Sept. 5, 1967 R. K. POTTER 3,340,361

SIGNALING SYSTEM WITH CATHODE RAY TUBE QUANTIZER

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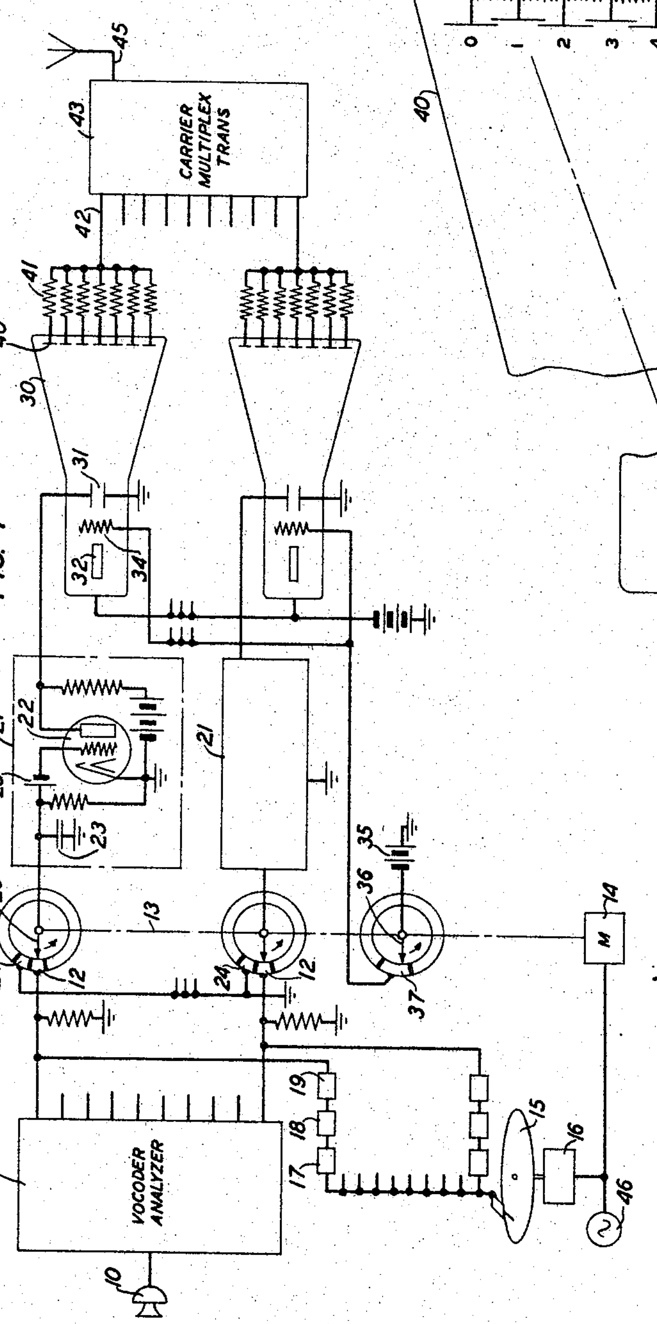

