitudes of the currents in the left hand actuation channel which go out at a constant frequency of 1,000 cycles are varied by and in accordance with the left hand component of the movements of the writing instrument 49. The currents in the right hand actuation channel go out at a constant frequency of 666 cycles and are varied in amplitude by and in accordance with the right hand component of the writing instrument. The currents in the left hand actuation channel flow from resistance 13 through wire 10, wire 16, wire 17, winding 19, resistance 40, wire 39, contact 44, and back through a portion of the resistance 13. The currents from the right hand actuation channel flow from resistance 14 through wire 10, wire 16, wire 17, winding 20, resistance 42, wire 41, contact 43, and a portion of resistance 14. Thus the right and left hand actuation currents are impressed upon the transformer 23 and hence the output winding 22 thereof.

As is apparent from the drawings, the space distribution of the windings of the resistances 13 and 14, and hence the distribution of their resistance spacially, is an empirical one following closely an exponential function. The purpose, of course, of this resistance distribution is to cause substantially equal changes in outgoing current for equal pencil displacements on the platen. In other words, the resistances in the form shown vary the outgoing currents in direct proportions to the writing instrument motions.

The 444 cycle current flows through its channel without modification in the following manner. Through wire 8, switch 14', wire 15, winding 18, wire 17, wire 16, wire 10, and wire 5, back to the other terminal of this current source. Thus the 444 cycle current is impressed upon transformer 23 and hence the output winding 22 thereof. Whenever the writing instrument 49 is raised out of contact with paper 66 the high negative bias is taken off of grid 31 so that current flows through the audion 30 energizing winding 27 to cause arm 24 to move to the left. This breaks the impression current circuit and removes the 296 cycle current from transformer 23.

After sufficient writing has been accomplished so that it is desired to provide a clean writing surface, the operator throws switches 11 and 12, 14' and 26 to the right, indicated by the legend "Roll" in the drawings, so that

switches 11 and 12 complete circuits connected to the right hand contacts thereof, and switches 14′ and 26 break the circuits connected thereto. The breaking of the circuits at switches 14′ and 26 interrupts the repulsion and impression circuits while switches 11 and 12 remove the two actuation channels from the pantograph control resistances 13 and 14 and place them on the ratchet contacts 62 and 61. The circuits completed are as follows: from resistance 1 to wire 6, switch arm 11, right hand contact thereon, wire 64 to contact 62 and from resistance 2 through wire 7 to switch 12, right hand contact thereof, wire 63 and contact 61. When the spring arm 60 is in a depression between two teeth on the wheel 59 it contacts with 62 to complete a circuit through wire 15 to winding 18 and thence through wire 17, wire 16, wire 10, and wire 5 back to the other terminal of resistance 1. When spring arm 60 rises to the top of one of the teeth of wheel 59 the circuit is completed from contact 61 to switch arm 60, wire 15, winding 18, wire 17, wire 16, wire 10, and wire 5 back to the other terminal of resistance 2. Thus, as drum 58 is rotated to feed fresh paper over the surface of the platen the spring arm 60 alternately connects the output of the 1,000 cycle source and the 666 cycle source across the primary winding 18 of transformer 23. These impulses are then fed out of the secondary 22 to the intervening transmitting medium to operate the rolls at the receiving apparatus. As soon as this operation is completed, switches 11, 12, 14′ and 26 are moved back to the left and the apparatus is again ready for the writing operations as described.

The various currents as described being impressed upon transformer 23 result in a composite current which flows in the secondary 22 of the transformer. The terminals 65 of this transformer are connected to various transmitting arrangements. For example, they may be connected to the input of a high frequency generator of any type producing a carrier wave so as to modulate that wave and then be transmitted through space or by connecting wires. Or, the various tones may be transmitted directly over wire lines, such as telephone and toll lines, connections being made directly from the telephone system to the secondary terminals 65 of transformer 23. Another possibility is that the terminals 65 can be connected to the input of any suitable audio frequency amplifier and converted by means of a sound reproducing device into sound waves. These sound waves may then be picked up at any reasonable distance and impressed upon a microphone and changed into varying currents for local writing or may be transmitted over telephone or similar lines for reproduction at a remote point. The interconnection of telephone and radio circuits gives a wide flexibility to this system of writing as the several tones may be transmitted anywhere and in any manner that the human voice is carried. This invention is not specifically directed to any of these methods of transmission but the above has been given to illustrate the scope of the invention and its possibilities.

