# United States Patent [19]

**Crandall et al.**

[11] **3,784,799**

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[54] **HIGH SPEED DEFLECTION MODULATOR ELECTRON BEAM SIGNAL PROCESSOR**


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[52] **U.S. Cl.** .............. **325/130,** 179/15 BM, 332/13, 332/25

[51] **Int. Cl.** .......................... **H04b 3/52,** H03c 3/34

[58] **Field of Search** .................. 332/13, 25, 21, 58, 332/7, 51 W; 179/15 A, 15 BM; 325/130


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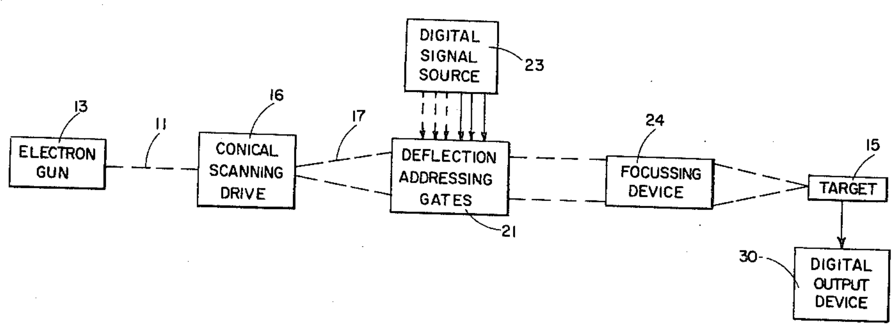
[57] **ABSTRACT**


A high-speed electron beam signal processor suitable for time-multiplexing a plurality of digital signals is disclosed. A focused electron beam, which may be developed by an electron gun, is conically scanned. The conical beam is passed through an addressing plate structure which includes a plurality of plate electrode members, each for receiving a separate digital input signal. The beam is deflected in accordance with the signals addressed to the addressing plates as it travels past these plates in succession. The beam passes from the addressing plates through an electrostatic lens which focus it onto a target. The target which may comprise a target diode provides a multiplexed output signal in accordance with the digital inputs fed to the addressing plates.


