

July 25, 1950

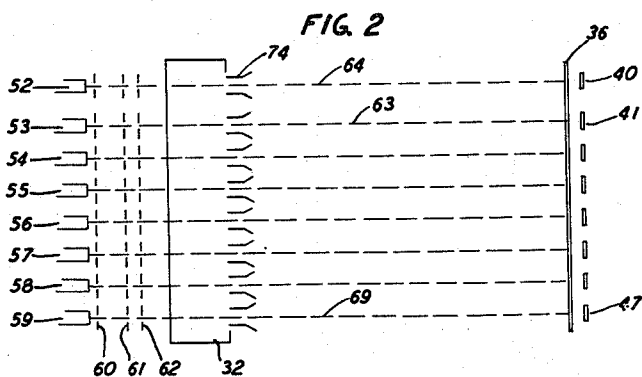
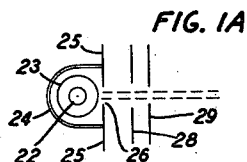
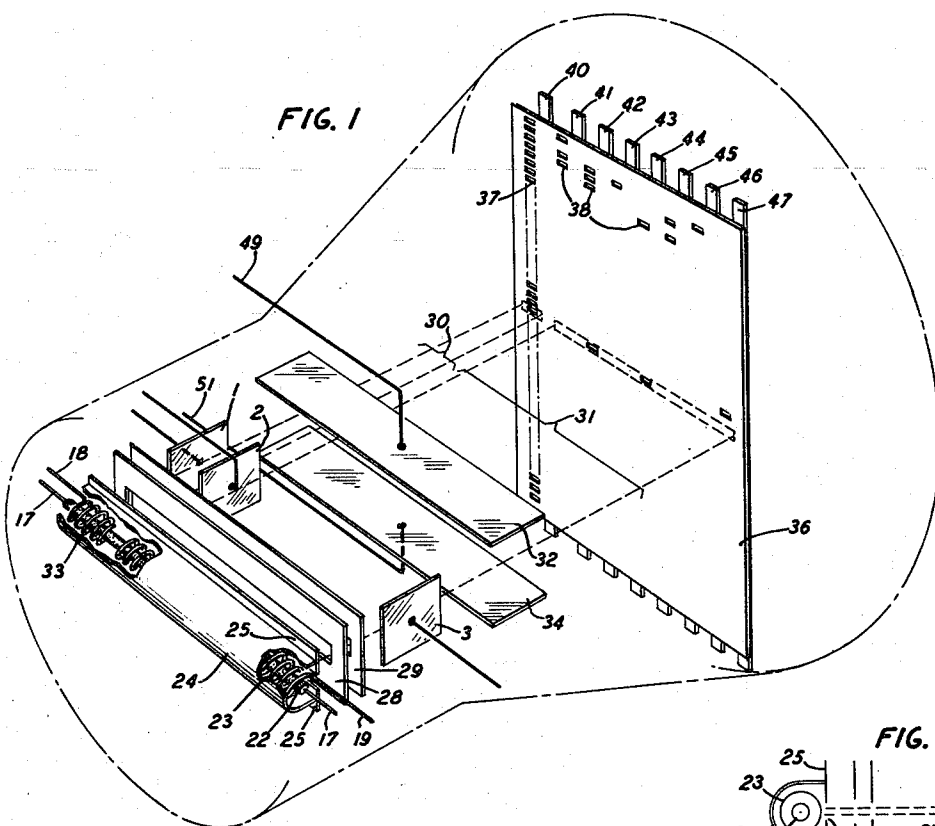
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2,516,752

