

Sept. 29, 1964

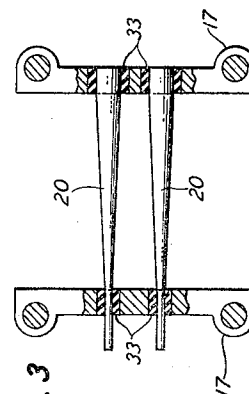
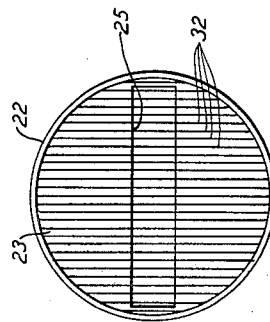
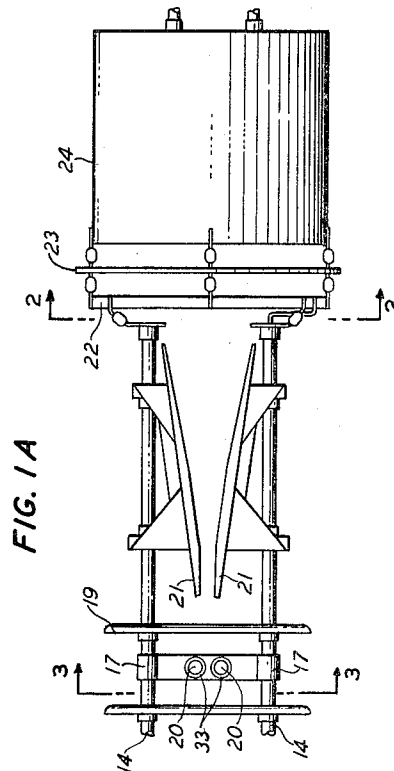
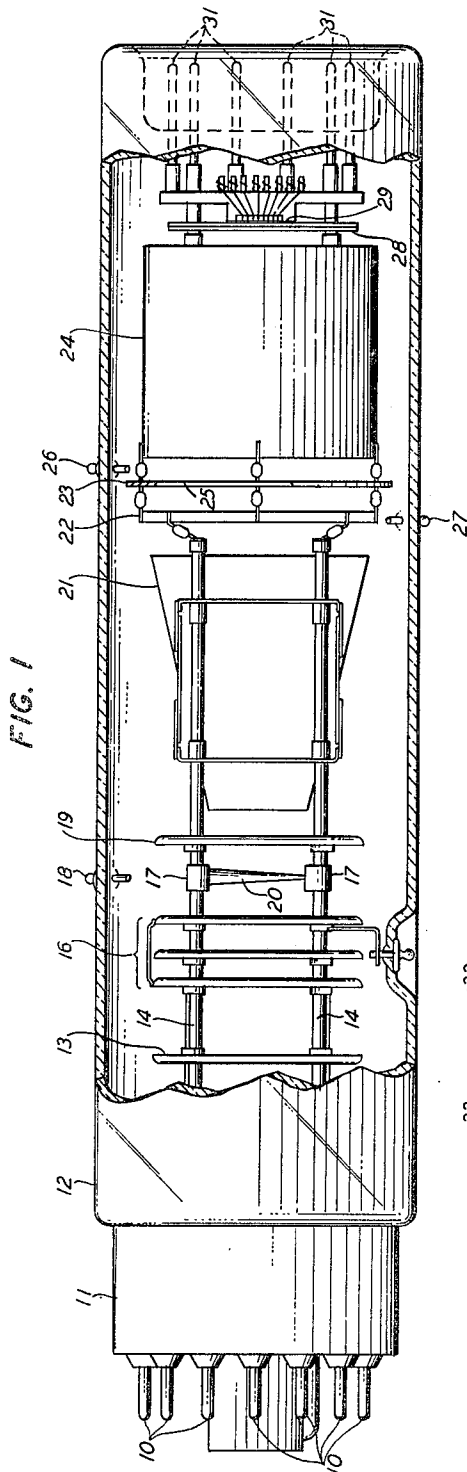
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3,151,270

