

June 2, 1964

S. L. EHRLICH
 LINEAR RADIATING ARRAY HAVING OMNIDIRECTIONAL
 CHARACTERISTICS IN AN AZIMUTHAL PLANE
 Filed April 30, 1959

3,135,944

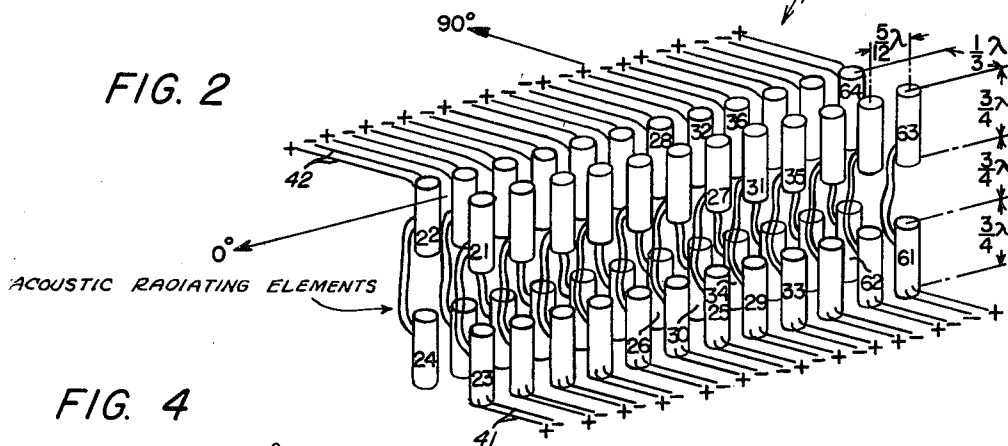
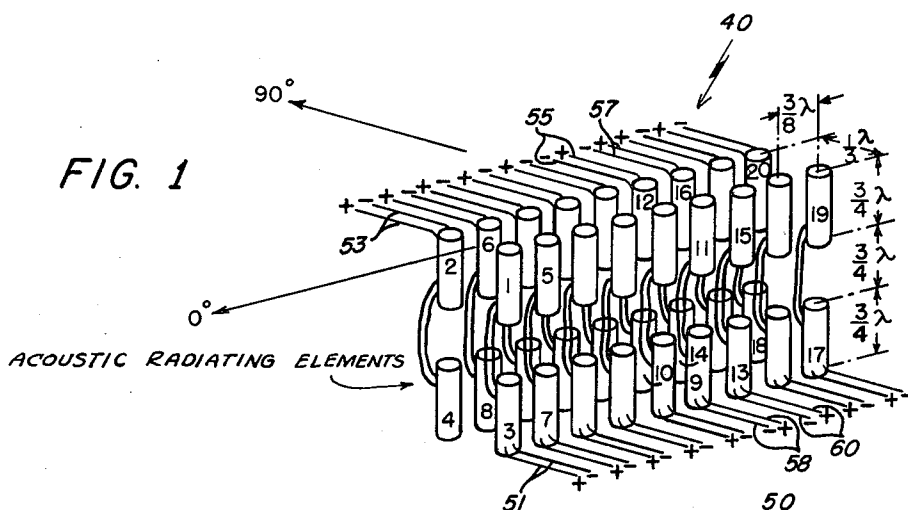
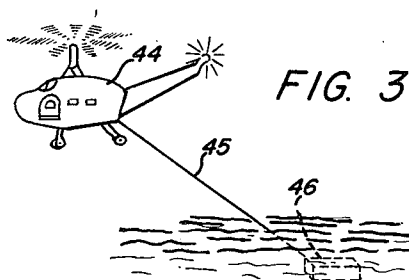
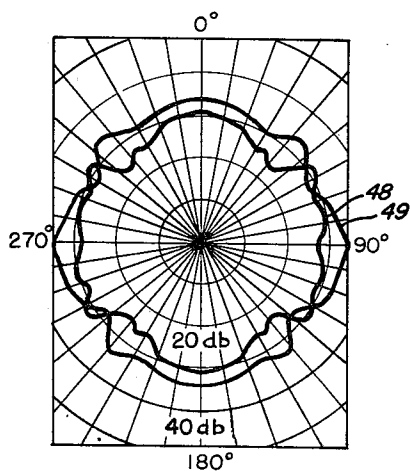


