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[21] Appl. No. 802,008
[22] Filed Feb. 25, 1969
[45] Patented Mar. 2, 1971
[73] Assignee the United States of America as represented
by the Secretary of the Navy

3,422,437 1/1969 Marston 343/854X
3,438,038 4/1969 Marston 343/854X

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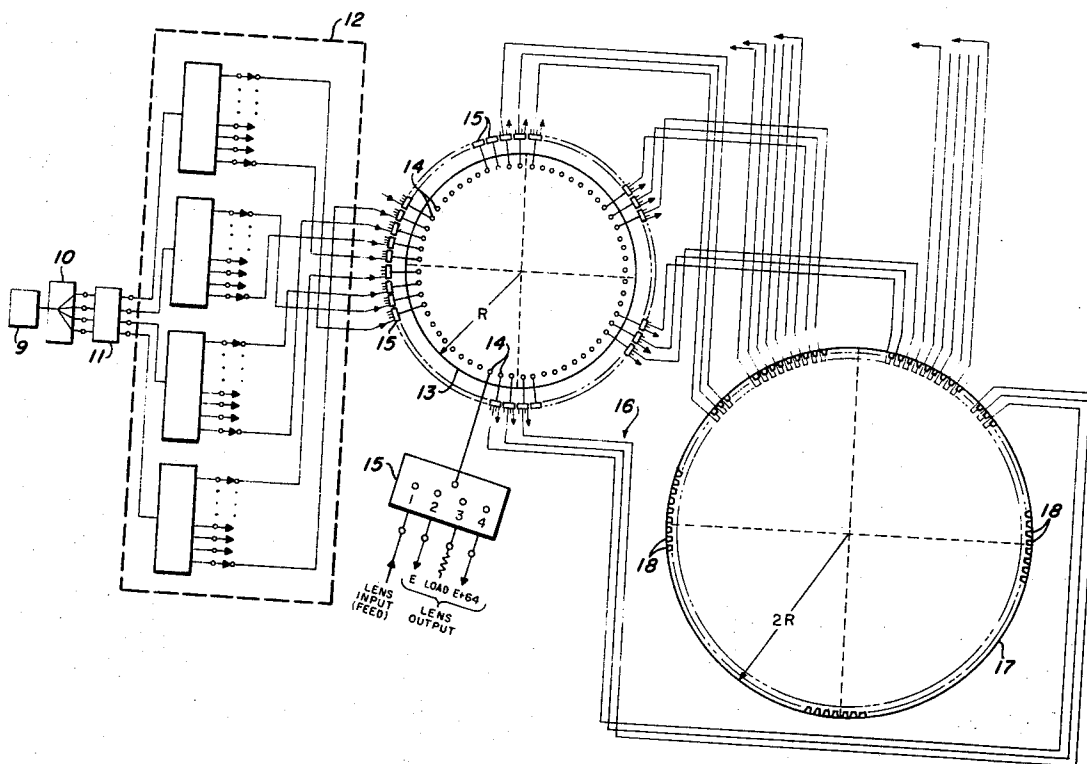
[54] PARALLEL-PLATE FEED SYSTEM FOR A
CIRCULAR ARRAY ANTENNA
4 Claims, 3 Drawing Figs.