**10 Claims, 6 Drawing Figures**



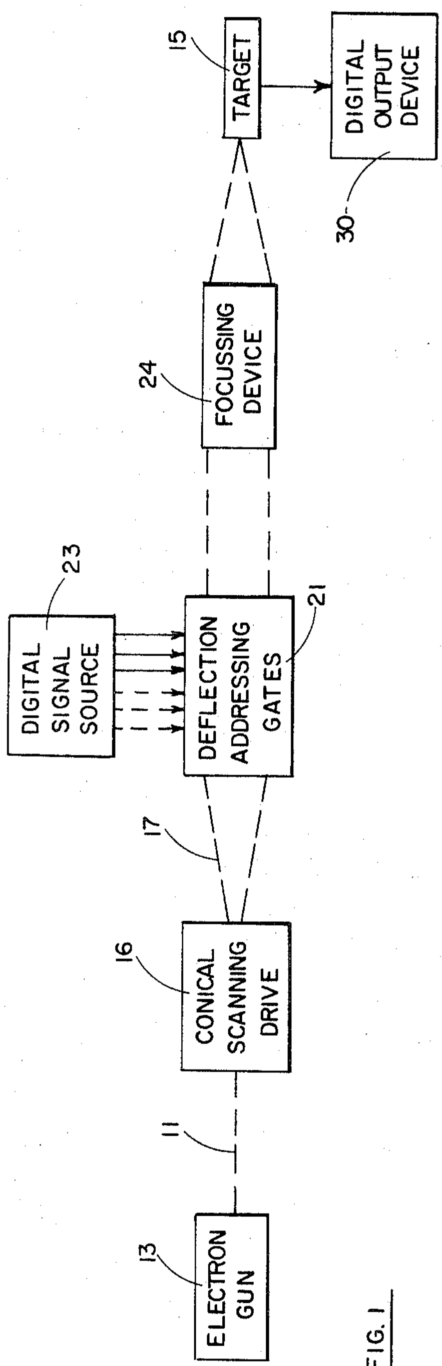



FIG. 1

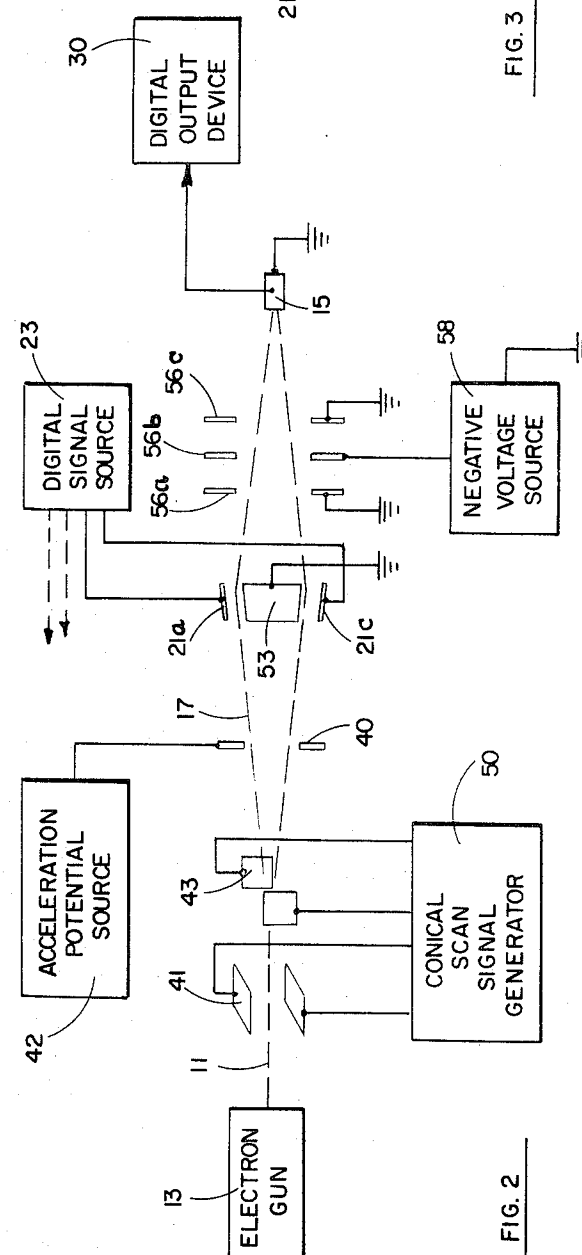



FIG. 2

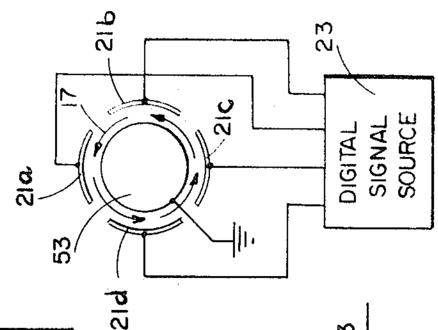



FIG. 3

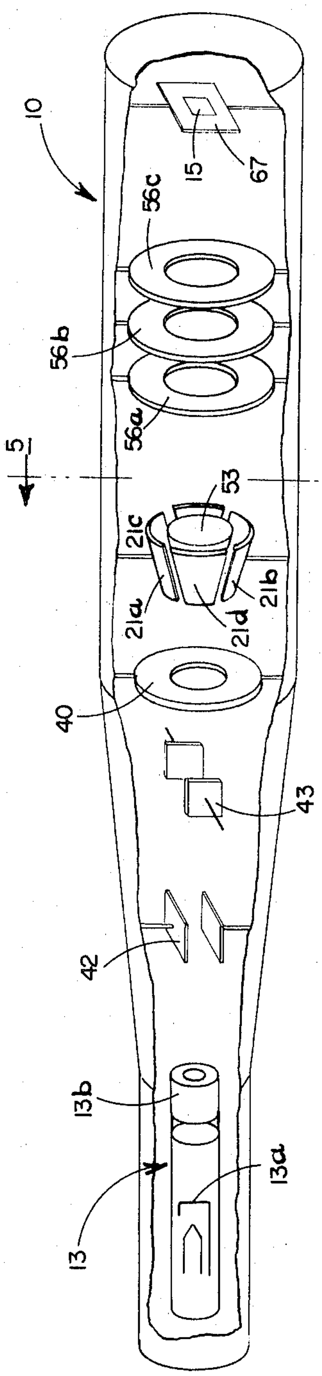



FIG. 4

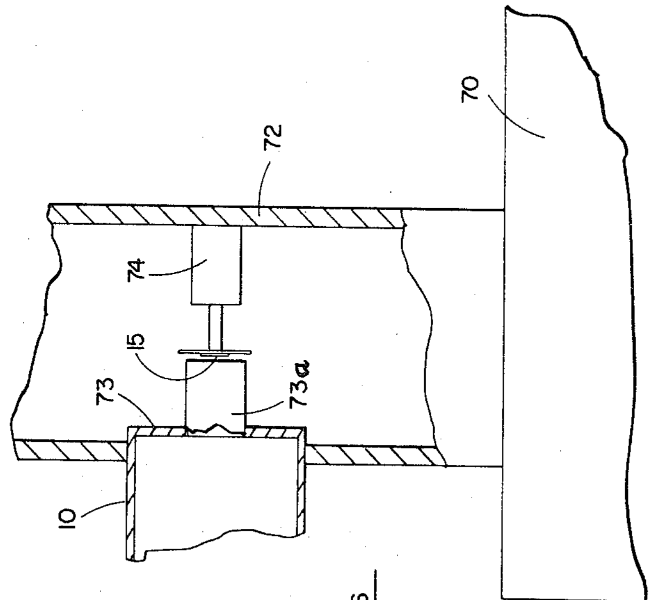



FIG. 6

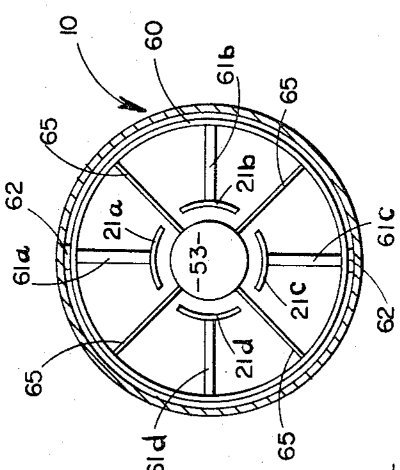



FIG. 5

## HIGH SPEED DEFLECTION MODULATOR ELECTRON BEAM SIGNAL PROCESSOR

This invention relates to electronic signal processing and more particularly to a signal processor in which digital signals are modulated onto an electron beam to multiplex these signals together.

In data processing and communications applications there is a great need for high-speed multiplexing of digital data which is to be transmitted over a communications channel or utilized in a computer. In systems of the prior art, such multiplexing is generally achieved by conventional semiconductor data processing circuitry. Such circuitry of the past and present art has distinct limitations in its speed of response, the best of such circuitry generally being incapable of handling speeds above 500 megabits/second. With growing demands for data processing, there is an ever-increasing need for higher speed data handling capabilities.

The system of this invention provides an improvement over prior art data processing systems in enabling the multiplexing of digital data onto a single channel at rates significantly higher than is possible with prior art systems and techniques. This end result is achieved by the system of this invention in a relatively simple manner utilizing a minimal number of components and a design which lends itself to economical fabrication. In addition to its general utilization in data handling, the system of the invention can be utilized to provide a high speed modulation source for directly modulating the carrier of a microwave communications transmitter.

It is therefore an object of this invention to provide an improved system for the high speed multiplexing of digital data.

It is another object of this invention to simplify and economize on the design of high speed digital processing systems.

