Aug. 24, 1965 R. L. TANNER 3,202,996

LOG-PERIODIC RHOMBIC ANTENNA ARRAY

Filed Dec. 26, 1962

Fig. 1

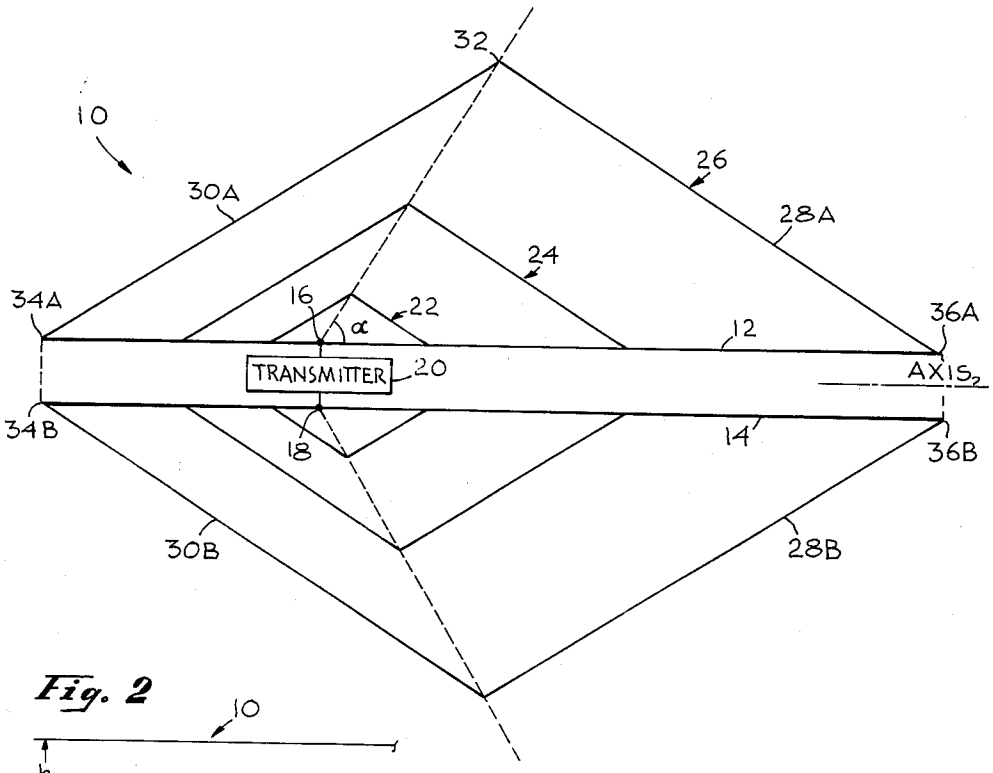


Fig. 2

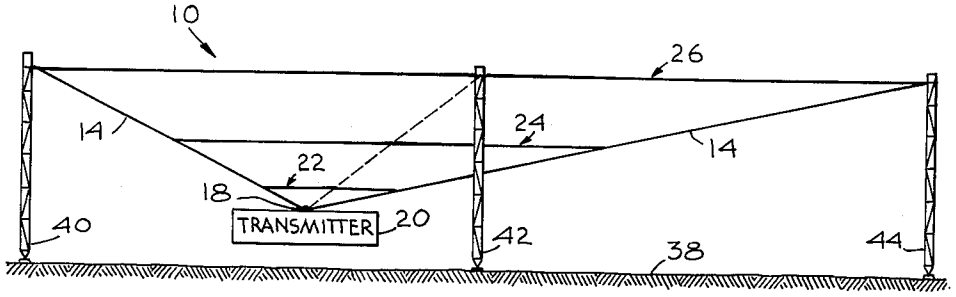


Fig. 3

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LOG-PERIODIC RHOMBIC ANTENNA ARRAY

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This invention relates generally to antenna apparatus and more particularly to an improved rhombic antenna construction.

