July 11, 1961 J. C. NYGARD 2,992,357

MICROWAVE LINEAR ACCELERATOR

Filed Sept. 29, 1958

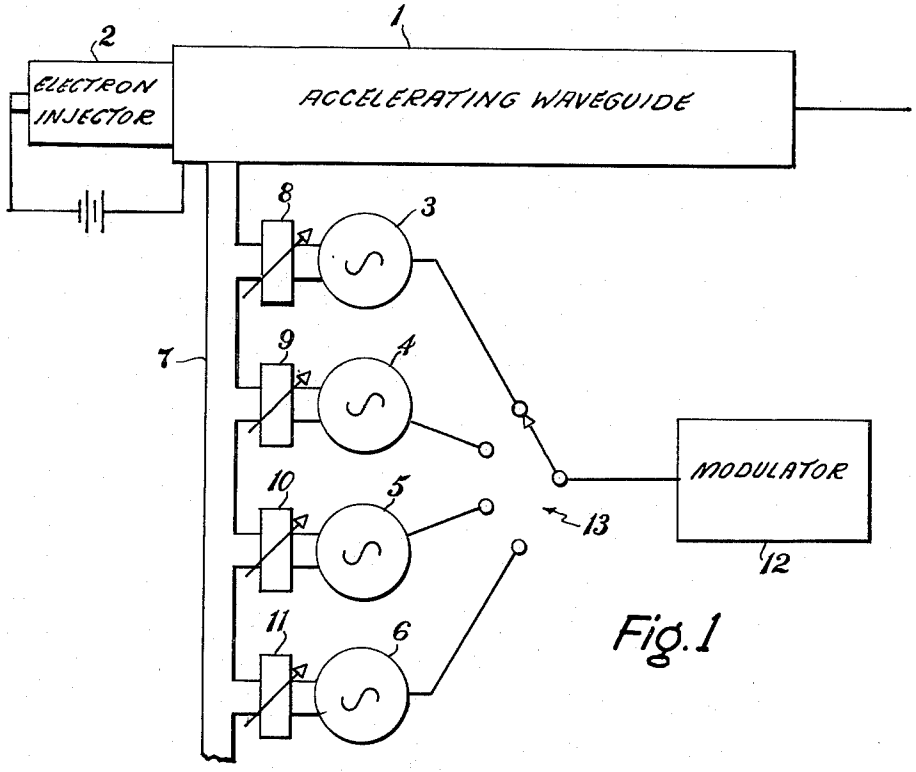

Fig. 1

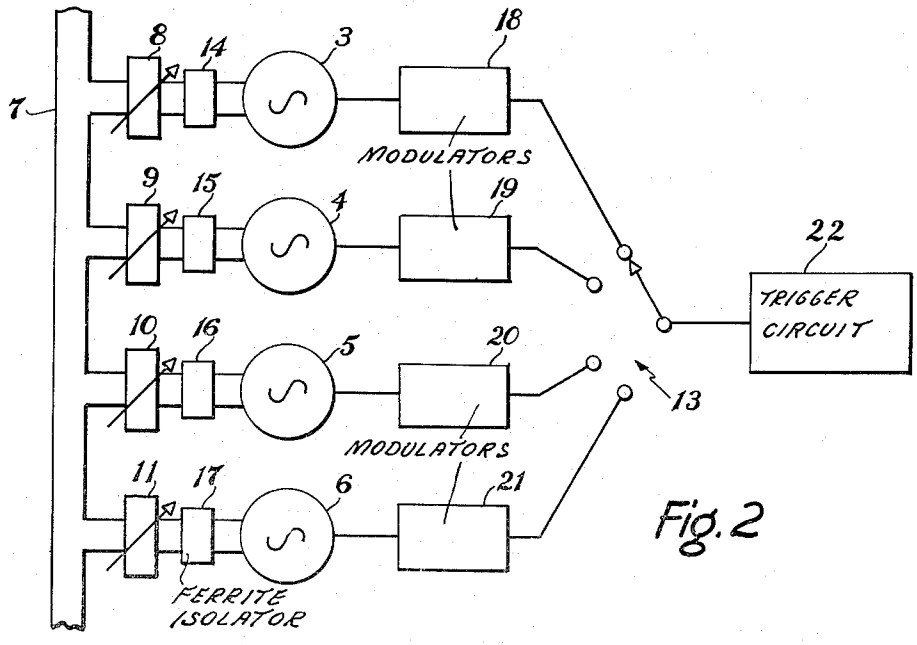

Fig. 2

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MICROWAVE LINEAR ACCELERATOR

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This invention relates to microwave linear accelerators and in particular to a microwave linear accelerator with which there is associated a plurality of radio-frequency power sources which are pulsed in sequence in order to provide high average power output. In accordance with one embodiment of the invention the pulsed radio-frequency sources may have their outputs adjusted in such a manner that it is possible to introduce energy spread into the radio-frequency spectrum in order to increase dose uniformity. For example, three radio-frequency power sources may be arranged to provide alternately 5 mev., 4 mev., and 3 mev. electron beams.

The invention may best be understood from the following detailed description thereof having reference to the accompanying drawing in which

FIG. 1 is a circuit diagram illustrating one form of the invention; and

FIG. 2 is another circuit diagram illustrating a modification of a portion of the circuit diagram of FIG. 1.