It is still a further object of this invention to provide a system for multiplexing data on a single channel having higher speed capabilities than prior art systems.

Other objects of the invention will become apparent as the description proceeds in connection with the accompanying drawings of which:

FIG. 1 is a functional block diagram illustrating the basic operation of the system of the invention,

FIG. 2 is a functional block diagram illustrating one embodiment of the system of the invention,

FIG. 3 is a schematic illustration of the deflection address gates of the system of FIG. 2,

FIG. 4 is a cutaway perspective view illustrating the structure of the embodiment of FIG. 2,

FIG. 5 is a cross sectional view taken along a plane indicated by 5—5 in FIG. 4, and

FIG. 6 is a schematic view illustrating the utilization of the invention for modulating the carrier of a microwave transmitter.

Briefly described the invention is as follows: A focused electron beam from an electron gun is converted to a conical scanning beam by a conical scanning drive. The conical scanning beam is then passed through deflection addressing gates each of which receives an input signal from a digital signal source. As the conical scanning signal passes through the deflection addressing gates, it is sequentially modulated in accordance with digital signals applied to the various gates. The conical scanning beam exiting from the deflection addressing gates is focused onto a target which may comprise a target diode which provides an output signal in response to the impingement of the beam thereon.



Referring now to FIG. 1, the basic operation of the system of the invention is illustrated. An electron beam 11 generated by electron gun 13 is accelerated towards target 15 by means of an accelerating potential source (not shown) located between the gun and the target. Beam 11 is conically scanned to produce a conical scanning beam 17 by means of conical scanning drive 16. Conical scanning drive 16, to be explained further on in this specification, may comprise a pair of horizontal and a pair of vertical electrostatic deflection plates which are driven by sine waves in quadrature phase relationship or may comprise other conventional techniques for attaining a conical scan.

Conical scanning beam 17 passes through deflection addressing gates 21 which may comprise a plurality of electrodes positioned in a circle about a common electrode. These electrodes are each driven by a separate output of digital signal source 23. As will be explained more fully further on in the specification, the beam is interrupted whenever it passes an electrode gate which is excited in a predetermined manner by its associated signal input from digital source 23. The conical beam passes from the deflection addressing gates 21 through focusing device 24 which re-focuses the conical beam down to a spot beam which is directed onto target 15. Focusing device 24 may comprise either an electrostatic or magnetic lens system. Target 15 is a p-n junction target diode, the electron beam being capable of penetrating to the diode junction with a sufficiently high energy level to excite the diode to provide a useable output signal to digital output device 30. The speed of response of the device is principally limited by the response characteristics of the target.

Referring now to FIG. 2 one embodiment of the system of the invention is schematically illustrated. The beam output of electron gun 13 is accelerated towards target 15, which comprises a target diode, by means of accelerating anode 40 which may comprise a metal ring having a high voltage applied thereto from accelerating potential source 42. The beam 11 passes between vertical deflection plates 41 and horizontal deflection plates 43. Plates 41 and 43 have sinusoidal deflection voltages applied thereacross; these voltages being supplied by conical scan signal generator 50. The sinusoidal signal applied between plates 41 may be in quadrature phase relationship with the signal applied between plates 43, to effect the conical scan; or advantage may be taken of the transit time of the electrons between plates to effectively provide such quadrature related signals.

The conical scanning beam 17 passes through addressing gates 21*a*–21*d* (see FIG. 3). The addressing gates 21*a*–21*d* receive digital signals from digital signal source 23. (For simplicity, only four gates are shown. In normal use the number will be larger, typically eight to 100) An electrostatic field is established between each of plates 21*a*–21*d* and an interior common conical electrode 53 whenever any of such plates is excited with a positive signal from the digital signal source. Whenever the beam passes a gating electrode 21*a*–21*d* which is so excited, the beam is deflected away from the target 15 such that the beam arriving at target 15 will be effectively interrupted during this portion of the conical scanning cycle. It thus can be seen that the signal arriving at target 15 will be modulated in accordance with the excitation of the various gating electrodes forming the deflection addressing gates.