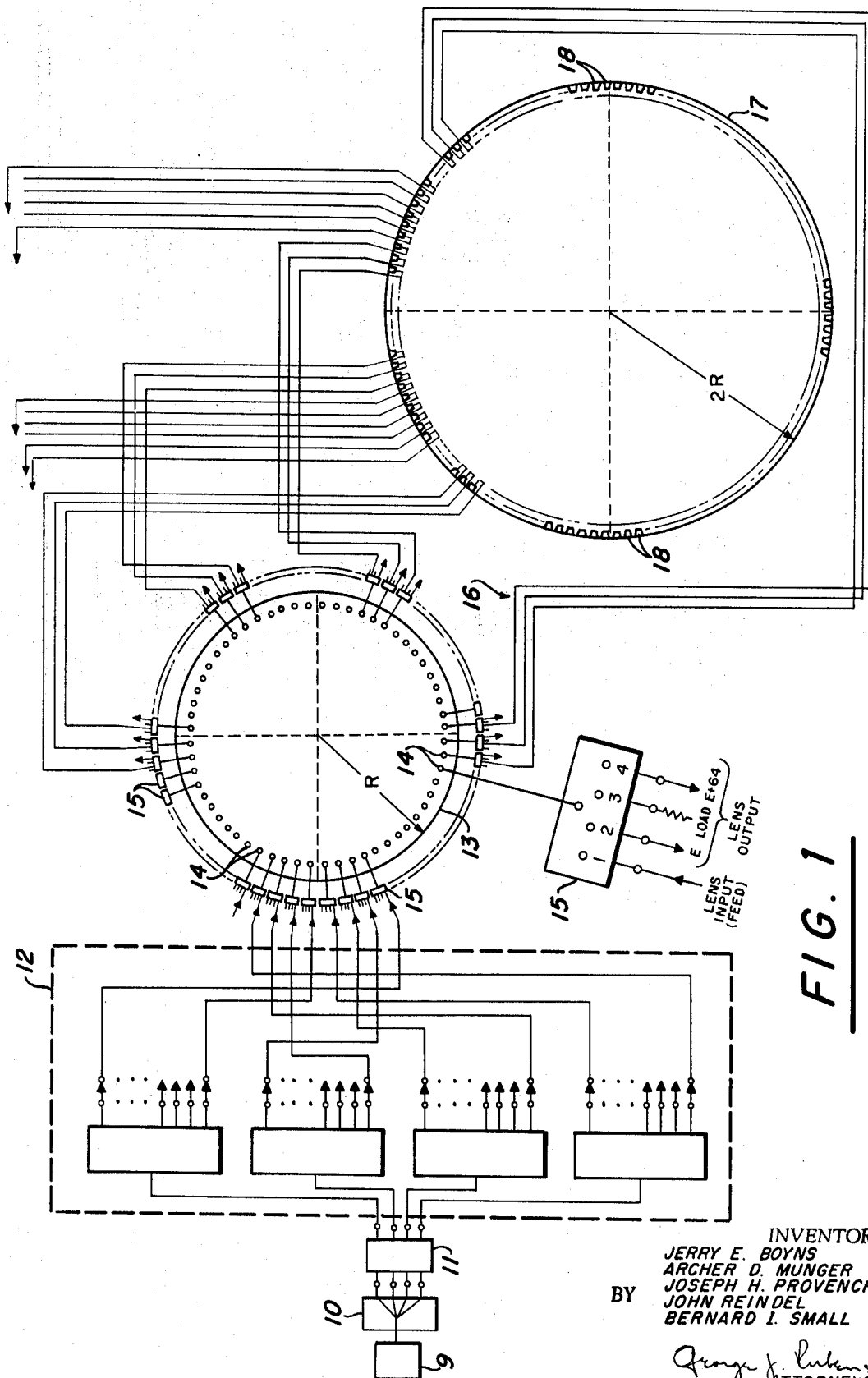
[52] U.S. Cl. 343/754,
343/854, 333/7
[51] Int. Cl. H01q19/06,
H01q3/26
[50] Field of Search. 343/853-
—854, 754, 876, 844, 909, 911; 333/7

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ABSTRACT: A parallel-plate feed system for a circular array antenna is disclosed. The feed system comprises a parallel-plate region which places the correct phases at the array radiating elements when the parallel-plate region and the array radii are in a 1:2 ratio. Positioned about the periphery of the region are a plurality of input-output ports or probes. A plurality of adjacent input ports are fed simultaneously with a tapered amplitude distribution. By feeding more than one of the input probes simultaneously, the energy propagated through the parallel-plate region is highly directive, and the amplitude distribution obtained at the output probes has a considerable taper. By applying the resulting amplitude distribution to a sector of the circular array with the proper phase from the region low sidelobe patterns can be obtained. The beam is scanned in azimuth by means of diode switches at each lens port and by additional circuitry to maintain the proper input-probe taper. The system is operable over a 20 percent frequency band.





