Nov. 5, 1968 M. S. O. SIUKOLA 3,409,893

ZIGZAG RADIATOR WITH PANEL REFLECTOR

Filed Oct. 29, 1965 2 Sheets-Sheet 1

Fig. 1.

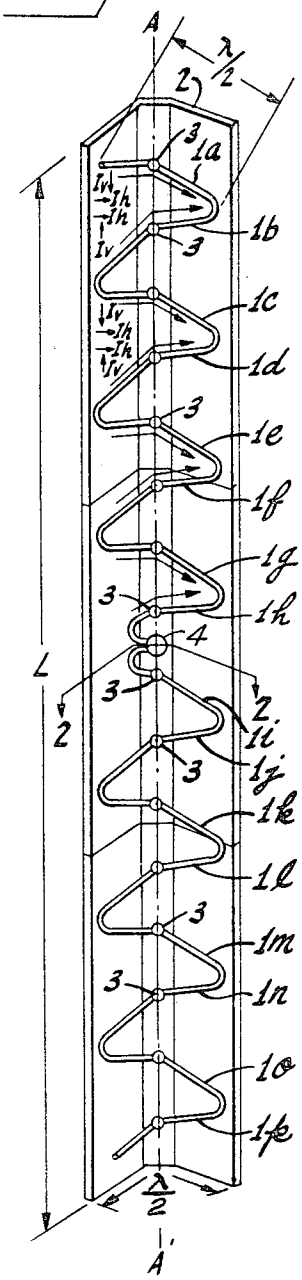


Fig. 2.

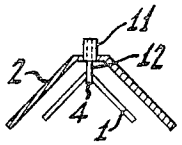


Fig. 7.

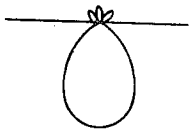


Fig. 8.

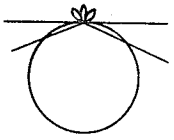


Fig. 5.

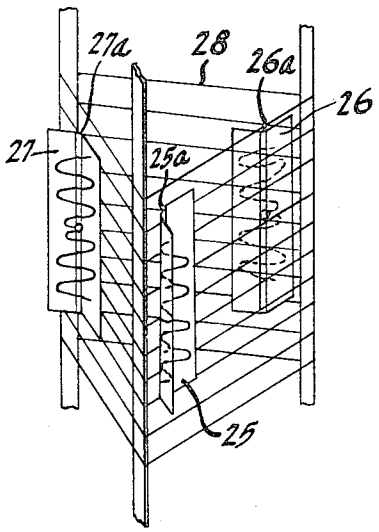
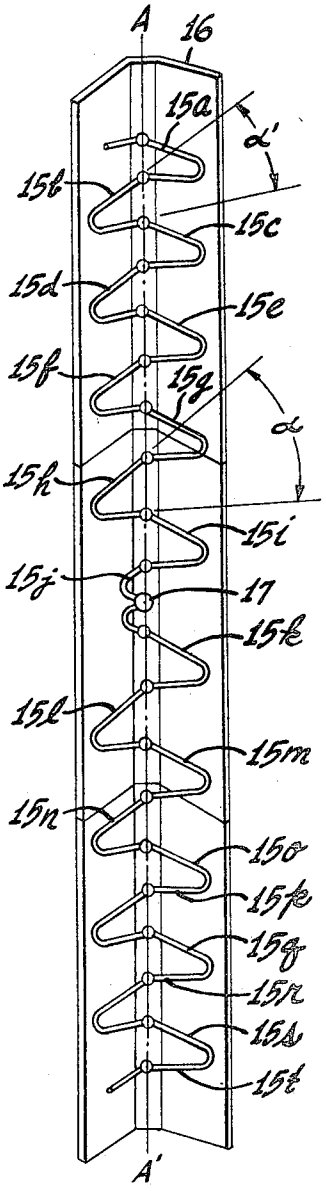


Fig. 3.



INVENTOR.
MATTI S.O. SIUKOLA
BY
Edward J. Norton
Attorney

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Fig. 4.