This simple rhombic antenna has been used extensively for many years for both transmitting and receiving in short wave, high frequency, radio, telephone, and telegraph systems for point to point communication. Generally speaking, a rhombic antenna is composed of long wire radiators, several wave lengths long, comprising the sides of a rhombus. The rhombic antenna has been widely accepted mainly due to its extremely simple construction and its highly directive radiation characteristics.

One unattractive characteristic of the simple rhombic antenna is that it produces side lobes, whose presence represents an expenditure of generator power not radiated in the desired direction. Recent advances in the antenna art have shown that properly excited concentric rhombics have patterns much superior to those of simple rhombics with respect to side lobes. Additionally, it has been noted that these concentric rhombics have band width characteristics superior to simple rhombics. However, despite their band width advantage over simple rhombics, the band width of concentric rhombics is still inferior to other types of antennas, such as log-periodic antennas.

Recent advances in the antenna art have brought to light the extremely broad band properties of log-periodic antennas. However, the known log-periodic antennas do not have particularly desirable directive characteristics and moreover have relatively complex constructions when compared to other antennas, such as the rhombic antenna.

An object of this invention is the provision of an improved rhombic antenna construction which reduces side lobes.

Another object of this invention is the provision of an improved rhombic antenna construction which has both highly directive radiation characteristcs as well as extremely broad band properties.

Still another object of the present invention is the provision of a unique antenna construction which combines the desirable features of both rhombic and log periodic antennas.

These and other objects of this invention may be achieved by an antenna construction which includes a pair of feed lines fed by a generator connected between points on the feed lines disposed intermediate the ends. A plurality of rhombic elements each including a pair of identical halves composed of a pair of equal length wire radiators are connected to the feed lines. More particularly one of each pair of rhombic halves is connected to each feed line. The rhombic elements are of identical shape but are of different sizes. The free ends of the wires of the smallest element are connected to the feed lines on opposite sides of the points to which the generator is connected. The remaining elements are connected to the feed lines in order of increasing size so that each encloses an area which includes the elements of smaller size. Adjacent elements in the antenna array are related in size by a common ratio, as is characteristic of log-periodic antennas in general.

The manner of feeding the array is rather unique. Rather than being fed at one end, and terminated at the other, as is done in conventional rhombic antennas, the array in accordance with this invention is fed at its center and requires no terminating impedance since a unidirectional radiation pattern is achieved without it. It will be appreciated that the elimination of the terminating impedance increases the percentage of the generator power available for useful radiation. Alternatively, a lower powered generator can be employed to provide the same amount of useful radiation.

An additional feature of the invention resides in the concentric but asymmetric manner in which the rhombic elements are positioned with respect to the points on the feed lines to which the generator is connected. The elements are arranged in a skewed or eccentric manner so that their vertices fall along a straight line making an acute angle with the axis on the array. The purpose of this skewing is to give the radiation pattern of the array a highly directional characteristic.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings, in which:

FIGURE 1 is a plan view of the invention illustrating in detail the structural relationship between the component portions thereof;

FIGURE 2 is a side elevational view of the antenna array of FIGURE 1 showing how the rhombic elements may be disposed in a horizontal co-planer relationship constituting a first embodiment of the invention; and

FIGURE 3 is a side elevational view of the antenna array showing how the rhombic elements of FIGURE 1 can be arranged in different planes to form a pyramid-like structure, constituting a second embodiment of the invention.

Reference is now made to FIGURE 1 which is a plan view of the antenna array **10** comprising an embodiment of the invention. The antenna array **10** includes a pair of spaced parallel lines **12** and **14**. Disposed on the feed lines **12** and **14** intermediate the ends thereof, are a pair of input terminals **16** and **18**. When the antenna array **10** is used for transmission, a generator **20** is connected between input terminals **16** and **18**. When the antenna array **10** is used for reception, appropriate receiving apparatus (not shown) is connected between terminals **16** and **18**.

Connected to feed lines **12** and **14** are a plurality of rhombic elements **22**, **24**, **26**. It is to be noted that each of the rhombic elements is identically shaped, but of a different size.

