

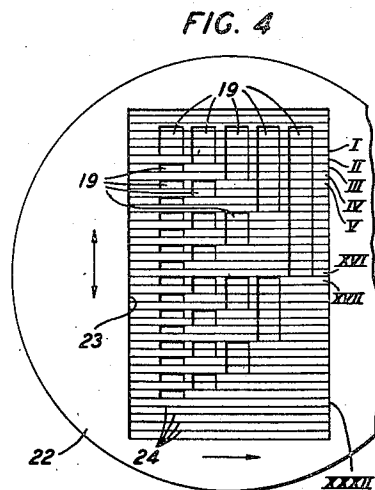
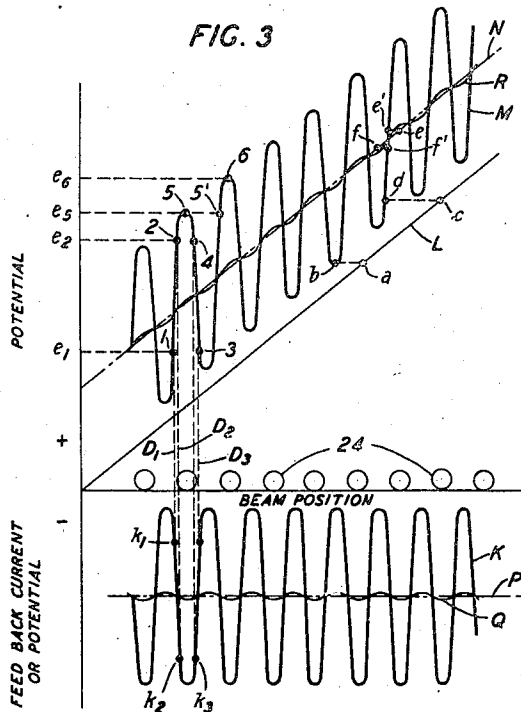
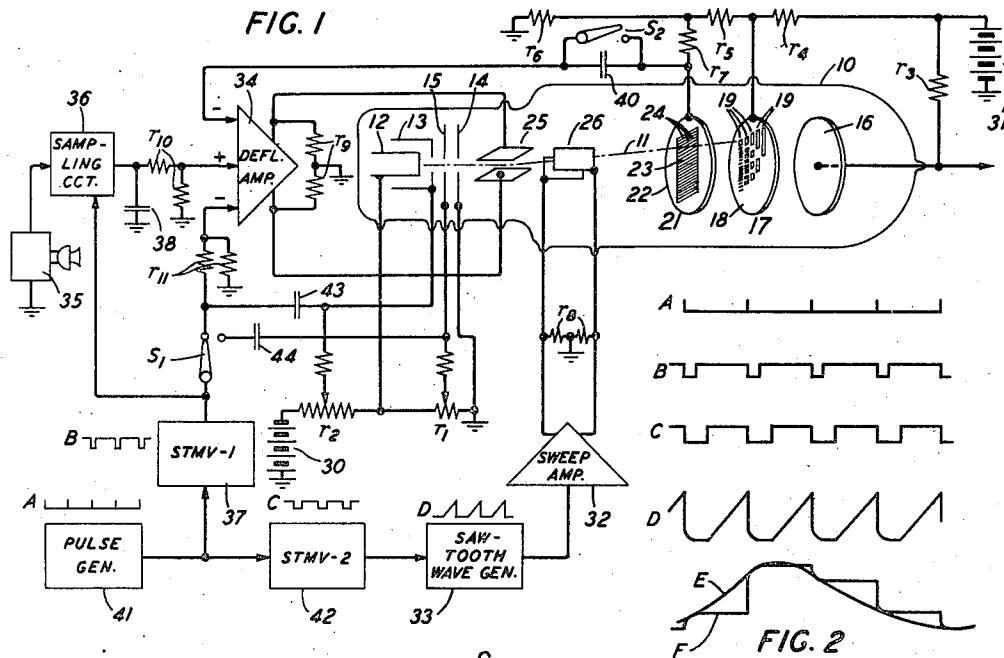
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STABILIZATION OF CATHODE BEAM TUBES

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STABILIZATION OF CATHODE BEAM TUBES

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This invention relates to the quantization and stabilization of electron beam deflections.

Electron beam tubes are known in which the beam is deflected, under control of a signal, to strike a selected one of a plurality of separate targets or target areas, thus to give rise to a current pulse or to a group or sequence of such pulses, distinguished from each other in form, arrangement or by reason of the particular characteristics of the output circuit in which they appear, in dependence on the location or other characteristic of the particular target area so struck.

Devices of this general character have been developed along particular lines to suit them to particular uses. One such device, and one to which this invention is particularly applicable, is a translator of signal samples to pulse code groups. It is described in Italian Patent 437,300, published June 30, 1948 and also in articles published in the Bell System Technical Journal for January, 1948, vol. 27, pages 1 and 44.

In coding systems including a cathode beam tube of the type disclosed in those publications, an electron beam is deflected in one direction in proportion to the amplitude of successive samples of a complex wave to be translated, such as a speech wave, and, for each such deflection, is then swept in another direction, e. g., at right angles to the first direction. Interposed in the beam path is a coding electrode or mask having a plurality of rows of apertures therein, the apertures in the several rows being arranged in a prescribed manner such that when the beam is swept across the electrode or mask in the second direction above-noted and along a particular aperture row, the beam will pass over a different combination of apertures and masking areas for each of a plurality of positions to which it has been deflected in the first direction by the signal sample. Electron beam current passing through any aperture strikes a collector anode, thus giving rise to a pulse of current in an external circuit. Sweep of the beam across all of the apertures of a particular row thus gives rise to a sequence of substantially like pulses in the external circuit. The sequence of pulses arising from the beam sweep across a particular row may be denoted a code group. Inasmuch as the disposition and arrangement of the apertures in each row differs from that in every other row, each of the different signal sample magnitudes is translated into a particular code group having characteristics which distinguish it from all the others.