FIG. 4



INVENTOR
 STANLEY L. EHRLICH
 BY *H. Vincent Harsha*
 ATTORNEY

1

3,135,944

LINEAR RADIATING ARRAY HAVING OMNIDIRECTIONAL CHARACTERISTICS IN AN AZIMUTHAL PLANE

Stanley L. Ehrlich, Waltham, Mass., assignor to Raytheon Company, Lexington, Mass., a corporation of Delaware

Filed Apr. 30, 1959, Ser. No. 810,176

2 Claims. (Cl. 340-9)

This invention relates to energy radiating and receiving arrays in which the energy pattern is shaped to provide a desired pattern characteristic, and more particularly to transducer and antenna arrays of the type wherein the radiating elements are spaced in a rectangular array having a low frontal area to permit towing of the array by a moving vehicle or aircraft.

In directional radiating systems of the kind employing a plurality of radiating elements arranged in a rectangular array for convenient towing, all the elements of said array are usually phased to direct a beam in a predetermined direction. By so phasing the elements of the array, a major lobe and a plurality of side lobes are produced having radiation nulls or minima between adjacent directional lobes. With a pattern characteristic of this type, it is difficult if not impossible to transmit energy simultaneously and linearly in all directions. In numerous applications, it is desirable to provide an omnidirectional beam pattern in the azimuthal plane during transmission of acoustic or electromagnetic energy and a beam pattern which is directional during reception of said energy. It is particularly desirable to provide a rectangular transducer array capable of a circular radiation pattern uniform within approximately $\pm$ three decibels for the transmission and reception of acoustic and electromagnetic energy.

In accordance with one embodiment of the invention, nine pairs of radiating elements are arranged in two parallel rows spaced approximately one-third wavelength apart at the operating frequency of the array. Each element comprises two transducer units mounted along a vertical axis and adapted to radiate energy from both ends of each transducer unit. Each transducer unit has a physical length approximating three-quarter wavelength at the operating frequency of said array and adjacent elements in a given row are spaced approximately three-eighths wavelength apart. To provide a uniform directional pattern from this rectangular array, the first five pairs of elements and the eighth and ninth pairs of elements from the front or towing end of the array are connected in one polarity i.e., to be fed with a current of one polarity providing a first phase relationship, and the sixth and seventh pairs of elements are connected in the opposite polarity, i.e., to be fed with current of the opposite polarity to provide a phase relationship opposite to the aforementioned phase relationship. In this manner, the radiating array is adaptable for towing as from a surface craft or helicopter inasmuch as the low frontal area of the rectangular array presents a minimum hydrodynamic and aerodynamic drag.

In another embodiment, the invention discloses a rectangular array of twelve pairs of energy radiating elements arranged in two parallel rows spaced approximately one-third wavelength apart. Each element comprises identical upper and lower substantially colinear transducer rods having a physical length approximating three-quarter wavelength and spaced three-quarter wavelength apart at the operating frequency of the array. In this embodiment the first six pairs of elements and the tenth and eleventh pairs of elements are connected to be fed with current of one polarity and the seventh, eighth, ninth and twelfth pairs of elements are connected to be fed with current of the opposite polarity.

While it is expected that an important application of the above-described radiating arrays will be for the transmis-

2

sion and reception of acoustic energy by incorporating transducer elements into the array, it should be understood that the invention, in its broader aspects, includes the incorporation of antenna elements for the transmission and reception of electromagnetic energy whenever an omnidirectional pattern is desirable. The rectangular array produces a field pattern characteristic which is simply controlled by a coupling network which connects predetermined pairs of elements in the same polarity, i.e., to be fed with current of one polarity to provide a first phase relationship, and the remaining pairs of elements of the array in the opposite polarity, i.e., to be fed with current of an opposite polarity to provide a second phase relationship opposite to said first phase relationship.

Further objects and advantages of this invention will be more apparent as the description progresses, reference being made to the accompanying drawing wherein:

FIG. 1 is a diagrammatic pictorial view of one embodiment of the invention;

FIG. 2 is a diagrammatic pictorial view of another embodiment of the invention;

FIG. 3 is a pictorial view, partially diagrammatic, of the invention showing an aircraft towing the array; and

FIG. 4 shows azimuthal field patterns developed by the arrays disclosed in the first and second embodiments of the invention.

