

March 9, 1943.

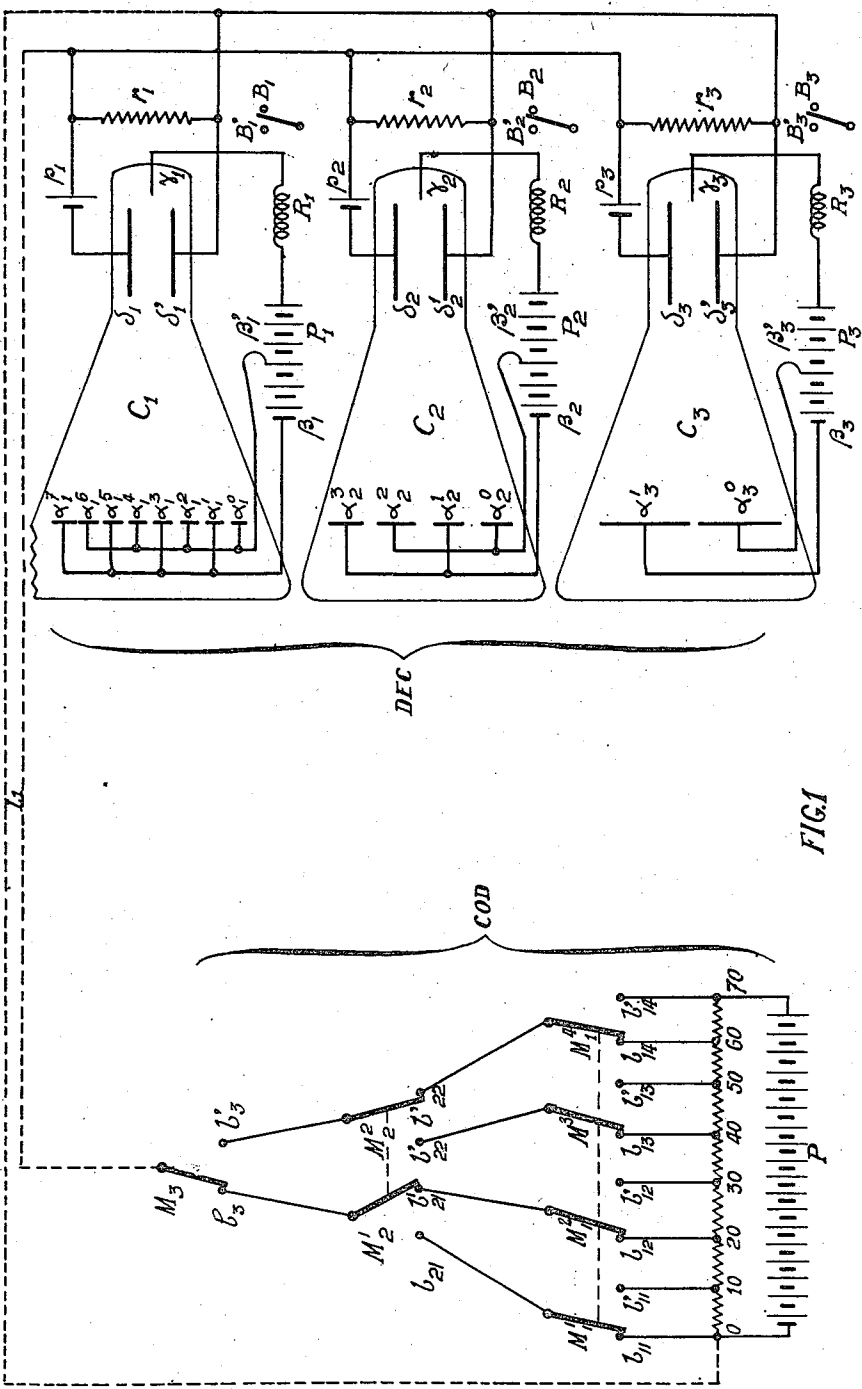
G. VALENSI

2,313,209

COMMUNICATION SYSTEM

Filed Nov. 17, 1939

5 Sheets-Sheet 1



INVENTOR  
George Valensi  
ATTORNEY  
E. J. Hanning

March 9, 1943.

G. VALENSI

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COMMUNICATION SYSTEM

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5 Sheets-Sheet 2

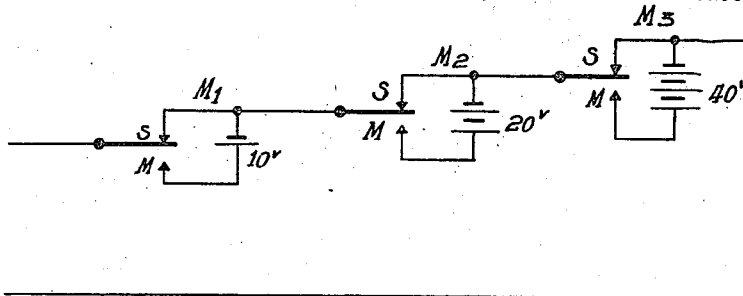


FIG. 1A.