There is a possibility in such devices that during the sweep of the beam along the apertures

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of a single row, the beam position relative to the rows of apertures may change, resulting in incorrect coding. For example, if the beam should start its sweep along a particular row and, after the sweep has started, move to an adjacent row, the first pulses of the resulting code group would correspond to the correct signal sample, but the later pulses of the group would correspond to a signal sample having a different magnitude. It is characteristic of existing pulse code modulation systems that such behavior may result in a coding error which far exceeds the error which would result if the beam had swept along a row different from but adjacent to the correct one in the first place.

Such deviation of the beam in the course of its sweep might result from electrical disturbances, for example, disturbances such as to alter the effective deflecting force on the beam in the first direction noted, sufficient to cause the beam to depart from its proper code position. It might also result from a disturbance or alteration in the beam deflection system such as to vary the direction of sweep of the beam across the rows of apertures in the coding electrode or mask. Again it might result from minute errors in the fabrication of the device, such as asymmetry in the construction or positioning of the various electrodes, such as are difficult to avoid in manufacture.

To reduce these coding errors, it has been proposed, specifically in an application of George Hecht, Serial No. 715,999, filed December 13, 1946, issued March 8, 1949 as Patent No. 2,463,535, to interpose in the path of the electron beam between the gun and the coding mask a net or grid of parallel wires, conforming in arrangement to the several rows of apertures in the mask. Each wire is aligned with the division between adjacent aperture rows, and each pair of wires defines a path between them for the electron beam from the gun to the apertures of a particular row. Any tendency of the beam to deviate from its correct path results in electrons striking one or other of these path-defining wires. This gives rise to a current which may be fed back to the deflecting elements of the cathode beam tube in a sense to counteract the deviation. Thus the grid tends to coerce the cathode beam to continue its sweep along the particular row at which the sweep started. In other words, it stabilizes the location of the beam. It has therefore been termed a stabilizing grid. Furthermore, because the grid restricts the beam to a finite number of different discrete paths, equal in number to the

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spaces between the grid wires, it in effect quantizes the beam deflection in the direction perpendicular to the aperture rows and, therefore, in effect quantizes the signal. It has therefore also been termed a "quantizing grid."

Although good in principle and serving to reduce coding errors to a considerable extent, the stabilizing or quantizing grid of the Hecht application still does not completely eliminate coding errors.

Accordingly, it is an object of this invention further to reduce the coding errors which remain after the teachings of the Hecht application have been carried out. More specifically, an object is to assure that the sweep of the electron beam shall commence at the correct aperture row as determined by the signal sample and shall continue along that row to the end without deviating to an adjacent row.

A related object is to secure greater rapidity of quantization and of coding.

More general objects are to assure correct deflection of the beam of a cathode ray device in accordance with a signal, and correct sweep of such beam along a prescribed path despite disturbances to and misalignment of the deflecting system.

These and other objects of the invention are attained, in accordance with the invention, by a refinement of the feedback current from the quantizing grid to the signal deflecting elements of the tube and the coordination of this feedback with the blanking or defocussing of the beam and with the signal sample pulses themselves such that the alteration of the location of the beam as deflected by a signal sample without feedback, when the feedback is applied, is minimized, while still maintaining at a high level the stabilizing and quantizing action of the feedback. In particular, the feedback current is recognized to have a beam-confining component which varies cyclically with the location of the beam with respect to the wires of the quantizing grid and an average or direct current component, and, in accordance with the invention, these two components are separated one from the other and separately utilized.

In coding systems employing a coder such as that disclosed in the aforementioned publications, it is usual so to adjust the gain of the signal deflection amplifier with respect to the deflection sensitivity of the coder tube that the peak signal amplitudes normally encountered in the speech or other signal wave being translated produce beam deflections to the first and last row of apertures, respectively; i. e., to the furthest ends of the coding mask. When these adjustments have been made, a signal peak of abnormally great amplitude produces a beam deflection beyond the end of the mask, i. e., beyond the last row of apertures, and produces no signal pulses. A condition of no pulses in the signal pulse group corresponds to a normal signal peak in one direction. Therefore, when the beam is deflected past the last row of apertures, in the other direction, and produces the same condition, the largest possible coding error results, with consequent degradation of fidelity in translation of the signal. With known apparatus, the only way of avoiding this occasional condition is to reduce the gain of the amplifier to such a point that even the abnormally great peaks of the signal still produce deflection within the compass of the coding mask. As a result, substantially less than the full number of aperture rows are utilized in

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the case of a normal signal. This too results in degradation of signal translation.

It is another object of the present invention to secure, automatically, an effective peak-limiting action in the very act of coding the signal.

To this end and in accordance with a further feature of the invention, the apertures of the end rows of the mask in at least one direction are greatly enlarged as compared with the apertures of all of the other rows. The system is then adjusted to the point where the full compass of the coding mask is just utilized for peak signal amplitudes normally to be expected. Then, when an excessive or abnormal peak signal occurs, the result is merely to deflect the beam still further over the end rows of apertures. As a result, the abnormally great peak amplitudes of the signal are translated into the same code groups as are normal peak amplitudes. Thus, the full scope of the coding mask is utilized under normal conditions while at the same time excessive transients due to the occurrence of abnormal signal amplitude peaks are greatly reduced.

