May 26, 1959 R. W. MASTERS 2,888,677

SKEWED ANTENNA ARRAY

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Fig_1

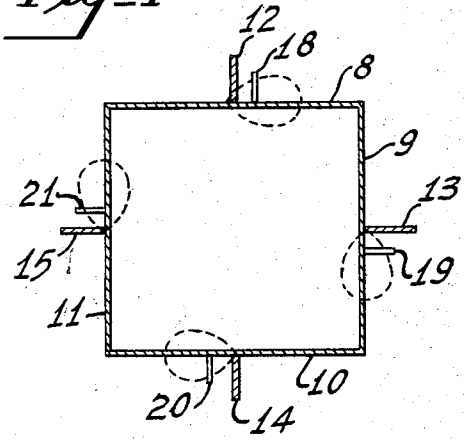
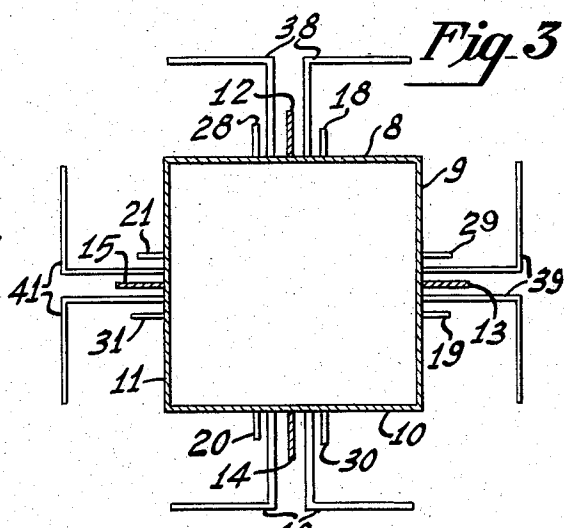


Fig_3



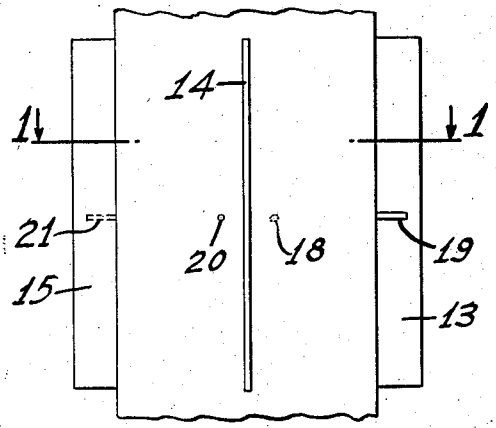


Fig_2

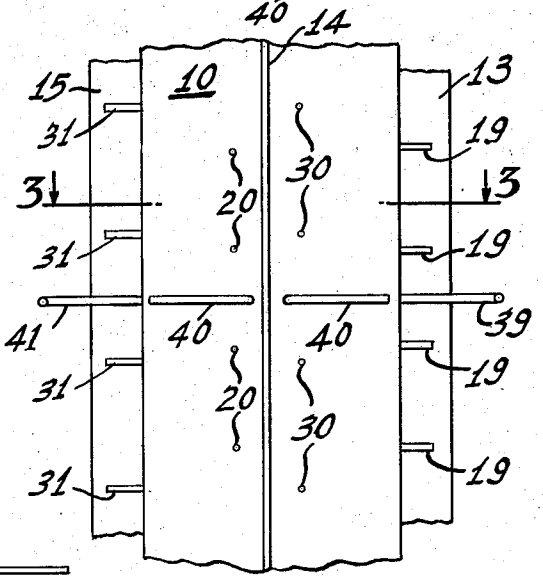


Fig_4

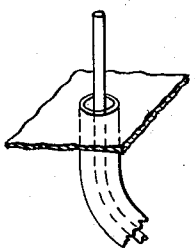


Fig_5

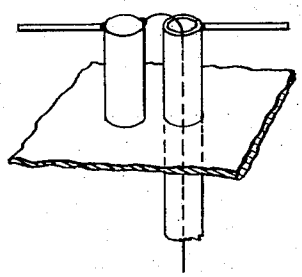


Fig_6

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SKEWED ANTENNA ARRAY

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8 Claims. (Cl. 343—798)

This invention relates to skewed antenna arrays, and more particularly, to antenna arrays wherein a plurality of antenna elements are mounted around the surfaces of a tower or building structure which is relatively large in cross-section, each antenna element being arranged to have maximum gain in a direction parallel with the corresponding surface. A symmetrical array provides substantially uniform field strength in all directions in a horizontal plane around the tower.

