

Aug. 26, 1947.

L. ESPENSCHIED

2,426,189

OBJECT LOCATING SYSTEM

Filed Oct. 4, 1941

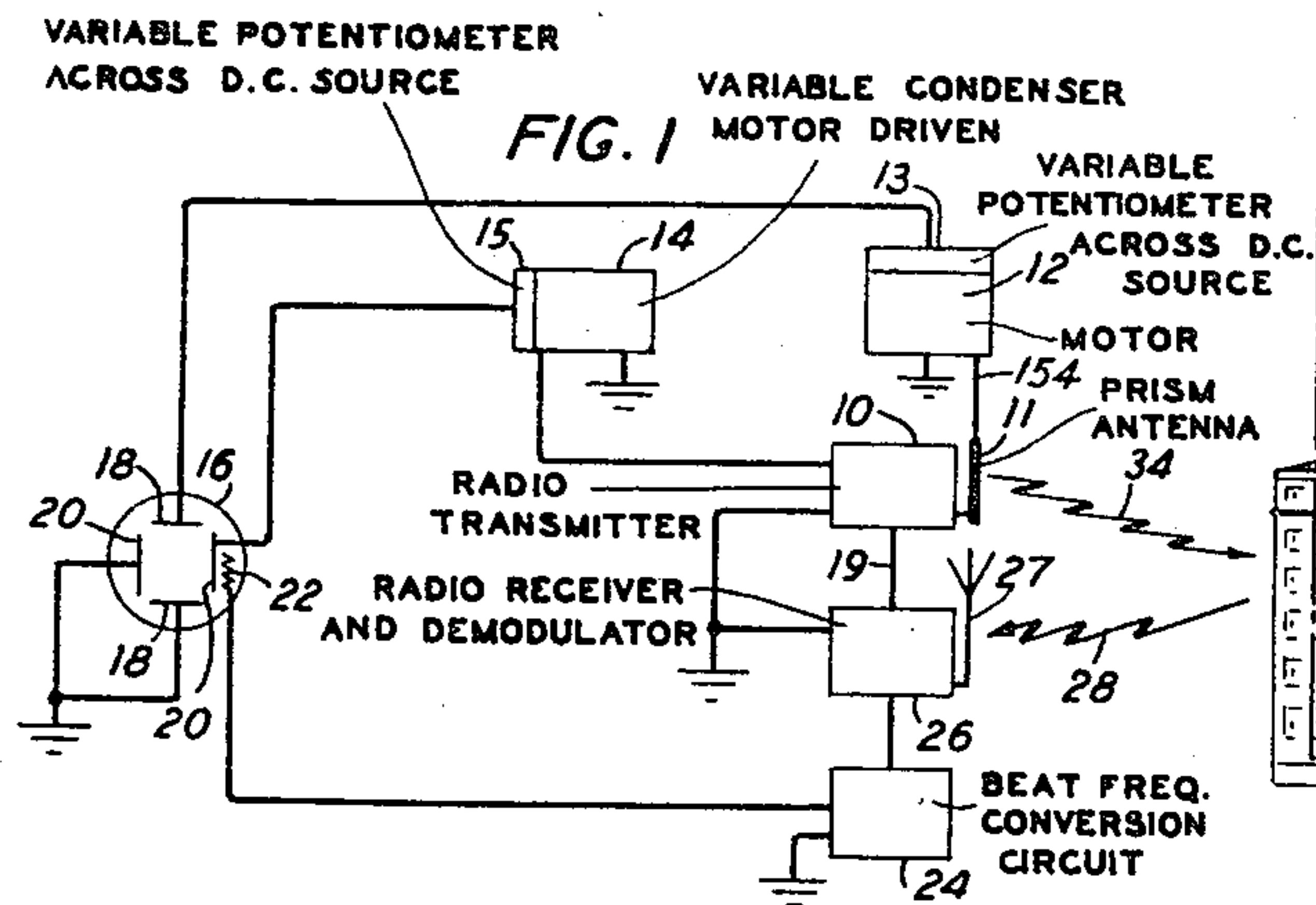