The invention and the various objects and features thereof will be fully apprehended from the following detailed description of preferred embodiments thereof, taken in conjunction with the appended drawings in which:

Fig. 1 is a schematic circuit diagram of a coding system embodying certain features of the invention;

Fig. 2 is a diagram showing the wave forms of pulse sequences which appear at various parts of the circuit of Fig. 1;

Fig. 3 is a diagram illustrating principles involved in the action of the stabilizing grid both with and without the improved feedback of the invention; and

Fig. 4 is an end view of a simplified coding mask and associated quantizing grid in accordance with a particular feature of the invention.

Referring now to the drawing, the cathode beam tube illustrated in Fig. 1 comprises an evacuated envelope 10 having at one end thereof an electron gun for projecting a concentrated electron beam 11 toward the other end of the envelope. The gun, which may be of known construction, comprises a cathode 12, a control electrode 13, an accelerating electrode 14 and a focusing electrode 15.

Mounted within the envelope 10 adjacent the other end thereof is an output electrode or collector anode 16 toward which the electron beam 11 is directed. A coding electrode or mask 17 is positioned in front of and parallel to the collector anode 16 and may be a circular metallic plate 18 having a number of parallel rows of apertures 19 therein. An enlarged end view is shown in Fig. 4. The number of aperture rows may be selected in accordance with practical consideration such as the required fidelity of signal translation, the amount of "granularity" which may be tolerated, the available frequency band width of the transmission channel, the required signaling speed and the like. As a practical matter, it has been found that 128 rows, each having seven "virtual" apertures is a good compromise. (By the term "virtual aperture" is meant a location, measured along the row, in which there is or is not an aperture.) In this application, however, to avoid complexity of description and to simplify the drawings, the coding mask may be envisaged as having 32 parallel rows, each of five virtual apertures. In the top row I all five of the virtual apertures are real apertures. In the second row II

the first virtual aperture is blank whereas the remaining four are real. In the third row III the second virtual aperture is blank whereas the first, third, fourth and fifth are real. In the fourth row IV the first two virtual apertures are blank, the third, fourth and fifth being real. In the sixteenth row XVI the first four virtual apertures are blank, only the fifth being real. In the seventeenth row XVII the fifth virtual aperture is blank, the first four being real, etc. The several rows constitute a five digit coding system, adapted to translate signals into 32 different code pulse groups.

Nothing is gained by providing a septum between real apertures of the same column in adjacent rows. Therefore it is customary in manufacture to merge such apertures. Thus, for example, in the fifth column, the last apertures of the first sixteen rows all merge to form one large rectangular hole.

As shown in Fig. 4, the real apertures of the first row and the virtual apertures of the last row all greatly exceed in size the apertures real or actual of all of the other rows.

A quantizing or stabilizing grid electrode 21 is mounted adjacent the face of the coding mask 17 toward the electron gun and parallel thereto, and comprises a foundation member or plate 22 having therein a rectangular aperture 23 aligned with the coding mask 17 and of such dimensions as to expose the entire rectangular area containing any and all of the apertures 19 of the mask 17 to the electron beam. This mounting plate bears a number of conductive grid wires 24 which run parallel with the aperture rows I, II, III, etc. of the coding mask 17 between points beyond each side of the latter. These grid wires 24 are aligned with the divisions between the several rows of the coding mask and define 32 parallel openings, each of which is opposite to a corresponding row of virtual apertures of the coding mask. In this connection, the term "opposite" is intended to denote alignment from the standpoint of the electron beam 11 which originates at the electron gun rather than from the standpoint of an observer at infinity. Thus, due to the fact that the path of the beam to the coding mask is slightly longer than the path to the quantizing grid, the spacing between the grid wires is preferably slightly less than the spacing between the aperture rows of the mask.

Two pairs of deflecting electrodes mounted at right-angles to each other, and hereinafter denoted, for the sake of definiteness only, as the "vertical deflecting electrodes" 25 and the "horizontal deflecting electrodes" 26 are mounted adjacent the electron gun, the vertical deflecting electrodes being placed parallel to the grid wires 24 of the quantizing grid 21.

As shown in Fig. 1, the electrodes constituting the electron gun are maintained at appropriate relative potentials by a battery 30 and a potentiometer r_1 , r_2 . The output collector anode 16 is held at a positive operating potential by a battery 31 and connected thereto through an output resistor r_3 . The coding electrode 17 may be held at a potential slightly less positive than the collector anode, differing therefrom by the potential drop across a resistor r_4 . The quantizing grid may similarly be held at a potential slightly less positive again, by reason of the voltage drop across another resistor r_5 . It is connected to the potentiometer r_4 , r_5 , r_6 by way of a resistor r_7 of high ohmic value, i. e., a megohm or more. The horizontal deflector plates 26 are balanced to ground

by way of a resistor r_8 with a grounded center tap and the vertical deflector plates 25 are similarly balanced to ground by way of a resistor r_9 with a grounded center tap. The horizontal deflector plates 26 are actuated by way of a balanced amplifier 32 by the application of a sweep voltage thereto, derived from a controlled sawtooth sweep generator 33. The vertical deflector plates 25 are actuated by a balanced amplifier 34 which is energized in part by signal samples, in part by a feedback current from the quantizing grid 21 and (in accordance with one embodiment of the invention) in part from a third source as hereinafter described. Relative magnitudes may be adjusted by resistance networks r_{10} , r_{11} .

The signal samples are to be regarded as positive in sign and as producing positive deflections. The feedback current, being in origin an electron current, is negative. Therefore its effect is to reduce the absolute magnitude of the beam deflection due to the signal pulses alone.