It is known to provide broadcast antenna arrays by mounting a plurality of half-wave dipole antenna elements around the four side surfaces of a tower having width dimensions in the order of a half wavelength, the dipoles being disposed parallel with the corresponding side surfaces. Since the cross-sectional or width dimensions of the tower are of the same order as the length of the dipoles, the resulting gain or field strength in all directions in the horizontal plane is substantially uniform. At higher frequencies, the cross-sectional dimension of the tower must be correspondingly reduced in order to obtain uniform gain in all horizontal directions. The limitation on the cross-sectional dimension of the tower may be such that the tower would have insufficient structural strength.

Occasions arise where it is desired to radiate relatively high frequency energy from an existing tower or building structure having such a cross-sectional dimension as to preclude obtaining an omni-directional response in the horizontal plane by following conventional antenna design practices. It is therefore a general object of this invention to provide an antenna array providing an omni-directional pattern from a tower or building structure having a cross-sectional dimension which is large relative to the wave-length of the energy handled.

In most communities there are relatively few advantageous sites for radio and television broadcasting antennas. The best site is often the top of the tallest building in the community. In this event, it may be desirable to mount all radio and television antennas serving the community at the top of a single building. It is especially desirable that all television antennas serving a community be located at or near the same point so that all of the directional receiving antennas may be directed in one direction to receive all broadcasts.

It is therefore desirable to interlace two or more antenna arrays on the same vertical portion of a single tower. However, a tower designed for radiating channel 2 television signals in the range of from 54 to 60 megacycles will have too great a cross-sectional dimension to support antenna elements for channel 9, operating in the range of from 186 to 192 megacycles, if the antenna array is constructed according to conventional techniques. It is therefore another object of this invention to provide interlaced antenna arrays operating at widely different frequencies and all mounted on a single tower to provide omni-directional patterns in the horizontal plane.

It is a further object of this invention to provide improved omni-directional antenna arrays characterized by simplicity of construction, ease of tuning, and low wind resistance.

In one aspect, the invention comprises a vertical tower of square cross-section having four conductive side surfaces such as may be provided by conductive screens attached to the structural members of the tower. Vertical reflectors are mounted perpendicular to the four sides of the tower near the centers thereof. A quarter-wave unipole is positioned near each reflector, the dipoles being on the same sides of the reflectors when viewed by going around the tower in one direction. The unipoles extend perpendicular with the tower sides and each reflector and unipole combination has greatest gain in a direction parallel with the corresponding tower side. The directions of greatest gain are the same when viewed going around the tower in one direction. The combined effects of the four reflector and unipole combinations is a substantially uniform pattern in all directions around the tower in the horizontal plane.

In another aspect, the invention comprises an antenna tower provided on the four faces or sides thereof with half-wave antenna elements or dipoles for operation at a first frequency. The tower sides are about a half-wavelength at the first frequency so that each dipole has greatest gain in a direction perpendicular with the corresponding tower side. One or more additional sets of four quarter-wave unipoles are mounted on the tower sides, together with vertically disposed reflectors, to provide operation at one or more higher frequencies. Each quarter-wave unipole together with the associated reflector provides a pattern having greatest gain in a direction parallel with a corresponding tower side. By this construction, a single tower supports two or three antenna arrays operating at three different frequencies, all being substantially omni-directional in the horizontal plane. A plurality of bays or sections of the three antenna arrays may be arranged along the vertical length of the tower to provide maximum gain in the vertical planes at the surface of the earth.

These and other objects and aspects of the invention will be more apparent to those skilled in the art from the following description taken in conjunction with the appended drawings, wherein:

Fig. 1 is a sectional view taken in a horizontal plane showing a vertical tower provided with an antenna array which provides a substantially omni-directional pattern in the horizontal plane;

Fig. 2 is an elevation of the antenna array shown in Fig. 1;

Fig. 3 is a sectional view taken in a horizontal plane showing a vertical tower provided with three antenna arrays operative at three different frequencies, and all providing omni-directional patterns in the horizontal plane;

Fig. 4 is an elevation of the antenna array shown in Fig. 3;

Fig. 5 is a fragmentary perspective view of a quarter-wave unipole such as may be employed in the antenna arrays of Figs. 1 thru 4; and

Fig. 6 is a fragmentary perspective view of a half-wave dipole such as may be used in the antenna array of Figs. 3 and 4.

Referring to the omni-directional antenna array shown in Figs. 1 and 2, a tower or building structure having a square cross-section is shown by the outline formed by the four sides **8**, **9**, **10** and **11**. The sides of the tower are conductive surfaces which may be inherent in the tower construction itself or may be provided by electrically conductive screens secured to the sides of the tower. The width dimension of each of the tower sides **8**, **9**, **10**

and 11 is large compared with the wavelength at which the desired antenna array is to operate. In other words, the widths of the sides are large compared with a half-wavelength at the operating frequency.