FIG. 2

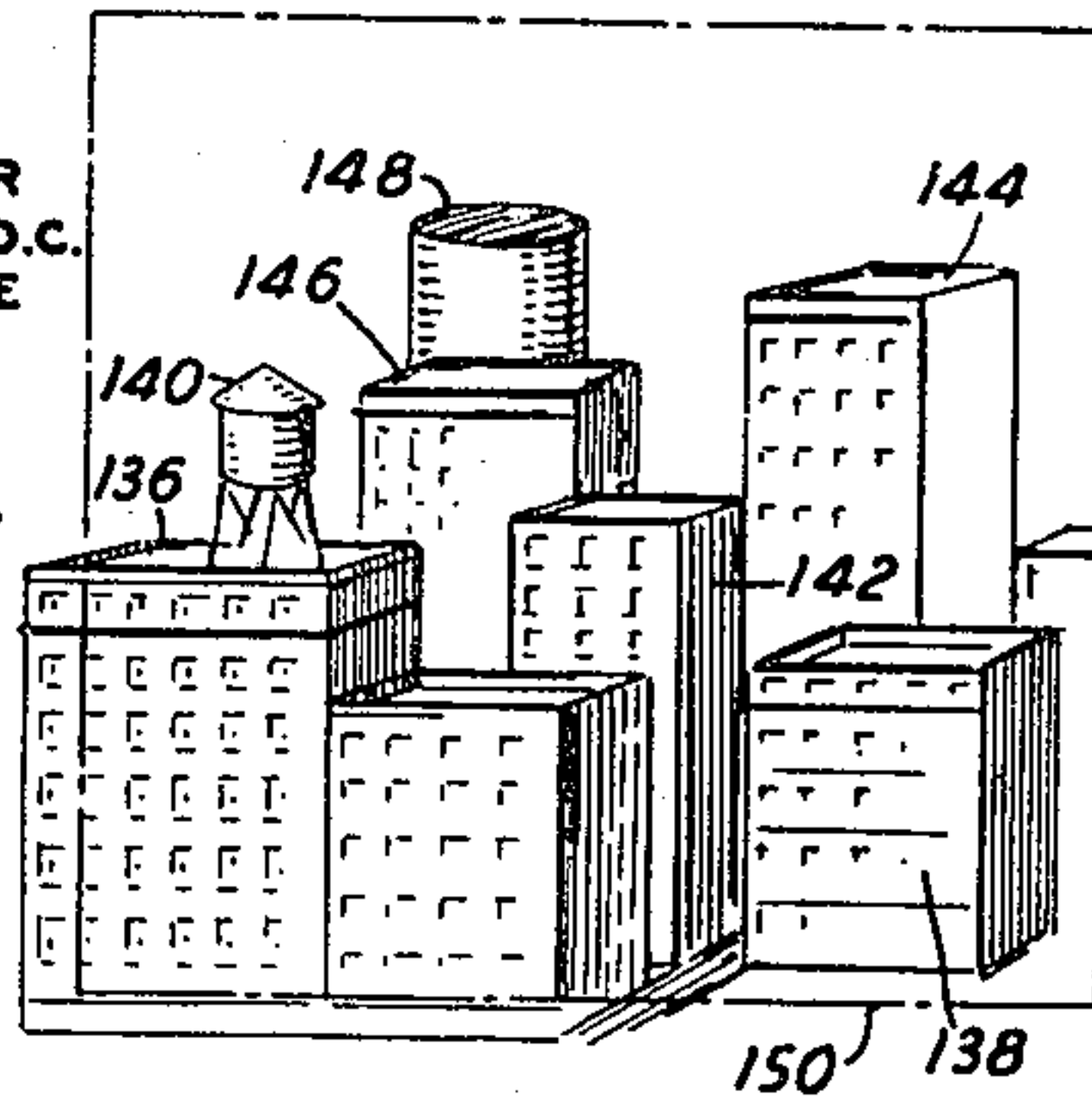


FIG. 4
CATHODE RAY
OSCILLOSCOPE
TARGET