A detailed description of the receiving apparatus will now be given. The input terminals 70 of the receiving apparatus may be connected to the transmission line or to the radiant energy receiving apparatus so that the transmitted energy will be impressed through wires 71 and 81 upon the primary windings 72, 74, 76, and 78 of the transformers 73, 75, 77 and 79. These transformers are designed to have the same efficiency at the respective frequencies which they pass. The output of transformer 73 is fed from the secondary winding 82 to the input of the audion amplifier 87. One terminal of winding 82 is connected to the grid 86 and the other terminal is connected through battery 89 to one terminal of the cathode 92. A condenser which may be fixed or variable is connected across the terminals of winding 82 so that the secondary of the transformer may be tuned to be resonant to a 1,000 cycle current. The cathode 92 is energized by the current source 90. The plate 91 is connected through variable resistance 94 to the primary of the coupling transformer 96. The other terminal of this primary winding 95 is connected through the current source 93 to the cathode 92. The secondary 97 of transformer 96 is connected at one terminal to the grid 99 of the audion 98 and at the other terminal to one terminal of cathode 102 through the negative potential source 89′. The cathode is energized by the current source 103 and is grounded as shown. A condenser 100 which may be fixed or variable is connected across the secondary 97 to likewise make the input circuit of the audion 98 resonant to a 1,000 cycle current. The plate 101 is connected through wire 105 to switch arm 106. A fixed condenser 104 of the order of 0.25 mf. is connected across the plate and cathode of audion 98. The input circuit on audion 87 selects and permits the passage therethrough of the 1,000 cycle left hand actuation channel. This current is amplified in the audion 87 and passed to the tuned input circuit of audion 98. The audion 98 functions as a rectifying tube by reason of the high negative bias placed on the grid 99 by the potential source 89′, thus operating the tube at the lower cut off point in a manner well known in the art. The amplified uni-lateral pulsations of 1,000 cycle frequencies are passed on to the plate circuit of this audion and are stored up in the blocking condenser 104 which discharges with a direct current flow through wire 105.

In a similar manner the audion 107 with its tuned input circuit connected to the secondary 83 selects, amplifies, and passes on the 666 cycle current to the input of transformer 108. The output winding of this transformer, together with its tuning condenser, impresses the 666 cycle current upon the rectifying tube 109 to cause a direct current flow to wire 110 which is connected to switch arm 111. Similarly the transformer 77, amplifier 113, transformer 114, and rectifying tube 115 select, amplify, rectify, and pass on the 444 cycle current in the form of a direct current through wire 116. Similarly the transformer 79, amplifier 117, transformer 118, and rectifier 119 select, amplify, rectify, and pass on the 296 cycle current in the form of a direct current to wire 120. The resistance 80 provided in the input circuit of all of the first section transformers is a simple non-inductive variable resistance used as a volume control. Each output circuit of the amplifier tubes is provided with a variable non-inductive resistance similar to resistance 94 for individually controlling and balancing the volume of the current in each channel. It is pointed out that each cathode of the rectifying tubes is grounded. Switch arms 106 and 111 are mechanically united by the insulating piece 112 provided with an armature adjacent the core of the magnet 125. The lower contact 141 is connected by wire 142 to the floating coil 143 which has its other terminal connected by wire 144 to one terminal of the floating coil 145. The other terminal of this coil is connected by wire 146 to the lower contact 147. Wire 116 connects to one terminal of the magnet 125 of which the other terminal is connected by wire 126 to one terminal of the floating coil 127. The other terminal of floating coil 127 is connected by wire 128 to one terminal of the floating coil 129. The other terminal of floating coil 129 is connected by wire 130 to one terminal of the current source 123 which is grounded by its other terminal at 124. Wire 120 is connected to one terminal of the electro-magnet 121, the other terminal of which is connected by wire 122 to one terminal of the current source 123.

Current source 123 is connected by wires 156 and 157 to each of the electro-magnet windings 170, 158, 160, and 159. In other words, each of these windings is connected in parallel across the current source 123. The winding 170 is provided with a core 171 which is cylindrical and has an enlarged upper end with straight sides. The core 172 for winding 158 is similar. The cores 173 and 174 of windings 160 and 159 respectively, have a straight cylindrical portion, a flared or conical portion which is circular, and another straight cylindrical portion. These four cores and their windings are each within a magnetic casing 200. As clearly shown, the floating coil 143 encircles the enlarged portion of core 171 and floating coil 145 encircles the enlarged portion of core 172. In a similar manner the floating coils 127 and 129 encircle the upper ends of cores 173 and 174. In the best practice the floating coils merely comprise a few turns of wire on an aluminum ring which is slightly larger in diameter than the largest diameter of the cores which they encircle so that they may slide freely thereover. The aluminum ring is best slotted so that the induced currents produced therein by their motion will not flow to produce an undesired electrical retardation of the motion. These floating coils are supported on any suitable non-magnetic cage, such as shown diagrammatically at 189. The vertical depth of the cage is such that the top thereof will not strike the top of the cores during any normal vertical movement of the floating coils. The conical portions of the magnet cores 173 and 174 are encircled by a cylindrical non-magnetic casing 175 and 178, respectively, to keep the floating coils 127 and 129 centered when they move opposite the conical portions of these cores. These casings do not have to be slotted and, in fact, the currents set up in them influence the floating coils to prevent their over-travel.