After the beam has passed through the addressing gates, it is focused by means of an electrostatic lens formed by electrostatic focusing rings **56***a*–**56***c*. These three rings form an Einzel lens such as described, for example, starting on page 98 of THEORY AND DESIGN OF ELECTRON BEAMS 92nd edition)—Pierce published by D. Van Nostrand, Princeton, N.J. (1954). Typically, plates **56***a* and **56***c* may be grounded with a negative voltage, which may be of the order of −5kV being applied to plate **56***b* from negative voltage source **58**. The beam is refocused into a spot and directed against target diode **15**. The beam striking target diode **15**, which is modulated in accordance with the signals applied to addressing gates **21***a*–**21***d*, has sufficient energy to penetrate to the junction of the diode and excite the diode to cause it to provide an output signal to digital output device **30**.

Target **15** may be a p-n junction target diode such as described starting on page 78 of PHYSICS OF SEMICONDUCTOR DEVICES by S. M. Sze, Wiley Interscience, New York (1969). Typically, a silicon-diffused p-n junction diode may be utilized for the target with the junction being located or positioned at a depth below the surface of about ½ micron. With a beam having an energy of 10 kilovolts, the junction depth of the target diode should be less than 1 micron for proper operation. It is to be noted that it is desirable to provide junction passivation at the junction of this diode so that the junction is not subject to damage by the electron beam. This can generally be achieved for example by growing an oxide or dielectric layer over the junction.

Referring now to FIGS. **4** and **5**, structural details of the embodiments of FIGS. **2** and **3** are illustrated. Supported in evacuated envelope **10** is electron gun **13** which includes a thermionic cathode **13***a*, and anode and electrostatic lens **13***b* for accelerating and focusing the beam. Vertical deflection plates **42** and horizontal deflection plates **43** are positioned in the envelope forward of the beam so that the beam passes therebetween and is deflected thereby. Next in succession is accelerating ring **40** which is a flat metal washer-like plate to which a high voltage is applied, the voltage being used to accelerate the elctron beam towards the target.

The deflection addressing gates **21***a*–**21***d* are supported on ring member **60** by means of insulative struts, preferably formed of a ceramic material, **61***a*–**61***d* respectively. Ring **60** is attached to the wall of enclosure **10** by means of brackets **62**. Center electrode **53** is supported on ring member **60** by means of insulating struts **65**. The deflection gating electrodes **21***a*–**21***d* together form a conically-shaped assembly having a taper corresponding to the inclination of the beam. An Einzel focusing lens if formed by washer shaped conductive members **56***a*–**56***c* which are supported in envelope **10** to focus the beam therethrough onto target **15**. Target **15** is supported in the envelope on an insulating substrate **67**. As already noted, magnetic focusing techniques well known in the art could be utilized in lieu of the electrostatic lens provided by members **56***a*–**56***c*. It is also to be noted that only four gating electrodes **21***a*–**21***d* have been shown but that the number of electrodes could be increased many-fold to modulate a great number of inputs onto the electron beam.

It is further to be noted that the frequency of data handling is determined by the frequency of the conical scan times the number of addressing gate electrodes utilized. In an operating embodiment of the device of the invention utilizing four gating electrodes as shown in FIG. **4**, a conical scanning frequency of 180 megaHertz was utilized to provide a 720 megabit/second output. Utilizing target diodes within the present state of the art, outputs at least of the order of 4 gigabits can be obtained by adding additional addressing gate electodes and/or increasing the conical scanning frequency.

The output of target **15** may be fed to a signal modulating element such as a PIN diode inside a microwave cavity or an electroptical device to modulate a light beam. Target **15** can also be placed directly in a wave guide which receives the output of a microwave communications transmitter operating typically in the 50–100 gigaHertz range to provide a modulation signal to the carrier of the transmitter, thus greatly facilitating the high speed handling of such signals for radio transmission. The use of this technique could solve a severe problem which exists in providing an adequate modulation source for such a carrier. By this technique, the change in the characteristics of the diode as current is passed therethrough modulates the mircowave energy, i.e., in the absence of forward current flow the intrinsic region of the semiconductor diode is depleted of carriers and thus does not absorb microwave energy while, when forward bias is applied, double injection occurs and hole-electron pairs are present to interact with the microwaves and produce absorption or reflection.