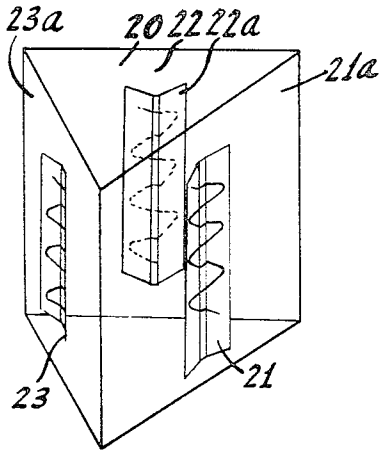
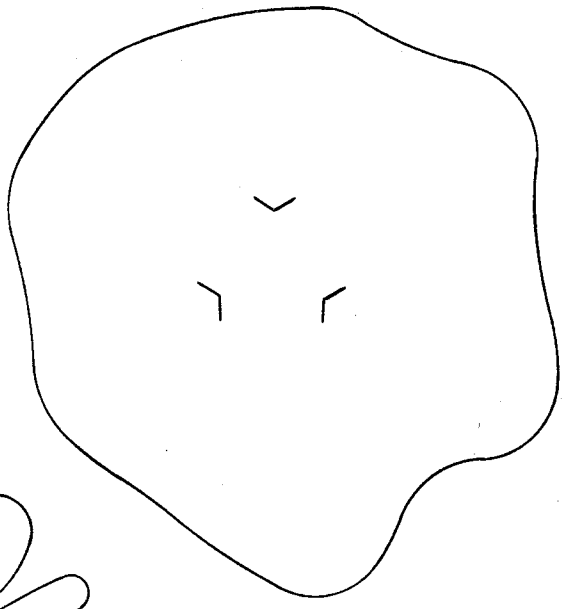


Fig. 9.



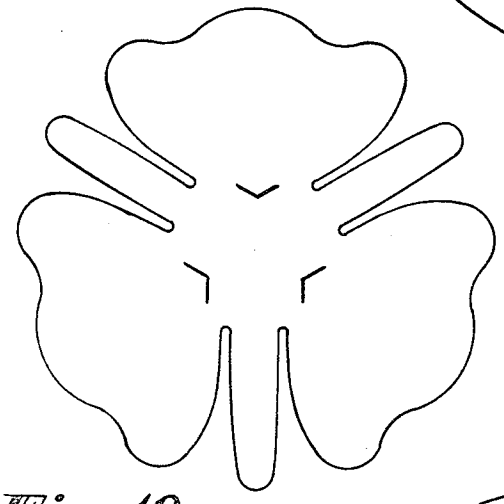


Fig. 10.

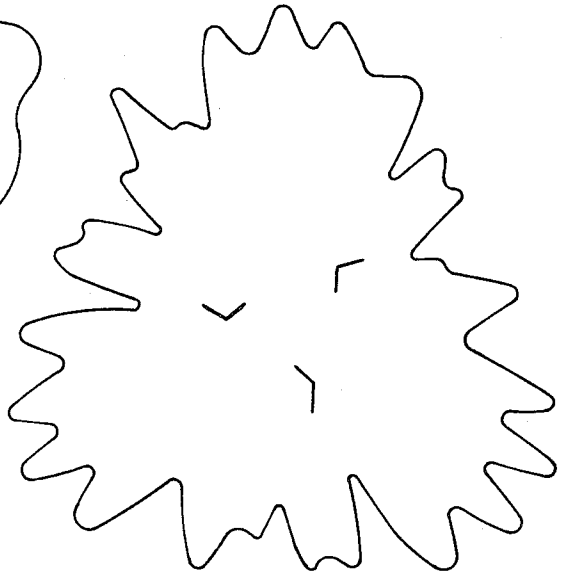


Fig. 11.

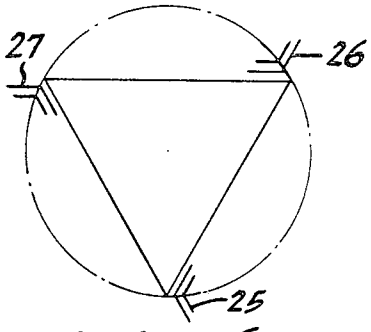


Fig. 6.