ELECTRON RIBBON BEAM ENCODER TUBE WITH BEAM TILT CONTROL

Filed March 31, 1961

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

FIG. 4

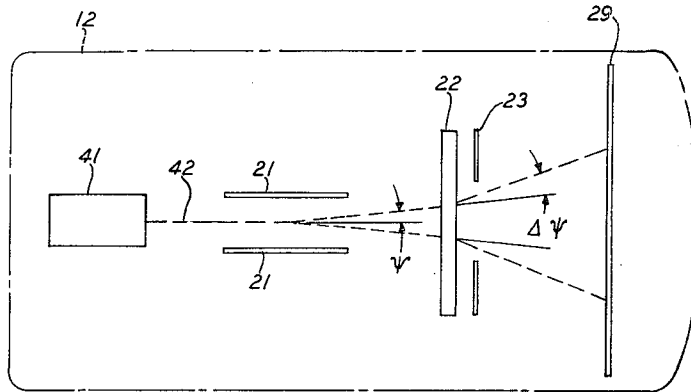
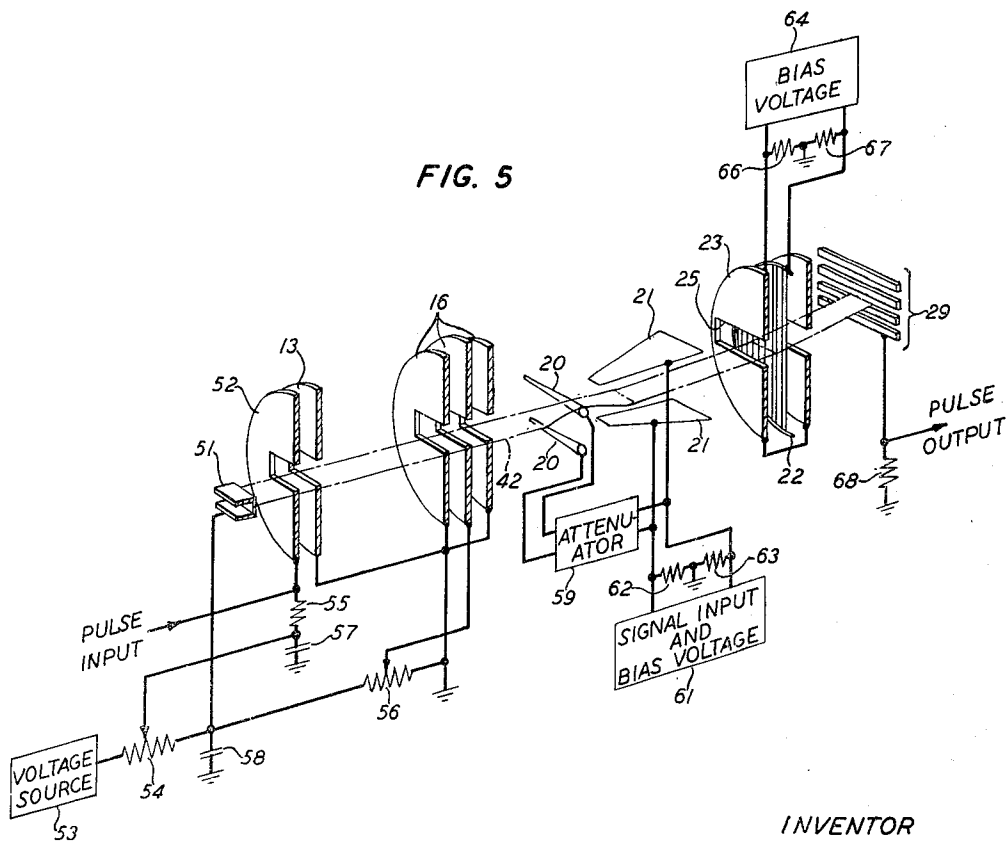


FIG. 5



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ELECTRON RIBBON BEAM ENCODER TUBE WITH BEAM TILT CONTROL

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This invention relates to electron beam tubes and more particularly to electron beam tubes in which the beam must be maintained in alignment with other elements in the tube while being deflected with respect thereto.

Electron beam tubes are of various types which may be employed in many different types of systems and circuits. For example, such tubes may be used as beam deflection amplifiers, cathode ray devices, or encoders. Although in certain aspects the present invention is not limited in application to any one type of electron beam tube, it will be described herein with particular reference to electron beam encoding devices, which generally comprise an electron gun for producing an electron beam, deflection plates for changing the direction of the beam in response to an input signal, a plurality of targets upon which the beam may impinge, and an apertured code plate positioned adjacent the targets between the targets and the deflection plates.