As in the sending apparatus, a fixed platen is provided as shown at 149 over which the paper 148 moves from roller 150 to roller 140. A pantograph is shown comprising the arm 182, secured to the rotatable roller 180 at one end and pivotally secured to the arm 185 at the other end. Similarly arm 183 is secured to the pivotally mounted roller 181 at one end and pivotally secured to the arm 186 at the other. Arms 185 and 186 are pivotally secured together to a writing instrument or pencil 187. At 184 are indicated springs which tend to force the writing instrument 187 down upon the paper 148. Cages 189 of the magnets having the cores 171 and 173 are united together by means of a cord or string 188 which passes over roller 180. In a like manner the cages 189 encircling cores 172 and 174 are united by the cord or string 191 which passes over the roller 181.

Upper contact 131 is connected by wire 132 to one terminal of the electro-magnet 133. The other terminal of this magnet is connected by wires 134 and 122 to one terminal of the current source 123. Upper contact 135 is connected by wire 136 to one terminal of the winding 137, the other terminal of which is connected by wires 134 and 122 to the current source 123. The electro-magnets 137 and 133 are placed opposite to each other on opposite sides of the spring arm 138, which cooperates with the teeth on toothed wheel 139. The toothed wheel 139 is secured to the same shaft as roller 140 for rotation therewith. Toothed wheels 59 at the transmitter and 139 at the receiver are the same size and

have the same number of teeth. A pivoted armature 194 is provided adjacent the electro-magnet 121 and is provided with a right angle projection 193 which extends through the casing of the apparatus (not shown) so as to be just above the platen 149, as is clearly shown in the dotted line. When the electro-magnet 121 is deenergized spring 195 urges the bar 193 upwardly in the dotted position, or to the left in the full line position, so as to raise arms 185 and 186 and the writing instrument 187 off the paper against the action of springs 184. It may be pointed out here that the electro-magnet 121 and its armature have been shown to one side of its actual position in order to clearly show the circuit connections and has been shown by dotted lines at the point where it actually is placed with respect to the pantograph arms and the platen. The transformer 153 is provided with an input winding having the terminals 155 to be connected to any suitable alternating current source, such as the common lighting circuit. The secondary 152 has one terminal connected by wire 154 to wire 122. It has its other terminal connected by wire 151 to wire 144.

The operation of this apparatus will now be given, keeping in mind previous operations described in connection with the sending apparatus, it being remembered that the composite current transmitted by any suitable means representing the various actions at the sending point is impressed across the terminals 70. The left hand actuation current reaches wire 105 as described before and flows through contact 141, wire 142, floating coil 143, wire 144, wire 151, winding 152, wire 154, current source 123, and thence to ground at 124. The right hand actuation current, amplified and rectified as described before, flows through wire 110, contact 147, wire 146, floating coil 145, wire 144, wire 151, winding 152, wire 154, and through current source 123 to ground 124. In each case the return circuit is respectively completed through ground to the grounded cathodes of the audions 98 and 109. It will be remembered that the repulsion channel, that is the 444 cycle channel, is sending energy continuously during the writing operations. This energy is picked out by the tuned secondary circuit of transformer 77 and impressed in amplified and rectified form on wire 116 through which it flows to winding 125, wire 126, floating coil 127, wire 128, floating coil 129, wire 130, current source 123 to ground at 124 and back to the grounded cathode of audion 115.

As a result the coil 125 is energized and switch arms 106 and 111 are pulled downwardly to complete the actuation circuits previously traced. Since the 444 cycle current is transmitted and received in a constant unvaried form its passage through the floating coils 127 and 129 causes their constant energization. It is, of course, to be remembered that coils 171, 172, 173 and 174 are energized from the current source 123.

When the writer at the sending point depresses his writing instrument into contact with the paper 66 it is remembered that the current flow through audion 30 at the sending station is blocked and switch arm 24 completes a circuit permitting the depression current to be impressed upon transformer 23. This current in the receiving circuit is picked out by the tuned secondary of transformer 79, amplified and rectified and passed through wire 120 to winding 121 and thence through wire 122 to ground 124 through current source 123. This circuit is completed back to audion 119 through the grounded cathode thereof.