FIG. 1

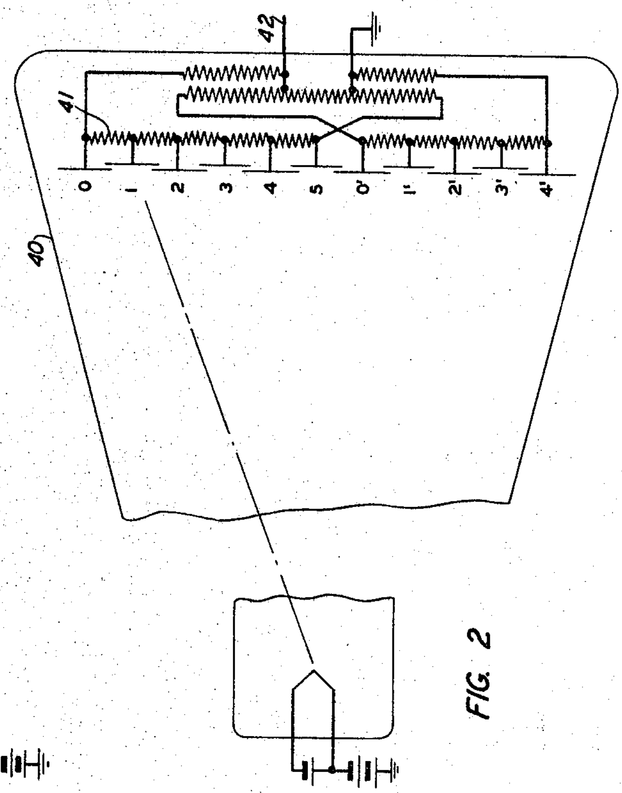

FIG. 2

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FIG. 3

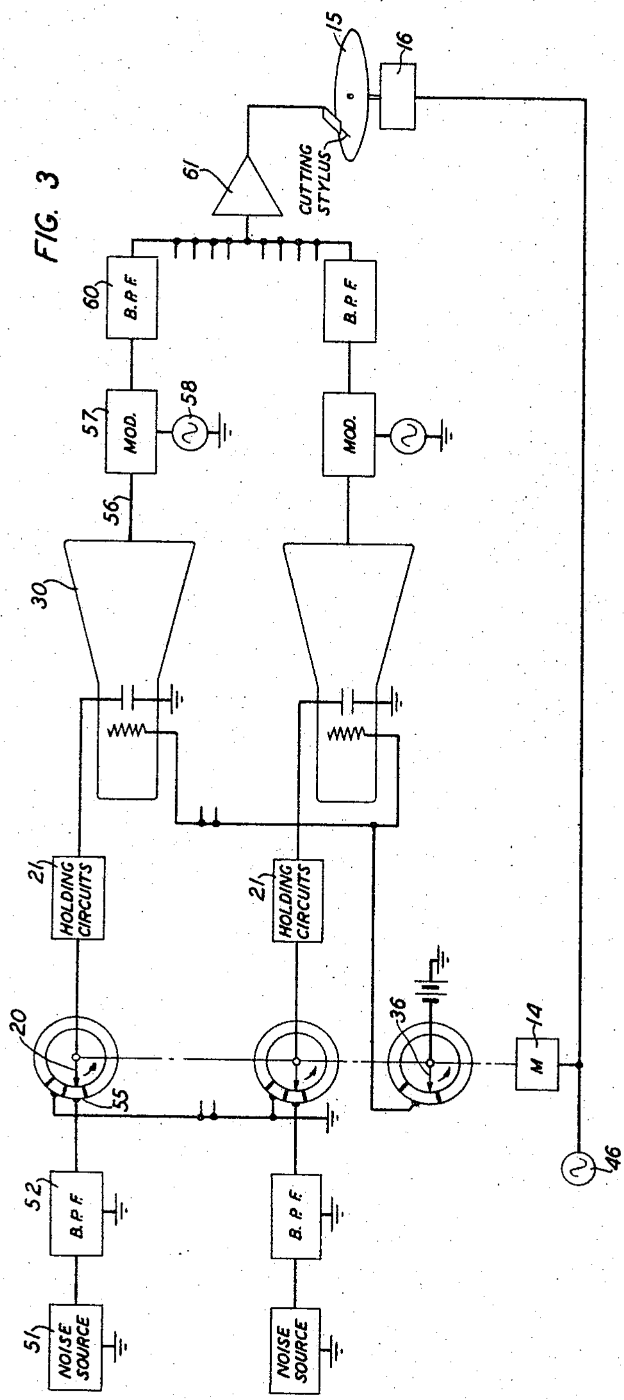
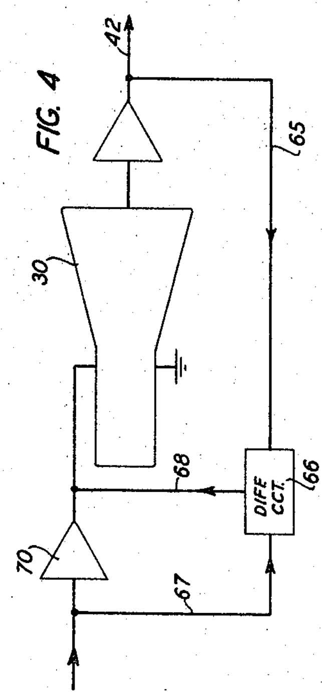


FIG. 4



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SIGNALING SYSTEM WITH CATHODE RAY TUBE QUANTIZER

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2 Claims. (Cl. 179—1.5)

The present invention relates to signal transmission and more especially to the use of cathode beam tubes as quantizers for the waves to be sent or received.