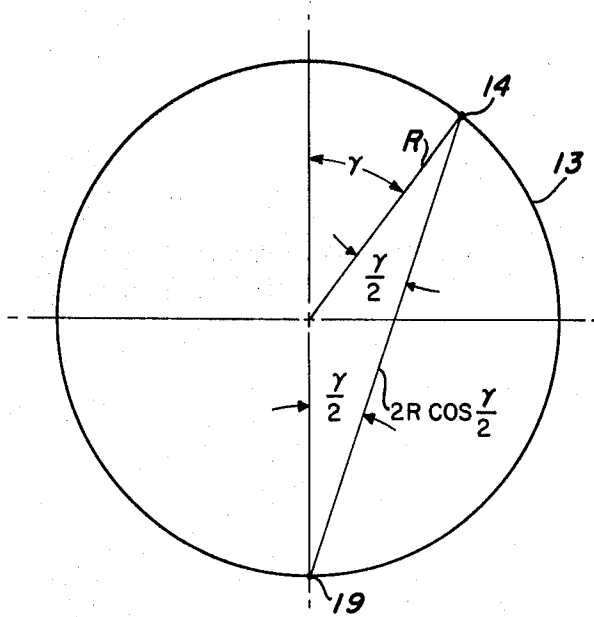


FIG. 2

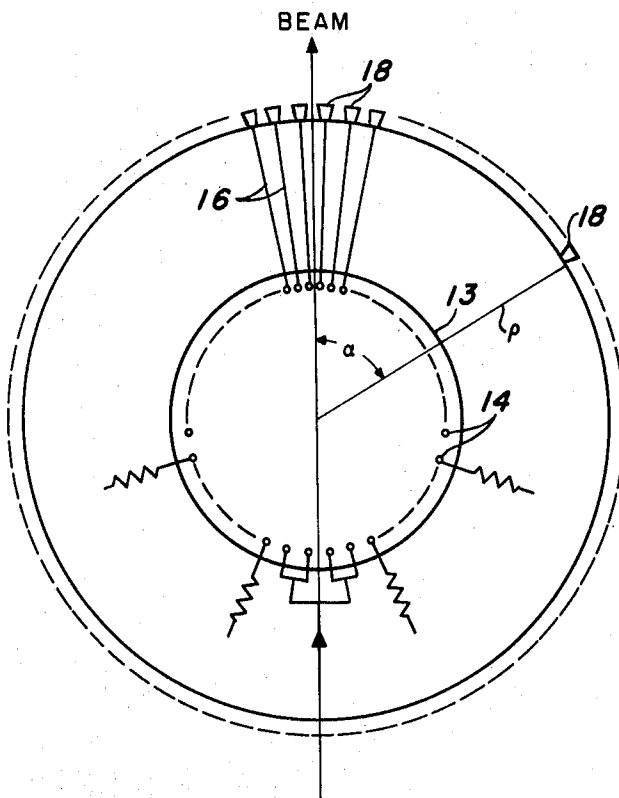


FIG. 3

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PARALLEL-PLATE FEED SYSTEM FOR A CIRCULAR ARRAY ANTENNA

BACKGROUND OF THE INVENTION

The need for more sophisticated shipboard radar systems grows with the increased variety and capability of enemy threats to surface vessels. Broad-spectrum signal capability, antenna beams with low sidelobes, and bearing agility independent of frequency, and automatic detectors are desirable characteristics for improving the capability of shipboard radar. For example, in a heavy jamming environment, wide-band antennas force a would-be jammer to use a wide variety of jamming equipment, thereby making his task more difficult.