A highly successful type of electron beam encoder is the ribbon beam or "flash" coder described in R. L. Carbrey Patent 2,516,752. The flash coder employs a flat or ribbon-like electron beam with a line focus which impinges on an apertured code plate. The apertures on the code plate are arranged in rows and columns, each column corresponding to a digit in a binary code and each row corresponding to different combination of the binary digits. Associated with each column is a collector electrode which is energized whenever a part of the electron beam passes through an appropriate aperture. The code plate is aligned in the encoder tube so that the aperture columns are perpendicular, and the aperture rows are parallel, to the plane of the ribbon beam. Thus, as the beam is deflected in accordance with varying signal amplitudes the set of collector electrodes is energized in different combinations corresponding to the various levels in the code.

The principal applications of electron beam encoding tubes is in pulse code modulation systems. Such tubes have been built which are capable of encoding 10^7 samples per second into a seven-digit binary code. However, studies of presently available transmission systems indicate a need for encoders capable of converting analog signals into digital information at sampling rates higher than 10 megacycles per second and with an accuracy or resolution substantially better than one part in two hundred. Such a degree of resolution requires a code of at least eight and preferably nine binary digits.

While the electron beam encoder as heretofore known is, in principle, well adapted for high speed, high resolution applications, a number of practical limitations have so far prevented such use. In particular, the development of a satisfactory beam-type encoder for encoding eight or nine binary digits has been inhibited by the fact that an increase in the number of digits in these devices is accompanied by a drastic narrowing of the mechanical and electrical tolerances which must be met to give the required accuracy. In general, the effect of adding one digit to a given encoding system is to halve the critical tolerances in the tube. Inasmuch as the tolerances in a seven-digit encoding tube of the best type hitherto known approach the limits of practicality, the feasibility of producing tubes capable of higher resolution is dependent

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on the discovery of new and different techniques for achieving or relieving these stringent requirements.

Among the critically important mechanical requirements of a beam type encoder capable of encoding a greater number of digits than previous encoder tubes is a code plate with precisely dimensioned and precisely spaced apertures. In a typical encoder tube of the type under consideration, the effective area of the code plate is 2.05 by 0.5 inches. Within this limited area must be arranged seven, eight, nine or more columns of apertures. In a nine-digit tube, there may be 128 apertures in the finest digit column. It is apparent that the size and spacing of the apertures would be less critical if a larger code plate were used. A number of factors, however, have served to limit the size of the code plates heretofore used. For instance, in a particular tube in which the distance from the deflection system to the code plate is fixed, the use of a larger code plate must be accompanied by a corresponding increase in the deflection sensitivity of the tube, or more powerful deflection driving circuits must be provided.

Priorly known electron beam-type encoders, however, have been characterized by a fairly low deflection sensitivity. The characteristics of such tubes have in fact been such as to necessitate the use of vacuum tube deflection amplifiers in otherwise completely transistorized systems. For instance, in a pulse code video transmission system described by R. L. Carbrey at page 1546 of Proceedings of the I.R.E. for September, 1960, a vacuum tube amplifier was required to drive the encoder tube although the rest of the system was entirely transistorized. The considerable advantages derivable from the use of transistor circuitry throughout such systems will be apparent to workers in the art.

A larger code plate may be employed in an encoder tube without adversely affecting the deflection sensitivity if the distance between the deflection systems and the code plate is increased. This expedient is, however, subject to a number of objections. In particular, it would enlarge the size of the tube envelope, thus making it more difficult to manufacture as well as more liable to structural failure. Furthermore, the larger the volume inside the envelope, the more difficult it is to control the environment of the electron emissive cathode surface. Larger tubes typically have a higher rate of cathode failure due to contamination of the emitter surfaces. In addition, such a tube would require a longer electron beam. It is well known however, that, due to space charge effects, the maximum current which may be focussed in a beam of given size varies inversely as the square of the distance to the focus. Increasing the length of the tube, therefore, is to be avoided whenever possible.

A further source of difficulty in prior encoding tubes arises from the need for exact alignment of the electron beam and the code plate. For instance, in one advantageous arrangement the rows of apertures in the code plate are perpendicular to the columns thereof. In order to eliminate a major source of encoding error in a tube comprising such a code plate, it is essential that the ribbon beam be parallel to the rows of apertures. A beam not so aligned is said to be tilted.