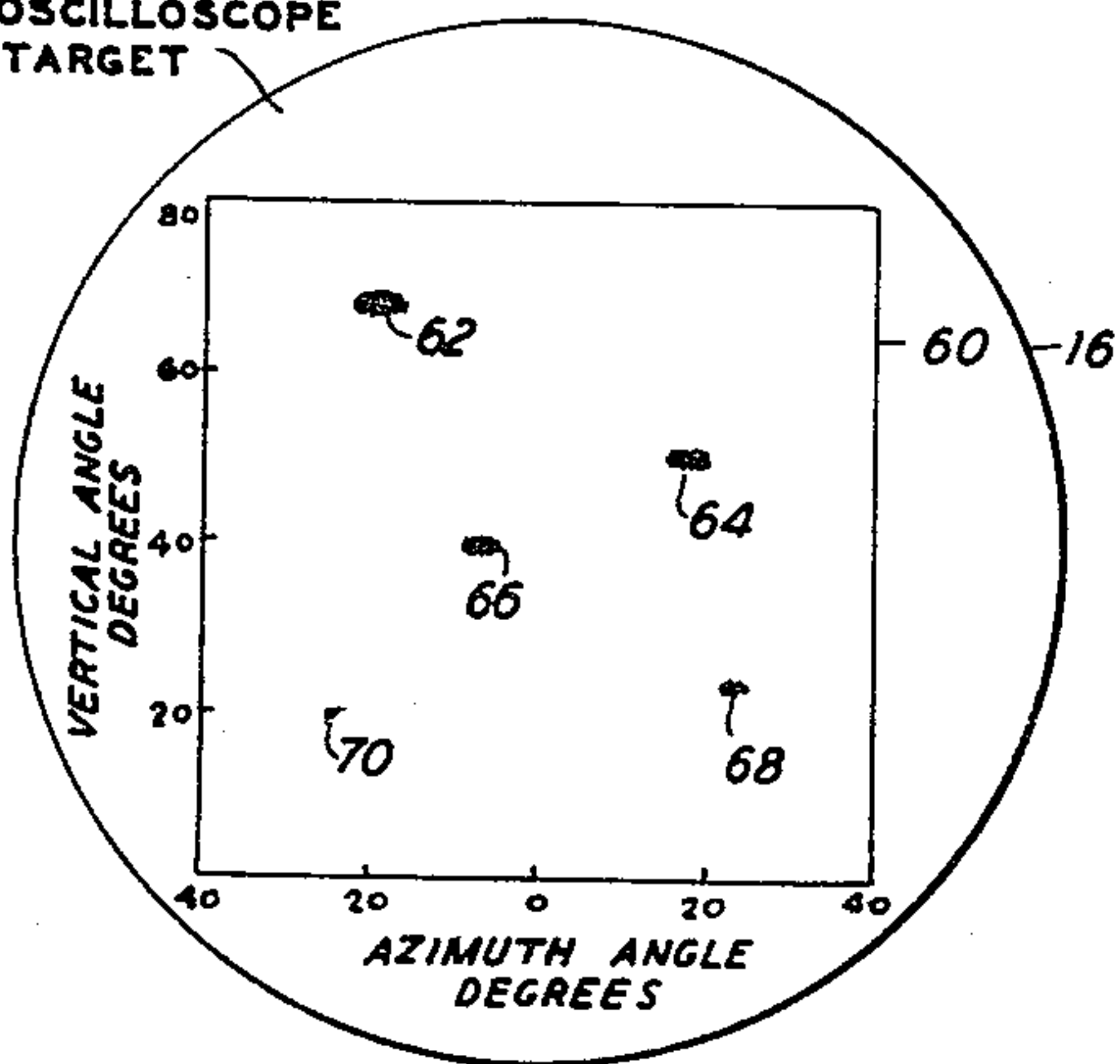


FIG. 3

CATHODE RAY
OSCILLOSCOPE
TARGET

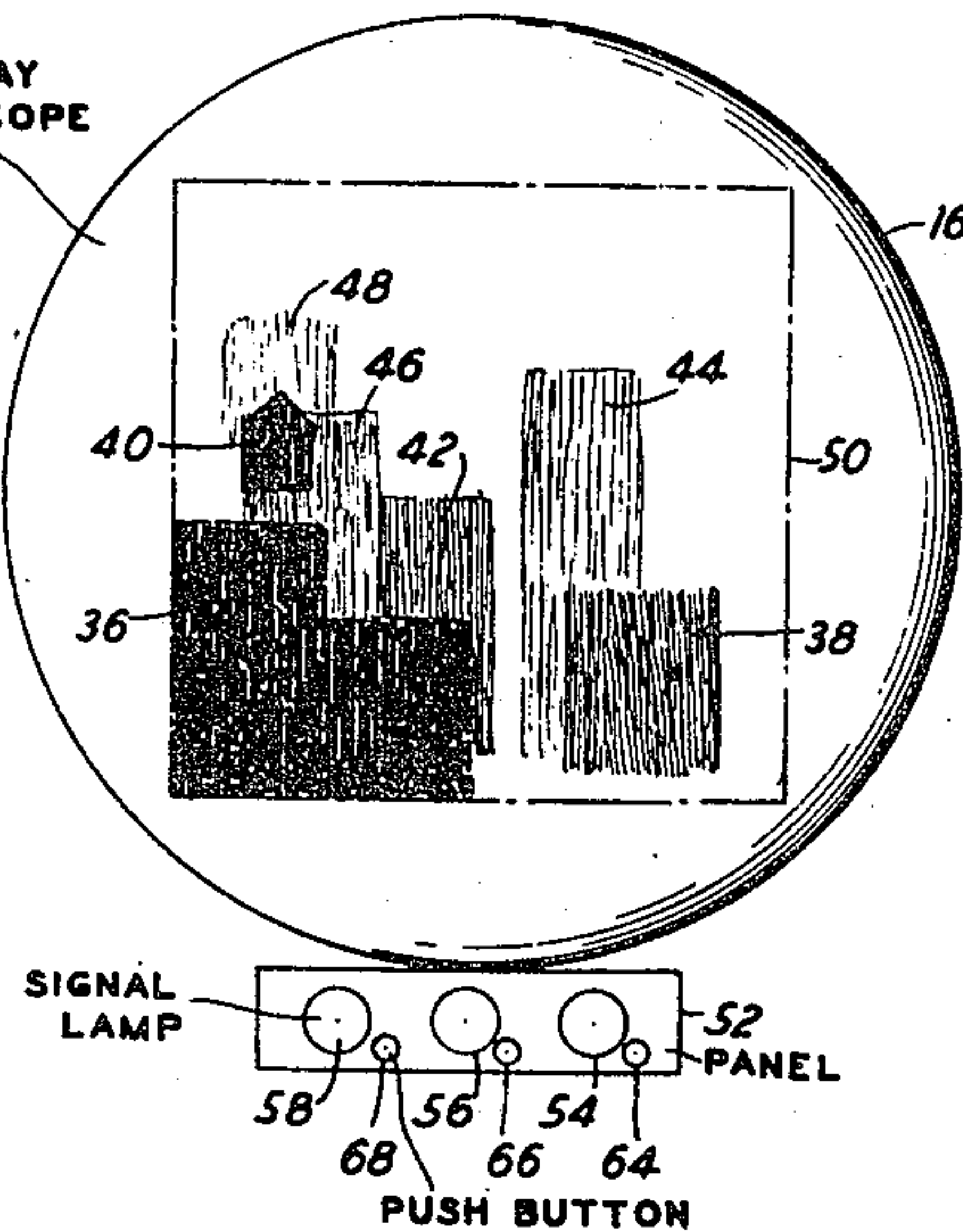


FIG. 5