Prior known apparatus of this type, which it will be remembered is in its present form operable only for short distances, employs coiled springs to oppose the movements of the floating coils which would correspond to the floating coils 143 and 145 of this invention. It is the vertical movement of the floating coils 143 and 145 through the agency of cords or strings 188 and 191 which operate the pantograph arms. Floating coil 143 is operated by the left hand actuation channel and controls the left hand link of pantograph system by means of cord 188 and roller 180; while the floating coil 145 is controlled by the right hand actuation channel and operates the right hand pantograph arms through the agency of cord or string 191 and roller 181. In this invention instead of opposing and counterbalancing the movements of these coils by means of mechanical springs it is proposed to oppose them by means of the floating coils 127 and 129 energized by the repulsion current sent out from the transmitting point.

This feature represents a tremendous advance over the prior known devices of this nature and one that is most essential in order to compensate for the effects of static or inductive interference and fading which would influence the writing instrument at the receiving end to cause distortion of the graphical representations being reproduced.

For purposes of description it may be pointed out that the two upper magnets and their floating coils represent what I call "actuation magnets," while the two lower magnets and their floating coils represent what I call the "repulsion magnets." As is apparent from the drawings, the actuation and repulsion magnets at the left operate in conjunction and the actuation and repulsion magnets at the right operate in conjunction.

Now, the repulsion magnets are operated by means of the 444 cycle channel and this is supplied with constant energy from the transmitting end. The actuation magnets

are supplied by the 1,000 cycle and 666 cycle channels, whose energies are varied by the transmitting pantograph arms. An increase in current in the 1,000 cycle channel will draw down the floating coil in the left hand actuation magnet until its associated repulsion coil is brought up into a stronger magnetic field to a counterbalancing position. The same action occurs in the right hand 666 cycle apparatus and is explained in greater detail in the next paragraph. It is thus seen that it is the ratio of current in the actuation channels to the current in the repulsion channel that is effective in producing motions of the receiving pantograph arms. This ratio is entirely governed at the transmitting station, and any increase or decrease in the transmitting efficiency of the intervening medium has no effect whatever on this ratio. A proportionate increase or decrease in the actuation and repulsion channels merely neutralizes itself. Furthermore, sudden surges due to static, etc. cause substantially equal impulses in the actuation and repulsion channels with a resulting nullification of this type of disturbance. Hence static and fading and kindred annoyances are overcome.

It is a well known fact that the mechanical force exerted by an electric coil in a magnetic field is proportional to the ampere turns of the coil and the strength of the field at the point where the coil is in the field. This is expressed by the following formula: $F=AT\times\phi$ where F represents the mechanical force; A represents the amperes flowing in the coil; T represents the turns in the coil; and ϕ represents the strength of the magnetic field. This formula clearly shows that the mechanical force exerted by the coil may be controlled entirely by the current flowing through the coil. In order to permit movement of the coil and at the same time preserve the mechanical motive force causing its movement as the sole function of the current in the coil, it is necessary to maintain the strength of the magnetic field, in which the coil moves, uniform throughout the coil's movement. The actuation magnets 171 and 172 are made so that their magnetic fields are uniform, throughout the length of motion of their respective floating coils 143 and 145. The fields set up by the windings 170 and 158 flow through the cores 171 and 172 across the uniform cylindrical gaps to the magnetic casings 200. By making the enlarged upper ends of the cores cylindrical and of uniform diameter and the outer casing cylindrical and of uniform diameter, uniform air gaps are provided. Thus for any position of the floating coils 143 and 145 within their original limits of movement, a uniform magnetic field is provided and the floating coils only tend to move in an amount directly proportional to the varying currents flowing therethrough.

In the repulsion magnets the conditions are quite different. The cores 173 and 174 energized by the windings 160 and 159 are provided at their upper ends with a cylindrical portion, at the lower ends with a cylindrical portion of smaller diameter, and the two cylindrical portions are united by a conical portion gradually reducing in diameter from the diameter of the larger portion to the diameter of the smaller portion. As before, these magnets are placed within the magnetic casings 200. By this arrangement it is apparent that the cylindrical air gap varies in length, increasing from the top downwardly. These repulsion magnets are used to produce the counterbalancing forces to resist the movements of the floating coils 143 and 145 in place of mechanical springs. In this case, if the current through the floating coils 127 and 129 is maintained constant the reaction of the coils on the magnetic field will be proportional to the field's strength and hence proportional to their position in the fields of varying strength. This reaction will be greatest when the coils are near the upper ends of the cores where the air gap is short and the field is strong, and least near the point of smallest diameter of the conical portions of the cores. By reason of the string connections between the two floating coils they must move together. Thus, as the currets (right and left hand actuation currents) vary in the floating coils 143 and 145, these coils will take different positions in their magnetic fields. With no currents in the floating coils 143 and 145, the corresponding floating coils 127 and 129 will move downwardly to their lowest position. As the current increases in the floating coils 143 and 145 they will move downwardly an amount proportionate to the strength of this current until the forces exerted thereby are counterbalanced by the opposing forces created by the upward movement of floating coils 127 and 129 in their magnetic fields of increasing strength. The position of equilibrium will be reached when the product of the ampere turns and field strength in the actuation magnets is equal to the product of the ampere turns and the field strength in the repulsion magnets. The above actions take place during the normal writing operations when the movements of the writing instrument at the sending station effect changes in amplitude of the right and left hand actuation currents which, in turn, effect similar movements of the writing instrument at the receiving point by reason of the flow of the right and left hand actuation currents through the floating coils 145 and 143. It is to be remembered that the repulsion current is supplied from the sending point and flows through the floating coils 127 and 129 in a constant and uni-