CODING TUBE FOR PULSE CODE MODULATION SIGNALS

Filed Sept. 30, 1948

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

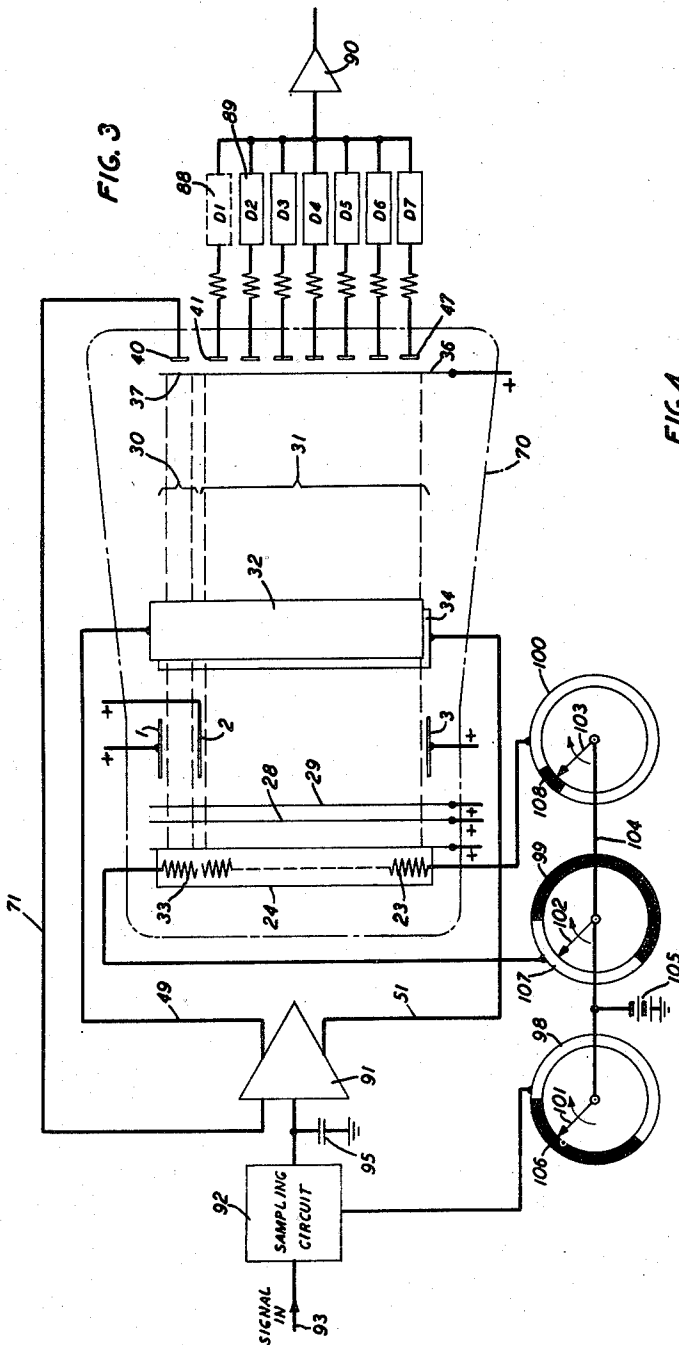


FIG. 3

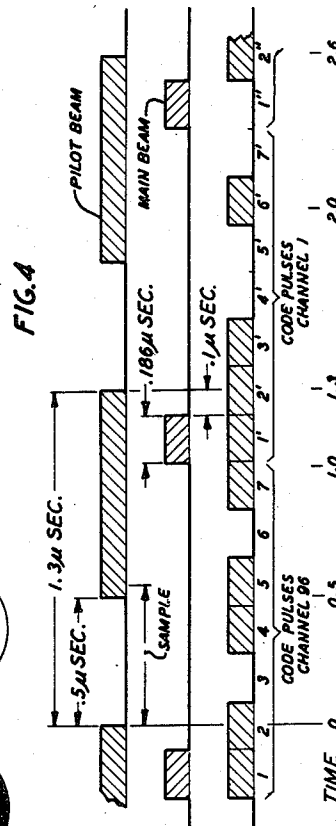


FIG. 4

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2,516,752

CODING TUBE FOR PULSE CODE
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9 Claims. (Cl. 315-13)

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The present invention relates to the automatic generation of pulses in code combinations indicative of instantaneous signal amplitude, under the direct control of signals to be coded. More specifically, the invention relates to automatic generation of code pulses by an electron beam coding tube in which the beam when deflected by different amounts by different signal amplitudes is caused to impinge upon certain ones of a set of electrodes in different combinations corresponding to the different digits of the code and to set up pulses on these electrodes.