Vertically arranged metallic wave reflecting screens 12, 13, 14 and 15 are connected along one edge to the sides 8, 9, 10 and 11, respectively. The reflector screens extend at right angles from the tower sides.

Quarter-wave unipoles 18, 19, 20 and 21 are mounted to extend perpendicular with the respective tower sides 8, 9, 10 and 11 at points spaced from the corresponding reflector screens. The quarter-wave unipoles are all on the same sides of the associated reflector screens when viewed by going around the tower in one direction. Referring to Fig. 1, the quarter-wave unipole 18 and reflector screen 12 result in a pattern having greatest gain parallel with the side 8 and extending to the right as shown by the dotted line pattern. Similarly, the other unipole and reflector screen combinations have a pattern with greatest gain in the direction parallel with the corresponding tower side, the directions being the same when considered by an observer going around the tower in a clockwise direction.

The quarter-wave unipoles may be fed in phase, or in quadrature phase sequence, depending upon the midth dimensions of the tower. The feed arrangement is designed by taking into account the width of the sides of the tower so as to provide patterns from the four antennas which add up vectorially to provide an omni-directional pattern in the horizontal plane.

Figs. 3 and 4 show three antenna arrays operative at three different frequencies and all mounted on the same vertical tower. The tower and one of the antenna arrays is the same as that shown in Figs. 1 and 2, and the same reference numerals have been used to designate the corresponding elements. The only difference is that a plurality of vertically spaced quarter-wave unipoles and half-wave dipoles are mounted on each tower side.

In addition, the antenna of Figs. 3 and 4 includes a plurality of quarter-wave unipoles 28 on tower side 8, a plurality of quarter-wave unipoles 29 on tower side 9, a plurality of quarter-wave unipoles 30 on tower side 10 and a plurality of quarter-wave unipoles 31 on tower side 11. The unipoles 28, 29, 30 and 31 are longer than the unipoles 18, 19, 20 and 21, and are positioned on the corresponding tower sides on opposite sides of the reflectors 12, 13, 14 and 15. Both the unipole antenna array and dipole antenna array utilize the common reflectors 12, 13, 14 and 15. The pattern of unipole 28 has a maximum gain in a direction to the left and parallel with the tower side 8. The patterns of unipoles 29, 30 and 31 similarly have maximum gain in directions parallel with the corresponding tower sides, all the directions being counter-clockwise, and opposite to the clockwise direction of radiation from unipoles 18 to 21. Like the antenna array including unipoles 18 thru 21, the second antenna array including unipoles 28 thru 31 has an omni-directional pattern in the horizontal plane. All of the quarter-wave unipoles may be fed in any convenient manner such as by a coaxial line as shown in Fig. 5 wherein the outer conductor of the coaxial line is connected to the tower side, and the inner conductor is extended to form the radiating element.

A third antenna array for operation at a third frequency lower than the frequencies of the first and second arrays, comprises half-wave dipoles 38, 39, 40 and 41 mounted parallel with the corresponding tower sides 8, 9, 10 and 11. The half-wave dipoles may be connected to coaxial transmission lines in the manner illustrated in Fig. 6, or in any other suitable manner.

It will be noted that the half-wave dipoles 38, 39, 40 and 41 have lengths which correspond roughly with the widths of the tower sides, and that the half-wave dipoles are arranged parallel with the corresponding tower sides. By this construction, each half-wave dipole has a pattern with maximum gain in the direction perpendicular with the corresponding tower side. The vector addition of the patterns of the four half-wave dipoles is such that the half-wave dipole array provides an omni-directional pattern in the horizontal plane.

The antenna shown in Figs. 3 and 4 may, for example, be employed in television broadcasting for the simultaneous transmission of three television signals of different frequencies. The first antenna array including quarter-wave unipoles 18 thru 21 may be employed to broadcast the signal of highest frequency, for example, a channel 13 signal having a frequency in the range of from 210 to 216 megacycles. The second antenna array including quarter-wave unipoles 28 thru 31 may be employed to broadcast an intermediate frequency signal, such as a channel 9 signal having a frequency range of from 186 to 192 megacycles. The third antenna array including half-wave dipoles 38 thru 41 may be employed to broadcast a television signal of lower frequency, such as for example, a channel 2 signal having a frequency in the range of from 54 to 60 megacycles.