It has been recognized in the prior art that a major source of beam tilt in electron beam-type encoders is misalignment of the electron gun and the code plate. As these two components are at opposite ends of a glass envelope which typically is rather large, uniform and accurate mechanical alignment is difficult to achieve. The error resulting from misalignment is independent of the angle of deflection and may be referred to as "static" tilt. Accordingly, it has been found advantageous to provide electrostatic means for aligning the electron beam with the code plate, thereby avoiding the necessity for

precise mechanical alignment. This may be accomplished by including in the encoder tube a pair of tilt correction plates as described in United States Patent 2,713,650 to R. W. Sears.

A hitherto uncompensated source of beam tilt is misalignment of the electrostatic deflection plates in the main beam-deflection system of the encoder tube. In an idealized deflection system in which the plates are absolutely planar and perfectly parallel, the tangent of the angle of deflection is directly proportional to the voltage across the plates and inversely proportional to their separation. It can be shown that the angle of beam tilt caused by a small change in separation of the plates across the beam width is dependent on the angle of deflection of the beam. That is to say, unlike the static tilt caused by misalignment of the electron gun and the code plate, the tilt caused by lack of perfect parallelism of the deflection plates is a function of the angle of deflection. This source of encoding error may be designated "dynamic" tilt.

The effect of encoding errors such as those caused by beam tilt is to increase the noise in the coded signal over that which would be present in a signal coded by a perfect encoder system using the same number of digits. The degradation of the signal due to coding errors may also be expressed as a reduction in the effective number of digits in the system. The adverse effect of dynamic beam tilt becomes progressively more serious as the number of digits in the code is increased. For example, in order to maintain the error from this source at an acceptable level in an eight-digit tube of typical design, the maximum allowable error in deflection plate separation is about 0.0050 inch. For a nine-digit tube of the same type the maximum allowable error is half that of the eight-digit tube or about 0.0025 inch. While it may be possible to build a deflection system that would meet these requirements, such precision renders the cost prohibitive and the design impractical.

An object of this invention, therefore, is to increase the deflection sensitivity of electron beam tubes without materially increasing the distance between the deflection system and the target.

A second object of this invention is to maintain proper alignment of an electron beam with another element in an electron beam tube as the beam is angularly deflected from a position in which it is properly aligned.

A third object of this invention is to increase the encoding accuracy of flash coding devices by maintaining proper alignment between the electron beam and the apertured code plate as the beam is deflected from a position in which it is properly aligned.

A further object of the invention is to improve the performance of flash coders employing ribbon electron beams, and to make feasible the construction of flash coders capable of encoding a greater number of quantized levels than prior beam-type encoders.

Yet another object of this invention is the accurate encoding of analog signals in multi-digit binary codes by means of an electron beam-type encoder capable of being driven by transistorized circuits.

These and other objects of the invention are achieved in a specific illustrative embodiment comprising, in an evacuated envelope, an electron gun for projecting a ribbon electron beam against a target, electrostatic deflection plates positioned between the gun and the target for deflecting the electron beam in a direction perpendicular to the plane of the ribbon beam, dynamic tilt correction means positioned between the electron gun and the deflection plates, and an electrostatic diverging lens positioned between the deflection plates and the target for increasing the deflection sensitivity of the beam deflection system.

A feature of this invention is an electrostatic diverging lens comprising two axially-spaced plane parallel conductive members having similar beam-passing apertures,

and a grid of very small closely spaced parallel wires defining a plurality of elongated apertures. The grid is positioned between the parallel conductive members with the elongated apertures aligned in the direction in which the divergence is to be produced. The two parallel members are maintained at one potential, and the grid is maintained at a lower potential. Beam divergence occurs in one dimension only, that is, in the dimension defined by the elongated apertures of the grid. Thus if the beam is deflected so that it is obliquely incident on the diverging lens, the lens acts to increase the angle of deflection, thereby increasing the effective deflection sensitivity of the tube.

It is another feature of this invention that a dynamic tilt correction system in an electron beam tube employing a ribbon beam comprises a pair of conductive members positioned on opposite sides of the ribbon beam and extending across the width thereof. Advantageously, the conductive members are uniformly tapered rods of circular cross section. In one preferred embodiment the axes of the tapered rods are parallel across the width of the ribbon beam. Alternatively, the conductive members may be rods of circular cross section and constant diameter, in which case they are arranged with a uniform variation in separation across the width of the beam.