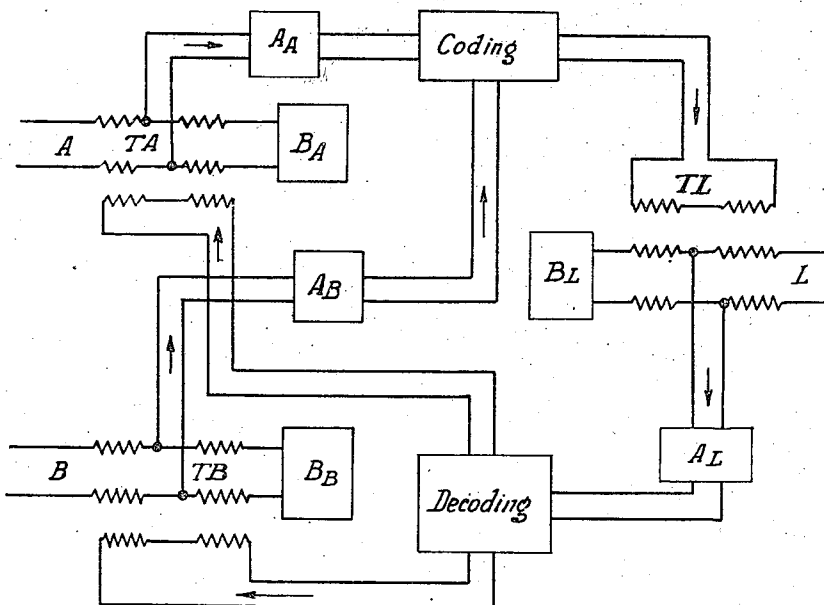


FIG. 2

INVENTOR  
George Valensi  
ATTORNEY  
E. D. Phinney

March 9, 1943.

G. VALENSI

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5 Sheets-Sheet 3

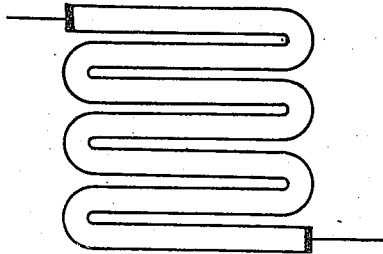


FIG. 3a

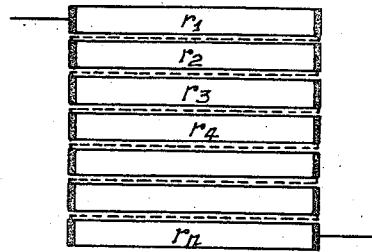


FIG. 3b

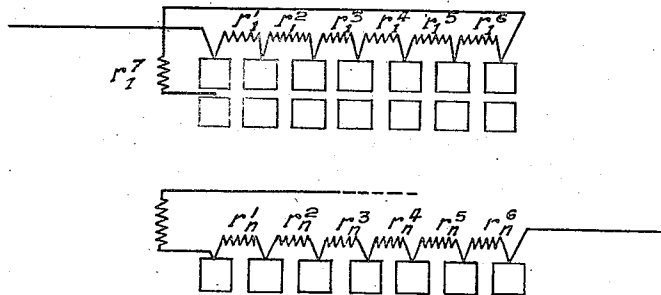


FIG. 3c

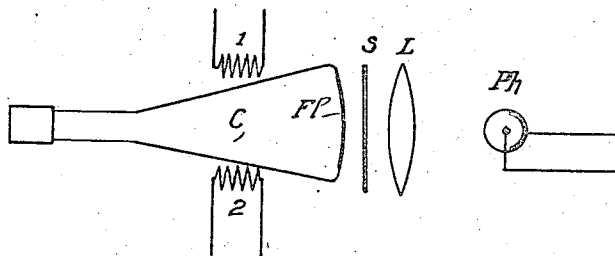


FIG. 4

INVENTOR  
George Valensi  
ATTORNEY  
E. O. Phinney

March 9, 1943.