CATHODE RAY
OSCILLOSCOPE
TARGET

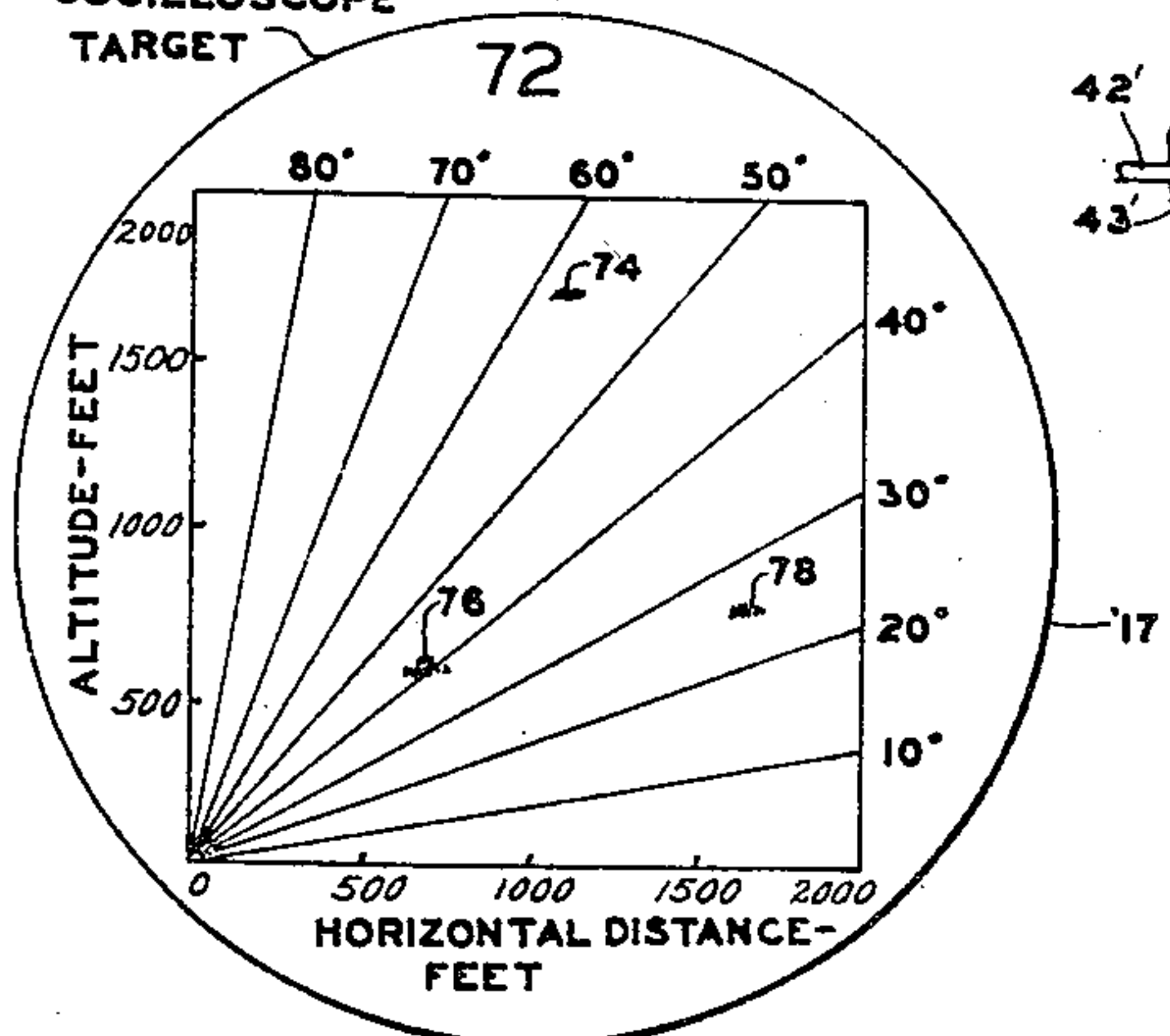
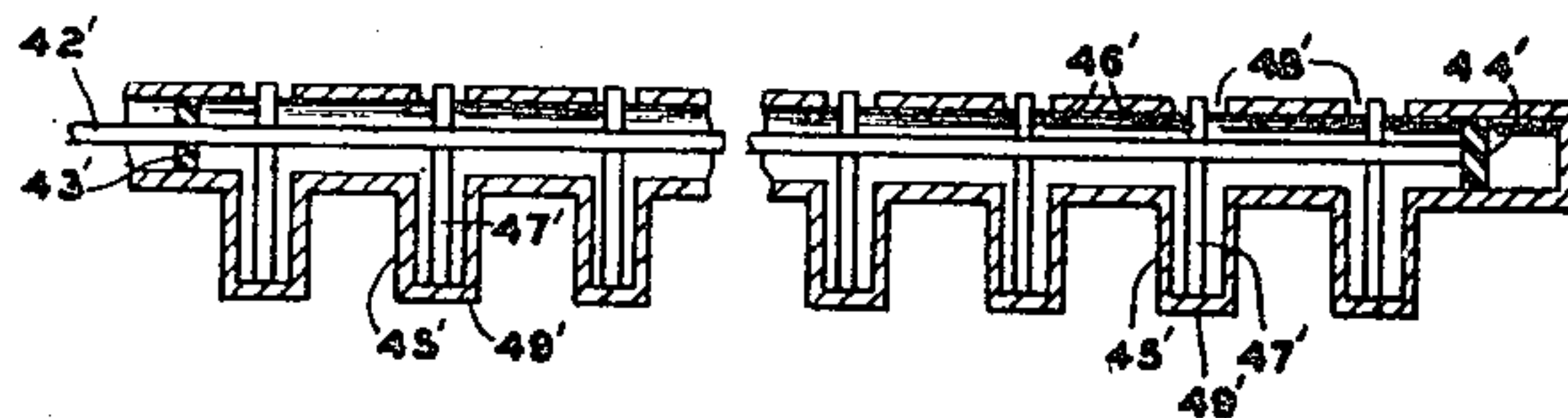