The operation of the device without the quantizing or stabilizing grid 21 is set forth fully in the Llewellyn application heretofore identified so that detailed explanation of such operation is deemed unnecessary here. However, it may be noted that the speech or other complex wave to be coded (curve E of Fig. 2) originating in a signal source 35, is sampled repeatedly by a sampling circuit 36 of suitable type, controlled as to timing by the output (curve B of Fig. 2) of a single trip multivibrator 37 and each sample, after being taken, is stored on a condenser 38 until the arrival of a new sample. Each of the samples is representative of the amplitude of the wave being sampled at the instant at which the sampling pulse (curve B) terminates. The resulting wave (curve F) which comprises a sequence of substantially steady signals, each of which changes rapidly to the next value during the sampling pulse, is applied to the vertical deflection amplifier 34 and thus to the vertical deflector plates 25. For each sample the electron beam 11 is thus moved by vertical deflection to a particular row of apertures I to XXXII of the coding mask 17, i. e., to a code position, corresponding to the amplitude of the sample. Then, the beam having been thus located at the beginning of the correct aperture row, it is swept across the coding mask and along this aperture row by the sawtooth sweep voltage of the generator 33 applied to the horizontal deflector plates 26 whereby a pulse code group, corresponding to the code position at which the beam 11 is located, is produced on the collector anode 16 and across the output loading resistor r_3 .

As has been pointed out heretofore, the opening between each pair of adjacent grid wires 24 of the quantizing electrode corresponds to a respective code position and code pulse group. In order that correct coding may be obtained, it is necessary that the beam commence its sweep between the proper two grid wires and remain there throughout each sweep, the feedback and associated circuit arrangement of the invention assure this condition.

This aspect of the invention is best described by first referring to the operation of a simple direct current feedback from the quantizing grid 21 to the vertical deflecting plates 26 by way of the amplifier 34. Thus, suppose that a signal pulse has deflected the beam to the fifth row V of the coding mask 17 and that the lateral sweep across the apertures of this row has commenced. Suppose, now, that due to some disturbance, the beam tends to wander upward toward the fourth

row IV. Electrons of the beam will strike the wire 24 of the quantizing grid 21 which bounds the upper edge of the fifth row. Therefore, a negative electric current will flow through the resistors r_7 , r_6 and to ground. A voltage proportional to this current appears across these resistors and is fed by way of the amplifier 34 to the vertical deflection plates 25. This signal is so poled that the resulting incremental deflection due to it is in opposition to the deflection due to the signal pulse, so that the wandering beam tends to come downward along the coding mask and so return to its proper position. Thus the beam 11, in effect, hugs the lower side of the quantizing grid wire 24. If, on the other hand, the polarity of the feedback current were reversed as compared with the message signal sample, the beam would tend to hug the upper side of the lower quantizing grid wire. By proper correlation of the wire diameter, the spaces between the wires, the diameter of the cathode beam, and the like, as well as the relative magnitudes of the signal and the feedback, these operations result in the effective center of the beam lying well within one or other of the aperture rows of the coding mask.

The principles and relationships involved in the operation of the quantizing grid, as well as the shortcomings of present systems, are illustrated in Fig. 3. It is apparent that if the beam 11 were to move over the wires 24 of the quantizing electrode 21, i. e., if it were deflected across the wires in a direction perpendicular to the normal sweep direction, current to the quantizing grid and hence the feedback voltage supplied to the vertical deflector plates 25 would vary cyclically in the manner indicated by curve K of Fig. 3, being a maximum when the beam is centered on any single grid wire and a minimum when the beam is midway between two adjacent grid wires. The absolute form of the beam position - feedback current relation and the maximum and minimum values of this current will be dependent, of course, upon the relative magnitudes of the beam diameter at the plane of the quantizing grid wires and the spacing between adjacent wires. For simplicity of illustration and discussion, the analysis hereinafter given is for the case in which the beam is of such diameter that the minimum value of the feedback current is approximately one-eighth of the maximum variation of this current between its maximum and minimum values. It will be understood, however, that the analysis is valid for other conditions.

The relation between beam position and deflecting voltage, i. e., voltage across the vertical deflector plates 25 or total input voltage to the vertical deflection amplifier 34, is a linear one and is indicated by the line L of Fig. 3. Thus, for any beam position, the total deflecting potential between the vertical deflector plates must fall on the line L. This potential, prior to the addition of the features of the present invention, comprises two components, namely, the voltage due to the signal applied from the sampling circuit 36 and the feedback voltage. As above stated, the feedback is preferably negative or inverse. In this case the total deflection voltage (line L) is the algebraic sum or absolute difference between signal voltage and the feedback voltage (curve K). Thus the signal voltage may be represented by the curve M. (The broken line N, which will be explained hereinafter is to be disregarded for the present.)

In the presence of the feedback current or volt-

age, conditions indicated by the points 1 and 2 of curve M, corresponding to signal voltages e_1 , e_2 and deflections D_1 and D_2 , respectively, and lying on portions of the M curve whose slopes are positive, are stable. This may be seen from the following: Suppose, for example, that the signal voltage is e_1 and the deflection D_1 , and that for some reason, the deflection tends to increase, i. e., move to the right along the deflection scale of Fig. 3 or upward along the quantizing grid of Figs. 1 and 4. As indicated on curve K of Fig. 3, there results an increase in the negative feedback current from the point k_1 to the point k_2 . The voltage due to this feedback current is applied to the vertical deflection amplifier 34 in a sense to oppose the signal voltage and therefore to reduce the deflection, which is thus restored to the value D_1 . Similarly, the points on the curve M, such as 3 and 4, lying on portions which have a negative slope are unstable. Thus, suppose conditions to be such that the beam 11 is deflected to the point D_3 , corresponding to the signal voltage e_1 . This condition corresponds to a negative feedback current indicated by k_3 . Suppose, now, some small disturbance tends to increase the deflection. The magnitude of the negative feedback current will decrease. Since its voltage opposes the signal voltage deflection, reduction of the feedback current produces a further increase of deflection. This action is cumulative, so that any condition represented by a point on any downward sloping portion of the curve M is unstable and immediately jumps either to the right or to the left.