Objects of the invention are, increased speed of coding, simplification of apparatus requirements, and improved operation.

Electron beam coding tubes of the kind to which the invention is applicable have made use of a quantizing grid and a feedback control from this grid to the beam deflecting means, for limiting the beam position to the grid aperture to which the beam was moved by the signal and for preventing the beam from assuming a position overlapping two grid apertures or only partially illuminating the intended grid aperture. Each grid aperture is lined up with a horizontal row of apertures in a code plate. Thus, registry of the beam with an aperture in the quantizing grid also causes proper registry of the beam with a given row of code apertures. The digit electrodes are located back of the code plate so that the beam in passing through apertures in the plate strikes the corresponding digit electrodes.

In the use of such tubes a time considerably longer than the duration of a code pulse is allowed for the stabilizing of the beam position, under control of the quantizing grid and its feedback action, in proper registry with a given row of code apertures. During this stabilizing period the beam is illuminating the digit electrodes and so producing pulses on them. In order to prevent these pulses from reaching the output circuit until the beam is stabilized and the pulses are wanted, gating amplifiers individual to the digit electrodes have been used and these amplifiers have been biased beyond cut-off until such time as the pulses were to be sent.

In accordance with this invention, the gating function is performed within the tube by blanking the electron beam used for the coding until such time as the pulses are to be impressed on the output circuit of the coding tube. In order to make use of the feedback principle to bring and hold the beam in proper registry with a given row of code apertures, an auxiliary, or pilot beam is provided together with a relatively nar-

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row quantizing grid arranged in the path of the pilot beam but out of the path of the main or coding beam. The same beam deflecting means serves in common for both beams. This allows the feedback control, through the agency of the pilot beam, to establish the necessary conditions on the deflecting means such as will cause proper registry of the main beam with a given row of apertures when the main beam is unblanked. The main beam may be turned on at the instant when the code pulses are to be generated and not until then. It is left on for the duration of a code pulse and is then turned off until the next code combination is to be generated. Thus, the main beam is used both to generate the pulses in proper code combinations and to time the occurrence and duration of the pulses. One advantage following from this action is that the gating amplifiers heretofore used may be dispensed with and if amplification as such as needed it can be supplied in a common amplifier, for example in the output of the distributor as will appear from the fuller description to follow.

The nature and objects of the invention will appear more clearly from the following detailed description of certain illustrative embodiments of the invention as shown in the accompanying drawings.

In the drawings, Fig. 1 is a perspective view of the electrode structure of an electron beam coding tube of one form according to the invention;

Fig. 1A shows a detail of the electron gun used in the construction shown in Fig. 1;

Fig. 2 is a schematic plan view of the electrode structure of a modified electron beam tube according to the invention;

Fig. 3 is a schematic view, in plan, of a tube of the Fig. 1 type showing the manner of connecting the tube into a pulse code transmitting system; and

Fig. 4 shows a timing diagram to be referred to in the description of Fig. 3.

Fig. 1 shows the electrode structure of a cathode beam tube, looking away from the small end of the tube at which the beam-forming means is provided toward the large end of the tube where the target electrodes are located. Provision is made for producing a pilot beam 30 of relatively narrow ribbon form and a main or coding beam 31 also of ribbon form and much wider than beam 30. These two beams impinge upon the code plate 36 and illuminate a horizontal line across the code plate, as shown.

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The code plate 36 is divided functionally into two distinct parts. The first part comprises the quantizing grid 37 which is in the path of the pilot beam 30 but is to the left and out of the path of the main beam 31. The other portion comprises the coding section of the plate 36, this portion being in the path of the main beam 31 but out of the path of beam 30. It will be understood that the two beams 30 and 31 are maintained spaced apart from each other and quite distinct and separate in their effect. Positively biased concentrating electrodes 1, 2 and 3 are provided to shape the electron beams and to assist in maintaining the spacing thereof.