FIG. 6



INVENTOR
L. ESPENSCHIED
BY *H.O. Wright*
ATTORNEY

UNITED STATES PATENT OFFICE

2,426,189

OBJECT LOCATING SYSTEM

Lloyd Espenschied, Kew Gardens, N. Y., assignor
to Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

Application October 4, 1941, Serial No. 413,587

8 Claims. (Cl. 250—1.74)

1

This invention relates to systems and methods employing reflected radio wave energy for visually presenting three-dimensional representations of the number and the respective positions and distances of objects within a region at a distance from the point of observation.

More particularly, the invention relates to systems and methods for use under conditions of fog, darkness or low visibility to provide a visual integrated representation of the number and the respective positions and distances of objects within a region at a distance from the point of observation.

In my joint application with J. G. Chaffee, Serial No. 353,902, filed August 23, 1940, a system is described wherein a two-dimensional representation of the number and position of objects within an area at a distance from an aircraft is provided. In this system, however, only azimuth angle (horizontal angle or position) and distance to each respective object in the area is presented.

In accordance with the present invention both vertical and horizontal positional indications are to be provided in addition to indications of the respective distances of each object within the region explored.

Briefly stated, the invention provides for the two-dimensional scanning of a region with electromagnetic waves, determining the reflection time for receipt of the reflected waves from each object within the region and the presentation as a two-dimension picture of the respective horizontal and vertical angles or positions of each respective object, with the third dimension (i. e., distance) represented in the picture in terms of the relative intensities of the marks that correspond to the objects.

For slow moving craft or for operation from a fixed position the scanning may be done mechanically by oscillating highly directive transmitting or receiving antennas or both to methodically scan the desired region and to receive reflections of wave energy from objects therein.

For rapidly moving craft, such as modern aircraft, electrical scanning, for example, that which can be obtained by passing a variable frequency wave through an electromagnetic prism is more suitable. One type of electromagnetic prism suitable for scanning a line by means of a radio beam deflected in a single plane is described in the copending application of W. P. Mason, Serial No. 381,236, filed March 1, 1941. By mechanically turning such a prism about its longitudinal axis an area can be scanned. More elaborate area scanning prisms are described in a second co-

2

pending application of W. P. Mason, Serial No. 434,396, filed March 12, 1942.

Horizontal and vertical dimensions, or can, of course, be readily reproduced in the picture itself by a movable member caused to scan an area of the picture or surface in synchronism with the scanning region by the electromagnetic waves. The movable member is most conveniently either light as employed in a two-dimensional gage type scanning oscilloscope or the electron beam of a cathode ray oscilloscope.

The distances to the respective objects are determined either by pulsing the transmission and determining the pulse travel time between transmission and receipt of the reflected pulses or by several well-known methods or by frequency modulation method described in Serial Nos. 2,045,071 and 2,045,072, both issued March 23, 1936, in which beat notes, the frequencies of which are indicative of the respective distances from the reflecting surfaces, are obtained. The distance indications are then employed to vary the intensity of the indication provided on the screen of the indicator for each of the objects. For example, objects a short distance away can be represented by bright or intense indicating marks and those more distant by less intense marks in proportion to the distance of the objects.

The above-indicated procedures provide a representation in which the horizontal and vertical directions, or angles, of an object are represented by the horizontal and vertical positions of a corresponding mark on the indicator and the distance to an object is indicated by the intensity or brilliance of its corresponding mark. Such representations should not be confused with photographic or pictorial representations in which variations of intensity indicate differences in color or reflecting properties, or illustrate the relative distances of the several objects and to a much lesser degree distance to the objects as seen directly by light frequencies.

Since electromagnetic waves readily penetrate fog or darkness, a representation of the type described in detail above will be of great value in the navigation of aircraft and other craft under conditions of poor, or no, visibility.

The primary object of the invention is to provide a method and system for representing the position and distance, and three-dimensional form, of all objects within a region extending an appreciable distance from the point of observation.

Another object is to provide improved means to aid and assist in the navigation of mobile craft in darkness or in fog.

A further object is the provision of a visual three-dimensional representation of a region at a point remote from the region, under conditions of low or zero visibility.

Other and further objects will become apparent during the course of the following description and in the appended claims.

The principles of the invention will be more readily understood from the following detailed description of an illustrative embodiment in conjunction with the accompanying drawings in which:

Fig. 1 illustrates in block grammatic form a system of the invention which may be employed to explore a region as indicated;

Fig. 2 represents in perspective a region containing numerous obstacles, mainly buildings which can be employed to illustrate the use of systems of the invention;

Figs. 3 and 4 are illustrative of the type of three-dimensional representations provided by systems of the invention;

Fig. 5 illustrates an auxiliary type of representation readily obtainable in conjunction with systems of the invention when used at a fixed station; and

Fig. 6 illustrates a form of electromagnetic wave prism type radiator or receiver which can conveniently be employed in systems of the invention.