G. VALENSI

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5 Sheets-Sheet 4

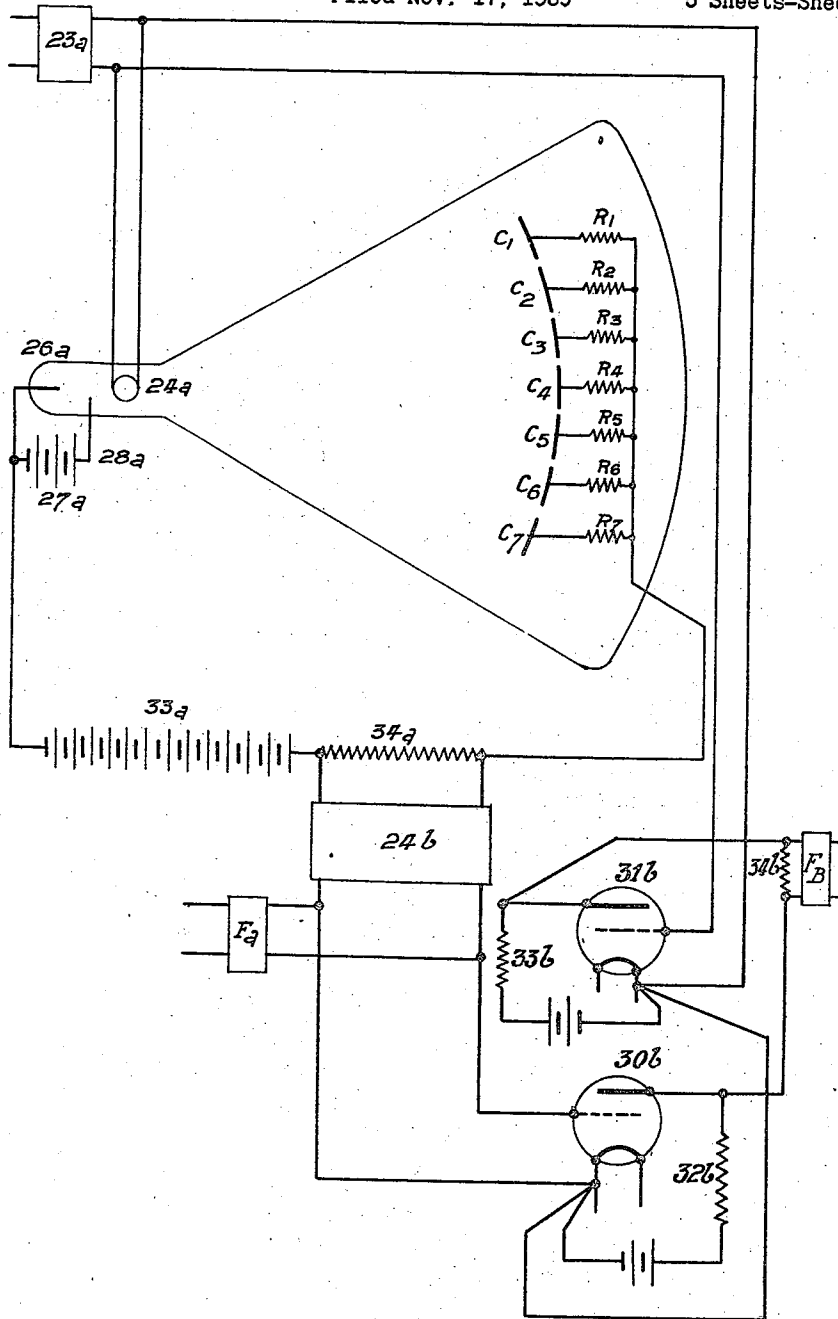


FIG. 5

INVENTOR  
George Valensi  
ATTORNEY  
Ed Phinney

March 9, 1943.