With this in mind, suppose the signal voltage to have the value e_1 and to be progressively increased. At first, conditions will change from point 1 towards point 2 with very little alteration in the deflection. As the signal voltage is further increased to the value e_3 , conditions will be as represented at the second peak of curve M. As the current is still further increased, and because of the unstable character of the whole downward sloping portion of the curve M from the second positive peak to the second negative peak, conditions will immediately jump from the point 5 to the point 5', and the corresponding deflection will suddenly change by substantially the center-to-center distance between the quantizing grid wires. Thereupon, with further increase of the signal voltage to the value e_5 , conditions will rise along the left-hand portion of the third peak of the curve M, with only a small change in deflection and a jump to the fourth peak will follow. In other words, as the signal current is progressively increased, conditions will change suddenly from one upper peak of the curve M to the next and this will take place as long as the signal current continues to increase.

If, now, the signal current is progressively reduced from a large value to a small one, the behavior will be similar but conditions will jump almost discontinuously from each downward peak of the curve M to the next lower peak, and the deflections will alter in like manner.

Evidently with such a system, the deflection corresponding to a particular value of the signal current is not unique, but depends on the recent history of the system, i. e., on whether it has recently advanced from a small value or from a large one. The lack of uniqueness in the relation between signal current and deflection is the price that must be paid for the high stability of the upward sloping portions of the curve M.

To avoid confusion and errors in coding, it is

therefore usual with systems of this character to blank the electron stream between each signal sample and the next following sample. When the electron stream is blanked, there is, of course, no feedback circuit and the electron beam is "virtual." Conditions may then be represented by the linear curve L. Suppose, for example, that, the beam being blanked, a signal sample has arrived whose magnitude is such as to deflect the beam to the point *a* of Fig. 3. Suppose, now, that this deflection exists and the beam is unblanked. Beam electrons will immediately strike one of the quantizing grid wires (the sixth wire in Fig. 3) and will cause a feedback current to flow which will immediately reduce the deflection. In the presence of feedback, conditions are represented by the curve M and, in this particular case by the point *b* which has the same value of signal voltage as the point *a* but a less deflection. Similarly, if, while the beam is blanked conditions are represented by the point *c* of the curve M and the beam is then unblanked, conditions will immediately shift to the point *d* of the curve M, represented by the same signal voltage and a substantially less deflection. By comparing the jumps from *a* to *b* and from *c* to *d*, it will be apparent that with this system and for the conditions represented in the figures the jump is never less than one half of the spacing between adjacent grid wires and may under extreme conditions be nearly twice the grid-wire spacing. Furthermore, with a less well-focussed beam, the minimum value of the feedback current is greater and, therefore, the space between the linear curve L and the signal current curve M is also greater. Under this condition, the jumps from *a* to *b* and from *c* to *d* are greater still. Therefore, to prevent jumps of excessive magnitude, it is imperative that the beam be focussed with great sharpness so as to reduce the minimum value of the feedback current to as small a value as possible.

The magnitude of the jump is objectionable on at least three grounds. First, it reduces the exactness of the relation between a signal pulse and the deflection produced by it and therefore introduces the hazard of locking the electron beam in the wrong position in the first place. Second, each such jump requires time, and, the longer the jump in distance the greater the time required. Thus coding speed is reduced. Third, and most important, the jump from the line L to the curve M always terminates at, or near, one or other of the lower peaks of the curve M, for example at the point *b* or *d*. Under these conditions, small disturbance such, for example, as a very slight change in the value of the signal current during the lateral sweep, if in the negative direction, will cause a jump to the next lower peak. In other words the stability margin is far greater in one direction than the other. In a sense, all of the objections are due to the presence in the feedback current of an average component, represented by the broken line P in Fig. 3, as well as the useful beam-confining or quantizing component. In accordance with the invention, therefore, the effect of this average component is eliminated. This may be done in various ways, circuit arrangements for carrying out two of them being shown in Fig. 1. In the first arrangement, represented by the switch *S*₁ in the position shown, the beam is blanked between successive signal samples as heretofore, with the result that the average component of the feedback current is intermittent. In accordance with this form of the invention, a negative pulse is applied to the

vertical deflection amplifier 34 of exactly the amplitude and duration to compensate for the loss of the average component of the feedback current. Thus a generator 41 of a sequence of short, sharp pulses, equally spaced in time, controls a single trip multivibrator 37 giving negative square pulses as indicated in curve B of Fig. 2. The latter serves both to control the signal sampling circuit 36 and, by way of a blocking condenser 43, the control grid 13 of the electron beam tube 10 so as to blank the beam 11 during the negative pulses. Also, in accordance with the invention, the same negative pulses are applied to the vertical deflection amplifier 34 and so to the vertical deflection plates 25. Inasmuch as the feedback current exists when the beam 11 is turned on and ceases when the beam is turned off, it will be seen that the negative pulses of the curve B precisely fill in the gaps in the average value of the negative feedback current. Thus, in effect, a steady bias is applied to the vertical deflection plates 25 which is due to two sources in alteration. When the beam is turned on, it is due to the average value of the feedback current from the quantizing grid. When the beam is turned off, it is due, instead, to the negative pulses arriving from the single trip multivibrator 37.