All of the apertures in the code plate 36 are arranged in horizontal rows. In a seven-digit system, assumed in this figure, there will be 128 horizontal rows. The quantizing grid 37 has 128 apertures arranged in a vertical column. Just back of this column of apertures is the target member or anode 40 so located as to be struck by the beam 30 whenever the latter passes through one of the apertures in the quantizing grid 37. The apertures in the coding portion of the plate 36 differ in number in each horizontal row from none to a maximum of seven in accordance with a binary system to form a permutation code and are positioned in seven vertical columns. A few of these apertures are shown at 38. The digit electrodes 41 to 47, inclusive, are located just back of the code plate 36 in position to be struck by portions of the beam 31 which pass through apertures in the corresponding column.

The beams 30 and 31 are shown in the figure in their middle position corresponding to zero applied signal. They can be deflected upward or downward to any chosen horizontal row of apertures by the application of proper voltage to the deflecting plates 32, 34. These voltages may be applied over the leads 49 and 51 respectively.

Any suitable type of electron gun structure may be provided for producing the beams 30 and 31 in ribbon form. The structure shown in Fig. 1 is a modification of that shown in United States patent to A. M. Skellett 2,293,567 granted August 18, 1942. The structure in Fig. 1 differs from that in the Skellett patent in that electrostatic focusing is used in Fig. 1 in place of magnetic focusing shown in the patent. The electron gun comprises an elongated linear cathode 22, which may be of the indirectly heated equipotential type as shown or may be of other forms, for example, filamentary, a cylindrical grid 23 for the main beam and a similar grid 33 for the pilot beam, each coaxial with the cathode 22, and a shield electrode including a U-shaped portion 24 coaxial with the cathode 22. This shield portion has attached to it a pair of coplanar plates 25 extending normal to the longitudinal axis of the tube or of the beam and spaced from each other to define an elongated linear aperture or slit 26, parallel to and in alignment with the cathode 22. This construction is shown more clearly in Fig. 1A. The grid 23 for the main beam is provided with a lead 19 and grid 33 for the pilot beam is provided with a lead 18. A lead 17 is also indicated for applying heating current to the cathode heater or filament.

Directly in front of the slit 26 is a pair of slotted plates 28, 29 to which proper bias voltages may be applied relative to the voltage of the plates 25, shield 24 and cathode 22 to pro-

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duce desired focusing. Portions of the shield 24 are broken away in Fig. 1 to show the two grids 23 and 33 as distinct and separated from each other. If desired, suitable shield means may be included in the space between the two grids within the shield member 24.

In the operation of the electrode structure of Fig. 1 a signal sample is applied across the leads 49, 51 for the deflector plates 32, 34. (The circuit arrangements for carrying out the functions in this brief description will be given in Fig. 3.) During the time the signal sample is applied to the deflector plates the main beam 31 is blanked by the application of a proper voltage to the grid 23, but the pilot beam 30 is not blanked at this time. The pilot beam 30 is therefore deflected under control of the signal voltage to the vicinity of a particular aperture in the quantizing grid 37 depending upon the amplitude of the signal. The beam may fall into exact registry with one of these apertures or may be only partially in register with an aperture and part way between two apertures. The portion of the beam that passes through an aperture strikes the target electrode 40 from which a voltage is fed back through an amplifier to the deflector plates 32, 34 such as to exert feedback control on the pilot beam 30. This feedback control is such as to shift the beam 30 slightly when necessary to change from the condition of partial registry of the beam with a given aperture into full registry of the beam with that aperture. (The manner in which the feedback control effects this result is disclosed more fully in an article by R. W. Sears entitled "Electron Beam Deflection Tube for a Pulse Code Modulation" published in the Bell System Technical Journal for January 1948, pages 44 to 57.) If the beam is partly cut off on its upper side so that only, say, its lower half is transmitted, then if the feedback acts so that stronger current to electrode 40 urges the beam downward (and weaker current urges it upward) an unstable condition exists and the beam will either move downward until further movement would begin to cut off its lower edge or it will move upward to a stable position in the next higher aperture.