Each rhombic element includes a pair of rhombic halves, respectively connected to feed lines **12** and **14**. For example, the upper half of rhombic element **26**, shown in FIGURE 1, includes a pair of wire radiators **28A** and **30A**. The wire radiators **28A** and **30A** are joined to each other at vertex **32A** of the upper half of rhombic element **26**. Wire **30A** is connected to feed line **12** at point **34A** while wire **28A** is connected to feed line **12** at point **36A**. Wires **28A** and **30A** form sides of the rhombic element **26** and are of equal lengths. The lower half of rhombic element **26** is identical in size and shape to its upper half and consists of wires **28B** and **30B**. These are connected to feed line **14** in the same manner as the upper half of rhombic element **26** is connected to feed line **12** at points **34B**, **36B**.

The respective halves of rhombic elements **24** and **22** are respectively connected to feed lines **12** and **14** in a manner similar to the one explained for rhombic element **26**. It is to be noted that the wires of rhombic element **22** are connected to the feed lines **12** and **14** on op-

posite sides of the input terminals 16 and 18. It is further pointed out that the wires of rhombic element 24 are connected to feed lines 12 and 14 to enclose the connections thereto of rhombic element 22. Similarly, the connections of rhombic element 26 to the feed lines 12 and 14 enclose the connections to the feed line of rhombic element 24.

As has been pointed out, each of the rhombic elements 22, 24, 26, is identical in shape but is of a different size. The size of the adjacent elements are related by a common ratio, as is typical of all log-periodic antenna arrays. More particularly, the length of the wire radiators of rhombic element 26 are in the same ratio to the length of the wire radiators of rhombic element 24 as the length of the wire radiators of rhombic element 24 are to the length of the wire radiators of rhombic element 22. Although the general concept of providing a plurality of elements which are related in size by a common ratio is typical of log-periodic arrays, it has been found that the common ratio which can be employed in the structure of the present invention is substantially greater than that which can be employed for log-periodic dipole arrays.

It should be noted that although all of the rhombic elements 22, 24, 26, are concentrically disposed about terminals 16 and 18, they are not symmetrically disposed thereabout. Instead, the rhombic elements are shifted toward the right such that the vertices 32, of the elements fall in a straight line extending from the input terminals and at an acute angle with respect to the feed lines 12 and 14, or to the axis of the array. It has been found that by disposing the elements in a skewed configuration as shown, a more highly directive radiation characteristic is achieved. For the arrangement shown in FIGURE 1, the antenna will radiate toward the right.

Whereas conventional rhombic antennas are fed at a first end and terminated at a second end, by some terminating impedance, the invention herein feeds the array at the approximate center thereof and eliminates the utilization of a terminating impedance. It has been found that the terminating impedance can be eliminated without adversely affecting the highly directive radiation characteristics of the antenna. By eliminating the terminating impedance, the power available from generator 20 for useful radiation is increased, and in addition, less power need be derived from generator 20 for a specific transmitting function.

The plan view of the invention shown in FIGURE 1 is identical for the two embodiments of the invention illustrated herein. The side elevational views of the two embodiments are distinguishable and are respectively shown in FIGURES 2 and 3.

In FIGURE 2 the rhombic elements 22, 24, and 26 are supported in co-planar relationship a fixed distance above ground 38.

In certain applications of the invention particularly in high frequency applications, the antenna will be erected as shown in FIGURE 3, with the elements each disposed in a different plane. These are supported by poles 40, 42, 44. The smallest of the elements 22, is placed closest to ground 38, while the largest of the elements 26, is disposed furthest therefrom. So arranged, the elements form an inverted skewed pyramid having its apex at the point at which the generator 20 is connected, which may be substantially at ground 38. The lines 12, 14, are bent to extend from lowest to highest elements at both sides of the apex. Alternatively, the apex may be some distance above ground.

Whereas the antenna array of FIGURE 2 will radiate in a horizontal direction to the right, the antenna of FIGURE 3 will radiate at an elevation angle as determined by the amount the rhombic elements are skewed. It has been found that if the generator is disposed at ground, as shown in FIGURE 3, the elevation angle at which the beam is radiated will not change appreciably with frequency. On the other hand, if the apex of the inverted

pyramid is placed some distance above the ground, the elevation angle of the main beam has been found to decrease with increasing frequency.