G. VALENSI

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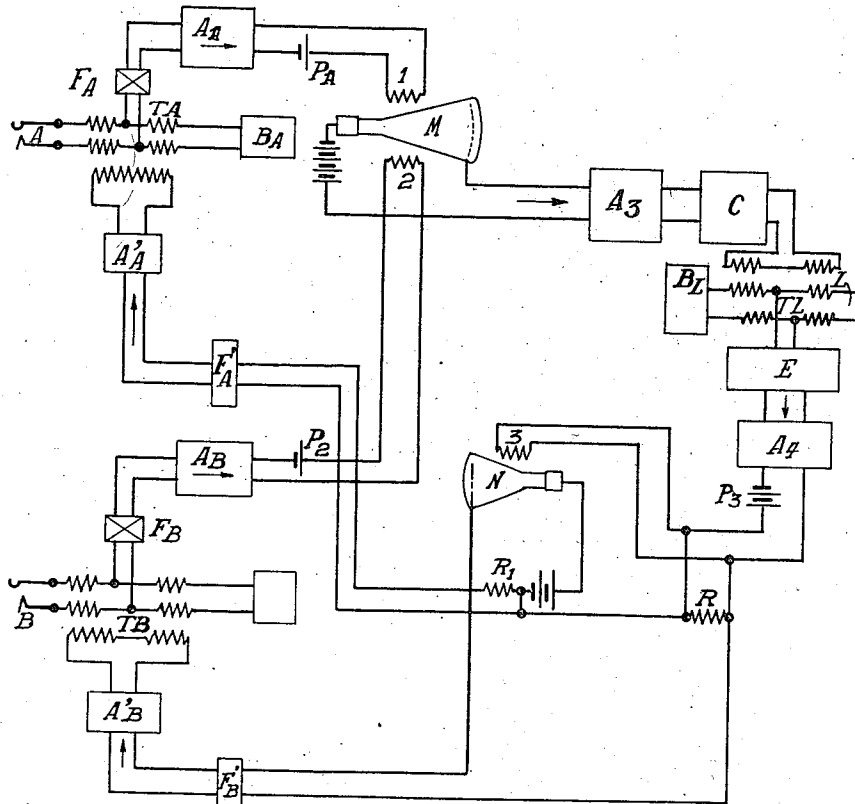


FIG. 6

INVENTOR  
 George Valensi  
 ATTORNEY  
 E. J. Kinney

# UNITED STATES PATENT OFFICE

2,313,209

## COMMUNICATION SYSTEM

Georges Valensi, Paris, France; vested in the  
Alien Property Custodian

Application November 17, 1939, Serial No. 304,884  
In France November 8, 1938

3 Claims. (Cl. 178—50)

The invention relates to improvements in or relating to communication systems and more particularly to telegraphy and telephony, and has for one of its objects a multiple transmission of messages over a given link without increasing the frequency band needed. Another object is to reduce the frequency band. Yet another object is to provide secrecy of transmission.

The present invention is based on the fact that for many telecommunication purposes and particularly for telegraphy and telephony, it is not necessary to reproduce at the receiving end of a transmission link the amplitudes of the currents with extreme precision. Even for telephony it will be sufficient to discriminate between a limited number of amplitude levels (say 6 or 10). If we assume that the link between the sending and receiving stations is able to transmit faithfully the amplitude variations in much greater detail than required to transmit the limited number of levels of one telephone channel, it may be considered possible to use the link to pass the necessary information to obtain a second telephone channel without increasing the frequency range.

A given amplitude of the line current may be considered as representing a certain combination of the instantaneous amplitudes of the two telephone channels, in accordance with a certain code. A system based on the above principle will therefore include a coding arrangement at the sending end and a decoding arrangement at the receiving end.

For telegraphy only two amplitude levels may be considered as satisfactory and the property of the link of transmitting faithfully much smaller variations in level may therefore be used to pass the information needed by several other telegraphic channels.

According to the present invention the respective simultaneous transmissions of intelligence are differentiated from one another, not according to frequency as in known multiplex communication systems, but according to amplitude, the respective channels having different amplitude ranges. A device herein termed a "coding device" is used at the transmitting station for converting the instantaneous amplitudes of the signal wave forms transmitted over the respective input channels to predetermined levels and for combining the latter into a single "coded signal" for transmission over a line or other transmission medium. At the distant receiving station, a device herein termed a "decoding device" responds to the coded signal and derives from it the original instantaneous amplitudes of the signal wave forms which are then impressed upon the respective output channels.

The above principle will be better understood by referring to the figures attached, of which:

Fig. 1 represents a typical arrangement en-

abling to send three telegraph messages through a single link.

Fig. 1A represents another arrangement of the sending part of Fig. 1.

Fig. 2 represents a typical terminal equipment to obtain two both-way telephone channels over a single link.

Figs. 3a, 3b, 3c represent resistance arrangements which can be used in the coding apparatus.

Fig. 4 indicates the principle of using a cathode-ray tube with fluorescent screen, code screen and photo cell.

Fig. 5 represents a typical decoding arrangement.

Fig. 6 represents a complete schematic of a terminal equipment for two both-way telephone channels.

In Fig. 1 the parts indicated by  $M_1^1$   $M_1^2$   $M_1^3$   $M_1^4$  represent a quadruple telegraph key (for example the 4 armatures of a transmitting relay which are mechanically, but not electrically, connected together) corresponding to the first telegraph channel. The parts  $M_2^1$   $M_2^2$  represent a double telegraph key corresponding to the second telegraph channel and  $M_3$  a simple telegraph key corresponding to a third telegraph channel.