It is a further feature of this invention that the conductive members in the dynamic tilt correction system are connected to the main beam deflecting plates through an attenuating network, whereby there is established between said members a potential difference which is a function of the primary beam deflecting voltage. The attenuating network is preferably of a frequency compensated type so that the amount of dynamic tilt correction applied to the beam is substantially independent of the frequency with which the beam is deflected. Thus as a voltage is applied to the deflection plates, thereby deflecting the beam and causing it to be undesirably tilted or rotated, a second derived voltage is applied to the correction system. The correction voltage pretilts the plane of the beam in a direction opposite the tilt produced by the misaligned deflection plates so that the two rotations cancel and the beam passes untilted to the code plate.

The above-mentioned and other objects and features will be fully understood from the following more detailed discussion taken in conjunction with the accompanying drawing in which:

FIG. 1 is a view of a ribbon beam encoding tube illustrative of the invention, with a portion of the envelope cut away to reveal the interior structure;

FIG. 1A is a side view of a portion of the interior structure of the tube shown in FIG. 1;

FIG. 2 is a partial sectional view of the tube structure taken along the line 2—2 of FIG. 1A;

FIG. 3 is a partial sectional view of the tube structure taken along the line 3—3 of FIG. 1A;

FIG. 4 is a diagrammatic representation of an electron beam tube having an electron beam diverging lens according to the invention; and

FIG. 5 is a schematic representation of an electron beam tube illustrative of the invention, showing one combination of circuit elements employable therewith.

Similar elements are indicated by like reference numerals throughout the drawing.

Turning now to FIG. 1, the specific illustrative embodiment there shown comprises an envelope 12 which may be of a convenient material such as glass. The envelope is evacuated during manufacture in any suitable manner known in the art. Advantageously, the exhaust tubulation, not shown, is enclosed in a base 11 having lead terminals 10 extending therethrough for making electrical contact to various elements contained within the envelope.

An electron gun assembly, not shown, of a type suitable for forming a flat or ribbon-shaped electron beam is

positioned in the base end of the envelope. An anode 13 is mounted on insulated support rods 14 which extend along the axial dimensions of the tube. Also mounted on the rods 14 are beam-forming and accelerating electrodes 16, which may be in the form of apertured discs.

In the specific illustrative embodiment shown, a dynamic tilt correction system in accordance with the invention comprises a pair of tapered conductive members 20 secured by metal brackets 17 which are supported on the rods 14. The form of the brackets 17 and the mounting of the tapered members 20 may be more clearly seen by reference to the side view in FIG. 1A and to the sectional view in FIG. 3. The tapered members 20 are electrically insulated from the brackets 17 and from each other by insulating bushings 33 which may be, for example, of a ceramic material. A portion of each member 20 protrudes beyond the bushing 33 in one of the brackets 17 to afford means for making electrical connection to each of said members individually. The individual connections are carried through the envelope 12 by lead terminals, such as lead terminal 18. In the interest of clarity the wires connecting the members 20 to the terminals 18 have been omitted from the drawing. A second lead terminal would extend through the portion of the envelope 12 which in FIG. 1 is cut away to reveal the interior structure of the tube.

Although the conductive members 20 in the illustrative embodiments are in the form of tapered or frusto-conical rods, other forms are possible and may be employed within the spirit of the invention. Thus the members 20 may comprise cylindrical rods having a varying separation across the width of the electron beam. More complex shapes may be devised by those skilled in the art to approximate the ideal configuration in which the field varies linearly across the width of the beam. Such shapes are also within the scope of the invention. However, the use of tapered rods or rods having a uniformly varying separation across the beam width is preferred because of the ease and low cost of fabrication and assembly, and because they add least to the length of the tube structure. As explained above, it is most desirable to make the tube as short as possible.

In one specific electron beam tube comprising a dynamic tilt corrector as described above, the length of the tapered members 20 between brackets 17 was 0.750 inch. The members 20 were of circular cross-section tapered from a diameter of 0.100 inch at one end to a diameter of 0.025 inch at the other end. The distance between centers was 0.200 inch.