One typical use to which quantizers of this type or stepping circuits may be put occurs in connection with privacy systems and the invention will be illustrated as embodied in and forming a part of a privacy system, this use being intended as illustrative rather than limiting.

A type of privacy system to which the invention is applicable is disclosed in Lundstrom-Schimpf application, Ser. No. 456,322, filed Aug. 27, 1942, and the present disclosure will be in accordance with the general plan of the system disclosed therein. In such a system secrecy is achieved by adding a secret key wave to the signal before transmission and, in effect, subtracting a duplicate key wave from the received waves in order to decipher the signal at the receiver. In such a system the transmitted wave is of stepped instead of continuously varying form. The steps are produced by stepper circuits in the transmitting terminal. Such a stepper is used in each signal channel after the key wave is added to the signal. The summation of the key and signal waves gives a total range of values which is greater than it is desired to transmit. For cryptographic reasons as well as for other transmission reasons it is desired to limit the range of the summation values of signal plus key waves to the maximum range of the signal wave alone and a so-called reentry circuit is made use of to reduce this range of summation values by causing a definite number of steps to be subtracted from the summation value whenever the summation wave exceeds a given maximum.

In the Lundstrom-Schimpf disclosure separate circuit portions were used for carrying out the two functions of stepping and reentering. The present invention is in the nature of a simplification of these circuit portions of the prior disclosure and accomplishes both functions directly in a single piece of apparatus. In accordance with the invention a cathode beam tube is provided with an array of targets so wired up to a common output circuit that each target when struck by the beam applies a distinct step value of current to the output. When the beam swings over these targets, therefore, a stepped form of output current is produced. Moreover, if the beam is moved by the summation wave beyond the point corresponding to the maximum step value to be transmitted the targets on which the beam strikes when moved to such an extent are so connected as to give lower rather than higher step values of output current thus accomplishing reentry in direct manner.

An object of the invention is to improve upon and simplify known types of circuits for converting gradually varying waves into waves of stepped form. A further and related object is to enable reentry to be directly accomplished by the same means that perform the stepping function. More specifically the invention has as its object to provide a stepped and reentered wave by means of a beam deflection tube.

The nature and objects of the invention will be more fully understood from the following detailed description of the illustrative embodiments shown in the accompanying drawings in which:

FIG. 1 is a block schematic diagram of a transmitting station embodying the present invention;

FIG. 2 is a partial view of opposite ends of a cathode beam tube in accordance with the invention showing details of the targets and resistances;

FIG. 3 is a block schematic diagram of a circuit for producing a key record by means according to the present invention; and

FIG. 4 is a diagram of a feedback circuit for a cathode beam tube according to one feature of the invention.

Referring first to FIG. 1, this figure shows the arrangement that might be used at the transmitting end of a telephone privacy system in accordance with the general plan of the Lundstrom-Schimpf disclosure. The speech waves spoken into the microphone **10** or coming over any suitable speech circuit are applied to a vocoder analyzer **11** which may be constructed in accordance with the disclosure of Dudley Patent 2,151,091, granted Mar. 21, 1939. This analyzer contains subdividing filters for dividing the total speech frequency band into a number of subbands and for deriving in each of a number of separate paths a low frequency speech defining wave, one at least of which represents the fundamental pitch variations, while the others represent spectrum or energy-frequency variations. Any suitable number of such speech defining paths may be used, such as ten, for illustration. Each of the spectrum defining channels includes in addition to the analyzing filter an integrating circuit and preferably a low-pass filter (not shown) for deriving the respective slowly varying direct current wave. The pitch defining channel contains apparatus for measuring the instantaneous fundamental pitch and its variations with time.

The ten low frequency channels emerging from the analyzer **11** are each connected to a fixed segment **12** of a rotary switch **20** having provision for making contact with the fixed element **12** once in each revolution. The movable arms of all of these switches are connected to the same shaft **13** driven from a motor **14**. The shaft may, for example, make fifty rotations per second thus sampling the currents in the ten separate channels fifty times per second.

A secret key wave is derived in any suitable manner such as from a photograph record **15** on which are recorded, in this case, ten separate key waves in the form of modulations of high frequency waves in accordance with multiplex carrier practice. The various key waves are separated by ten selecting filters **17**, each of which is followed by a detector **18** and low-pass filter **19**. Each signal current, therefore, in the vocoder channels has added to it a secret key wave from the corresponding key channel the summation of these waves being impressed upon the respective contacts **12**.