form strength (disregarding the effects of static, fading, induction interferences, attenuation, and the like, created by the intervening transmission medium).

It will, of course, be understood that the moving parts of this system work most efficiently when they are made of light materials which is, of course, a consideration of prime importance in their construction. Since the forces involved will be relatively small, and particularly so as the floating coils in each system approach their position of equilibrium, it is necessary to provide some means for overcoming the static friction of the moving parts which is well known to be about three times greater than the moving friction. This static friction would cause errors in the movements of the writing instrument and I have, therefore, provided means for reducing or substantially eliminating the static friction of the moving parts. The agitation means provided comprises the transformer 153 in which alternating current is caused to flow through the secondary 152 thereof. This current flows from one terminal through wire 122, current source 123 to ground at 124. It flows from the other terminal through wire 151 to wire 144 and in both directions therethrough to each floating coil 143 and 145. The other terminal of each of these coils is connected through wires 142 and 146, respectively, to their channels which are grounded at the cathode of the rectifying tubes. Thus, an alternating current is superimposed upon the direct current in these coils causing them to move upwardly and downwardly a minute distance at a rate depending upon the frequency of the current supplied thereto. I have found that ordinary 60 cycle current produces the desired effect. This effect is similar to the effect produced by tapping an instrument, such as a sensitive electrical meter, as is often done in making delicate measurements. The agitating movement of these floating coils is completely successful in overcoming the sticking or static friction of the moving parts which would otherwise prevent the writing instrument at the receiving point from exactly duplicating the motions of the writing instrument at the transmitting point. It is desirable for best results to apply the agitation current to the floating coils 143 and 145 which operate in constant magnetic fields rather than to the floating coils 127 and 129 in non-uniform magnetic fields. The agitating force is thus maintained constant, irrespective of the position of the floating coils and as the static friction is constant on every position of the coils, the agitating force just offsets it at all times. Of course, many other mechanical precautions well known to those skilled in the art are advisable in order to provide a system of moving parts which is light and substantially devoid of friction so that danger of distortion from these causes is substantially eliminated.

The following operation for feeding new paper across the platen at the receiving point will now be described. It will be remembered that during the rolling operation switches 11, 12, 14′ and 26 at the transmitting station are moved to the right. This throws the 1,000 and the 666 cycle currents onto the fixed contacts 62 and 61, respectively. At the same time the repulsion and impression currents are interrupted so that they no longer reach the receiving station. The interruption of the repulsion current deenergizes magnet 125 at the receiving station. Spring arms 106 and 111 which have been held down by magnet 125 move upwardly to contact with the contacts 131 and 135. As a result the actuation currents are supplied through wires 132 and 136 to the magnets 133 and 137. As the operator at the transmitting point rotates drum 58 by hand, the spring arm 60 moves back and forth as the teeth of wheel 59 pass it; causing alternate contact with the contacts 62 and 61. When spring arm 60 lies in a depression between two teeth it makes contact with point 62. The 1,000 cycle current therefore flows through wire 15 to transformer 23, thence through space or wire connections to the terminals 70 at the receiving station. The 1,000 cycle current then reaches wire 132 in a rectified and magnified condition through which it flows to magnet winding 133 and thence back through wires 134 and 122 to ground at 124. This pulls spring arm 138 to the right causing the toothed wheel 139 and drum 140 to rotate the space of one tooth. Continued rotation of drum 58 at the transmitting station causes spring arm 60 to ride up on a tooth of wheel 59 causing it to contact with the fixed contact 61. The 666 cycle current then flows through wires 63 and 15 to transformer 23. This current then flows through the 666 cycle channel at the receiving point to wire 136 in rectified and magnified condition. This current flowing through winding 137 and wires 134 and 122 to ground at 124 causes the magnet 137 to draw spring arm 138 to the left a distance of one tooth. Upon reenergization of magnet 133 spring arm 138 moves to the right rotating toothed wheel 139 and drum 140 the space of another tooth. This continues as long as the drum 58, transmitting point, is rotated. Thus, no matter how slowly, how fast, or with what regularity the paper 66 is advanced at the sending point, the paper 148 at the receiving point will be advanced a similar amount and in synchronism therewith. To continue writing it is only necessary to throw switches 11, 12, 14′ and 26 back to the left and depress the writing instrument 49 onto the paper 66, at the transmitting station. The action at the receiving set is entirely automatic.