In a second specific tube the dynamic tilt corrector comprised two cylindrical rods of diameter 0.100 inch and length 1.00 inch. The distance between centers was 0.200 inch at one end and 0.250 inch at the other end. It may be shown that such an arrangement will rotate the plane of the ribbon beam by an amount

$$\tan \theta = 0.3 \frac{ZV_o}{V_o} \quad (1)$$

where V_o is the potential difference between the rods, V_o is the energy of the electrons in the beam, and Z is the distance between the dynamic tilt corrector and the target assembly. If Z is about 6 inches and V_o is about 1,000 volts, the tilt sensitivity is about 0.1 degree per volt. Of course, the sensitivity may be varied by changing the parameters of the dynamic tilt corrector, but the above has been found sufficient to ease the mechanical requirements imposed on the deflection system to a point where manufacture is relatively easy and inexpensive. Moreover, the use of the beam diverging lens which is a part of this invention results in greater effective sensitivity of the corrector. In the preferred arrangements the parameters are adjusted so that the maximum voltage required by the dynamic tilt corrector is no greater than the maximum voltage applied to the main deflection sys-

tem, so that the combined beam controlling means may be driven by a single source.

Also supported by the rods 14 are deflection plates 21 which, as can be seen from FIG. 1A, are advantageously closer together at the base end of the tube than at the target end. Such an arrangement, as is known in the art, results in greater deflection sensitivity. In addition it has been found advantageous to place a shield electrode 19 between the dynamic tilt corrector and the deflection plates 21 to reduce the interaction between the time varying electric fields produced in the adjoining portions of the electron beam path. The shield electrode 19 may be in the form of an apertured conductive disc.

Adjacent the deflection plates 21 on the side nearest the target end of the tube is situated an electron beam diverging lens in accordance with the invention. As shown in FIG. 1 the diverging lens comprises a planar grid 22 and a planar electrode 23 in spaced parallel relation therewith. The grid 22 comprises a set of very small closely spaced conductive members 32 and is illustrated in greater detail in FIG. 2. The members 32 form a plurality of elongated apertures which, advantageously, are aligned in the direction in which the beam divergence is to be produced. In the tube shown in FIG. 1 the ribbon-shaped electron beam is to be deflected in a direction normal to the plane thereof, so that the grid 23 is aligned in a plane normal to that of the beam.

The planar electrode 23 may be in the form of a disc having a rectangular beam passing aperture 25 there-through. In order to minimize the effect of electric field distortion near the ends of the aperture, it is desirable that the length thereof be as great as is convenient. Advantageously, the aperture 25 extends across the major portion of the disc 23, sufficient metal being left at the edges of the disc to maintain its shape. Furthermore, it may be desirable in some instances to extend the aperture 25 across the entire width of the disc 23, so that the latter is divided into two separate and independently supported sections which may be electrically connected by a wire at the edge of the gap between them.

It is preferred that the elongated apertures of the grid 22 be terminated at as great a distance as is possible from that region of the grid through which the electron beam actually passes. Such a configuration minimizes the aberrational and defocussing effects of the grid apertures in the direction normal to the plane of the ribbon beam. This objective is conveniently obtained by shaping the grid 22 to conform in general to the cross-sectional shape of the tube envelope. Thus, in the cylindrical tube shown in FIG. 1, the grid 22 is circular and the apertures therein extend almost to its periphery.

In a specific electron beam tube embodying this aspect of the invention, the grid 22 was 2 inches in diameter. The apertures therethrough were about 0.0017 inch wide and were defined by parallel conductive members 32 which were about 0.0003 inch thick. The grid was placed 0.250 inch from the end of the deflection plates 21 and 0.500 inch from the lens electrode 23. This tube was operated with a potential difference of 300 volts between the grid 22 and the electrode 23. The gain in deflection sensitivity amounted to about 50 percent.

The apertured grid 22 was formed by winding .0003 inch diameter tungsten wire about an annular member, brazing the wire thereto, and cutting the annular member to divide it into two similar planar grids. Other techniques for forming the lens grid will appear to those skilled in the art.