In more detail in Fig. 1 transmitter 10 energizes a highly directive antenna 11 to emit radio waves. Since the size of the apparatus and the degree of directivity are both functions of wavelength, the shortest practicable wave-lengths will preferably be employed in systems of the invention, particularly for systems to be employed on aircraft. In the present state of the art, waves in the neighborhood of ten centimeters in length can conveniently be employed for aircraft use. In one convenient form transmitter 10 can be a conventional vacuum tube oscillator and antenna 11 can be an electromagnetic prism of the type described in the first of the above-mentioned co-pending applications of W. P. Mason, the prism having its longitudinal axis vertical. The electromagnetic prism is described in Mason's above-mentioned application, Serial No. 381,236, as being in one preferred form a coaxial line structure as shown in Fig. 6 of the accompanying drawing. The latter figure is substantially identical with Fig. 5 of the last-mentioned Mason application except that the designation numbers are primed.

As taught by Mason, the coaxial line structure of Fig. 6 comprises a main section of coaxial line having outer conductor 40' and inner conductor 42', this section of line being a dozen or more wave-lengths, of the highest frequency of the system, long, and being provided with regularly spaced shunting coaxial stub lines, comprising outer conductors 45', inner conductors 47' and short-circuiting end members 49', the main and stub lines being proportioned to constitute multisection band-pass wave filter, as described by Mason and R. A. Sykes in the Bell System Technical Journal for July 1937, at page 278, the outer conductor 40' of the main coaxial line having a small orifice 48' opposite each shunting stub line.

This structure will directly radiate each frequency within the pass-band of the wave filter

at a particular predetermined frequency for each frequency different adjacent frequencies so that applied to the prism is frequency swung over a the pass-band of the structure in the plane of the longitudinal coaxial line structure will

To improve the radiating holes Mason provides a small conductor 46' extending from the end of inner conductor 47' to inner conductor 44' centrally positioned within the outer conductor 40'.

For the shunting stub conductors 47' all extend upwardly connected to the inner conductor 44' and the outer conductor 40' connect with the outer conductor 40' line respectively.

Energy to be radiated from the left ends of conductors 44' and 46' at the opposite ends of these conductors 44' having a distance equal in magnitude to the impedance of the prism, energy from the right end is eliminated and possible reactive properties of the prism are avoided. Spacing insulator 42' within conductor 40'.

The prism can, of course, be used for reception as well as for transmission corresponding properties most efficiently to a particular frequency within the pass-band of the prism. When received energy. When receiver is, of course, connected to the free ends of conductors 44' and 46' at the right end to avoid unwanted reflections of energy which could upset the directive properties of the prism.

Prisms of this type transmit maximum efficiency in the longitudinal axis of the prism and, of course, from the holes and, of course, from the device about its longitudinal axis at the same time swinging or varying the energy or varying the frequency of the energy being radiated, over the pass-band of the prism the scanning of the prism, such as azimuth and elevation.

Modulator 14, which is a motor driven variable capacitor, varying the frequency of the transmitted beam through the prism in the above-mentioned manner as taught in the above-mentioned application of W. P. Mason.

Motor 12 provides for the scanning of the prism by means of shaft 154 about its oscillatory manner so that the prism scans horizontally as well as vertically successively scan a large number of elements of a region, for example, of Fig. 2, which it is desired to scan.

The motor of modulator 14 is a drive variable potentiometer, which are bridged by current potential sources

voltages for the horizontal deflecting plates 20 and vertical deflecting plates 18, respectively, of cathode ray oscilloscope 16 causing the ray of the tube to scan its target in synchronism with the scanning of the region 150 by the electromagnetic wave 34.

The use of potentiometers bridged across appropriate direct current potential sources and an oscilloscope in this manner is well known in the art and is, by way of example, illustrated and described in detail in my above-mentioned co-pending joint application. The use of a motor to produce oscillatory motion about a given axis is, of course, also well known in the art.

Receiving antenna 27 is preferably only broadly directive so as to receive reflections from any point within the region scanned by the highly directive beam of transmitting antenna 11. Alternatively the transmitting antenna could be broadly directive to cover the entire region simultaneously and antenna 27 could be highly directive and arranged to scan the region point by point. Or again both antennas could be made sharply directive and the two synchronized in their scanning action.

The received reflected waves 28 are combined and detected in receiver 26 with energy of the instantly transmitted waves derived from transmitter 10 over line 19, and beat-note frequencies resulting from this process, as described in my above-mentioned patents, are provided to conversion circuit 24.

Conversion circuit 24 converts the beat-note frequencies into direct current voltages whose magnitudes are proportional to the respective frequencies of the beat notes as described for the circuit actuating the indicating meter (altimeter) shown in United States Patent 2,247,662, issued July 1, 1941, to R. C. Newhouse. To avoid any likelihood that amplitude modulation of the reflected waves might result in incorrect intensity modulation of the cathode ray of systems of the present invention the principles taught in co-pending application of R. C. Newhouse, Serial No. 351,759, filed August 7, 1940, can be employed. United States Patent 2,261,272 issued to Newhouse on this application, November 4, 1941.

Circuit 24 further amplifies the direct current voltages thus obtained in a direct current amplifier having a negative slope so that a direct current voltage is obtained which varies inversely with the beat-note frequency. This voltage is then applied to the control grid 22 of cathode ray tube 16 and provides intensity modulation of the cathode ray.