One antenna configuration that satisfies these characteristics and in addition offers important advantages is the stationary switch-beam cylindrical array, a smooth-walled structural cylinder which supports a plurality of circular arrays, or rings, in a stacked relationship to each other. The streamlined design of the cylindrical array reduces wind and blast resistance, and because fewer radiating elements than in a linear array are required, an appreciable saving of space and weight is achieved.

If all the radiating elements in a ring are excited, the tolerances on the amplitude and phase required at each element for adequate sidelobe level, beam width, and band width are difficult to control.

However, the desired results can be achieved from a circular array by the application of a beam-cophasal distribution and a tapered amplitude distribution.

A device which will produce a beam-cophasal distribution is the parallel-plate region, a wide-angle scanning system that provides configuration focusing. The conventional region design uses a single input port, and thus limits the output amplitude distribution of the region with respect to the taper which can be obtained. Since the amplitude distribution affects the sidelobe level, low sidelobes cannot be obtained.

SUMMARY OF THE INVENTION

The present invention comprises apparatus for feeding a circular array antenna to produce low sidelobe patterns. The circular array comprises a plurality of radiating elements embedded along the circumference of a metallic cylinder. The array is fed by means of a parallel-plate region consisting of two circular metal plates having a plurality of input-output ports equispaced along the circumference of the region. The parallel-plate region is fed by simultaneously exciting a plurality of input ports positioned adjacent to each other with a tapered amplitude distribution. The ports which are thus excited comprise, in effect, substantially a small linear array, and thus some control over the amplitude distribution obtained at the output ports can be achieved. The amplitude distribution that results at the output ports has a considerable taper, and when it is applied to the radiating elements with the proper phase from the parallel-plate region, low sidelobe patterns can be obtained. Various numbers of input and output ports are selected to obtain the amplitude and phase distribution required for an antenna beam of the desired sidelobe level and beam width.

Steering of the antenna beam through a desired number of discrete steps for 360° coverage is achieved by means of a diode switch at each port and additional switches to provide for scanning the input ports around the parallel-plate region.

STATEMENTS OF THE OBJECTS OF THE INVENTION

An object of the present invention is to provide apparatus for feeding a circular array antenna in a manner that produces antenna beams with low sidelobe patterns.

Another object of the present invention is to provide apparatus for feeding a circular array antenna to produce antenna beams having bearing agility independent of frequency.

Another object of the present invention is to provide apparatus for feeding a circular array antenna to produce an antenna beam which can be steered through 360° in a predetermined number of discrete steps.

Another object of the present invention is to provide a feed system for a circular array antenna in which a single parallel-plate region is used as a feed structure to obtain the amplitude and phase distribution required for low sidelobe patterns.

Another object of the present invention is to provide a parallel-plate feed system for a circular array antenna in which a plurality of input ports are excited simultaneously.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of the parallel-plate feed system of the present invention;

FIG. 2 is a representation of the geometry of the parallel-plate region used in the feed system of the present invention; and

FIG. 3 is a schematic of a typical circular antenna array connected to the feed system of the present invention.

In the drawings, like numerals refer to identical parts.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 is a schematic drawing of the parallel-plate feed system of the present invention. In FIG. 1, sending apparatus 9, which can be either transmitting or receiving means, is connected to the input of power divider 10. The output of power divider 10 is connected to an amplitude pass-around switch 11 in series with a switching network 12 consisting of four single-pole-16-throw switches.

A parallel-plate region 13 consists of two circular metal plates having a radius R approximately equal to $13\lambda/2$ where λ represents a free-space wavelength, and spaced in parallel relationship to each other at a distance of approximately $\lambda/3$. Equispaced and supported about the circumference or periphery of the parallel-plate region 13 are 64 input-output ports designated by numeral 14. The ports are located with proper spacing between each other and the region enclosing ground plane to minimize reflections of electromagnetic energy.