To each part of the keys ( $M_1^3$  for instance) corresponds a back (or spacing) position ( $b_{13}$  for example) and a front (or marking) position ( $b'_{13}$  for example). The stops of the quadruple key of the 1st channel in which the level differences are small, are electrically connected to tapings of a current supply apparatus (for example 10-volt steps of an accumulator battery P). The stops of the double key of the 2nd channel are electrically connected to the 4 parts of the quadruple key of the 1st channel, so that for this 2nd channel the level variations are greater than for the 1st channel. The stops of the simple key  $M_3$  of the 3rd channel are electrically connected to the double key of the 2nd channel, so that for this 3rd channel the level variations are again greater. It is understood that in operation the keys for each of the channels must be in one of the marking or spacing positions and not in an intermediate position.

The following table indicates for each combination of the signals of the 3 channels, the value of the E. M. F. acting on the link  $L_1$  and produced by the coding arrangement COD.

| E. M. F. acting on the link (in volts) | Signal in the first telegraph channel | Signal in the second telegraph channel | Signal in the third telegraph channel |
|----------------------------------------|---------------------------------------|----------------------------------------|---------------------------------------|
| 0                                      | Spacing                               | Spacing                                | Spacing                               |
| 10                                     | Marking                               | do                                     | Do.                                   |
| 20                                     | Spacing                               | Marking                                | Do.                                   |
| 30                                     | Marking                               | do                                     | Do.                                   |
| 40                                     | Spacing                               | Spacing                                | Marking                               |
| 50                                     | Marking                               | do                                     | Do.                                   |
| 60                                     | Spacing                               | Marking                                | Do.                                   |
| 70                                     | Marking                               | do                                     | Do.                                   |

The same result can be obtained by the arrangement of Fig. 1A, on which are shown the keys  $M_1M_2M_3$  corresponding to the 3 telegraph channels and sources of current of variable E. M. F. (for example 10, 20, 40 v.).

This figure shows more clearly that, in the above case, the line signals are the addition of the signals of the various channels.

At the receiving end (Fig. 1) the decoding arrangement DEC consists for example in three cathode ray switches  $C_1, C_2, C_3$ , having electron-emitting cathodes  $\gamma_1, \gamma_2, \gamma_3$ , and accelerating anodes which are not shown. The deflector plates ( $\delta_1 \delta_1' \delta_2 \delta_2' \delta_3 \delta_3'$ ) are connected (through polarising batteries  $p_1 p_2 p_3$ ) to the resistances,  $r_1, r_2, r_3$ , which are in parallel with the line L. The potentials between the deflector plates are the same for the 3 tubes and the deflections are proportional to the variations of the E. M. F. at the sending end.

The resistances  $r_1, r_2, r_3$  and the batteries  $p_1, p_2, p_3$  are adjusted in such a way that the electron beams touch  $\alpha_1^0$  in  $C_1$ , the lower part of  $\alpha_2^0$  in  $C_2$  and the lower part of  $\alpha_3^0$  in  $C_3$  when the E. M. F. operating on the line is 0. When the E. M. F. has its full value (70 v.) the contacts  $\alpha_1^7, \alpha_2^3$  (upper part) and  $\alpha_3^1$  (upper part) are touched.

The plates  $\alpha_1^0 \dots \alpha_1^7$  of the cathode switch  $C_1$  are connected to two points  $\beta_1, \beta_1'$  of the current supply  $P_1$  which is connected to the cathode  $\gamma_1$  through the winding of the receiving telegraph relay of the first channel. The plates  $\alpha_2^0 \dots \alpha_2^3$  are connected to the points  $\beta_2, \beta_2'$  of the source  $P_2$  which is connected to the cathode  $\gamma_2$  through the telegraph relay of the second channel. The plates  $\alpha_3^0$  and  $\alpha_3^1$  are connected to the points  $\beta_3, \beta_3'$  of the source  $P_3$ , connected to the cathode  $\gamma_3$  through the relay  $R_3$  of the third channel. As the distance between successive plates  $\alpha$  (in  $C_1, C_2, C_3$ ) is supposed to be negligible in comparison with the width of these plates, the electron beams scan these plates in such a way that the receiving telegraph relays  $R_1, R_2, R_3$  take the required spacing and marking positions in accordance with the following table:

Decoding table

| E. M. F. acting on the line (in volts) | 1st telegraph channel  |                         | 2nd telegraph channel  |                         | 3rd telegraph channel  |                         |
|----------------------------------------|------------------------|-------------------------|------------------------|-------------------------|------------------------|-------------------------|
|                                        | Plate touched in $C_1$ | Position of relay $R_1$ | Plate touched in $C_2$ | Position of relay $C_3$ | Plate touched in $C_3$ | Position of relay $R_3$ |
| 0.....                                 | $\alpha_1^0$           | Spacing...              | $\alpha_2^0$           | Spacing...              | $\alpha_3^0$           | Spacing.                |
| 10.....                                | $\alpha_1^1$           | Marking..               | $\alpha_2^0$           | do.....                 | $\alpha_3^0$           | Do.                     |
| 20.....                                | $\alpha_1^2$           | Spacing...              | $\alpha_2^1$           | Marking..               | $\alpha_3^0$           | Do.                     |
| 30.....                                | $\alpha_1^3$           | Marking..               | $\alpha_2^1$           | do.....                 | $\alpha_3^0$           | Do.                     |
| 40.....                                | $\alpha_1^4$           | Spacing...              | $\alpha_2^2$           | Spacing...              | $\alpha_3^1$           | Marking.                |
| 50.....                                | $\alpha_1^5$           | Marking..               | $\alpha_2^2$           | do.....                 | $\alpha_3^1$           | Do.                     |
| 60.....                                | $\alpha_1^6$           | Spacing...              | $\alpha_2^3$           | Marking..               | $\alpha_3^1$           | Do.                     |
| 70.....                                | $\alpha_1^7$           | Marking..               | $\alpha_2^3$           | do.....                 | $\alpha_3^1$           | Do.                     |

While the above description clearly points out the operation of the system an explanation of the conditions presented in the present showing of Figure 1 may further simplify an understanding of the system. As shown, armatures  $M_1^1, M_2^1, M_3^1, M_1^2, M_1^3, M_1^4$  are on their spacing contacts,  $M_2^1, M_2^2$  are on their marking contacts and  $M_2$  is on its spacing contact. Across line 1, a voltage of 20 volts is applied from point 20 on the resistance across  $P, b_{12}, M_1^2, b_{21}, M_2^1, b_3, M_3, r_1, r_2$  and  $r_3$  in parallel to 0. The cathode rays of the tubes will be deflected into contact with  $C_1$  to  $\alpha_1^2$  (spacing),  $C_2$  to  $\alpha_2^1$ , lower half (marking) and  $C_3$  to  $\alpha_3^0$ , near center (spacing). Movement of any one of the keys to a different position, for example,  $M_3$  to marking, will apply 60 volts across the line, applying spacing potential in  $C_1$  at  $\alpha_1^6$ , marking potential in  $C_2$  at  $\alpha_2^3$ , and marking potential in  $C_3$  at  $\alpha_3^1$ .

It is understood that the transit time of any of the keys is shorter than the marking or spacing period.

It will be seen that the receiving relays take the positions corresponding to those required by the coding table.

The code used contains  $2 \times 2 \times 2$  combinations as there are 2 positions for each of the 3 channels. With  $n$  channels having  $p_1$  levels for the first channel  $p_2$  levels for the second and  $p_n$  levels for the  $n$ th channel, the code would have  $p_1 \times p_2 \times \dots \times p_n$  combinations.

In case of telephony some 6 to 10 levels may be needed and if we consider 2 channels, we would need  $6 \times 6 = 36$  to  $10 \times 10 = 100$  combinations. The intervals between the levels of one of the channels would be 6 to 10 times the intervals between the levels of the other channels. The signals of one channel would be added to the signals of the other channel at the sending end and at the receiving end the signals can be received by using two cathode ray tubes in an arrangement similar to that of Fig. 1. As the telephone channels must operate in both directions, an arrangement similar to that of Fig. 2 can be used.

This figure represents the terminal equipment needed to enable two subscribers to communicate over their lines A and B with their correspondents over the common line L. The usual hybrid coils  $TA, TB, TL$ , and balancing networks  $BA, BB, BL$  are used in such a way that speech coming from

A and B is directed respectively through the amplifiers  $A_A$  and  $A_B$  to the coding arrangement.

The coded signals are then directed through  $TL$  to the line L. Signals arriving from the line  $TL$  are directed through the amplifier  $A_L$  to the de-

coding arrangement and from here respectively to the lines A and B.

It is understood that the transmission equivalent of the line should be kept constant within certain limits and that this may be done eventually by using a pilot frequency and automatic regulation. Repeater gains may be kept constant by using negative feed-back.

We may now consider more closely the coding arrangement.

In the simplest case the telephone currents would be amplified in such a way that the maximum level of one channel is, say 6 times greater than that of the other, and the two currents would be added together. This can be done by means of a three-winding transformer or by passing each current through a resistance (or a reactance), connecting these resistances in series and taking the total potential difference as input of an amplifier for example.

Instead of such a simple network, the current of one or both channels may go first to a vacuum tube and the addition of the currents or potentials be made afterwards.

The coding arrangements may also use a kind of cathode ray tube, the electron beam (of circular or rectangular cross section) being controlled electrostatically or electro magnetically by the speech currents.