From the above it is evident that lower beat-note frequencies result from reflections from nearer objects in the region scanned and are ultimately converted into larger direct current potentials which cause the cathode ray beam to become more intense (or brighter) than for higher beat-note frequencies which result from reflections from more remote objects in the region scanned. Where no reflections are obtained no voltage is provided control grid 22 by circuit 24 and the normal bias on grid 22 is sufficient to reduce the intensity of the ray to a substantially negligible value. This arrangement is, as was previously suggested, somewhat analogous to intensity modulation of the ray of an oscilloscope in television systems, the chief and very important difference being that in the latter systems the intensity modulation is employed to represent light or color contrasts whereas in the systems of the present invention intensity modulation is em-

ployed solely to represent third dimension distance.

In Fig. 2 a representative region 150 of is indicated in which an assortment of buildings 136, 138, 142, 144 and 146 of various heights and water tanks 140 and 148 are in perspective.

In Fig. 3, upon the target 16 of a cathode oscilloscope, is indicated a representation substantially such as would be obtained upon scanning region 150 of Fig. 2 with a system of the invention, such, for example, as that illustrated in Fig. 1, mounted on an aircraft approaching the region. In representation 50, the indication being the most intense, represents the building 136 in the area and the progressively more distant buildings 138, 142, 144 and 146 represented by the progressively less intense indications 38, 42, 44 and 46, respectively. 148 being the most distant object in the region represented by the faintest indication 48 of. As previously mentioned, it should be particularly noted that the intensity modulation of the cathode-ray beam in the systems of this invention controlled by positive measurements of the distances to the several reflecting objects is of very substantial significance for it is well established in this art that the amplitude of a received reflection is by no means a true indication of the distance to the object. For example, it has been repeatedly observed that a particular object at a known substantial distance will provide reflections of varying amplitudes depending upon the angle at which energy is reflected from the object, analogous to the glints obtained in the reflection of light from particular objects when at particular angles. At the correct angle, the objects otherwise invisible or substantially so.

For convenient reference a block or plate 56 carrying several calibrated electrical lamps 54, 56 and 58 which when depressed will illuminate adjacent lamp, respectively, is provided adjacent the oscilloscope target to assist the observer in estimating from the intensities of the representations and approximate distances thereof. For example, the potential applied to lamp 54 push button 64 is depressed can be adjusted so that the intensity of the lamp corresponds to the intensity of the indication provided by the system for an object at a measured distance in feet; similarly, lamps 56 and 58 can provide intensities corresponding to indications provided by the system for objects at specific distances, such, for example, as 2500 feet and 5000 feet, respectively. These adjustments can conveniently be made, for example, with the lamps in a fixed position and with fixed target. The desired measured distances in which the intensities are to be adjusted.

Systems of the invention such for example as that illustrated in Fig. 1, can also be employed for fixed observation points, for example at a fixed point to scan regions of the air and to provide an integrated representation of all aircraft in the region scanned, the azimuth angle of a particular aircraft with respect to the point of observation indicated by the horizontal location of the corresponding indication, its vertical angle by the vertical location and its distance by the intensity of the indication, the intensity, of course, increasing as the craft approaches or decreasing as the craft recedes from the observation point. A representative pattern is indicated in

indications 62, 64, 66, 68 and 70, representing aircraft at various horizontal and vertical angles and at various distances. The pattern of Fig. 4 is, of course, identical in nature with that of Fig. 3.

For use at such fixed observation points for following the movements of aircraft it will be advantageous to add a second cathode ray indicator 17 of Fig. 5, the beam of which scans an area 72 radially from a point in the lower left corner, the scanning angle being varied in synchronism with the vertical scanning motion of the exploratory radio beam of the system. Further provision is then made to arrest the turning motion of antenna 11 at any desired azimuth angle while continuing the frequency modulation of transmitter 10, so that vertical scanning is continued, and the beam is intensity modulated by the receipt of reflected waves so that for a vertical plane at any azimuth angle of the region scanned, a plan view of aircraft therein, their respective vertical angles, altitudes, and distances is visually presented. A representative pattern of this type is shown in Fig. 5, indications 74, 76 and 78 representing aircraft in a particular vertical plane (i. e., at the same azimuth angle but at different vertical angles). Radial scanning and distance indication for this single vertical plane arrangement can be effected in accordance with principles and systems described in the copending application of N. W. Bryant, Serial No. 423,757, filed December 20, 1941. In a typical system of this last-mentioned application, a highly directive antenna is rotated about a vertical axis, the distance to each object is determined by measuring the reflection time of reflected energy received therefrom and the azimuth angles and distances of all objects from which reflected energy is received are represented on a circular pattern the center of which represents the position of the exploratory apparatus, each object being represented by a mark at its corresponding azimuth angle and at a radial distance from the center point proportional to its actual distance from the exploratory apparatus. In the present instance, however, scanning through radial angles of a 90-degree range will usually be sufficient, since a vertical rather than a horizontal plane is being investigated.

Numerous additional applications of the principles of the invention will occur to those skilled in the art and no attempt has here been made to exhaustively cover all applications thereof. The scope of the invention is defined in the appended claims.

What is claimed is:

1. In an object locating system of the type which employs an exploratory energy beam to scan in azimuth and elevation, a region remote from said system, receives reflections of said beam from objects within said region and employs the received reflected energy to actuate an indicating mechanism having a movable marking member, the marking member being arranged to scan a two-dimensional area on a screen in synchronism with the scanning of the region by the energy beam, whereby the indicating mechanism presents a two-dimensional diagram of the position of objects within the region scanned by the system, the method of representing a third dimension, namely, distance, for the respective objects appearing in the two-dimensional representation which comprises determining the distance from the system to each object by measuring the reflection time of waves projected to

strike the object and varying representations for the severance with the determined distances thereto, respectively tances to respective objects intensities of their respective the diagram.