Referring to FIG. 1, the reference numeral 40 denotes a rectangular omnidirectional array comprising nine pairs of elements positioned in two parallel rows and spaced one-third wavelength apart. The first radiating element of a pair of elements comprises two colinear transducer units 1 and 3 connected in parallel and adapted to be energized from a transmitter, not shown, through parallel connecting leads 51. Each transducer unit is three-quarter wavelength in length and is adapted to radiate acoustic energy from both ends thereof. The units are spaced three-quarters wavelength apart in the same plane and supported by a conventional support structure, not shown. The other element making up the first pair of elements comprises transducer units 2 and 4, symmetrically spaced one-third wavelength from units 1 and 3, and connected in parallel by leads 53. Leads 51 and 53 are connected in parallel aiding relationship to the transmitter or source of energy. In like manner, a second pair of elements making up the rectangular array, comprise transducer units 5, 6, 7, and 8 also connected in parallel aiding relation and spaced three-eighths wavelength from the first pair of elements. Each pair of elements of the array is connected in a similar manner with the exception of the sixth and seventh pairs of elements from the front or towing end of the array. The latter pairs of elements comprise units 9-12 and 13-16. Each of these pairs of elements are connected in a polarity opposite to the polarity of the other pairs of elements, i.e., to be fed in opposite phase relationship as indicated by the plus and minus signs on their respective pairs of leads 55, 57, and 58, 60 indicating the phase relationships of the respective feed currents at a given instant. The leads of each pair of elements are connected in parallel and in opposition to the remaining elements of the array.

In order to provide directivity during reception of incoming acoustic or electromagnetic energy, the end pair of elements 17, 18, 19 and 20 are connected to the energy source during reception and disconnected from the energy source during transmission. In this manner the combination of the double row of elements and the addition of the end pair of elements during reception provide a multiplicity of overlapping beam patterns having directivity in a combination of sixteen directions. The double row of elements is generally used to separate the beams on the right or zero to 180 degree direction from the beams found on

the left or 180 degree to 360 degree direction of the array, as indicated in FIG. 1.

For sonar purposes, the array is enclosed in a towed housing or fin-like hull mounting structure, not shown, and towed by a surface craft or, alternately, by an aircraft, as shown in FIG. 3. Each transducer unit contains a conventional transducer element. While a conventional towed housing can be used, a variable depth towing device is described in detail in United States Patent No. 2,879,737 of W. G. Gorton, issued March 31, 1959, and assigned to the assignee of this invention.

It should be understood that the transducer elements in the embodiment of FIG. 1 consists simply of magnetostrictive rods supported in a well-known manner for vibration within each unit and provided with transducer windings disposed along each rod. As noted, when piezoelectric or polarized ceramic rods are used, the electrodes for each rod are mounted either on the inner or outer surface of the rods or as stripes at intervals along each rod. The connecting wires for a particular element of the array are then connected to each stripe or electrode in parallel aiding or opposing according to the location of the pair of elements along the array. Thus, as shown in FIG. 1, the pairs of elements comprising units 9-12 and 13-16 are connected in a polarity opposite to the polarity of the other pairs of elements. While the elements are connected directly to the source of energy during transmission, during reception of acoustic energy, a conventional beam forming system is used. In this system each element is provided with a separate delay line to form a beam in a well-known manner as described in detail in the United States Patent No. 2,786,193 issued March 19, 1957, to S. R. Rich, and assigned to the assignee of this invention.

It should be further understood that while the elements are shown connected in parallel, a series connection can be used for either sonar or electromagnetic energy radiation and reception. In addition, the spacing along the rows of an array is dependent upon the number of elements in each row which is, in turn, dependent upon the number of beams to be formed. During reception, therefore, in order that the crossover between receiving beams remain at a fixed level of attenuation, say at three decibels, nine elements per row are used with three-eighths wavelength spacing to provide a directional array having sixteen overlapping beams. However, when it is desirable to increase the directivity of the array by increasing the number of beams during reception, twelve elements per row spaced five-twelfths of a wavelength apart are used to provide a total of twenty-four overlapping beams.