The reason for picking the particular frequency separations in the four channels will now be further described in connection with the question of harmonic generation. This becomes particularly important if the transmitting and receiving apparatus are connected by wires, as for instance a long telephone toll line in which a plurality of vacuum tube amplifiers and repeaters are used and in the case where radio apparatus comprising audio amplifiers is connected in the circuit ahead of the apparatus at the receiving station. The passage of any particular alternating current through a vacuum tube tends not only to amplify the original currents at their fundamental frequency but also to create therefrom a new current of double the frequency. Such a current is called the second harmonic of the first current. This is an inherent difficulty of all vacuum tube amplifiers. Under normal conditions the amplitude of this second harmonic current is relatively small as compared with the fundamental frequency undergoing amplification. However, under conditions which often occur in practice the second harmonic currents reach amplitudes which would produce disturbing effects on the receiving apparatus. Thus if the right and left hand actuation currents were 1,000 and 500 cycle currents, respectively, the second harmonic current (1,000 cycle) produced in the 500 cycle channel would flow through the 1,000 cycle channel at the receiving apparatus to cause distortion of the right hand components of the movements of the writing instrument at the receiving station. Thus the particular frequency separations employed in the four channels of this invention have been selected so that none of the channels is resonant to any of the harmonics of any of the other currents. This same frequency differential gives ample separation for relatively simple tuning filters at the receiving end and yet places the respective channels on frequencies that are remotely removed from harmonics created by the other channels.

Furthermore, the total range of frequencies covered between the impression channel on 296 cycles and the left hand actuation channel on 1,000 cycles is so reasonable that associated electrical apparatus, such as telephone repeating coils, input modulation transformers in radio transmitters, etc., through which these tones pass do not materially discriminate against any of them. This is an important point and limits the excessive separation of the tones employed. The potentiometers 1, 2, 3 and 4 on the output circuits of the transmitting oscillators are used for individual adjustment on the several channels for the specific purpose of compensating for any slight discrimination that might occur with the chosen frequencies. The variable non-inductive resistors in the plate circuits of the amplifying tubes in the tuned receiving filters indicated as 94 in the 1,000 cycle channel, are used to vary the receiving amplification for the same purpose.

The effects of surges, static, fading, and the like on the system of this invention will now be considered. In devising the various instrumentalities the danger from disturbances of this nature has been continually kept in mind and the various instrumentalities so devised and associated are not materially affected thereby. With respect to the magnets 137 and 133 used for rolling operations at the receiving station it is pointed out that only one tone at a time is transmitted and any variation in the incoming current due to fading, and the like, merely tends to increase or decrease the strength which that particular magnet attracts the spring arm 138 and hence could in no case interfere with the operation of the apparatus except in the one possible instance where fading may so decrease the strength of the current as to render it ineffective in attracting the spring arm 138. This would represent a very unusual condition which would seldom arise. Static and induction surges would equally affect both the 1,000 and 666 cycle channels and would create momentary pulls on the armature 138 by each of the magnets 137 and 133. These would obviously oppose each other with no resulting effect on the roller. With regard to the magnet 125, here again any changes in current strength due to these factors would merely vary the force with which this magnet attracts its armature and only when the current was abnormally decreased by extreme fading would there be any undesired effects. Similar remarks apply with respect to the magnet 121. The one possible but unlikely condition which might occur here is that when the writing instrument 187 is off the paper and is permitted to contact therewith due to a sudden surge passing through magnet 121 causing armature 194 to be attracted by the magnet. This would merely produce a dot and not materially interfere with the operation of the apparatus. As is apparent, the most delicate part of the system with respect to these disturbances would be the actuation and repulsion magnets which operate the pantograph arms. The system here devised, however, is absolutely independent of any visible effects caused by static, induction interference, fading, and the like within the energy limitations of the receiving apparatus. Any disturbances occurring in the media between the transmitting and receiving apparatus equally affect the left hand actuation and repulsion magnets and the right hand actuation and repulsion magnets so that the resultant effect would be zero. In other words, any increase in the carrier wave or a static surge would increase the currents in the left hand channel simul-

taneously in floating coils 143 and 127 so that to in effect be balanced out and produce no motion of the left hand pantograph links. The right hand actuation magnets would not be effected for the same reason. Likewise any reduction in the currents due to fading would occur in the corresponding sets of floating coils and not cause any actual movement of the pantograph links. It is the ratio between the actuation and repulsion channels that produces motion and any variations in the intervening transmission medium do not effect this ratio. The ratio is entirely controlled at the transmitting station.