The electrons may reach conducting electrodes brought out of the tube and connected to different potentials as shown in Fig. 1 or connected to different resistances in series with a given E. M. F. These resistances will be of an order of magnitude equal to the resistance of the electron beam. When resistances are used, they may be placed inside the tube so that only one wire need be brought out. The resistance may in this case consist of a resistant layer deposited on an insulator in one continuous train as shown in Fig. 3a or in several ones  $r_1, r_2, \dots, r_n$  connected together by good conductors as shown in Fig. 3b. In these cases the electron beam when directed at a certain moment to some point of this layer insert in the circuit a certain length of the layer. The current variations would be gradual, at least when the electron beam is deflected in one direction.

The variable current may also be obtained by providing a series of square or rectangular conducting plates connected together through resistances  $r_1, r_1^2, \dots, r_n, r_n^2, \dots$  as shown in Fig. 3c. The distances between the plates would be small compared to their dimensions if "square" signals are wanted. Refinements using auxiliary plates and resistances or an electron beam of relatively large section could be provided if the signals have to be shaped in some special way.

The resistances between the plates may all have the same values or have different values, some plates may be strapped together, etc., depending on the particular code used.

Another method of obtaining the current variations would be to produce secondary emission on the spot touched by the electrons. The intensity of this secondary emission would vary from point to point either due to the nature of the surface touched, to variable electric or magnetic conditions, or to the use of screens.

The coding arrangement may also use a cathode ray tube C with fluorescent screen F1, the light of which, concentrated by an optical system L, acts on a photocell Ph as shown by Fig. 4. The variations of photocell current could then be obtained by inserting a code-screen S with

opaque compartments between the tube and the cell producing the required variations in the light reaching the photocell. Such an arrangement is particularly interesting when it is desired (as in case of secret service) to change the code at certain times. With a fixed code, the fluorescent screen and the code screen can be combined inside the tube. A thin insulator, such as a mica plate, would be coated on one side with the fluorescent material and on the other side with a more or less opaque layer producing the required variations in the light transmitted to the photocell.

Regarding the decoding arrangement several solutions, similar to those of the coding arrangement, may be considered.

The signals have to be split into their constituent parts. This may be done by extracting individually all the parts from the line current or (particularly in the case of two telephone channels) by extracting first the signals of the channel using large variations in level and then subtracting these from the total line currents. An example of the first procedure has already been given in Fig. 1 for the case of telegraphy. Fig. 5 gives an example of the other procedure. The coded signal coming from the transmitter is sent into an amplifier 23-a which supplies current to a deflecting coil 24-a controlling the direction of the electron beam emitted by the cathode 26-a of a cathode ray tube 25-a, and accelerated by the anode 28-a to which is applied a certain potential by the D. C. supply 27-a. Depending on the instantaneous value of the deflecting current the electron beam will reach one of the conducting plates  $C_1, C_2, \dots, C_6, C_7$  fixed in the tube. These plates are connected to the high tension supply 33-a through resistances  $R_1, R_2, \dots, R_6, R_7$ , and a common resistance 34-a. The current in the resistance 34-a will vary by steps when the beam passes from one plate to the next one. The resistances will be calculated in such a way that, if the current is I when the beam reaches  $C_1$ , the current will be  $2I, 3I, \dots, 7I$ , when reaching  $C_2, C_3, \dots, C_7$  respectively.

It will be seen that in this way it is possible to obtain in the resistance 34-a the current values of one of the telephone channels. By subtracting the potential between the terminals of 34-a from that of the total signal, we will obtain the variations corresponding to the second channel. This subtraction is obtained by connecting the resistances 32b and 33b of the plate circuits of the vacuum tubes 30b and 31b in opposition. The apparatus 24b can be adjusted in such a way that the required gain (or attenuation) is obtained.

The Fig. 5 shows vacuum tubes, but a similar result could be obtained by sending the cathode ray tube currents through a resistance connected in series with another resistance through which passes a current proportional to the total line current in the required phase relation so that the difference between line current and cathode ray tube current may be obtained for reproducing the second speech channel, as explained further in relation with Fig. 6.

We may now consider the complete schematic of Fig. 6 showing a preferred arrangement of the terminal equipment used for two both-way telephone channels. In this figure, two subscriber lines may be connected to the jacks A and B and the subscribers should be able to communicate with their correspondents through the common line L.

The currents from A are directed by means of the hybrid coil T<sub>A</sub> through a high pass filter F<sub>A</sub> (which eliminates the frequencies below 300 c./s., which are not effectively transmitted by the line) to the amplifier A<sub>A</sub> which is provided with an automatic volume control arrangement and then to the deflecting coil 1 of the coding cathode ray tube M. A source of E. M. F. P<sub>A</sub> is provided to have unidirectional deflections of the electron beam.