Although the beam diverging lens as shown in FIGS. 1 and 2 comprises a planar grid and a single planar electrode in spaced parallel relation therewith, several variations are possible within the scope of the invention. Thus the electrode 23 as shown in FIG. 1 is situated between the grid 22 and the collector shield 24. Inasmuch as the lens is operated with the electrode at a positive potential with respect to the grid, this will be disig-

nated the accelerating configuration. The electrode 23 may, however, be positioned between the grid 22 and the deflection plates 21. This will be referred to as the decelerating configuration. In a third variation, shown schematically in FIG. 5, the grid 22 is located between two planar electrodes 23. This may be designated the unipotential configuration, although different potentials may be applied to the two electrodes.

FIG. 4 illustrates schematically the manner in which a beam diverging lens acts to increase the deflection sensitivity of an electron beam tube. An electron gun 41 produces a beam 42 which is deflected by an angle ψ as it passes through the electric field between the deflection plates 21. The path of the beam 42 is bent again as it passes through the lens comprising grid 22 and electrodes 23, the diverging effect being indicated by the angle $\Delta\psi$. The gain in deflection sensitivity may be represented by

$$\frac{Y}{Y'} = 1 + \frac{Z_1}{f} \left(1 - \frac{Z_1}{Z_d} \right) \quad (2)$$

where Y is the amount of deflection at the target 29 with the lens, Y' is the amount of deflection without the lens, f is the focal length, Z₁ is the distance from the lens to the target 29, and Z_d is the distance from the center of deflection to the target.

The manner of operating an electron beam tube embodying the invention may be understood by referring to FIG. 5. A stream of electrons emitted by the cathode 51 under the influence of anode 13 and the control electrode 52 is formed into a flat or ribbon-like beam 42 by the accelerating and beam-forming electrodes 16. A voltage source 53 acts in combination with resistors 54, 55 and 56, and with capacitors 56 and 57 to maintain appropriate potential differences between the various elements of the electron gun. It is to be understood that any suitable type of electron gun may be used to form the electron beam, and that the gun shown in FIG. 5 is by way of illustration only.

In the preferred embodiment of the invention the dynamic tilt corrector comprising the members 20 is characterized by a tilt sensitivity such that the voltage required at any angle of deflection is less than the voltage applied to the deflection plates 21. The tilt correction voltage is then conveniently derived directly from the deflection plates through an attenuating network 59. Advantageously, the attenuator 59 is frequency compensated so that the proper potential is supplied to the members 20 irrespective of the frequency with which the beam is deflected. Networks of this type are known in the electronics art.

In the event that the tilt sensitivity of the rods 20 is insufficient to permit the use of an attenuating network as described, it will be necessary to provide a voltage amplifier or other means for supplying thereto a voltage dependent on the deflection voltage. In either case the rods 20 are to be connected to the potential supplying means so that they produce a dynamic tilt or beam rotation opposite in direction to that caused by misalignment of the deflection plates 21. The proper polarity of the connection will vary from tube to tube due to the randomness of the errors introduced in the manufacturing process, and may be determined empirically after the ribbon beam 42 has been statically aligned with the target assembly 29.

After being deflected by the field between the plates 21 the beam 42 passes through the diverging lens which, in FIG. 5 is of the unipotential type. In this type of lens the electrodes 23 preferably are both maintained at the same positive potential with respect to the grid 22 by means of the bias source 64 in combination with resistors 66 and 67. The diverging effect of the lens is modified if the electrodes 23 are maintained at different positive potentials respectively.

It can be seen from the above specification that the inclusion, in an electron beam encoder tube, of a dynamic tilt correction system and a beam diverging lens permits the construction of such a tube capable of encoding a greater number of signal levels and having an improved deflection sensitivity, all without the drastic narrowing of mechanical and electrical tolerances which would otherwise be required.

It will also be appreciated by workers in the electron beam art that the dynamic tilt corrector may be used with pencil beam which must be deflected and swept across a target in alignment therewith. Furthermore, the diverging lens in accordance with the invention may be employed in other beam devices where one dimensional divergence is desirable.

What is claimed is:

1. An electron beam tube comprising target means, an electron gun for projecting a ribbon electron beam in an initial plane toward said target means, electrostatic deflection means intermediate said gun and said target means for deflecting said beam away from said plane in a direction perpendicular to said plane, electrostatic diverging means intermediate said deflection means and said target means for causing said beam to diverge in the direction of deflection, dynamic tilt correction means intermediate said gun and said deflection means for maintaining the alignment of said beam and said target as said beam is deflected, said tilt correction means comprising conductive members positioned on opposite sides of the plane of said ribbon electron beam, and means for supplying to said dynamic tilt correction means potentials of a magnitude functionally dependent on the amount by which said beam is deflected.