The positioning of the pilot beam in the manner described so as to be in full registry with a particular aperture in the quantizing grid 37 results in the establishment of such voltages on the deflector plates 32, 34 that when the main beam is turned on it will immediately strike the corresponding horizontal row of holes in code plate 36 in full registry therewith. It thus becomes practicable to turn on the main beam for just the short interval corresponding to the duration of a code pulse and then turn the beam off again, since the quantizing grid and feedback action through the agency of the pilot beam has prepared in advance the proper voltage condition on deflector plates 32, 34 for causing correct registry of the main beam with the corresponding row of code determining apertures. Portions of the main beam pass through these apertures and strike the corresponding digit electrodes 41 to 47 producing voltages on those particular, and only those, digit electrodes.

The fact that the two electron beams 30 and 31 are of widely different dimensions does not prevent the type of control just described from taking place. The important thing is to have the accelerating potentials for the two beams maintained equal and this result is achieved by generating the beams from a common cathode

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as disclosed and also making the other portions of the electron gun system including the focusing element common to the two beams.

The code pulses generated in this manner on the digit electrodes 41 to 47 may be made use of in any desired manner. For example, they may be simultaneously transmitted over individual transmission channels or they may be applied to a distributor operating to arrange them in sequential order suitable for transmission over a single channel.

Referring to Fig. 3, the signal which may be speech or other suitable signal is shown as coming in on lead 93 to the signal sampling circuit 92. The latter may be an electronic switch of the type which permits conduction in either direction when closed. Such switches are sometimes referred to as two-way clamps. The switch would be biased open to prevent conduction except for the time during which a signal sample is to be taken and applied to the storage condenser 95. The timing control for the sampling circuit 92 and for other functions to be carried out would in practice be accomplished by means of electronic timing circuits under the prime control of a crystal oscillator of highly constant frequency, with the various timing periods determined by capacitance-resistance timing circuits operating in conjunction with vacuum tubes in a manner generally well known in the art. For simplicity of illustration in Fig. 3 the timing control is shown as obtained from rotating brushes 101, 102, 103 cooperating with segmented rings. A negative voltage from battery 105 is shown as applied to the common shaft 104 for the three brushes. The sampling circuit 92 is biased open during the portion of the cycle in which the brush 101 is in contact with the conducting portion 98 of the segmented ring but this bias is removed during the time the brush 101 is in contact with the insulating segment 106. It is during this latter interval that the sampling circuit 92 is allowed to take a sample of the impressed signal in lead 93 and store it upon the condenser 95.

During all or the greater part of this sampling period both the main beam 31 and the pilot beam 30 are suppressed by the application of high negative voltage to the grids 23 and 33 by brushes 103 and 102 in contact with respective conducting segments 100 and 107. The pilot beam is shut off during this period to allow the voltage conditions on storage condenser 95 to become stabilized. The high negative bias is removed from grid 33 near the end of the sampling period, allowing the pilot beam 30 to become projected.

The signal voltage stored on the condenser 95 is amplified in the push-pull amplifier 91 and is applied over the leads 49, 51 to the upper and lower deflecting plates 32, 34. The pilot beam 30 is thus deflected to an extent determined by the signal amplitude. The quantizing grid 37, electrode 40, feedback connection 71 to the input of amplifier 91, amplifier 91 and deflector plates 32, 34 cooperate in the manner above described to position the pilot beam 30 in full registry with the aperture corresponding to the nearest quantized value of the signal. A considerable time is allowed during which this feedback quantizing operation is being carried out in order to permit the pilot beam to become fully stabilized in its final position. During this period the brush 103 is traversing the segment 100 and maintaining high negative bias on grid 23 thus suppressing the main beam. After a time sufficient for stabilized conditions to be reached, brush 103 arrives

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at insulating segment 108 and removes the negative bias from grid 23 allowing the main beam 31 to be projected for the duration of the code pulse. For this purpose the segment 108 is shown as quite short. After the projection of the main beam both beams are again suppressed and switch 101 permits sampling circuit 92 to take a new sample of the applied signal.