Connected to each port 14 is an SP4T diode switch 15. The input of each of the switches 15 is connected to an appropriate output terminal of switching network 12. Each of the SP4T switches 15 has an input terminal 1 to the parallel plate region, and three output terminals 2, 3, and 4 as shown in the expanded view of switch 15. Terminals 2 and 4 are connected by means of equal-length cables 16 to two diametrically opposite radiating elements 18 located on the cylindrical array antenna 17 and designated as E and E+64 in the expanded view of switch 15. Output terminal 3 is terminated in a characteristic impedance load when the output port is unused.

The circular array antenna 17 consists of 128 radiating elements equispaced at a distance of approximately $\lambda/2$ and embedded in a smooth-walled cylinder having a radius of approximately 13λ at the center frequency. Usually, a plurality of such circular arrays, or rings, are "stacked" upon each other within a cylinder to constitute a cylindrical array. The radiating elements can be sectoral horns of the type described in a copending application, Ser. No. 795,512 (Jan. 31, 1969), filed in the name of Jerry E. Boyens, and entitled "Coaxial-Line to Waveguide Transition for Antenna Arrays." The sectoral horns are end-fed by means of a miniature connector which is connected to the end of a rectangular waveguide opposite the open end of the waveguide. The miniature connectors are adapted to received a cable 16 connected at the opposite end to the parallel-plate region output ports 2 and 4 of switch 15.

The parallel-plate region feed system of the present invention,

however, is not restricted to the use of radiating elements of the type described herein and in said pending application.

THEORY AND OPERATION

To obtain the characteristics of broad-spectrum signal capability, antenna beams with low sidelobes, and bearing agility independent of frequency, a feed system is required which can overcome certain difficulties which normally exist in the application of the cylindrical array. First, to utilize the symmetry of the cylinder, the directional pattern must be rotatable, i.e., steerable, by electronic means, and, in general, the methods which can be used to accomplish this are more complicated than the simple phasing of a linear array. Second, the amplitude taper must also be rotated. Since the individual element pattern is a function of array radius and elevation angle, deterioration of the azimuth beam results when the elevation angle departs from the normal. The difference in amplitude and phase for most elements of the array and the variation of these differences around the array present stringent requirements for control of the amplitude and phase distributions for adequate limitation of the sidelobe level over a wide frequency band.

A circular-array, or ring, in a cylindrical-array antenna will provide the desired radiation pattern characteristics if a Tchebycheff distribution is applied to all of the radiating elements in the circular-array and if the interelement spacing is properly chosen, as is well known to those skilled in the art. For some configurations, however, the allowable interelement spacing exceeds the limits imposed by the Tchebycheff formulation. For example, if the desired characteristics from the circular array antenna of the preferred embodiment are 128 beam positions with a beam crossover of an about -2db , a half-power beam width on the order of 4° , and a sidelobe level of -25db , the Tchebycheff distribution cannot be used since the interelement spacing limits are exceeded.

However, the application of a beam-cophasal distribution and a tapered amplitude distribution to a sector of the array will produce approximately the same results. If a maximum of 90° on each side of center of a feed system providing a beam-cophasal distribution is used, satisfactory agreement between the cophasal and Tchebycheff values for this region can be obtained.

One method of providing a beam-cophasal distribution to the array is to use a parallel-plate region 13 having a geometry as shown in FIG. 2. If the spacing between the parallel sheets in less than $\lambda/2$, then the electric field will be normal to the parallel sheets. The phase distribution required to position a beam at 0° elevation and any azimuthal position at angle α can be readily determined from the following equation: $\psi(\alpha) = K \rho [1 - \cos(-\alpha)]$ where $\psi(\alpha)$ is the required phase for a radiating element located on the antenna at an angle α , ρ is the radius of the array, not shown, in any azimuthal position, and K is a constant. The angle α and array radius ρ are shown in FIG. 3.