2. A navigational aid for ring means on said craft for dimensional representation of active positions of objects with tance from the craft, means positively determining the object from said craft and m intensities of the representative objects in accordance determined distances where is effectively represented.

3. A system for seeing by projected from an observational view which comprises means radio waves as a sharp beam sional cross section of the at said point, including a cat for scanning synchronously ray beam over a corresponding screen picture, means for r said beam and means for m tervals of reflections receive determining thereby the di tive reflecting objects in t said point, and means for tern of reflections as a two according with the two-dim beam scanning, the brilliant which picture being cont with the positive distances ceived reflections, respectively.

4. In a system for rendering torial form at an observational gathered by receiving reflected following combination, a fr of high frequency oscillati beam transmitting antenna displacement of the radio l observation in accordance swing, a receiver of the reflected waves for producing portional to the respective ing objects, a picture forming graph the beam of which is dimensional screen in synchroning of the radio transmitting for controlling the intensity beam in accordance with ing beat frequency output c impart information, as to respective objects from t to the picture.

5. In an object locating antenna passing a particular a shaft supporting said antenna the longitudinal axis thereof shaft to rotate, a source of said antenna, a motor act nected to said source of ex the frequency of the energy within the first stated pa by the beam emitted by said a region in space in two each other, a receiving an ceive reflections of said be in the region scanned by receiver and demodulator receiving antenna, a cor

receiver and said source of energy directly providing said receiver with a small amount of the energy of said source, said receiver combining said directly derived energy with the received reflected energy and demodulating it to obtain beat notes the frequencies of which are indicative of the distances to the respective objects from which they are received, a cathode ray oscilloscope having horizontal and vertical deflecting plates and a control anode, a first variable potentiometer connected across a direct current source, the potentiometer being varied by the motor rotating the prism antenna the variable voltage obtained across the potentiometer being connected across one pair of deflecting plates, a second variable potentiometer connected across a direct current source, the potentiometer being varied by the motor actuating the modulator, the variable voltage obtained across the second potentiometer being connected across the other pair of deflecting plates whereby the ray of the oscilloscope when present is made to scan a two-dimensional area on its target in synchronism with the scanning of the region by the emitted beam of said prism antenna, a beat frequency conversion circuit connected to said receiver and demodulator, said conversion circuit converting the beat note frequencies of said receiver into direct current voltages the values of which are inversely proportional to frequency, and a connection between the output of said conversion circuit and said control anode of said cathode ray oscilloscope whereby indications are provided by changes of intensity of the beam of said oscilloscope when reflected waves are received, the intensities being inversely proportional to the distances of the objects from which reflections are received and the directions of the objects being indicated by the position of the indications on the cathode ray oscilloscope target.

6. In an object locating system, the combination which comprises a source of wave energy, a directional energy beam projector connected to said source, a control mechanism moving said directional beam to scan a particular area, an oscilloscope having an indicating element and deflecting and intensity control elements operative to control said indicating element, a second control mechanism coupled with the first stated control mechanism and the deflecting control elements of said oscilloscope to control the movement of the indicating element in accordance with and synchronously with the scanning motion of said directional beam, a wave energy receptor adapted to receive reflections of said beam from objects within the area scanned and a reflection time measuring device interconnecting said receptor and the said intensity control element of said oscilloscope whereby indications are provided on said oscilloscope the positions of which indicate the directions of reflecting objects within the area scanned and the intensities of which represent the distances to the reflecting objects respectively.

7. In the art of object location by means of energy waves, the method of providing simultaneous indications of the distance from an observation point to a plurality of objects within a predetermined region which comprises projecting a defined exploratory beam of energy at said region thereto a scanning motion such that the beam repeatedly scans in a regular manner a predetermined region, imparting to a marking element associated with said device a scanning motion with respect to the screen of said device similar to and synchronous with the scanning motion imparted to the beam, receiving reflections of said beam from objects within the region scanned, determining for each reflected energy received the time required for that energy to travel from the observation point to the reflecting object and back to the observation point, controlling the marking element of said device to provide indications at points on the scanning path corresponding to those of the scanning path of the exploratory beam, whereby reflections of the projected beam which are received, the intensity of these indications being varied in proportion to the travel time determined for each path of reflection whereby the direction of each reflecting object within the region scanned is denoted by the position of its corresponding indication on the screen of the oscilloscope and the distance to each object is indicated by the intensity of its corresponding indication, the intensities of indications on the screen of the device are controlled solely in accordance with the distances of the reflecting objects respectively from the point of observation, the intensities being controlled entirely independently of the amplitude of the reflected energy received.

8. In an object locating system, means for emitting a directional energy beam from an observation point for emitting a directional energy beam, means for directing said beam to scan a predetermined region, means for receiving reflections of said beam at said observation point from objects within the region scanned, means for determining the times of the received reflections, means for indicating on a two-dimensional screen the respective relative positions of the objects from which reflections are received, means for controlling the intensities of the indications afforded by the indicating element in accordance with the reflection time of the reflections for the received reflections, respectively.

LLOYD ESPEN

REFERENCES CITED

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

UNITED STATES PATENTS

Number	Name
2,231,929	Lyman