These timing relations are shown for further illustration in Fig. 4. It is assumed for illustration in Fig. 4 that the coder is being used in a 96-channel telephone system with speech samples taken at the rate of 8,000 per second. The coding period for any one speech sample is therefore 1.3 microseconds. Beginning at time 0 in Fig. 4 the sampling period is shown as lasting for about half a microsecond. The pilot beam is shown as coming on near the end of the sampling period and lasting throughout the remainder of the first 1.3-microsecond interval. Experience shows that it requires somewhat less than 0.5 microsecond for the action of the quantizing grid and its feedback control to become fully stabilized. The main beam is represented as not being turned on therefore until near the end of the 1.3-microsecond interval. The coder therefore produces a main beam pulse near the end of every coding period and pulses of the duration of the main beam pulse, shown as .186 microsecond, will appear simultaneously on those of the digit electrodes 41 through 47 for which the beam was in registry with apertures in the coding plate 36. Typical code groups of pulses obtained by distribution in time of the simultaneously appearing pulses are shown in Fig. 4 for channels 96 and 1.

Fig. 3 shows a type of distributor suitable for use in distributing the code pulses sequentially in time so as to make them suitable for transmission over a single channel. This is done by the use of delay circuits 88, 89, etc. individual to the seven-digit targets 41 to 47. These delay lines are associated with the respective digit targets through isolating resistors 81 as shown. The first delay line D_1 shown at 88 is represented in dotted outline indicating that this line may have zero delay and therefore that the delay line may be omitted, if desired. The amount of delay increases in succeeding delay lines D_2 , D_3 , etc. by .186 microsecond, the time interval between the beginning of one pulse and the beginning of the next pulse. Thus the code pulse generated on digit electrode 47 is delayed six full pulse periods longer than the one generated on digit electrode 41, that on digit electrode 46 is delayed five pulse periods longer, etc. A common amplifier 90 is shown as serving for the transmission of the various permutation code pulses. This may also include shaping circuits to standardize the code pulse amplitudes if desired.

Some of the distributed code pulses are represented in the timing diagram of Fig. 4. At the end of the coding cycle immediately prior to time 0, the main beam pulse is assumed to have set up a coding pulse on each of digit electrodes 41, 42, 44, 45 and 47. Corresponding pulses 1, 2, 4, 5 and 7 are therefore represented in the timing diagram as they would be sequentially arranged in time by the distributor delay lines. Another sequence generated near the end of the first 1.3-microsecond interval is shown by the pulses 1', 2', 3', and 6'.

Fig. 2 shows a modified type of electrode construction in which eight individual electron beams are used, one of these, 64 in the figure, being the pilot beam and the other seven being

coding beams shown at 63 to 69. Individual electron guns including separate cathodes 52 to 59, inclusive, are provided. Individual focusing apertures which are to be suitably biased, are shown at 60, 61, 62. These focusing elements are supplemented by the collimating tubes or shields shown at 74, suitably biased. This type of construction permits of individual control of the various beams to equalize their intensities. Also somewhat more intense beams can be obtained and used with this construction. A single pair of beam deflecting plates of which the upper one is shown at 32 is used as in the previous figures. The manner of connecting into the circuit would be the same as described in connection with Fig. 3, the various coding beam controlling grids being paralleled.

What is claimed is:

1. The method of generating pulses in code combinations by electronic action comprising producing two parallel electron beams subject to like deflection under signal control, initially applying the signal control to only the first of said beams to deflect the same to a desired position dependent upon the signal amplitude while blanking the second beam, establishing by feedback action, effective upon the first beam, voltage conditions determinative of the deflection of the second beam when existent, such as to cause the second beam to assume a position limited to electrode areas determinative of one particular code group, and thereafter and while said conditions are still maintained, turning on said second beam for a time corresponding to the length of code pulse to be generated.

2. In an electron beam pulse code producer, means to produce two electron beams parallel to each other, common deflecting means for both beams, a quantizing grid located in the path of the first or pilot beam but out of the path of the second or main beam, code generating target areas in position to be engaged by said main beam when deflected by different amounts, a feedback control from said quantizing grid to said deflecting means for establishing and maintaining proper registry of said main beam with the particular target areas producing the desired code, and means to suppress said main beam during the time such proper registry is being established by said feedback control but to turn on said main beam during the time such proper registry is being maintained.