The currents from B follow a similar path and reach the coil 2 which produces a deflection at right angles with that of coil 1. The electron beam sweeps over an assembly of plates and resistances as illustrated by Fig. 3c and produces current variations which are amplified by A<sub>2</sub>. The levels are compressed by the arrangement C and then sent to the line L through the hybrid coil T<sub>L</sub>. The use of this compressor avoids too low levels on the line and consequently possible distortion of signals due to noise, crosstalk and interference.

The currents coming from the line L pass to the expander E which restores the correct levels, then to the amplifier A<sub>4</sub> and to the coil 3 of the decoding cathode ray tube N. An E. M. F. P<sub>3</sub> is provided to restore the D. C. component. The cathode ray tube N contains as many plates and resistances as there are levels in channel A so that the current flowing through the resistance R<sub>1</sub> reproduces the level variations of this channel. These variations reproduce the speech current, a low pass filter F<sub>A'</sub> eliminating the components above 2400 c./s. An amplifier A<sub>A'</sub> gives the required output level to the speech currents which pass through the hybrid coil T<sub>A</sub> and to the line A.

The resistance R<sub>1</sub> is connected in series with the resistance R through which passes a current proportional to the incoming currents. The difference of the potentials at the terminals of R<sub>1</sub> and R gives the level variations of the channel B and these signals, after passing through the low pass filter F<sub>B</sub> and the amplifier A<sub>B</sub> are sent through the hybrid coil T<sub>B</sub> to the line B.

In the preceding cases no attempt has been made to reduce the frequency band which has to be transmitted over the line. The purpose was to transmit several messages without needing more than the total frequency band available. It may however be interesting in certain cases to transmit only one message, but to reduce the frequency band. Supposing we want to transmit speech over a line passing only frequencies from 300 to 1300 c./s.: if the original speech band contains frequencies from 300 to 2300, this band could be split into two parts by means of filters and the highest part (1300 to 2300) be transposed by suitable modulation to the range 300-1300. The two parts can then be considered as two messages to be transmitted together over the line as in the preceding cases.

At the receiving end, one of the parts would be replaced in its initial frequency position and be added to the other part to reconstitute the original speech.

The present invention gives a certain secrecy, as a mere listening on the line would only enable to understand parts of the conversations, mainly of the channel using high levels.

This secrecy may be increased by using codes in which the line currents are not merely the sum of the individual channel currents, but in which a certain line amplitude would represent any combination of channel amplitudes. This would be particularly easy when cathode ray tubes and photo-electric cells are used.

In case of a single telephone channel, the line signals could be completely distorted by providing a second channel carrying only a disturbing noise. At the receiving end, the separation would be done in the same way as for two telephone channels. The noise could be charged from time to time if required. In case of telegraphy, several telegraph channels could be mixed with one noise channel.

I wish it to be known that I do not desire to be limited to the exact details of construction shown and described, for obvious modifications will occur to persons skilled in the art.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In a two-way two-channel telephone channel, for each channel a hybrid coil, a balancing network and a coding system for replacing the original voice-frequency wave by a series of finite amplitude levels according to the amplitude of the wave, and a decoding system for separating incoming superposed amplitude levels, and means for connecting said coding and decoding devices to the multiplex transmission line comprising a hybrid coil and the balancing network.

2. In a transmission system in which the signals are analysed in a finite series of amplitude levels, means for effecting such transformation comprising a cathode ray tube, means controlled by signal currents for deflecting the cathode rays of said tubes, and multiple anodes connected to series resistances of approximately same magnitude as electron beam resistances, placed inside or outside the cathode ray tube.

3. A multiplex telecommunication system in which a plurality of intelligence channels are provided over the same transmission medium, comprising a plurality of independent signal sources, one for each channel, means to transmit signal currents from each of said sources at different amplitude levels, the range of amplitude levels being different for each channel, a coding device for combining signal currents from said sources into a common coded signal current having an amplitude varying according to the sum of the instantaneous amplitudes of the wave forms of the signal currents from said sources, means for transmitting said coded signal currents over the transmission medium to a receiving station, and decoding means at said receiving station for deriving from said coded signal currents separate signal currents corresponding to those transmitted from said sources, said coding device comprising a cathode ray tube, means controlled by signal currents for deflecting the cathode ray of said tube, and multiple anodes connected to series resistances of approximately the same magnitude as the resistance of the electron beam, said resistances being located inside the cathode ray tube.

GEORGES VALENSI.