Referring to FIG. **6**, the utilization of the system of the invention in accomplishing this end result is schematically illustrated. The output of microwave transmitter **70** is fed to waveguide **72**. Inserted in the waveguide is the end of an envelope **10** of an embodiment of the system of the invention, similar to that described with reference to FIGS. **2–5**. The envelope **10** has an end portion **73** with a protuberance **73***a* thereon forming a "window." Target diode **15** is positioned within the waveguide cavity mounted on post **74** which is supported on the waveguide wall and thus performs the desired modulation functions. The window portion **73***a* is suitably thin and/or of a material to permit the passage of electrons therethrough.

The system and technique of this invention thus provides a relatively simple and economical means for handling high speed digital data. Substantially higher handling speeds are possible than with prior art techniqes. Also, for the system of the invention, complete decoupling of the input from the output load is afforded so that the output circuits do not affect the operation of the input circuits.

While the system and technique of this invention has been described and illustrated in detail, it is to be clearly understood that this is intended by way of illustration and example only, and is not to be taken by way of limitation, the spirit and scope of this invention being limited only by the terms of the following claims:

We claim:

**1.** A device for multiplexing a plurality of digital signals together comprising:

means for providing an electron beam,

a target,

means for accelerating said beam towards said target,

means for causing said beam to cyclically scan,

addressing gate means interposed between said means for causing said beam to scan and said target, said addressing gate means comprising a plurality of electrodes arranged along the path of said beam,

means for providing a separate binary digital signal to each of said electrodes for modulating said beam, and

means for focusing said beam to a spot which impinges on said target when said signal is in one of its binary states, said beam being deflected so as not to impinge on the target when the signal is in the other of its binary states,

whereby said beam is successively modulated by the binary digital signal on each of said electrodes.

2. The device of claim 1 wherein said beam is cyclically scanned in a conical scanning pattern, said electrodes being arranged in a substantially circular pattern.

3. The device of claim 2 wherein said means for causing said beam to conically scan comprises a pair of horizontal and a pair of vertical deflection plates and means for applying quadrature-related sinusoidal signals to said pair of plates.

4. The device of claim 1 wherein said target is a target diode said focusing means focusing said beam to a spot which impinges on said diode after it has passed said addressing gate means.

5. The device of claim 1 and additionally including a microwave transmitter and a waveguide for receiving the output of said transmitter, said target being positioned in said waveguide to modulate the output of said transmitter.

6. A device for multiplexing a plurality of digital signals together comprising:

means for generating an electron beam,

a target,

means for accelerating said beam towards said target,

means interposed between said means for generating an electron beam and said target for causing said beam to scan conically,

addressing gate means interposed between said means for generating said beam and the target, said addressing gate means comprising a plurality of electrodes arranged along the scanning path of said beam,

means for providing a binary digital signal to each of said electrodes for successively modulating said beam, and

means for focusing the beam to a spot which impinges on the target with the signal in one binary state, said beam being deflected so as not to impinge on the target with the signal in the other binary state.

7. The device of claim 6 wherein said electrodes comprise plate members arranged in a conical pattern.

8. The device of claim 6 wherein said target comprises a target diode said focusing means focusing said beam to a spot which impinges on said diode after it has passed through said addressing gate means.

9. The device of claim 6 wherein said means for causing the beam to conically scan comprises a pair of horizontal and a pair of vertical deflection plates and means for applying sinusoidal signals to said deflection plates said sinusoidal signals being in quadrature relationship with each other.

10. The device of claim 8 and additionally including a microwave transmitter and a waveguide for receiving the output of said transmitter, the target diode being positioned in said waveguide to modulate the transmitter output.

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