Referring to the drawing and first to FIG. 1 thereof, a conventional microwave linear accelerator comprises an accelerating waveguide **1** into which electrons are injected from an electron injector **2**. These electrons are then accelerated by means of a traveling electromagnetic wave which is produced in the accelerating waveguide **1** by means of radio-frequency power which is fed into said waveguide **1** from a suitable power source. In accordance with the invention, a plurality of power sources are provided and in FIG. 1 are shown at **3**, **4**, **5** and **6**. These power sources may be of any conventional type such as klystrons, magnetrons or traveling-wave tubes and are each connected to a transmission line **7** by an appropriate phase shifter, indicated at **8**, **9**, **10** and **11** for the power sources **3**, **4**, **5** and **6** respectively. A modulator **12** is alternately connected to the power sources **3**, **4**, **5** and **6** by means of an appropriate distributing device **13**, so that the power sources **3**, **4**, **5** and **6** are alternately energized. By appropriate adjustment of phase shifters **8**, **9**, **10** and **11** mismatches are avoided.

Referring now to FIG. 2 of the drawing, the device therein shown is similar to the device of FIG. 1. However, between the phase shifters **8**, **9**, **10** and **11** and the transmission line **7** there are provided ferrite isolators **14**, **15**, **16** and **17**, respectively. Moreover, each power source **3**, **4**, **5**, **6** has its own modulator **18**, **19**, **20** and **21**, respectively, and sequential operation is obtained by means of an appropriate trigger circuit **22** which sequentialy fires the modulators **18**, **19**, **20**, and **21** by means of the operation of an appropriate distributor device **13**.

Each ferrite isolator **14**, **15**, **16** and **17** acts to reflect radiation incident from the transmission line **7**, but transmits radiation incident thereon from the power sources **3**, **4**, **5** and **6**, respectively. In principle, each ferrite isolator could be replaced by any other device which permits energy incident from the utilization system to be reflected but permits radiation incident from the power sources to be transmitted. In short, the function of each ferrite isolator is to act as a switch junction or gating device and might be replaced, for example, by a mechanical shutter which permits energy transmission only when the corresponding power source is pulsed.

By adjusting the relative outputs of the radio-frequency power sources so that they are heterogeneous in nature an energy spread is introduced to the radio frequency spectrum, the result of which is to introduce energy spread into the electron stream produced by the linear accelerator. For example, two radio frequency power sources may be arranged to provide in sequence 5 mev. and 1 mev. electron beams. The effect is the same as having a main generator producing an electron beam of 5 mev. electrons and an auxiliary generator producing an electron beam of 1 mev. electrons. The effect of such an arrangement on dose distribution in a product being irradiated by these electron beams is described in detail in U.S. Patent No. 2,724,059, issued to A. J. Gale, and need not be described herein in any detail.

Having thus described the principles of the invention together with several illustrative embodiments thereof, it is to be understood that although specific terms are employed, they are used in a generic and descriptive sense and not for purposes of limitation, the scope of the invention being set forth in the following claims.

I claim:

1. A microwave linear accelerator comprising in combination a waveguide adapted to support a traveling electromagnetic wave having an axial electric field component whose phase velocity is sufficiently slow for electron acceleration, means for injecting electrons into said waveguide in the proper phase relationship with said wave for acceleration thereof, a plurality of radio frequency power sources, means for transmitting radio frequency power from each of said radio frequency power sources to said waveguide, whereby each of said radio frequency power sources is adapted to produce a traveling wave in said waveguide, and means for energizing said power sources in sequence and in proper phase relationship with the injected electrons, whereby successive sequential pulses from said power sources operate on different electrons.

2. Apparatus in accordance with claim 1 wherein each power source comprises a radio-frequency oscillator each of said oscillators being energized by a common modulator to which they are connected by a distributor device.

3. Apparatus in accordance with claim 1 wherein each power source comprises a radio-frequency oscillator and a modulator, said modulators being each connected to a common trigger circuit by a distributor device.

4. Apparatus in accordance with claim 1 wherein the outputs of said power sources are heterogeneous, whereby energy spread is introduced into the electron stream produced by said waveguide.

5. A microwave linear accelerator comprising in combination a waveguide adapted to support a traveling electromagnetic wave having an axial electric field component whose phase velocity is sufficiently slow for electron acceleration, means for injecting electrons into said waveguide in the proper phase relationship with said wave for acceleration thereof, a plurality of radio frequency power sources, means for transmitting radio frequency power from each of said radio frequency power sources to said waveguide, whereby each of said radio frequency power sources is adapted to produce a traveling wave in said waveguide, means for energizing said power sources in sequence and in proper phase relationship with the injected electrons, whereby successive sequential pulses from said power sources operate on different electrons, and means for introducing energy spread into the radio frequency spectrum by varying the output characteristics of said radio frequency power sources with respect to each other.

(References on following page)

References Cited in the file of this patent

UNITED STATES PATENTS

2,545,595	Alvarez	Mar. 20, 1951
2,556,978	Pierce	June 12, 1951
2,653,271	Woodyard	Sept. 22, 1953
2,724,059	Gale	Nov. 15, 1955
2,813,996	Chodorow	Nov. 19, 1957
2,860,279	Hester et al.	Nov. 11, 1958