INVENTOR.
MATTI S.O. SIUKOLA
BY
Edward J. Norton
Attorney

United States Patent Office 3,409,893 Patented Nov. 5, 1968

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ZIGZAG RADIATOR WITH PANEL REFLECTOR

Matti S. O. Siukola, Westmont, N.J., assignor to Radio Corporation of America, a corporation of Delaware

Filed Oct. 29, 1965, Ser. No. 505,623
9 Claims. (Cl. 343—836)

ABSTRACT OF THE DISCLOSURE

A unidirectional panel type antenna constructed of a reflector panel and a zigzag radiator conductor a plurality of wavelengths long at the operating frequency. The reflector panel is also several wavelengths long at the operating frequency and is placed collaterally along the zigzag conductor and the associated panel are both bent about the center vertical axis of the zigzag conductor so that the dihedral angle formed by the two planes of the reflector panel and the two planes of the zigzag conductor are both on the order of 120 degree angles.

This invention relates to antenna systems and particularly to an antenna system suitable for broadcasting television and other radio signals.

With the advent of broadcasting over UHF bands as well as VHF bands, there is a demand to provide additional broadcast antennas to handle these new channels. One method for providing such additional broadcast antennas involves mounting the necessary antenna elements on existing support tower structures. An antenna of the type using a continuous zigzag wire or rod as the radiating element provides a multi-unit unidirectional radiator for use in such applications. By arranging several such antenna elements about an existing supporting structure, it is possible to obtain an omnidirectional pattern as desired in the particular application.

It is an object of the present invention to provide an improved antenna system by which the number of unidirectional arrays which are required to provide an omnidirectional antenna system is minimized.

Another object is to provide a television or radio broadcast antenna system having improved pattern characteristics.

A further object is to provide an improved zigzag antenna in which the antenna is compensated for lesser radiating power at the end points of the antenna.

Briefly, in accordance with one embodiment of this invention, there is provided a zigzag radiating conductor which is a plurality of wavelengths long at the desired operating frequency. The zigzag conductor is constructed of a wire, rod, or ribbon that is bent so that it reverses direction symmertically about a center axis in a common plane every half wavelength at the mean operating frequency. A reflector panel having a length several wavelengths long and a width approximately one-half a wavelength at the operating frequency is placed collaterally along the zigzag radiating conductor. The zigzag radiating conductor as described above and the associated reflector are bent about the center axis of the zigzag antenna array so that the dihedral angle formed by the two planes of the reflector panel and the dihedral angle formed by the two planes of the zigzag conductor are both obtuse angles. A first feed terminal is connected to the electrical center of the zigzag conductor with the second feed terminal being connected at the adjacent point on the reflector panel.

A more detailed description follows in conjunction with the accompanying drawings in which:

FIG. 1 is a perspective view of an antenna array in accordance with this invention;

FIG. 2 is a cross-sectional view taken at the 2—2 axis shown in FIG. 1;

FIG. 3 is a perspective view of another antenna array in accordance with this invention;

FIGS. 4 and 5 are perspective views of omnidirectional antenna array systems according to this invention;

FIG. 6 is a top plan view of an omnidirectional antenna array according to this invention;

FIGS. 7 and 8 are horizontal patterns of a directional antenna array useful in describing the invention; and

FIGS. 9, 10, and 11 are horizontal patterns obtained using omnidirectional antenna array systems useful in describing the invention.

Referring to FIGS. 1 and 2, FIG. 1 shows a perspective view of a continuous zigzag radiating conductor and associated reflector panel bent at an obtuse angle according to this invention. FIG. 2 shows a cross-sectional view taken along line 2—2 shown in FIG. 1. Reflector panel 2 has a width of approximately one-half wavelength and has a length L a plurality of wavelengths long along its linear lengthwise axis. Reflector panel 2 can be constructed of a thin metal sheet, or a grid or screen equivalent to a metal sheet. The zigzag conductor 1 can be constructed of a metallic wire, rod or ribbon. The zigzag conductor 1 is first bent so that it reverses direction symmertically about a center axis A–A′ in a common plane every half wavelength at the mean operating frequency. The zigzag conductor is mounted to the reflector panel 2 using insulative and capacitive acting supports 3 so that the common plane of the conductor is parallel to and in close proximately to reflector panel 2 and so that the center axis A–A′ of the zigzag conductor array 1 is collateral with the center lengthwise axis of reflector panel 2. The zigzag conductor 1, which is maintained in a spaced relation to the reflector panel 2, and the reflector panel 2 are bent about the symmetrical center axis A–A′ of the zigzag conductor array 1 so that the dihedral angle formed by the two newly formed planes of the reflector panel and the dihedral angle formed by the two newly formed planes of the zigzag conductor array 1 are both equal obtuse angles such as 120°. For practical mounting of the feed point 4 and supports 3 to the reflector panel 2, the actual center axis of the reflector panel 2 remains flat as shown in the cross-sectional view of FIG. 2. The width of the flat portion of the reflector 2 has been exaggerated for clarity and in practice need only be sufficient to accommodate the supports 3. The radio frequency signal is fed by a coaxial transmission line having its outer conductor 11 connected to the flat portion of bent reflector panel 2 and its inner conductor 12 connected to zigzag conductor 1 at center feed point 4.