From the foregoing disclosure, which has been given in great detail, it will be apparent that the system of this invention has many novel and desirable features. It will be at once apparent to those skilled in the art that numerous changes in the details of construction, circuit arrangements, and methods of operation could be made without departing from the spirit and scope of the principles of the invention and I do not, therefore, desire to be strictly limited to the disclosure in the drawings and specification given for the purposes of illustrating the principles and mode of operation of this invention but rather to the scope thereof as it is set forth in the appended claims. As is apparent from the drawings, the invention has been set forth diagrammatically without particular reference to structural details, which may, of course, assume many physical formations, as I do not desire to limit the invention by structural details.

What I seek to secure by United States Letters Patent is:

1. In a method of transmitting intelligence in the form of graphical representations to a distant point comprising providing alternating currents of constant amplitudes at two constant frequencies, varying the amplitudes of said currents by and in accordance with the right and left hand components of graphical representations made at the transmitting point, supplying an alternating current of another frequency, controlling said current by and in accordance with the vertical components produced in making the graphical representations, transmitting all of said currents to a distance, and converting said currents into mechanical movements at a receiving point to reproduce the graphical representations at the receiving point.

2. In the method of transmitting intelligence in the form of graphical representations to a distance in which a writing surface is provided at the transmitting point, the steps of providing alternating currents of two frequencies, alternately transmitting said currents to a distance under the control and by and in accordance with the movements of the writing surface at the transmitting point, and employing said currents to effect a simultaneous movement of a similar writing surface at the receiving point.

3. In the method of transmitting intelligence in the form of graphical representations to a distance, the steps of providing an alternating current, and controlling said current in its transmission to a distant point by the vertical movements of a writing instrument at the transmitting point in making graphical representations.

4. In the method of transmitting intelligence in the form of graphical representations to a distance, the steps of providing an alternating current, controlling said current in its transmission to a distant point by the vertical movements of a writing instrument at the transmitting point, and translating said current at the receiving point into vertical movements of a writing instrument thereat.

5. In a method for transmitting intelligence in the form of graphical representations to a distance comprising providing alternating currents of constant amplitudes at two frequencies, varying the amplitudes of said currents by and in accordance with the movements of a writing instrument at the transmitting point, providing a third alternating current, controlling said current by and in accordance with the vertical movements of the writing instrument, combining all of said currents into a composite current, transmitting said composite current to a distance, and converting said currents at a receiving point into mechanical movements at the receiving point to reproduce the graphical representations made at the transmitting point.

6. In a method for transmitting intelligence in the form of graphical representations to a distance comprising providing alternating currents at two frequencies, varying the amplitudes of said currents by and in accordance with the movements of a writing instrument at the transmitting point, providing a third alternating current, controlling said current by and in accordance with the vertical movements of the writing instrument, combining all of said currents into a composite current, transmitting said composite current to a distance, separating said composite current into its three component currents, translating the two currents into right and left hand movements of a writing instrument at the receiving point and the third current into vertical movements of said writing instrument.

7. In a method for transmitting intelligence in the form of graphical representations to a distance, comprising providing alternating currents at two frequencies, varying the amplitudes of said currents by and in accordance with the movements of a writing instrument at the transmitting point, providing a third alternating current, controlling said current by and in accordance

with the vertical movements of the writing instrument, combining all of said currents into a composite current, transmitting said composite current a distance, separating said composite current into its component currents, amplifying and rectifying each component current, and converting said currents into mechanical movement of a writing instrument at the receiving point comprising the right hand, left hand and vertical components.

8. In a system of the type described, the combination comprising an input circuit, a plurality of filter channels tuned to pick out currents of particular frequencies, means connected to at least two of said channels for reproducing lines represented by the currents from said channels, connections between another of said channels and said means whereby said means is partially controlled by the currents therefrom, and means connected to the other of said channels for influencing said means for reproducing lines.

9. In a combination of the type described, an input circuit, four filtering, amplifying and detecting channels connected to said input circuit, electro-magnetic means connected to the output of two of said channels, connections between said electro-magnetic means and another of said channels, pantograph arms connected to said electro-magnetic means for operation thereby, additional electro-magnetic means for controlling the vertical movements of said pantograph arms, and connections between the other of said channels and said additonal electro-magnetic means whereby a composite current flowing in said input circuit is separated and delivered to the proper elements to effect the reproduction of graphical representations produced at a distance.

10. In an apparatus of the type described, the combination comprising rotatable means for supporting a roll of paper, rotatable means for receiving the paper, and means connected to said rotatable means for receiving the paper for alternately transmitting two alternating currents of different frequency as it rotates.