Referring again to Fig. 3, this arrangement is equivalent to moving the linear curve L to the position occupied by the broken line N. Evidently conditions are now greatly improved from the standpoint of the magnitude of the jumps which take place from the linear curve N to the signal current curve M. Thus, when the beam 11 is blanked, suppose conditions to be represented by the point *e*. When the beam is turned on, feedback immediately commences and conditions jump to the nearest stable value on the curve M, namely, to the point *e'*. Again, if conditions in the absence of the beam are represented by the point *f*, then, when the beam is turned on, they jump to the point *f'*. Evidently the magnitude of the jump is greatly reduced, as compared with the jump from the linear curve L to the signal curve M. Furthermore, the fact that the jumps are greatly reduced in length results in a corresponding reduction in the time required for the jumps to take place and thus in an increased rapidity of the coding process as a whole.

It may be noted, furthermore, that the magnitudes of the jumps in this arrangement are quite independent of the magnitude of the minimum value of the feedback current and that after the jump has taken place, the system provides equal margins of stability against disturbances in both directions.

As an alternative to the application of a pulsed negative bias to the deflector plates 25, replacing the negative bias derived from the feedback current when the latter ceases due to blanking of the beam, Fig. 1 also shows an arrangement in which these two steps are replaced by a single one, namely, to defocus the beam 11 between signal samples instead of blanking it. Thus, referring to Fig. 1, when the switch *S*₁ is thrown to the right, the negative pulses from the single trip multivibrator 37 continue to control the sampling circuit 36 as before, but now no longer furnish a negative bias either to the vertical deflection amplifier 34 or to the control grid 13 for blanking. Instead, they are applied by way of a blocking condenser 44 to the focussing electrode 15 of the tube 10. Thus, at the instant at which a signal sample is altered from one value to another, the electron beam 11 is defocussed, so that

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its trace on the quantizing grid 21 extends over a number of grid wires and therefore over a number of the spaces between, perhaps four or five. Inasmuch as the potential of the control grid 13 of the tube has not altered, the total beam current remains unchanged, and, as the cross-section of the beam is expanded, its electron density is reduced in proportion. Therefore, while the cyclic component of the feedback current is greatly reduced, its average value (broken line P) remains the same. This average value is continuously fed back to the vertical deflection amplifier 34 and furnishes a steady bias to the vertical deflection plates 25. On the other hand, when the beam is defocussed, the cyclic component is reduced to a low value as indicated by the curve Q of Fig. 3. The signal voltage e , which is the resultant of the voltage of this reduced cyclic feedback current and the unchanged average component, is represented by the curve R. The latter is a wavy line departing only slightly from the linear curve N and whose slope is everywhere positive. Therefore, every point on this curve represents a condition of stability, there being only a slight departure from linearity of the relation between signal voltages and deflections. When, now, the beam is refocussed by the removal of the pulses of the single trip multivibrator 37 (curve B of Fig. 2) from the focussing electrode 15 and the latter is returned to its normal potential, so that the beam 11 is sharply focussed, the wavy line R immediately expands to occupy the position of the curve M of Fig. 3. Thus stabilization of the beam in the apertures between the grid wires and consequent effective quantization of the vertical beam deflection on the coding mask 17 are intermittently applied and removed. Thus all the advantages of strong, tight, stabilization of the beam are achieved without the usual disadvantages of substantial jumps from the unstabilized condition to the stabilized condition. Furthermore the margins of stability are substantially alike in both directions.

The sequence of events in time may now be reviewed with reference to Fig. 2, in which curve A represents a sequence of sharp pulses which occur at definite intervals derived from a pulse generator 41 which may be of known construction. Curve B represents the output of a single trip multivibrator 37 which delivers square pulses which commence upon the arrival of each sharp pulse from the pulse (A) generator 41 and endure for a preassigned time determined by the parameters of the circuit. These pulses serve to control the sampling circuit 35 which samples the signal to be translated, a representative part of which is illustrated in the curve E, delivering samples of the form illustrated in the curve F. The pulses from the single trip multivibrator 37 also provide the intermittent bias, either on the vertical deflection amplifier 34 and the control grid 13 or on the focussing electrode 15. The pulse generator 41 (curve A) also controls a second single trip multivibrator 42 delivering negative pulses (curve C) at the same frequency as those of the first multivibrator 37 but of greater duration. These pulses control a sawtooth wave generator 33 whose output increases steadily with time as long as the pulses of the second multivibrator 42 have positive values and fall to zero and remain there as long as the latter have negative values. These sawtooth waves are applied as shown in Fig. 1 to the horizontal deflecting plates 26. The pause between each sawtooth deflection voltage and the next one, corresponding in dura-

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tion to the negative pulses C of the second multivibrator 42, permits the vertical deflection amplifier 34 to receive a signal sample and to furnish the necessary deflection to the virtual beam to place it in the correct coding position. This pause also allows the beam to be turned on if it has been blanked or to be refocussed if it has been defocussed and finally allows for the necessary short interval in which the beam moves from its unquantized to its quantized position.

In the operation of the system cyclic components of the feedback current appear and disappear in a somewhat random fashion and at a frequency at least as high as the pulsing or sampling rate. In the first modification, in which the electron beam is intermittently blanked, the average component appears and disappears with this rapidity while in the second modification in which the beam is intermittently focussed, it is steady. The high rate of appearance and disappearance of this feedback current, or at least of the cyclic stabilizing component thereof, is such that it is entirely possible to pass it through a blocking condenser whose impedance is negligible at the sampling frequency, but which nevertheless offers a substantially infinite impedance to direct current. Such a blocking condenser 40 is shown in Fig. 3 and is placed in the feedback path merely by opening the switch S₂. The use of this condenser offers the advantage that with it, it is entirely feasible to select the operating potential of the quantizing grid 21 without regard to its effect on the input circuit of the vertical deflection amplifier 34.

While described in connection with a coding system for translating message signal samples into pulse code groups by the deflection of an electron beam to a particular position on a coding mask and the subsequent sweeping of the beam laterally across the apertures in the mask, the invention, which is defined by the appended claims, is not limited to such use, which has been explained merely for illustrative purposes. Evidently the invention may equally be applicable to modifications of this coding system in which, for example, a broad flat electron beam is "flushed" simultaneously on all the apertures of a particular row of a coding mask, to give rise to a group of simultaneous pulses on a plurality of separate anodes located behind the mask, which pulses may then be selectively delayed or otherwise sorted in any desired manner. Furthermore, the invention is applicable to any system or device in which it is required to quantize the deflection of a cathode beam and localize or stabilize it as so quantized, while introducing a minimum amount of alteration in the behavior of the apparatus as a whole.

What is claimed is:

1. Signal translating apparatus which comprises an electron discharge device having means for projecting a focussed beam of electrons, a target member for said beam having a plurality of different discrete target areas, means controlled by a signal to be translated for deflecting said beam to selectively strike one of said areas, and means for preventing wander of said beam from an area first struck, said wander-preventing means comprising an auxiliary electrode in the path of said beam comprising a plurality of elements aligned with the divisions between the separate areas of said target member, each pair of adjacent elements defining a beam path from said beam-projecting means to one of said areas, means for feeding back to said deflecting means

a current flowing by way of said beam from said beam projecting means to any of said elements, said feedback current having a beam-confining component which varies cyclically with the location of said beam with respect to said elements and having an average value, means for interrupting the beam-confining component of said feedback current, and means for applying to said beam-deflecting means a current which is equal to said average value independently of said interruptions.

2. Signal translating apparatus which comprises a coding device having means for projecting a focussed beam of electrons, a target member for said beam having a plurality of rows of openings, a collector of electrons passing through said openings, means controlled by a signal to be translated for deflecting said beam to selectively engage one of said rows, means for sweeping said beam along the row engaged, and means for preventing wander of said beam from said rows in the course of said sweep, said wander-preventing means comprising an auxiliary electrode in the path of said beam comprising a grid of wires aligned with the divisions between adjacent rows of openings of said target member, each pair of adjacent elements defining a beam path from said beam-projecting means to one of said rows, means for feeding back to said deflecting means a current flowing by way of said beam from said beam projecting means to any of the wires of said grid, said feedback current having a beam-confining component which varies cyclically with the location of said beam with respect to said wires and having an average value, means for interrupting the beam-confining component of said feedback current and means for applying to said beam-deflecting means a current which is equal to said average value independently of said interruptions.

3. Signal translating apparatus which comprises an electron discharge device having means for projecting a focussed beam of electrons, a target member for said beam having a plurality of different discrete target areas, means controlled by a signal to be translated for deflecting said beam to selectively strike one of said areas, and means for preventing wander of said beam from an area first struck, said wander-preventing means comprising an auxiliary electrode in the path of said beam comprising a plurality of elements aligned with the divisions between the separate areas of said target member, each pair of adjacent elements defining a beam path from said beam-projecting means to one of said areas, means for feeding back to said deflecting means a current flowing by way of said beam from said beam projecting means to any of said elements, said feedback current having a beam-confining component which varies cyclically with the location of said beam with respect to said elements and having an average value, means for interrupting said beam to allow the signal-controlled deflection to reach a new value, and means for applying to said beam-deflecting means a current which is equal to said average value independently of said interruptions.

4. Signal translating apparatus which comprises an electron discharge device having means for projecting a focussed beam of electrons, a target member for said beam having a plurality of different discrete target areas, means controlled by a signal to be translated for deflecting said beam to selectively strike one of said areas,

and means for preventing wander of said beam from an area first struck, said wander-preventing means comprising an auxiliary electrode in the path of said beam comprising a plurality of elements aligned with the divisions between the separate areas of said target member, each pair of adjacent elements defining a beam path from said beam-projecting means to one of said areas, means for feeding back to said deflecting means a current flowing by way of said beam from said projecting means to any of said elements, said feedback current having a beam-confining component which varies cyclically with the location of said beam with respect to said elements and having an average value, and means for defocussing said beam to allow the signal-controlled deflection to adopt a new value without hindrance from the beam-confining component of said feedback current.

5. Signal translating apparatus which comprises an electron discharge device having means for projecting a focussed beam of electrons, a target member for said beam having a plurality of different discrete target areas, means controlled by a signal to be translated for deflecting said beam to selectively strike one of said areas, and means for preventing wander of said beam from an area first struck, said wander-preventing means comprising an auxiliary electrode in the path of said beam comprising a plurality of elements aligned with the divisions between the separate areas of said target member, each pair of adjacent elements defining a beam path from said beam-projecting means to one of said areas, a path coupling said elements to said deflecting means for feeding back to said deflecting means a current flowing by way of said beam from said beam projecting means to any of said elements, said feedback current having a beam-confining component which varies cyclically with the location of said beam with respect to said elements and an average value and being zero when the beam is interrupted, means for interrupting the beam, and means for applying to said beam-deflecting means a current which is equal to said average value independently of said interruptions.

6. Signal translating apparatus which comprises an electron discharge device having means for projecting a beam of electrons, a target member for said beam having a plurality of different discrete target areas, a beam-focussing element for focussing said beam on a target area, means controlled by a signal to be translated for deflecting said beam to selectively strike one of said areas, and means for preventing wander of said beam from an area first struck, said wander-preventing means comprising an auxiliary electrode in the path of said beam comprising a plurality of elements aligned with the divisions between the separate areas of said target member, each pair of adjacent elements defining a beam path from said beam-projecting means to one of said areas, a path coupling said elements to said deflecting means for feeding back to said deflecting means a current flowing by way of said beam from said beam projecting means to any of said elements, said feedback current having a beam-confining component which varies cyclically with the location of said beam and whose magnitude is inversely related to the sharpness of focus of said beam, and means for intermittently defocussing said beam between successive values of said signal-controlled deflection.

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7. Signal translating apparatus which comprises an electron discharge device having means for projecting a focussed beam of electrons, a beam-blanking element, a target member for said beam having a plurality of different discrete target areas, means controlled by a signal to be translated for deflecting said beam to selectively strike one of said areas, and means for preventing wander of said beam from an area first struck, said wander-preventing means comprising an auxiliary electrode in the path of said beam comprising a plurality of elements aligned with the divisions between the separate areas of said target member, each pair of adjacent elements defining a beam path from said beam-projecting means to one of said areas, a path coupling said elements to said deflecting means for feeding back to said deflecting means a current flowing by way of said beam from said beam projecting means to any of said elements, said feedback current having a beam-confining component which varies cyclically with the location of said beam with respect to said elements and having an average value, a source of a sequence of pulses, connections for applying said pulses to said beam-blanking element, and connections for applying said pulses to said beam-deflecting means.

8. Signal translating apparatus which comprises an electron discharge device having means for projecting a focussed beam of electrons, a target member for said beam having a plurality of different discrete target areas, means controlled by a signal to be translated for deflecting said beam to selectively strike one of said areas, and means for preventing wander of said beam from an area first struck, said wander-preventing means comprising an auxiliary electrode in the path of said beam comprising a plurality of elements aligned with the divisions between the separate areas of said target member, each pair of adjacent elements defining a beam path from said beam-projecting means to one of said areas, said auxiliary electrode drawing from said beam a current having a beam-confining component which varies cyclically with the location of said beam with respect to said elements and having an average value, means for feeding back said cyclically varying current component to said deflecting means and for blocking said average value, and means for applying to said beam-deflecting means a current which is equal to said average value.

9. Signal translating apparatus which comprises an electron discharge device having means for projecting a focussed beam of electrons, a target member for said beam having a plurality of different discrete target areas, means controlled by a signal to be translated for deflecting said beam to selectively strike one of said areas, and means for preventing wander of said beam from an area first struck, said wander-preventing means comprising an auxiliary electrode in the path of said beam comprising a plurality of elements aligned with the divisions between the separate areas of said target member, each pair of adjacent elements defining a beam path from said beam-projecting means to one of said areas, a path including a series condenser for feeding back to said deflecting means alternating components of a current flowing by way of said beam from said beam projecting means to any of said elements, said feedback current having a beam-confining component which varies cyclically with the location of said beam with respect

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to said elements and having an average value, means for interrupting the beam-confining component of said feedback current, and means for applying to said beam-deflecting means a current which is equal to said average value independently of said interruptions.

10. An electron discharge device comprising an electrode member having an opening therein, means opposite one face of said member for projecting an electron beam toward said member, means for deflecting said beam toward said opening, means for feeding back to said deflecting means a current flowing by way of said beam from said projecting means to said member, said feedback current having a minimum value when said beam is centered on said opening and a maximum value when said beam is off said opening, means for interrupting said beam, and means for maintaining a beam-deflecting current equal to the average of said feedback current despite said interruptions.

11. Signal translating apparatus which comprises means for generating an energy beam, means for directing said beam to a selected one of a plurality of preassigned positions under control of a signal to be translated, means in the path of said beam responsive to a departure of said beam from a selected position, the responses of said means to equal departures from the various positions being substantially alike, and in excess of a signal change capable of producing an equal departure, means for applying said responses when present to said beam-directing means in opposition to said signal, and means for continuously applying the average value of said responses to said beam-directing means, thereby to reduce excessive departures due to intermittent application of said responses.

12. Signal translating apparatus which comprises an electron discharge device having means for projecting a focussed beam of electrons, a target member for said beam having a plurality of different discrete target areas, means controlled by a signal to be translated for deflecting said beam to selectively strike one of said areas, and means for preventing wander of said beam from an area first struck, said wander-preventing means comprising an auxiliary electrode in the path of said beam comprising a plurality of elements aligned with the divisions between the separate areas of said target member, each pair of adjacent elements defining a beam path from said beam-projecting means to one of said areas, means for drawing a current from said auxiliary electrode due to impact of said beam on said electrode, which current comprises a beam-confining component which varies cyclically with the location of said beam with respect to said elements and an average value, means for feeding back said beam-confining component to said deflecting means, means for interrupting said feedback, and means for applying to said beam-deflecting means a current which is equal to said average value independently of said interruptions.

13. Signal translating apparatus which comprises means for projecting an energy beam, means for directing said beam to a selected one of a plurality of preassigned areas under control of a signal to be translated, and means for preventing wander of said beam from an area first impacted by said beam, said wander-preventing means comprising an auxiliary electrode in the path of said beam comprising a plurality of elements aligned with the divisions between separate

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areas, each pair of adjacent elements defining a beam path from said beam-projecting means to one of said areas, means for drawing a current from said auxiliary electrode due to impact of said beam on said electrode, which current comprises a beam-confining component which varies cyclically with the location of said beam with respect to said elements and an average value, means for feeding back said beam-confining component to said beam-directing means, means for interrupting said feedback, and means for applying to said beam-directing means a current which is equal to said average value independently of said interruptions.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,298,922	Beatty -----	Oct. 13, 1942
2,300,394	Beatty et al. -----	Nov. 3, 1942
2,332,881	Woerner -----	Oct. 26, 1943
2,357,922	Ziebolz, et al. ----	Sept. 12, 1944
2,404,106	Snyder -----	July 16, 1946
2,417,450	Sears -----	Mar. 18, 1947
2,436,677	Snyder -----	Feb. 24, 1948