The supports 3 described above as being insulative and capactive acting play an important role in the operation of the zigzag antenna. It is necessary to provide support for the radiating wire, rod or ribbon 1 without causing disturbances in the traveling wave. Changes in capacitance and inductance occur in the zigzag antenna due to effects at the corners where each successive one half wavelength long section of the conductor 1 is bent so as to reverse direction, due to changes in mutual coupling between successive half wavelength sections, and due to image reflections on the other side of the reflector. All of these changes take place every half wavelength which tends to break up the traveling wave and provide high standing waves. To reduce these standing waves, to rematch each half wavelength segment, and to support the radiating conductor 1 without causing disturbances, a support which is both capacitive and insulative acting is placed approximately at the half way point of each one half wavelength section. While the support 3 can be made in any known manner, one technique by way of example only is to provide a tubular member of insulating material such as Teflon. A U-bolt secures the conductor 1 to the support 3, there being a metallic washer in contact with the conductor 1 and

U-bolt to provide one plate of a capacitance. The reflector **2** acts as the other plate of the capacitance. Again, by way of example only, the tubular support **3** may be four inches high, an inch and one-half in diameter, with a one-half inch notch cut in its free end to accommodate the conductor. The value of the capacitance provided can be designed according to the given application.

When the radio frequency signal is applied between the feed point **4** and the reflector panel **2**, currents are produced in the zigzag conductor **1**. At a given polarity of applied radio frequency, the instantaneous currents are as shown by the arrows drawn along side some of the half wavelength portions **1***a* through **1***d* of conductor **1**. (See FIG. 1.) These instantaneous currents can be resolved into their horizontal I_h and vertical I_v components. The vertical components essentially cancel each other with the adjacent half wavelength sections. For example, vertical components in the one-half wavelength portions **1***c* and **1***d* are shown in FIG. 1 in opposite directions and therefore cancel each other. The horizontal components I_h, however, are in the same direction and therefore combine to produce a strong horizontal field. This strong horizontal field provides a radiation which is polarized at right angles to the length of the aperture. Experimentation has revealed that a wider radiation pattern can be obtained by bending the zigzag conductor **1** and associated panel reflector **2** about their center symmetrical axis so that the dihedral angles newly formed by the two planes of the reflector panel **2** and by the two new formed planes of the zigzag conductor array **1** is an obtuse angle such as 120 degrees. This unique feature provides an improved pattern when it is desirable to provide a wider pattern per zigzag panel antenna. FIG. 7 illustrates the horizontal pattern of a prior art flat panel zigzag radiator. FIG. 8 illustrates the pattern obtained by bending the same zigzag radiator in the manner described above in accordance with this invention.