Referring now to FIG. 2, the reference numeral 50 denotes an array in which the number of elements in each row is increased to twelve in order to take advantage of a greater number of narrower directive beams during reception and to provide a higher intensity level than the array of FIG. 1 during transmission, while at the same time maintaining a uniform radiation pattern within four decibels. In order to achieve this pattern characteristic, FIG. 2 shows the first pair of elements 21, 22, 23, and 24 connected in parallel aiding relation by means of leads 41 and 42. In like manner, the first six pairs of elements from the zero degree or towing end of the array and the tenth and eleventh pairs of elements are connected in parallel aiding the same phase. The seventh pair of elements 25-28, the eighth pair of elements 29-32, the ninth pair of elements 33-36, and the twelfth pair 61-64 are connected, as shown, by the polarity of their leads, in parallel opposition to the remaining elements of the array. The two rows of elements in the array are spaced one-third wavelength apart and adjacent elements in the same row are spaced five-twelfths wavelength apart. In this manner, a full 360 degree coverage on both transmission and reception is achieved. The transducer units can be driven singly or in groups from the energy source by means of well-known power amplifiers, not shown.

Referring to FIG. 3 a helicopter 44 is shown towing, by means of a tow line 45, a housing 46 in which is mounted the rectangular array. The tow line 45 preferably supports the connecting leads for the transducer units and the transmitter and receiver, not shown, can be in the helicopter. The housing 46, as noted, is preferably streamlined to present a low frontal area to the water during tow in order to minimize hydrodynamic drag.

Referring to FIG. 4, the beam pattern for the rectangular array having nine pairs of active transducer elements is shown by the curve 48, and the substantially omnidirectional azimuthal plane characteristic of the array for twelve active elements is shown by the curve 49. These patterns are substantially the same for acoustic or electromagnetic radiations.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention. Accordingly, it is desired that the invention not be limited to the particular details of the embodiments disclosed herein except as defined in the appended claims.

What is claimed is:

1. An energy radiating array comprising nine pairs of energy radiating elements arranged in two parallel rows spaced approximately one-third wavelength apart at the operating frequency of the array, adjacent elements in a given row being spaced approximately three-eighths wavelength apart, each of said elements comprising substantially colinear transducer rods, means interconnecting the first five pairs of elements and the eighth and ninth pairs of elements from one end of said array to corresponding pairs of terminals to transfer energy arriving at said terminals in additive phase relationship, and means interconnecting the remaining pairs of elements of said array to corresponding pairs of terminals to transfer energy arriving at said terminals in the opposite phase relationship.

2. An energy radiating array comprising nine pairs of energy radiating elements arranged in two parallel rows spaced approximately one-third wavelength apart at the operating frequency of the array, adjacent elements in a given row being spaced approximately three-eighths wavelength apart, each of said elements comprising substantially colinear transducer rods, each of said rods having a physical length approximating three-quarter wavelength and being spaced from the corresponding colinear rod three-quarter wavelength at the operating frequency of said array, means interconnecting the first five pairs of elements and the eighth and ninth pairs of elements from one end of said array to corresponding pairs of terminals to transfer energy arriving at said terminals in additive phase relationship, and means interconnecting the remaining pairs of elements of said array to corresponding pairs of terminals to transfer energy arriving at said terminals in the opposite phase relationship.

References Cited in the file of this patent

UNITED STATES PATENTS

1,733,718	Blondel	Oct. 29, 1929
1,882,394	Pierce	Oct. 11, 1932
2,009,451	Kunze	July 30, 1935
2,361,177	Chilowsky	Oct. 24, 1944
2,405,226	Mason	Aug. 6, 1946
2,405,605	Goodale et al.	Aug. 13, 1946
2,409,944	Loughren	Oct. 22, 1946
2,417,830	Keller	Mar. 25, 1947
2,416,314	Harrison	Feb. 25, 1947
2,521,642	Massa	Sept. 5, 1950
2,838,850	Stephenson et al.	June 17, 1958
2,898,593	Ruze	Aug. 4, 1959
2,921,288	O'Neill et al.	Jan. 12, 1960
2,961,636	Benecke	Nov. 22, 1960
2,961,638	Padberg	Nov. 22, 1960