3. In an electron beam coding tube, a main beam, a pilot beam, common deflecting means for said beams, a quantizing grid in the path of said pilot beam but out of the path of said main beam, a feedback beam-centering control from said grid to said deflecting means, code-determining target areas positioned to be engaged by said main beam when deflected by successive amounts, said areas coordinated spatially with the grid apertures such that said control centers the main beam on respective code-determining areas, and means to suppress said main beam independently of said pilot beam.

4. In an electron beam coding tube, means to produce a main beam, a plurality of target exposure areas arranged in patterns according to a code, means to deflect the main beam under control of a signal voltage to be coded, so as to be intercepted by certain of said exposure areas depending upon the signal amplitude, means to suppress said beam except for times during which codes are to be generated, means to produce a pilot beam, special target exposure areas ar-

ranged opposite said plurality of exposure areas, means including said deflecting means for moving said pilot beam to one of said special areas under control of a signal to be coded, while said main beam is suppressed, to predetermine the position to be assumed by said main beam, said last means also including a feedback control from said special area to which said pilot beam was moved, to said deflecting means, for predetermining proper register of said main beam with said certain exposure areas.

5. In an electron beam coding tube, a coding element having a plurality of defined areas each representing a signal amplitude, means for establishing an electron beam in said tube, means for deflecting said beam in accordance with the amplitude of a signal to be coded to the corresponding one of said defined areas, means for limiting the possible positions of said beam to those corresponding to said defined areas, said means comprising means for generating an auxiliary electron beam within the tube, a quantizing electrode disposed beside said coding element to intercept said auxiliary beam, and having openings positioned opposite said defined areas, said auxiliary beam being deflected by the signal to be coded acting through the means for deflecting the first-mentioned beam, and means for feeding back from said quantizing electrode a control voltage for application to said deflecting means.

6. A beam tube for producing permutation code pulses, comprising means to project a main beam and a pilot beam side by side within and along said tube, common deflecting means for both beams, a separate and independently controllable beam suppressing means for said main beam, said main beam being many times wider than its vertical or thickness dimension, target exposure areas arranged in horizontal rows one above another, the individual areas being arranged in a pattern conforming to a permutation code, a vertical column of other target exposure areas each horizontally aligned with a different one of said rows, said deflecting means being positioned when supplied with deflection controlling voltages to move both of said beams to be intercepted by any given one of said horizontal rows of areas and by the area aligned therewith respectively, and means operating in response to interception of the pilot beam by said latter area for maintaining said beams in register with the areas to which they were moved respectively.

7. In an electron beam coding tube, means to produce a main beam and to project the beam toward a target area, means to deflect the beam to different positions on said target area dependent upon the amplitude of an impressed signal, said target area having a different exposure pattern for each different amplitude of signal to be coded, and means to reduce ambiguity in coding comprising means to produce and project a pilot beam, said deflecting means for the main beam also deflecting the pilot beam by the same amount, special target exposure areas arranged to be intercepted by said pilot beam and individually corresponding with the different exposure area patterns, means operating in response to interception of said pilot beam by a given one of said special exposure areas for feeding back a voltage to said deflecting means such as to maintain said main beam in register with the corresponding exposure area pattern, and a separate and independently controllable beam suppressing means for said main beam.

8. A two-beam electron coding tube including

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main target areas and pilot target areas aligned therewith, means for initially directively projecting a pilot beam, under control of a signal voltage to be coded, against one of said pilot target areas while maintaining the main beam suppressed, a feedback control from said pilot target for the pilot beam for properly centering the pilot beam on said one pilot target area, and means subsequently operative under control of said signal voltage and feedback centering control for projecting the main beam against the respectively aligned main target area.

9. A two-beam electron coding tube including code determining target areas and guide target areas aligned therewith, means to produce a pilot beam and a coding beam, beam deflecting means, means for initially suppressing said coding beam and for causing said deflecting means to direct said pilot beam, under control of a signal voltage to be coded, against one of said guide target areas, a feedback control from said guide target area to

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said deflecting means for establishing proper register of said pilot beam on said guide target area, and means including said deflecting means subsequently operative under control of said signal voltage and feedback control for projecting said coding beam against the corresponding code-determining target area.

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