Referring to FIG. 2, it can be seen that energy introduced at point 19 travels a distance equal to $2R \cos \gamma/2$ where it is received a pickoff probe 14 at an angle γ . The ring array of radius R requires that the distance the energy must travel be equal to $R \cos \alpha$ for an antenna element located at an angle α . The proper phase distribution will be provided by the parallel-plate region if

$$R = \frac{1}{2} \rho$$

and $\gamma = 2\alpha$

Thus, a parallel-plate region having a radius equal to one-half the radius of the cylindrical array and having N ports is required if the array has $2N$ radiating elements. Each port output feeds two diametrically opposite elements on the array. In the preferred embodiment, for 128 radiating elements, 64 ports are required. However, the value of N is limited only by the physical dimensions permissible for the parallel-plate region and the cylindrical array.

During operation, energy from sending apparatus 9 is applied to power divider 10 to provide the proper amplitude taper required to obtain the desired antenna radiation characteristics. Amplitude pass-around switch 11 and switching network 12 feed the tapered amplitude distribution from power divider 10 to several adjacent input ports 15 of the parallel-plate region.

Usually, the conventional parallel-plate region is fed by a sectoral horn or a single probe, and thus the amplitude distribution produced at the output ports cannot be easily controlled. Since the amplitude distribution directly affects the sidelobe level, low sidelobes cannot be obtained. In the present invention, however, it is possible to excite several adjacent input ports simultaneously by means of the switching network. By exciting several, usually three or four, adjacent ports simultaneously with a tapered amplitude distribution, a desired amplitude distribution is achieved at the output ports. That is, by feeding region 13 through substantially a small linear array, the amplitude distribution at the output probes can be controlled.

The SP4T diode switches 15 at each port determine whether the port is an input port 1, an output port 2 or 4 connected to either one of two radiating elements, or unused and terminated in a characteristic load impedance. Thus, by means of the switches 11, 12 and 15, which constitute a scanning switch network, the antenna beam can be electronically steered through a full 360° in 128 discrete steps.

The amplitude distribution produced at the output ports is applied to the desired radiating elements 18 by means of equal-length electrical cables 16. Since the amplitude distribution has a considerable taper, when it is applied to the radiating elements with the proper phase from the parallel-plate region 13, low sidelobe patterns can be obtained.

Experiment has demonstrated that a total of 32 or 33 of the 128 radiating elements are excited by the parallel-plate region output ports depending on whether four or three input probes of the region are used.

Obviously many modifications and variations of the present invention are possible in the light of its teachings and it is therefore to be understood that within the scope of the disclosed concept the invention may be practiced otherwise than as specifically described.

We claim:

1. A parallel-plate feed system for a circular-array antenna comprising:
 - a. sending apparatus;
 - b. power divider means connected to said sending apparatus;
 - c. a parallel-plate region consisting of two circular, metal plates of radius R spaced in parallel relationship to each other;
 - d. a plurality of ports equispaced and supported substantially about the circumference of said parallel-plate region;
 - e. means connected between the output of said power divider means and the inputs of said ports for providing a tapered amplitude distribution simultaneously to a predetermined number of adjacent ports;
 - f. a circular-array antenna of radius $2R$ consisting of $2N$ radiating elements equispaced substantially about the circumference of said circular array, wherein N equals the number of said ports; and
 - g. equal-length cables connected between the output of each of said ports and the inputs of two diametrically opposite radiating elements.
2. The parallel-plate feed system of claim 1 wherein $N = 64$.
3. The parallel-plate feed system of claim 2 wherein said radius R is approximately equal to $13\lambda/2$, where λ is a free-space wavelength.
4. The parallel-plate feed system of claim 3 wherein said metal plates are spaced less than $\lambda/2$ between each other.