The size of an antenna in accordance with this invention, is determined by the lowest frequency of operation desired, which sets the size of the largest element. Typically, the largest element will have a side length on the order of 2 to 3 times the wavelength of the lowest frequency of operation. Assume a common ratio on the order of 1.35 to 1.75. By typical "log-periodic" parlance

$$\tau=\frac{1}{C.R.}=.75 \text{ to } .57$$

The number of elements in the antenna is determined by the bandwidth. Thus assuming a desired bandwith of 6:1

$$\text{Bandwidth}=6\cong(C.R.)^n$$

where C.R.=the common ratio and $n=$ the number of elements. Using 1.5 as the common ratio, 5 elements are required.

From the foregoing, it should now be apparent that an improved antenna array has been disclosed herein which incorporates the characteristics of simple rhombic antennas, concentric rhombic antennas, and log-periodic antennas. Many of the well known techniques employed by antenna designers to effect desired results in these conventional arrays can be employed in the antenna herein disclosed. For example, in order to decrease the impedance of a rhombic antenna, it has often been suggested that the individual wire radiators of the elements can be made up of two or more wires to increase their effective electrical area. Such a design consideration and other similar considerations are equally applicable to the improved antenna design shown herein.

Although two preferred embodiments of the invention have been disclosed, it should be understood that there is no intention to limit the scope of the invention to the specific structural organization illustrated and it is understood that modifications within the scope of the invention will readily occur to those skilled in the art. Accordingly, it is intended that all such suitable modifications and equivalents fall within the scope of the invention as claimed.

I claim:

1. An antenna array comprising first and second feed lines of finite length, first and second input terminals on said first and second feed lines disposed intermediate their ends, generator means connected between said input terminals, a plurality of rhombic elements each respectively including first and second identical rhombic halves each comprised of a pair of wires of equal length, each of said plurality of rhombic elements being of identical shape but of a different size, and means concentrically connecting said first rhombic halves to said first feed line and said second rhombic halves to said second feed line.

2. An antenna array comprising first and second feed lines of finite length, first and second input terminals on said first and second feed lines disposed intermediate their ends, generator means connected between said input terminals, a plurality of rhombic elements each respectively including a pair of identical rhombic halves comprised of a pair of wires of equal length, and means connecting the free ends of the pair of wires of a first of said pair of halves to said first feed line on opposite sides of said first input terminal and the free ends of the pair of wires of a second of said pair of halves to said second feed line on opposite sides of said second input terminal.

3. The antenna array of claim 2 wherein each of said plurality of elements is an identical shape and of a unique size, and means concentrically connecting the halves of each of said elements to said feed lines so that smaller halves are connected to points on said feed line included between the points to which larger halves are connected.

4. An antenna array of claim 3 wherein a vertex is de-

fined in each element half at the junction of the two wires, and means positioning said halves so that the vertices of all the halves connected to each feed line lie in a straight line extending from said input terminals at an acute angle with respect to said feed lines.

5. The antenna array of claim 3 wherein there is a common ratio between the wire length of each of said elements and the wire length of an adjacently connected element.

6. The antenna array of claim 5 wherein said rhombic elements are co-planer.

7. An antenna array of claim 5 wherein each of said rhombic elements lies in a different plane.

8. An antenna array comprising first and second feed lines of finite length, a plurality of rhombic elements each respectively including first and second identical rhombic halves each comprised of a pair of wires of equal length, each of said plurality of rhombic elements being of identical shape but of a different size, and means concentrically connecting said first rhombic halves to said first feed line and said second rhombic halves to said second feed line.

9. An antenna array of claim 8 wherein a vertex is defined in each element half at the junction of the two wires thereof, and means positioning said halves so that the vertices of all the halves connected to each feed line lie in a straight line extending from said input terminals at an acute angle with respect to said feed lines.

10. The antenna array of claim 8 wherein there is a common ratio between the wire length of each of said elements and the wire length of an adjacently connected element.

11. The antenna array of claim 8 wherein said rhombic elements are co-planer.

12. The antenna array of claim 8 wherein each of said rhombic elements lies in a different plane.

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