The three antenna arrays occupy the same vertical portion of the tower and yet they do not interfere one with the other. There is very little coupling between the first antenna array including quarter-wave unipoles 18 thru 21, and the second antenna array including quarter-wave unipoles 28 thru 31 because the tower sides are wide in terms of wavelengths, and because of the isolation effected by the reflector screens 12 thru 15. There is practically no coupling between the third antenna array including half-wave dipoles 38 thru 41 and the first and second antenna arrays because of the widely spaced operating frequencies thereof and because the antenna arrays are operatively oriented at right angles with each other. The isolation between the third antenna array and the first two is further improved when, as is preferred, the antenans of the first and second arrays are fed in phase, and the antennas of the third array are fed in quadrature sequence.

It will, of course, be understood that Fig. 4 shows one vertical section or bay of a complete antenna which may include a plurality of similar sections or bays mounted one above the other to provide the desired directivity in vertical planes.

It is apparent that, according to the construction shown in Figs. 3 and 4, two additional higher frequency antenna arrays may be added to an existing tower on which there is a half-wave dipole antenna array of conventional design. The two additional higher frequency antenna arrays occupy the same vertical section of the tower as the existing lower frequency antenna array without interference between the arrays.

If a pattern in the horizontal plane other than omni-directional is desired, antennas may be mounted only on any two or three tower sides to provide any desired pattern in the horizontal plane. To obtain some irregular patterns, it may be necessary to unequally distribute radio frequency power to the several antennas.

What is claimed is:

1. An antenna comprising a vertical tower of rectangular cross-section having four conductive sides, four reflector screens, one of said screens being secured on one edge thereof intermediate the edges of each of said sides of said tower in a vertical position and extending at right angles therewith, a first antenna array comprising four quarter-wave unipoles each mounted perpendicularly on one of said tower sides in spaced relation with the corresponding one of said screens, all of said unipoles being on the same side of said screens when viewed going around said tower in one direction, and a second antenna array comprising four quarter-wave unipoles each mounted perpendicularly on one of said tower sides in spaced relation with the corresponding one of said reflector screens, all of said unipoles of said secondary

array being on the opposite sides of said reflector screens with respect to said unipoles of said first array.

2. An antenna comprising a vertical tower of rectangular cross-section having four conductive sides, four reflector screens, one of said screens being secured at one edge to each of said sides of said tower in a vertical position and extending at right angles therewith, at least four quarter-wave unipoles, one of said unipoles being mounted perpendicularly on each of said tower sides in spaced relation with the corresponding one of said reflector screens, all of said unipoles being on the same side of said reflector screens when viewed going around said tower in one direction, and four half-wave dipoles, one of said dipoles being mounted on each of said tower sides.

3. Antenna arrays as defined in claim 2, wherein said tower sides each have a width in the order of a half-wavelength at the operating frequency of said half-wave dipoles, and wherein said quarter-wave unipoles are operative at a higher frequency.

4. Three antenna arrays mounted on a tower comprising a vertical tower having four conductive sides arranged generally in the form of a square, four reflector screens, one of said screens being secured on one edge to each of said sides of said tower in a vertical position intermediate the edges of said side and extending at right angles therewith, a first antenna array including in combination with said reflector screens a plurality of quarter-wave unipoles each mounted perpendicularly on one of said tower sides in spaced relationship with said reflector screens on the same sides thereof when viewed going around said tower in one direction, a second antenna array including in combination with said reflector screens a plurality of quarter-wave unipoles each mounted perpendicularly on one of said tower sides in spaced relationship with said reflector screens on opposite sides thereof from the unipoles of said first antenna array, and a third antenna array including four half-wave dipoles each mounted on one of said four tower sides.

5. Antenna arrays as defined in claim 4, wherein said tower sides have a width in the order of a half-wavelength at the operating frequency of said half-wave dipoles constituting said third array, and wherein said quarter-wave unipoles constituting said first and second arrays are operative at different frequencies higher than the operating frequency of said third antenna array.

6. Antenna arrays as defined in claim 5, wherein said half-wave dipoles constituting said third antenna array are mounted in spaced parallel relation with said corresponding sides by means of parallel spaced supports extending from said tower sides, and wherein said reflector screens are mounted on said tower sides between said supports.

7. Antenna arrays as defined in claim 4, wherein the unipoles constituting said first array are fed in phase, said unipoles constituting said second array are fed in phase, and said dipoles constituting said third array are fed in quadrature sequence.

8. An antenna array comprising a structure having at least three conductive sides connected together to form a structure having a polygonal transverse cross-section and having an axis, an individual radiator screen fastened to each of said sides, said screens extending from their respective sides at substantially a right angle with respect thereto and in planes parallel to said axis of said structure, an individual quarter-wave unipole mounted on each of said sides on corresponding sides of said screens when viewed going around said structure in one direction, and an individual half-wave dipole mounted on each of said sides.

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