An improvement in the radiating energy at the end points of the radiating conductor can be accomplished by effectively increasing the number of half wavelength portions of the conductor **1** towards the end points of the zigzag antenna. Less radiating energy exists at the end points of conductor **1** than at the center of conductor **1** because the current decreases along the conductor as it progresses away from the center feed point **4**. Referring to FIG. 3, FIG. 3 shows a perspective view of a zigzag conductor **15** and associated reflector panel **16** bent in accordance with this invention when there is provided more radiating wavelength sections **15***a* through **15***t* per length of panel **16** at the end points than at the center of the panel. FIG. 3 shows angle α as the angle between succeeding half wavelength portions of the conductor **15** near the center portion of the conductor **15**. By decreasing the angle α at the end portions of the conductor to angle α' there is effected more half wavelength sections at the end portions of the conductor. This provides more current at the end points of the radiating panel **16** than at the center portions of the radiator and therefore increases the radiated energy from the end portion of the radiating panel. FIG. 3 shows conductor **15** mounted in space relation to reflector **16** and both bent about symmetrical center axis A–A′ so the newly formed planes of the reflector **16** and conductor **15** form an obtuse dihedral angle. Conductor **15** is center fed at feed point **17** and is made up of half wavelength portions **15***a* through **15***t*. Half wavelength portion **15***i* located near the center feed point **17** is bent at an angle α to the adjacent half wavelength portion **15***h* which is in a reverse direction. Half wavelength portion **15***c*, located near the end of conductor **15**, is bent at an angle α' to the adjacent half wavelength portion **15***b*. With angle α' being less than angle α, more half wavelength portions are needed to progress a given linear distance along the center axis A–A′. By having more wavelengths per linear distance, there is provided more current per linear distance. By providing more current per linear length at the end portions of the conductor **15**, there is a corresponding improvement in the radiating energy at these end points of the zigzag conductor **15**. In this manner, lesser radiating power at the end points of the conductor due to current decreases along the conductor can be compensated for by increasing the number of radiating elements per linear distance along the center axis of the conductor.

An alternate method for increasing the radiating power at the end points is by spacing the conductor at a greater distance from the screen to increase the current near the end points and by terminating the element far ends at a point where the remaining impedance matches the characteristic impedance and thereby eliminating the reflected wave and radiating the remaining power.

Referring to FIG. 4 there is shown an omnidirectional antenna system comprising three zigzag directional antennas **21**, **22** and **23** which are bent in accordance with this invention. Each of these directional antenna arrays are mounted to the corresponding sides **21***a*, **22***a* and **23***a* of a triangular configuration **20** corresponding to the shape of a triangular tower. The arrays **21**, **22**, **23** are shown positioned in a vertical lengthwise sense substantially at the center of the respective sides **21***a*, **22***a*, **23***a* of the tower **20**. Although not shown on the drawing, the interior of the tower can be fitted with a ladder or other means for access to and servicing of the antenna, and the tower would be provided with hardware for mounting the necessary transmission line. The horizontal pattern developed by such an arrangement on a relatively small tower, for example about 2 feet on a side, provides an omnidirectional radiation pattern during the radial firing using only three directional zigzag antenna arrays. FIG. 9 illustrates the horizontal pattern obtained using only three directional antenna arrays mounted on a relatively small tower in the manner shown in FIG. 4. The same arrangement can be provided using more than three panel reflectors to form the supporting structures or by mounting more than three directional zigzag panel arrays on multisided towers. The use of the directional zigzag antenna array bent according to this invention reduces the number of directional zigzag panel arrays necessary to provide an omnidirectional antenna system, since the directional zigzag panel array bent according to this invention provides a wider pattern characteristic. Since many existing tower structures are triangular, the directional zigzag panel antenna array bent according to this invention can provide an omnidirectional system by simply mounting an antenna of this type on each of the three sides.

However, on large antenna structures, for example, towers about 7½ feet on a side, it is possible for nulls to occur in the horizontal pattern. FIG. 10 illustrates the horizontal pattern which might be obtained using three directional zigzag antenna arrays mounted on a large triangular tower. Note the nulls in the horizontal pattern between each of the directional patterns shown in FIG. 10. Referring to FIG. 5, there is illustrated three directional zigzag antenna arrays **25**, **26** and **27** mounted to the three sides of tower **28** in a manner so that the elbow or apex **25***a*, **26***a* and **27***a* of each zigzag antenna **25**, **26** and **27** is skewed away from the center of the supporting tower **28**. The antennas are oriented in a common plane on the tower **28** with their centers of radiation arranged in an arc of a horizontal circle. The principal axis or center of the radiation pattern of each antenna **25**, **26** and **27** is non-radial with respect to the radii of the above arc of the horizontal circle.

FIG. 6 shows a top plan view of the omnidirectional antenna array shown in FIG. 5 mounted in the skewed fashion described above with the centers of radiation of the antenna arrays arranged in a common plane in the arc of a horizontal circle. FIG. 11 illustrates a horizontal pattern developed by such an arrangement during radial firing on a large tower, for example about 7½ feet on a side, using only three directional zigzag antenna arrays bent according to this invention and mounted in

the skewed fashion described above. This arrangement provides a greatly improved horizontal pattern and thereby makes possible an improved omnidirectional antenna system.