The brush arm of each rotary switch **20** leads to a holding circuit **21** comprising a suitable vacuum tube **22** having a storage condenser **23** connected across its grid circuit. As the rotating brush makes contact with the segment **12** the summation of signal plus key current in the corresponding channel is sampled and a corresponding charge is placed upon the condenser **23**. As the brush breaks contact with segment **12** and continues its rotation the charge on the condenser **23** remains substantially constant until the brush reaches the grounded discharge segment **24**, the effect of which is immediately to discharge the condenser **23** and prepare it for the reception of a fresh charge. The holding circuits and the arrangements generally as described are similar in each of the ten channels.

Each channel leads to a cathode beam tube **30** having a pair of deflecting electrodes **31** one of which is grounded and the other of which is connected to the output side of the holding circuit of the respective channel. The cathode beam tube is provided with a suitable beam forming, focusing and projecting structure generally indicated at 32 but not specifically shown since this may be of any well-known and suitable type for producing electrons, forming them into a well defined beam and projecting them as a narrow beam between the deflecting plates 31 and toward the array of targets 40 shown at the large end of the tube. With zero voltage impressed on the holding circuit 21 the beam is caused by suitable means to impinge upon the uppermost target of the array 40. (This could be accomplished by the bias received from the plate battery of tube 22 or by use of auxiliary biased deflecting plates or by tube geometry or by other means known in the art.) When different voltages are applied from the holding circuit to the upper deflecting plate the beam is deflected downward in the figure as a function of the strength of the applied voltage. The tube 30 is or may be provided with a suppressor grid 34 arranged to have a high negative bias applied to it from battery 35 whenever the rotary switch arm 36 makes contact with segment 37. When this occurs the beam is prevented from reaching any of the targets 40.

The targets 40 in FIG. 1 are illustrated as connected through individual resistors 41 to a common output lead 42. These resistors vary in value from target to target so that a different weighting is given to the current in output circuit 42 depending upon the particular target on which the beam is resting. The values of these weighting resistances are so chosen as to provide the desired sized steps in the output current.

It will be understood that there are ten of these cathode beam tubes 30, one for each vocoder channel, and that they are similarly controlled by the currents in the respective channels. Each of the ten outgoing conductors 42 leads to the carrier multiplex transmitting equipment 43 which may be constructed in accordance with usual multiplex carrier practice to cause each of the incoming currents to modulate a separate high frequency wave for simultaneous transmission on a multiplex basis over the outgoing channel 45 which may be a line or radio transmitting antenna.

In the operation of FIG. 1 the speech currents are analyzed into low frequency speech defining currents in the separate channels as already described, these currents having in practice a maximum frequency of variation of about 25 cycles per second. Good transmission is attained by sampling them at the rate of fifty times per second. The duration of contact made by each rotary brush with the segment 12 may be, for example, 2 milliseconds and the duration of contact of the brush with the discharging segment 24 may also be 2 milliseconds. The negative bias on the suppressor grids 34 is applied just before the rotary brushes 20 make contact with the discharging segments 24 and is removed at about the time the rotary brushes leave segments 12. In one form shown in the Lundstrom-Schimpf disclosure, the line pulses were assumed to have a duration of 14 milliseconds with 6-millisecond spaces between pulses. Assuming the same timing in the present disclosure, the segment 37 has a length corresponding to 6 milliseconds thus allowing for a 2-millisecond contact with each segment 24 and 12 with a slight margin for making contact with segment 37 in advance of the making of contact with the discharging segments 24.

Each of the holding circuits is provided with a sufficiently high voltage negative grid bias source 25 to provide plate current cut-off and therefore highest output voltage when there is no charge on the condenser 23. With these considerations in mind it is seen that as soon as the suppressing voltage is removed from the suppressor grids 34 by the rotary contact 36 passing off segment 37 a new value of charge has been placed on each of the condensers 23 and the beam in each tube 30 is projected directly against the corresponding target 40 without having to sweep over other targets to reach the particular target. The beam remains upon the particular target for about 14 milliseconds until the high negative bias is again placed on the suppressor grid 34. A definite stepped value of output current is, therefore, produced in each of the outgoing circuits 42.

The timing of the various rotary switches and of the phonograph drive is accomplished by driving the motors 14 and 16 from the same source 46 of constant frequency waves.

Not only do the tubes 30 convert the gradually varying currents in the vocoder channels into waves of stepped form but they also accomplish the reentry function in a manner that will now be described in connection with FIG. 2. In this figure eleven targets are shown in the array 40 numbered 0, 1, 2, 3, 4, 5, 0′, 1′, 2′, 3′, 4′. It is assumed that the output signal is to vary is six steps 0 to 5, counting zero as one step, and that the summation of signal plus key has a maximum range such as to swing the beam from the zero target down to the 4′ target. Whenever the beam is on any one of the targets 0 to 5, the resistances 41 making up the resistance network between the targets are so proportioned as to give the corresponding step value of output current in circuit 42. If, however, the summation signal plus key current has a value corresponding to six steps, causing the beam to impinge on the 0′ target, the wiring and arrangement of resistances for this target are the same as for the 0 target resulting in production of step zero output current in circuit 42. Similarly, if the summation current is such as to cause the beam to strike target 1′ corresponding to seven steps, an output current of one step is produced, the effect being the same as though the beam were incident upon target 1. If the maximum value of current is present, causing the beam to strike target 4′, an output current of four steps is produced.

In FIG. 1 no attempt has been made to illustrate the actual number of targets in the array 40 but it is assumed that the number of targets and also the values of the resistors 41 are such as to accomplish the reentry function as described in connection with FIG. 2. In FIG. 2 the targets are shown arranged one behind the other and slightly overlapping so as not to allow any vacant space between targets.

The waves sent out from the circuit of FIG. 1 can be received by means of the receiving circuits shown in the Lundstrom-Schimpf application and it is not deemed necessary to an adequate disclosure of the present invention to disclose also a receiving station the counterpart of FIG. 1. It will, of course, be necessary to choose the magnitudes of voltages, number of channels and timing of the various parts properly so as to cooperate with the Lundstrom-Schimpf receiving circuits. For one thing, it may be necessary to introduce an inversion in the circuits at some point and this may be done in the transmission line between keying points, such as in the circuits 42 leading to the carrier multiplex transmitter by, in effect, subtracting the currents from a constant value of current. Adaptations of this type if and where necessary will occur to those skilled in the art. It will be obvious in view of the disclosure in FIG. 1 that stepper reentry tubes 30 may also be applied to the receiving terminal in an analogous manner to replace the stepper and reentry circuits of the Lundstrom-Schimpf receiver thus resulting in a similar simplification of the receiver terminal.

FIG. 3 illustrates how stepper tubes 30 may be employed in a system for cutting the key record 15. In this figure the same source of current 46 drives the phonograph motor 16 and the motor 14 for the rotary switches 20 and 36. The tubes 30 may be constructed similarly to the corresponding tubes of FIG. 1. The key currents are derived in the first instance from resistance noise currents produced by the respective noise sources 51. These may be of a type known in the art comprising a high resistance in the grid circuit of a high gain amplifier tube or they may comprise a gas tube operated with a continuous discharge.

In either case sufficient amplification is assumed to bring the level of the noise currents up to the required value. Band-pass filters **52** select from the noise currents a suitable band, for example, of the order of 2 kilocycles in width. The output of the filter is connected to segment **55** of the corresponding rotary switch. These switches are the same as the switches **20** of FIG. 1 except that it is preferred to make the contacts **55** considerably shorter so that the sampling time is only a fraction of a millisecond. The object is to sample the random noise variations as nearly instantaneously as feasible, once every fiftieth of a second, and place a corresponding charge on the condenser in the holding circuit **21**. This results in the production of key currents varying from instant to instant in random manner. The holding circuits prolong each sampled fragment and apply them to the deflecting plates of the beam tubes **30**.

These beam tubes operate in similar manner to those described in FIG. 1 to convert the varying noise current values into stepped key currents in the circuits **56** leading to the modulators **57**. Each modulator is supplied with a different frequency carrier wave from source **58** and the resulting modulation components are selectively transmitted through band-pass filters **60** and through amplifier **61** to the cutting stylus of the record **15**.