11. In an apparatus of the type described, the combination comprising rotatable means for supporting a roll of paper, rotatable means for receiving the paper, means connected to said rotatable means for receiving the paper for alternately transmitting two alternating currents of different frequency, means at a distance for rotatably supporting a roll of paper, additional rotatable means for receiving the paper from said rotatable means, and means mechanically connected to said additional means and electrically connected to said means for alternately transmitting two currents of different frequency whereby any movement of the paper at the first point effects a simultaneous and similar movement of the paper at the second point.

12. In an apparatus for reproducing graphical representations at a distance, the combination comprising pantograph arms, electro-magnetic means for causing the movement of said arms and electro-magnetic means for opposing and counterbalancing the operation of said first means.

13. In an apparatus for making graphical representations at a distance, the combination of a pantograph system comprising two sets of links pivotally united together, electro-magnetic means of uniform field strength including a floating coil connected to each of said sets of links, electro-magnetic means having a non-uniform field including a floating coil connected to each of said sets of links, and connections between corresponding sets of floating coils whereby said pantograph system may be operated by and in accordance with varying currents supplied to at least two of said floating coils.

14. In a system of the type described, the combination of means for influencing and transmitting a plurality of alternating currents by and in accordance with means for producing graphical representations, means for reproducing the graphical representations including pantograph arms, electro-magnetic means connected to said arms and operated by said alternating currents, and electro-magnetic means connected to said first electro-magnetic means for opposing and counterbalancing their movements.

15. In a system for controlling the movement of a writing instrument, the combination comprising an electro-magnet of uniform field strength, a second electro-magnet having a varying, as to space distribution, field strength and connected floating coils one for each of said magnets whereby the floating coil for the magnet of uniform field strength may be displaced by a varying current flowing therethrough a distance proportional to the strength of the current against the reaction of the other floating coil through which a constant current flows.

16. In an apparatus of the type described, the combination comprising a pantograph system comprising two sets of pivotally connected links, electrical means for operating each of said set of links in accordance with varying currents representing graphical representations to cause the point where the two sets of links are pivotally connected together to trace out the graphical representations, and balanced electrical means connected to said electrical means for overcoming the static resistance of all of the moving parts.

17. The method of transmitting graphical representations comprising varying the amplitudes of two normally constant amplitude alternating currents by and in accordance with the movements of a writing in-

strument, providing a third alternating current of constant amplitude, transmitting all of said currents to a distance, and reproducing said graphical representations by translating said currents into mechanical movements proportional to the changes in ratio between each of said alternating currents varying in amplitude and said alternating current of constant amplitude.

18. In an apparatus of the type described, the combination including a transmitting writing instrument capable of movements in a horizontal and vertical plane, means controlled by vertical movement of the writing instrument for sending an alternating current to a distance, a receiving writing instrument also capable of movement in a horizontal and vertical plane, and means energized by the transmitted alternating current for causing the receiving writing instrument to duplicate the vertical movements of the transmitting writing instrument.

19. In an apparatus as described, the combination including means for controlling an alternating current, a writing instrument capable of movement in a vertical plane, a conducting platen, a multi-electrode audion having at least a cathode, an input circuit for said audion including the grid, platen, writing instrument cathode and a source of negative potential and an output current including said controlling means and a current source, whereby when the writing instrument is in electrical contact with the platen said controlling means operates to transmit the alternating current.

20. In the method of transmitting intelligence in the form of graphical representations at a distance the steps of varying in accordance with the graphical representations and conveying through a transmitting medium two alternating currents of different frequencies, simultaneously transmitting a third alternating current of another frequency and translating said two varying alternating currents into graphical representations while opposing the forces generated thereby with said third alternating current.

21. In an apparatus for making graphical representations at a distance, means including a writing instrument at a transmitting station for varying two alternating currents of different frequencies by and in accordance with the movements of said writing instrument, means including a writing instrument at a receiving station actuable by said currents for reproducing at the receiving station the movements of the writing instrument at the transmitting station, and electrodynamic means energized from the transmitting station for counter-balancing the movement of the writing instrument at the receiving station.

22. In the method of transmitting graphical and the like representations to a distance, the steps of modifying a plurality of alternating currents of different frequencies in accordance with components of the representations, transmitting said modified currents over a transmitting channel to a receiving point, simultaneoulsy transmitting another alternating current over said channel and translating said modified currents into copies of said representations under the influence of said other current, all of said currents being equally affected by said channel whereby effects of distortion, static, fading and the like occurring in said channel have no appreciable effect on the modified transmitted currents.

In testimony whereof I have hereunto set my hand on this 19th day of December, A. D. 1928.

DAVID GRIMES.