While not shown in FIGS. 4 and 5 for reasons of clarity of drawing, any suitable conventional transmission line or other means may be provided to feed signal energy to the antennas in proper phase rotation in a manner to provide the desired omnidirectional pattern from the antennas. The actual connection of the transmission line to the respective antennas can be made in the manner shown in FIGS. 1, 2 and 3.

What is claimed is:

1. A unidirectional antenna array for operation at a mean operating frequency comprising;
a zigzag radiating conductor a plurality of wavelengths long at said mean operating frequency said conductor formed by an elongated member reversing direction symmetrically about a center axis in a common plane every half wavelength at said mean operating frequency,
a reflector panel placed in close proximity to and collaterally with said zigzag radiating conductor and having a length longer than said zigzag radiating conductor and a width approximately one half wavelength at said mean operating frequency,
said zigzag radiating conductor and said reflector being bent about said center axis so that the dihedral angle formed by the two planes of said reflector panel and by the two planes of said conductor are each on the order of 120 degrees,
a first feed terminal connected to a point on said zigzag conductor,
and a second feed terminal connected at the point on said reflector panel adjacent said point on said conductor.

2. A unidirectional antenna system for operation at a mean operating frequency comprising:
a reflector panel having a width of approximately one half a wavelength at said mean operating frequency and a length several wavelengths long at said mean operating frequency,
said reflector panel having a linear lengthwise axis,
a zigzag radiating conductor several wavelengths long at said mean operating frequency,
said zigzag conductor formed by a conducting member reversing direction symmetrically about a center axis in a common plane every half wavelength at said mean operating frequency,
means for spacing said zigzag radiating conductor parallel to and collateral with said reflector so that said conductor extends along said lengthwise axis of said reflector,
said reflector panel and said zigzag radiating conductor being bent about said center axis so that the dihedral angles formed by the two planes of said reflector and by the two planes of said conductor are each 120 degrees,
a first feed terminal connected to the electrical center of said zigzag conductor, and
a second feed terminal connected to said reflector panel at the point adjacent said electrical center of said conductor.

3. A unidirectional antenna array for operation at a mean operating frequency comprising:
a zigzag radiating conductor several wavelengths long at said mean operating frequency formed by an elongated member which reverses direction symmetrically about a center axis in a common plane every half wavelength at said mean operating frequency,
the angle at which said radiating conductor reverses direction being progressively smaller towards the ends of said conductor than at the center of said conductor,
a reflector panel placed in close proximity to and collaterally with said zigzag radiating conductor and having a length longer than said zigzag radiating conductor and a width approximately half a wavelength at said operating frequency,
a first feed terminal connected to the electrical center of said zigzag conductor, and
a second feed terminal connected at a point on said reflector panel adjacent said electrical center of said conductor.

4. A unidirectional antenna array for operating at a mean operating frequency comprising:
a sheet reflector panel having a width of approximately one half a wavelength at said mean operating frequency and a length a plurality of wavelengths long at said mean operating frequency,
said reflector panel having a linear lengthwise axis,
a zigzag radiating conductor a plurality of wavelengths long at said mean operating frequency formed by an elongated member which reverses direction symmetrically about a center axis in a common plane every half wavelength at said mean operating frequency,
the angle at which said radiating conductor reverses direction being progressively smaller towards the ends of said conductor than at the center thereof,
means for spacing said conductor parallel to and collaterial with said reflector so that said conductor extends along said lengthwise axis of said reflector,
said zigzag conductor and said panel reflector being bent about said center axis so that the dihedral angle formed by the two planes of said reflector panel and the dihedral angle formed by the two planes of said conductor are each on the order of 120 degrees.

5. An omnidirectional antenna system comprising;
three unidirectional antenna arrays for operating at a mean operating frequency,
each of said unidirectional antenna arrays comprising a sheet reflector panel having linear lengthwise axis and a width of approximately half a wavelength at said mean operating frequency and a length several wavelengths long at said mean operating frequency, a zigzag radiating conductor several wavelengths long at said mean operating frequency formed by an elongated conducting member which reverses direction symmetrically about a center axis in a common plane every half wavelength at said mean operating frequency, means for spacing said conductor parallel to and collateral with said reflector so that said conductor extends along said lengthwise axis, said sheet reflector panel and said zigzag radiating conductor being bent about said center axis so that the dihedral angle formed between the two planes of said reflector panel and the dihedral angle formed between the two planes of said conductor are each on the order of 120 degrees,
means for physically mounting said unidirectional antenna arrays to provide from said arrays when energized a desired omnidirectional radiating pattern.