2. An electron beam tube as in claim 1 wherein said electrostatic diverging means comprises first and second axially-spaced plane parallel conductive members having first and second similar beam-passing apertures respectively, said apertures being so dimensioned as to pass the entire thickness of the ribbon beam at all deflections of said beam, a planar grid between said members in plane parallel spaced relation thereto, said grid comprising a set of very small closely-spaced parallel conductors defining a plurality of elongated apertures, the long dimension of said apertures being perpendicular to said plane, and means for maintaining said first and second axially spaced members at a positive potential with respect to said grid.

3. An electron beam tube as in claim 1 wherein said electrostatic diverging means comprises at least one planar conductive member having a beam-passing aperture so dimensioned as to pass the entire thickness of the ribbon beam at all deflections of said beam, a planar grid spaced from said member in plane parallel relation thereto, said grid comprising a set of closely-spaced parallel conductors defining a plurality of elongated apertures, the width of said conductors being smaller than the separation between them, the long dimension of said apertures being perpendicular to said plane, and means for maintaining said planar member at a positive potential with respect to said grid.

4. An electron beam tube as in claim 1 wherein said dynamic tilt correction means comprises a pair of conductive members positioned on opposite sides of the plane of said electron beam and having a uniformly varying separation across the width thereof, and means for applying to said members a potential difference proportional to the angle by which said beam is deflected from a reference position.

5. An electron beam tube as in claim 4 wherein said conductive members are cylindrical rods.

6. An electron beam tube as in claim 1 wherein said dynamic tilt correction means comprises a pair of uniformly tapered conductive rods of circular cross-section, said rods being positioned on opposite sides of the plane of said electron beam with their axes parallel and extending across the width thereof, and means for applying to

said rods a potential difference proportional to the angle by which said beam is deflected from a reference position.

7. An electron beam tube comprising target means, an electron gun for projecting a ribbon electron beam in an initial plane against said target means, deflection means intermediate said gun and said target means for angularly deflecting said beam away from said plane in a direction perpendicular to said plane, dynamic tilt means intermediate said deflection means and said target means for tilting said beam by an amount dependent on the angle by which said beam is deflected, dynamic tilt means comprising a pair of tapered rods positioned on opposite sides of the plane of said beam with their axes parallel in a plane perpendicular to the direction of said beam, and means for applying to said rods a potential difference proportional to the angle by which said beam is deflected from a reference position.

8. An electron beam tube comprising target means, an electron gun for projecting a ribbon electron beam in an initial plane against said target means, deflection means intermediate said gun and said target means for angularly deflecting said beam away from said plane in a direction perpendicular to said plane, dynamic tilt means intermediate said deflection means and said target means for tilting said beam by an amount dependent on the angle by which said beam is deflected, said dynamic tilt means comprising a pair of conductive rods of uniform cross-section, said rods being positioned on opposite sides of the plane of said beam and having a uniformly varying separation in a plane perpendicular to the direction of said beam, and means for applying to said rods a potential difference proportional to the angle by which said beam is deflected from a reference position.

9. An electron beam encoder tube comprising a plurality of target electrodes, an electron gun for projecting a ribbon electron beam toward said target electrodes, a code plate situated between said electron gun and said

target electrodes, said code plate having a plurality of beam passing apertures therethrough for permitting combinations of said target electrodes to be selectively energized by a ribbon electron beam impinging thereon, electrostatic deflection plates intermediate said electron gun and said code plate for deflecting a ribbon electron beam with respect to said code plate, dynamic tilt correction rods intermediate said electron gun and said deflection plates for maintaining alignment between said code plate and an electron beam deflected by said deflection plates, said rods being adapted to produce a varying electric field across the width of a ribbon beam passing therebetween, a voltage attenuating network connecting said rods and said deflection plates for applying to said rods a voltage dependent on the voltages applied to said deflection plates; and an electrostatic diverging lens intermediate said deflection plates and said code plate, said lens comprising a planar grid having a plurality of closely spaced elongated apertures, the long dimension of said apertures being aligned in the direction in which beam divergence is to be produced, a planar conductive member spaced from and parallel to said grid, said member having a ribbon beam passing aperture therethrough, and means for maintaining a potential difference between said grid and said member.

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