By arranging the targets in all of the embodiments as shown in FIG. 2 to leave no blank spaces between targets and by restricting the cross-section of the beam to substantially a line form (beam in form of a sheet) the likelihood of the beam splitting between two adjacent targets is minimized. This likelihood may be still further reduced by employing a feedback circuit of the type illustrated in FIG. 4. In this figure some of the final output current is taken off by a feedback path **65** and applied to one branch of a differential circuit **66**. Also some of the input voltage is taken off through conductor **67** and applied to differential circuit **66**. This circuit is also arranged in known manner, for example, as in Hansell Patent 2,080,204, May 11, 1937, so that when the two voltages in the conductors **65** and **67** are equal, no voltage appears on the conductor **68** but when one or the other applied voltage predominates a direct current voltage of one or the other polarity is produced in conductor **68**. The current or voltage in conductor **68** is reapplied to the input circuit at a point following amplifier **70**.

By proper adjustment of the amount of feedback, matters can be arranged so that when the beam is incident upon the center of one of the targets there is no resultant feedback and the voltage on control conductor **68** is zero. Taking as an example a particular target such as that corresponding to step **1** of FIG. 2, the same output current is produced, of course, for all positions of the beam on this target. Slightly different values of input voltage, however, tend to position the beam at different points along the target. This means that for different positions of the beam along the target the feedback current in lead **68** may be in the negative direction for some of these positions and in the positive direction for other positions.

Assuming, to facilitate the description, a gradually increasing signal, if the signal is tending to move the beam downward across target **1** toward target **2**, after the beam has passed the center of target **1** the effect of voltage in lead **67** upon the feedback may predominate over that of the voltage in lead **65**, tending to retard movement of the beam downward. As soon as the signal causes some of the beam to reach the edge of target **2** the current in lead **65** suddenly tends to increase by a cumulative action, reversing the polarity of the current in conductor **68** and quickly shifting the beam to target **2**. With this type of adjustment of the feedback connections the feedback tends to hold the beam on a target until the beam would otherwise tend to divide between this target and the next, when the feedback changes from a retarding type to an advancing type. This holds true for both increasing and decreasing signals.

If, under these assumptions, a plot is made of input as abscissae against output as ordinates, a staircase graph is obtained, the horizontal portions of which represent the steps of output current. A feedback adjustment can be found by trial which will give nearly vertical line transitions from one step value to the next showing that no split-beam condition exists, the beam being always on some one and only one target.

While this example has assumed a continuously applied signal of uniformly varying strength, the circuit of FIG. 4 may be directly substituted for tube **30** of FIG. 1 in which case the input signal is applied in pulses and the action as regards prevention of beam splitting is the same.

The suppressor grid **34** may not be necessary in particular cases and may be omitted if desired. The beam in being deflected to some particular target may be made to pass over the preceding targets very quickly and if the disturbances produced in the output current from this cause are of negligible effect the grid suppression can be dispensed with. While discharging segments **24** are shown, these can be dispensed with in many cases where the input circuit is such as to permit both adding to and subtracting from the condenser charge during the time of contact on segments **12**.

What is claimed is:

1. In a signaling system, a signal input circuit, a cathode beam tube connected to receive signal voltage variations from said circuit and comprising a plurality of targets, means to move the beam from target to target under control of said signals and as a function of signal strength, a common output circuit and resistances of different value connected between individual targets and said output circuit for applying to said output circuit voltages varying in steps as the beam moves from target to target, and a feedback circuit from said output to said input circuit comprising a differential feedback control for causing the feedback to oppose movement of the beam by the signal from the center toward the edge of any target but to aid movement of the beam by the signal from the edge toward the center of any target, said system including means providing gain for signals in said input circuit, means for comparing input signals against output signals to obtain a differential voltage, and means controlled by said last voltage to control the gain for signals in said input circuit.

2. A circuit for producing reentry coding including a source of message waves and a source of key waves, means for adding the key waves to the message waves to form summation currents representing a signal to be transmitted, a cathode beam tube, means to deflect the beam by said signal, a first group of targets arranged in sequence in the path of the beam, a second group of targets beyond said first group and arranged to be passed over by said beam in its further movement, corresponding targets in the two groups representing a difference in signal strength equal to the maximum value of the message wave, an output circuit, connections to said output circuits from said targets including varying amounts of resistance for causing the output current to vary in steps, the connections from the targets of both groups to said output circuit including like amounts of resistance for causing like step values of current in response to impingement of the beam on like targets of each group.

References Cited

UNITED STATES PATENTS

2,096,653	10/1937	Soller	250—27
2,224,677	12/1940	Hanscom	250—27
2,357,922	9/1944	Ziebolz et al.	250—27

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