6. An omnidirectional antenna system comprising:
a triangular supporting tower,
a separate unidirectional antenna array for operation at a mean operating frequency mounted to each of the three sides of said tower,
said arrays being positioned equi-distant from the center axis of said tower,
each of said three unidirectional arrays comprising a reflector panel having a linear lengthwise axis and a width of approximately one half a wavelength at said mean operating frequency and a length several wavelengths long at said mean operating frequency, a zigzag radiating conductor several wavelengths long at said mean operating frequency formed by a member which reverses direction symmetrically about a center axis in a common plane every half wavelength at said mean operating frequency, means for spacing

said conductor parallel to and collateral with said reflector so that said conductor extends along said lengthwise axis, said sheet reflector panel and said center axis so that the dihedral angle formed by the two planes of said reflector panel and the dihedral angle formed by the two planes of said conductor are 120 degrees,

said unidirectional arrays being oriented on said tower with said lengthwise axis of an array parallel to said lengthwise axes of the other two arrays.

7. An omnidirectional antenna system comprising;

a multisided supporting tower,

a separate unidirectional antenna array adapted for operation at a mean operating frequency positioned on each side of said tower,

each of said unidirectional antenna arrays comprising a reflector panel having a width of approximately one half a wavelength at said mean operating frequency and a length several wavelengths long at said mean operating frequency, said reflector panel having a linear lengthwise axis which is parallel to and along the vertical axis of said tower, a zigzag radiating conductor several wavelengths long at said mean operating frequency formed by a member having a component of direction transverse to the length of said conductor which reverses direction symmetrically about a center axis in a common plane every half wavelength at said mean operating frequency, means for spacing said conductor parallel to and collateral with said reflector so that said conductor extends along said lengthwise axis, said reflector panel and said zigzag radiating conductor being bent about said center axis so that the dihedral angle formed between the two planes of said reflector panel and that formed between the two planes of said conductor are each on the order of 120 degrees,

and means by which said arrays are mounted to said structure with said arrays being in substantially a common plane having their centers of radiation arranged in an arc of a horizontal circle.

8. An omnidirectional antenna system comprising:

a supporting structure having three sides spaced from the vertical axis of said structure,

three unidirectional antenna arrays for operation at a mean operating frequency,

each of said unidirectional arrays having a radiation pattern with a principal axis and comprising a reflector panel having a linear lengthwise axis and a width of approximately one half a wavelength at said mean operating frequency and a length several wavelengths long at said mean operating frequency, a zigzag radiating conductor several wavelengths long at said mean operating frequency formed by a member which reverses direction symmetrically about a center axis in a common plane every half wavelength at said mean operating frequency, means for spacing said conductor parallel to and collateral with said reflector so that said conductor extends along said lengthwise axis, said reflector panel and said zigzag radiating conductor being bent about said center axis so that the dihedral angle formed by the two planes of said reflector panel and the dihedral angle formed by the two planes of said conductor are 120 degrees,

means by which said arrays are mounted to said structure with a single one of said arrays effectively on each of said sides of said structure and with said arrays being substantially in a common plane having their centers of radiation arranged in an arc of a horizontal circle,

said arrays each being positioned on said structure so that said principal axis of its pattern is non-radial with respect to the radii of said arc of said circle.

9. An omnidirectional antenna system as claimed in claim 8 and wherein said arrays are oriented on said structure with said lengthwise axis of their respective reflectors parallel to said vertical axis of said structure.

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ELI LIEBERMAN, *Primary Examiner.*

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,409,893 November 5, 1968

Matti S. O. Siukola

It is certified that error appears in the above identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, lines 15 and 16, "conductor and the associated panel" should read -- conductor. The zigzag conductor and the associated panel --; line 53, "symmertically" should read -- symmetrically --. Column 7, lines 3 and 4, "and said center axis so that" should read -- and said zigzag radiating conductor being bent about said center axis so that --.

Signed and sealed this 31st day of March 1970.

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents