

Oct. 1, 1957

V. J. ANDREW

2,808,585

SKEW ANTENNA SYSTEM

Filed June 11, 1952

5 Sheets-Sheet 1

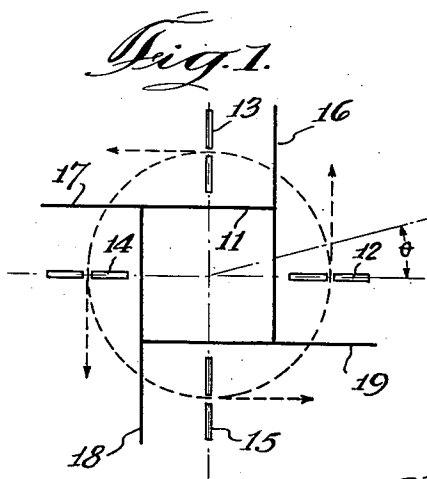
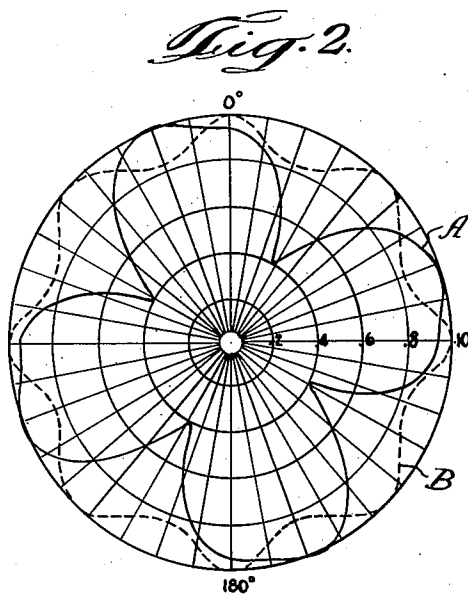
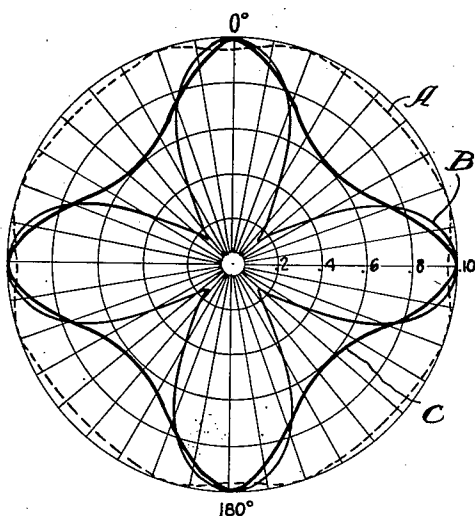
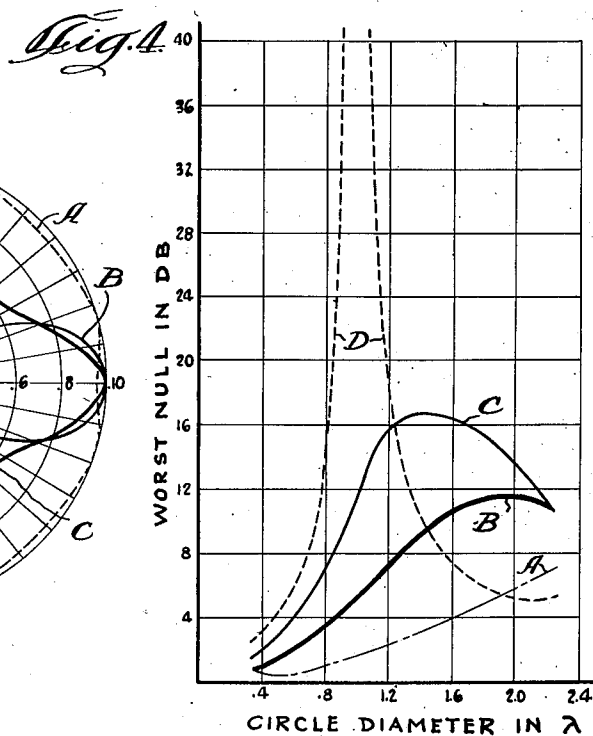


Fig. 3.



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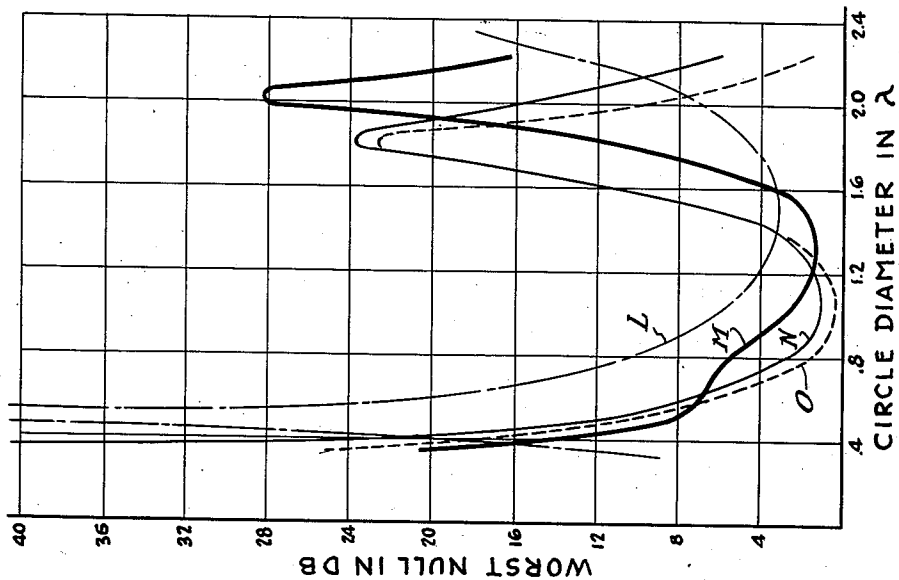


Fig. 7.

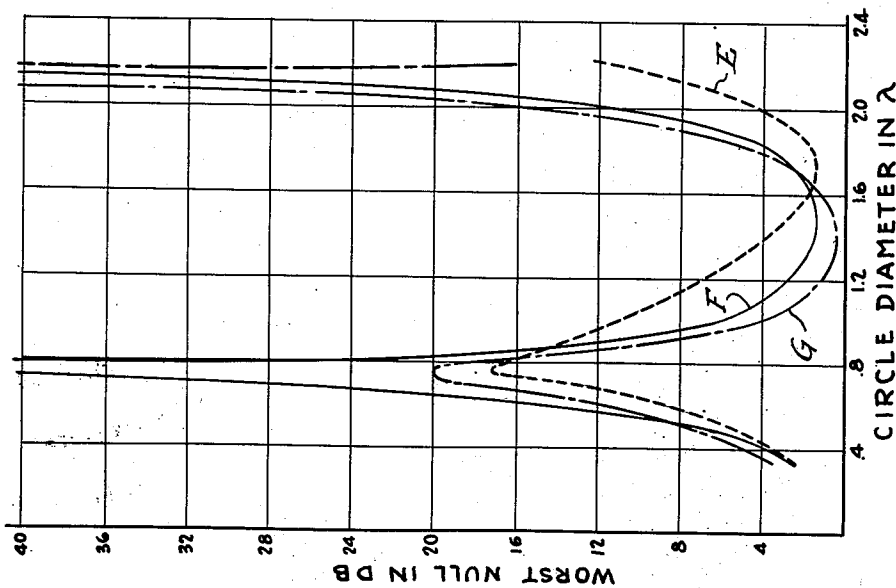


Fig. 5.

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Fig. 12.

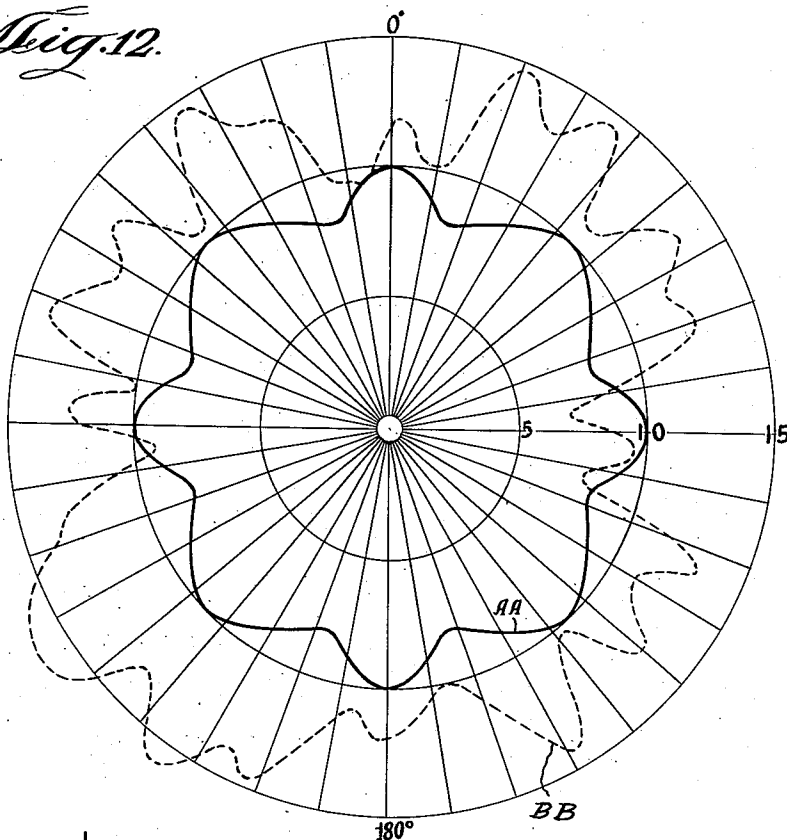
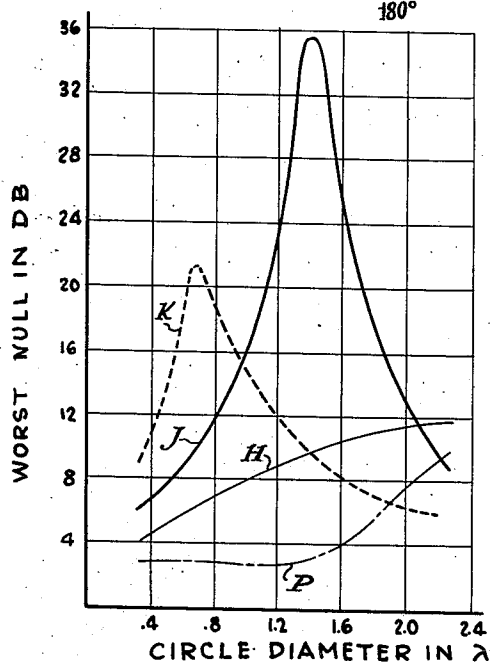


Fig. 6.

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Fig. 10.

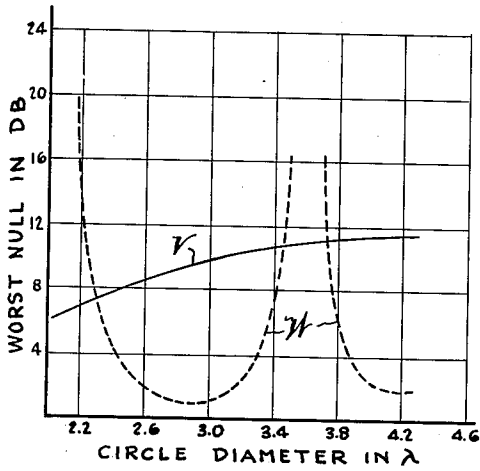


Fig. 8.

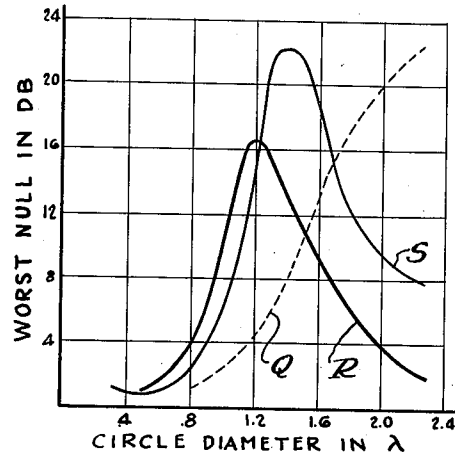
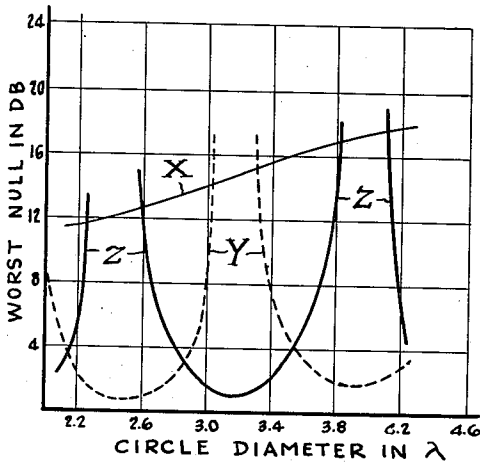


Fig. 11.

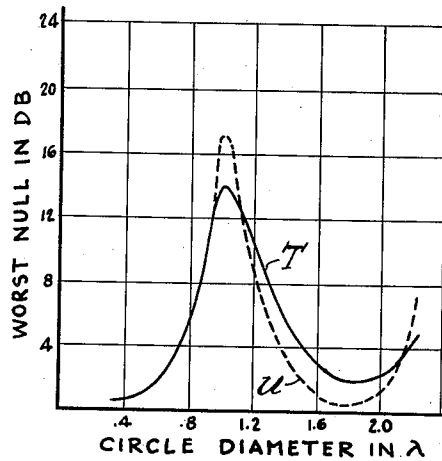


Fig. 9.

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Fig. 13.

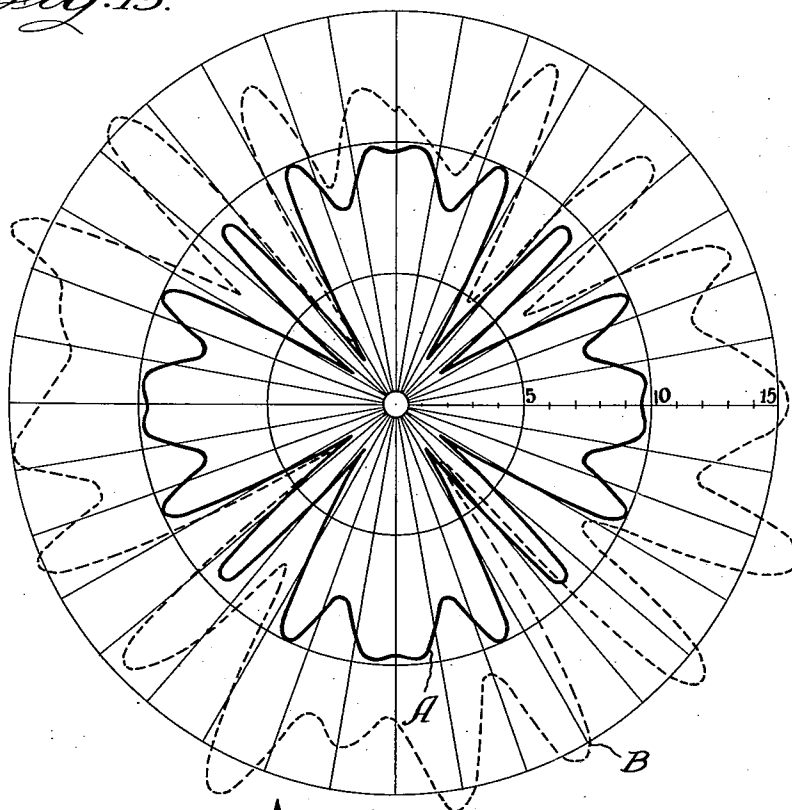
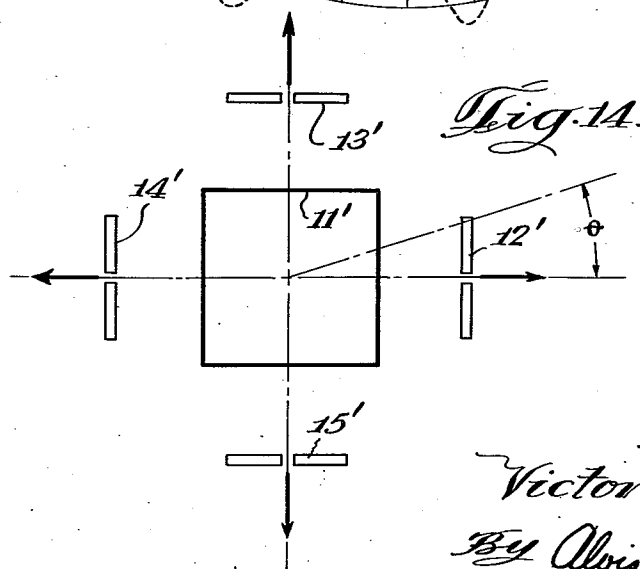


Fig. 14.

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SKEW ANTENNA SYSTEM

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5 Claims. (Cl. 343-799)

The present invention relates to an antenna system, and more particularly to an antenna system utilizing a plurality of polarized radiating elements mounted about a central support structure.

Heretofore multiple horizontally polarized radiating elements have been mounted around a central support structure to comprise an antenna system. In all cases the individual radiating elements have been beamed away from the axis of the support structure in radial directions. This has resulted in a definite limitation in the radiation pattern.

It would be desirable to provide an antenna system using a multiplicity of unidirectional radiating elements which would have an improved radiation pattern. In accordance with the present invention it is proposed to overcome certain disadvantages heretofore encountered in other antenna systems by arranging the individual radiating elements so that they are beamed at an angle to a line extending through the center of the element and the axis of the support structure. It furthermore is contemplated in accordance with the present invention to provide a phase rotation in the energization of the various radiating elements arranged around a central support structure.

It, therefore, is an object of the present invention to provide an improved antenna system utilizing a plurality of unidirectional radiating elements mounted around a central support structure.

Another object of the invention is to provide an improved antenna arrangement for unidirectional radiating elements thereby to obtain an improved radiation pattern.

Still another object of the invention is to provide an improved antenna system utilizing a plurality of unidirectional dipole radiating elements.

A still further object of the invention is to provide an antenna system utilizing a plurality of unidirectional dipole radiating elements energized in phase rotation.

Other and further objects of the invention subsequently will become apparent by reference to the following description taken in conjunction with the accompanying drawing, wherein:

Figure 1 is a diagrammatic representation of an antenna system illustrating the principles of the present invention;

Figure 2 graphically illustrates the radiation pattern characteristic of prior art systems;

Figure 3 graphically illustrates one radiation pattern characteristic of the present invention;

Figures 4 through 9 graphically illustrate the relations between different circle diameters on which antenna elements are located and effects obtained by phase rotation energization of the elements;

Figures 10 and 11 graphically represent calculations for larger circle diameters for the support of the individual antenna elements;

Figure 12 graphically illustrates calculated and measured values for a radiation pattern explanatory of the present invention;

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Figure 13 graphically illustrates calculated and measured values for a radiation pattern explanatory of the prior art arrangement; and

Figure 14 diagrammatically shows the prior art arrangement of an antenna system.

In Figure 1 there is represented a central support structure 11 which may comprise a square tower. Arranged about the tower are four dipole radiating elements 12, 13, 14 and 15. The faces of the tower 11 have been provided with extension surfaces 16, 17, 18 and 19 to provide reflecting surfaces for the antenna elements since they are located at an angle of 90° with respect to the conventional arrangement heretofore used in the prior art. The dotted line representation in the figure shows that the centers of radiation of the elements are in a circle.

In the prior art arrangement represented by Figure 14, all of the dipole elements 12', 13', 14' and 15' would have been arranged parallel to the four faces of the support tower 11' so that their energy would have been beamed radially from the center of the support structure 11'.

The advantage to be gained by the antenna system comprising the present invention will be appreciated by a consideration of the characteristics obtained by prior art arrangements. In those arrangements the four dipole antenna units had substantially unidirectional radiation components which are normal to the surface of the square support tower 11' of Figure 14. In order to determine the radiation pattern of this system one must move about the tower in a large circle and add up vectorially the individual radiations being received. At an angle such as θ indicated in Figure 14 it is necessary to consider the sum of the radiations from antennas 12' and 13'. If the angle θ increases from zero to 90° the radiation energization received from the antenna element 12' decreases roughly in a cosine curve. Likewise the radiation received from the antenna element 13' increases from zero in accordance with a sine curve. Where the angle θ is 45° equal radiations will be received from the antenna elements 12' and 13'.

It may be assumed that the antenna elements are still arranged in accordance with the teaching of the prior art and are fed with energization which is in phase. With an angle of 45° for θ the phase of the radiated energizations are the same and at a great distance they appear equidistant, however any deviation from the 45° angle will produce a phase difference. Where the angle is less than 45° the radiations received from the antenna 12' will appear to arrive sooner than those from antenna 13'. Conversely when the angle is greater than 45° the reverse will be true. If it is assumed that the antenna elements 12' and 13' are mounted with their centers of radiation in a circle having a radius of one-half wave length the mathematical computations show a phase difference of 2.22° per degree of rotation.

The foregoing may now be compared with the results obtained by an arrangement of the antenna elements in accordance with the present invention indicated in Figure 1. If we assume measurements now with an angle where θ is 45° the radiations received will be from antenna elements 12 and 15 which are no longer equidistant from the point of observation. If the phase variation in a slight change from the 45° angle is measured it will be found that the phase difference per degree of rotation is .193° thus showing a much smaller variation than in the previously examined case. Accordingly it will be appreciated by those skilled in the art that this reduced variation produces an improved radiation pattern.

Those skilled in the art, however, will appreciate that at the point of observation with an angle differing widely from 45° for θ , a poor pattern may be obtained due to destructive interference, and hence an examination must

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be made of the entire radiation pattern. Accordingly certain experiments and measurements were undertaken from which certain relations are obtained to provide the basis for the best possible operation of the antenna arrangement contemplated by the present invention.

The results obtained from the present invention will best be understood by a comparison of the calculated radiation pattern of the prior art with the calculated radiation pattern obtained by the present antenna system.

Figure 2 shows the calculated radiation patterns obtained from the conventional arrangement of four dipole antenna elements arranged about a square support structure so that they are beamed radially from the axis of the structure, as indicated by Figure 14. With a 90° rotation provided in the energization of the several antenna elements as is customary the radiation pattern will appear as curve A. If, however, all of the radiating elements were energized in phase the radiation pattern would appear as curve B.

If the antenna elements are now arranged in accordance with the present invention as illustrated in Figure 1, the calculated radiation patterns obtained will correspond to Figure 3. Where the phase rotation of the energization of the antenna elements is counter-clockwise the radiation pattern is shown by the curve A. If the phase rotation is clockwise there will be obtained the radiation pattern B. Because of the skewed arrangement of the antennas a difference is obtained between clockwise and counter-clockwise phase rotation thus resulting in curves A and B. This is not obtained from the prior art arrangement because the antennas therein are all beamed radially from the support structure. If in the present invention all of the radiating elements are energized without any phase difference the radiation pattern will appear as curve C.

For a more comprehensive understanding of the real possibilities of the present invention where the antenna elements are arranged in skewed manner it is necessary to consider different distances of separation corresponding to tower support structure dimensions. There is no direct relation between the skewed antenna position and the tower size, but a variation of the diameter of the circle on which the antennas are mounted is an important factor. This could perhaps be determined from examining a large number of radiation patterns similar to those shown in Figures 2 and 3, but it was found more significant to present the relation by other curves indicating the worst null in the radiation pattern. Since the angle of skew for the antenna element is by no means limited to 90°, different relations or values for skew have also been considered.

In Figure 4 the curve A shows the pattern variation for the angle of skew zero degrees and the circle diameter has been varied in terms of the wave length energization radiated. In curves B, C and D there is shown the relations obtained where the skewed angles are plus or minus 15°, 30° and 45° respectively. All of the antenna elements were energized in phase. Figure 5 shows further curves E, F and G for the same in phase operation by skewed angles of plus or minus 60°, 75° and 90° respectively. In Figures 6 and 7 the curves J, K, L, M, N and O show the relations obtained by skewed angles of plus 15°, 30°, 45°, 60°, 75° and 90° with the antenna element energized in 90° progressive phase rotation. The curve H shows zero skew angle. In Figures 6, 8 and 9 the curves P, Q, R, S, T and U show the results obtained by 90° phase rotation energization of the antenna elements and negative skew angles of 15°, 30°, 45°, 60°, 75° and 90° respectively.

Figure 10 shows the relation between circle diameter in wave length and the worst null where the curve V is for zero skew angle and the curve W is for a skew angle of either plus or minus 90° with the antenna elements energized in phase. In Figure 11 the antenna elements are energized 90° in progressive phase relation so that

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the curve X shows a zero skew angle. The curves Y and Z are for plus 90° and minus 90° skew angle respectively. The curves shown in Figures 4 to 11 were obtained from calculations. The manner in which these calculations agree with measured results is indicated by the two curves in Figure 12 wherein the skew angle is 90° and the antenna elements are energized in phase. The calculated pattern is the curve AA whereas the measured pattern is the curve BB.

The significance of agreement between the calculated pattern and the measured pattern is further emphasized by the relation illustrated in Figure 13. In that figure the centers of radiation of the antenna elements were arranged in a circle diameter of 4.2 wave lengths the same as mentioned in connection with Figure 12. The centers of radiation of the antenna elements were arranged in accordance with the teaching of the prior art as shown in Figure 14 and the elements were energized in phase. The curve A shows the calculated pattern for in phase energization whereas curve B shows the measured pattern for the same arrangement and type of operation. A comparison between the patterns obtained as shown in Figure 12 with those shown in Figure 13 graphically illustrates the improvement obtained by the practice of the present invention.

From the foregoing representations provided by Figures 4 to 12 certain conclusions may be reached. Where the antenna elements have zero skew relation the best possible pattern is obtained when there is no phase rotation in the energization of the individual elements. When the antenna elements are energized with a 90° phase rotation a direction of skew may be selected which will give a good pattern or circle diameter as is the case where the skew is 90° in magnitude. All skew angles provide good radiation patterns with no phase rotation of the energization of the elements at small circle diameters. An acceptable radiation pattern is obtained with no phase rotation in the energization of the elements where the circle diameter of the centers of radiation of the antenna elements is 1.4 wave length and the skew angles are between 60° to 90°. With a 90° skew arrangement it is possible to select a phase rotation of the antenna elements which will always give a good radiation pattern. In general the best radiation patterns are obtained when the skew angles are in the proximity of 90°. For any angle of skew in the proximity of 90° and a fixed radius of the circle passing through the centers of radiation of the elements, it is possible to select a phase relationship between the energization of the elements which will give an optimum radiation pattern for the system. Likewise it is possible for angles of skew in the vicinity of 90° and a fixed phase relationship between the energization of the elements to select a radius for the circle passing through the centers of radiation of the elements which will give an optimum radiation pattern for the system.

The foregoing representations of results obtained are directly applicable to horizontally polarized antennas. Since the antenna elements are utilized with reflectors it will be apparent that the principles set forth apply to vertically polarized antennas.

For the purpose of illustrating and describing the present invention it was found convenient to show the relations obtained where four radiating elements are employed, although it will be understood that a greater or lesser number of radiating elements will produce comparable results. When a system with more than four radiating elements is employed, the radiation patterns of the individual elements will need to be narrowed in proportion to the total number of elements used, in order to obtain the maximum benefit of skew. When antenna elements arranged in skewed formation are mounted on tower surfaces it is possible to reduce the actual radiator length in half by the use of a half corner reflector. This has the effect of placing the center of radiation nearer the center of the tower thereby reducing the effective circle

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diameter. Such arrangement also has physical and economical advantages in that the individual elements are reduced in size by nearly one-half.

While for the purpose of illustrating and describing the present invention certain preferred embodiments have been shown in the drawings and described in the specification, it is to be understood that the invention is not to be limited thereby since such variations and embodiments are contemplated as are commensurate with the spirit and scope of the invention as defined in the accompanying claims.

I claim as my invention:

1. An antenna system comprising a plurality of substantially unidirectional radiating elements, each element having a certain radiation pattern with a principal axis, said elements being substantially in a common plane having their centers of radiation arranged in an arc of a horizontal circle, said elements each being oriented so that the principal axis of its radiation pattern is non-radial with respect to the radii of said arc of said circle.

2. An antenna system comprising a plurality of substantially directional radiating elements in a common plane having their centers of radiation arranged on a circle with equal angles therebetween, said elements radiating predominantly in non-radial directions to produce a horizontal radiation pattern for the system wherein a progressive angular change of a receiver location about said elements is accompanied by an inappreciable change in the phase relation of the energies received from said radiating elements.

3. The antenna system of claim 2 wherein each element is a dipole provided with a reflector.

4. An antenna system comprising a plurality of substantially unidirectional radiating elements, each element having a certain radiation pattern with a principal axis, said elements being substantially in a common plane and

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having their centers of radiation arranged in an arc of a circle, said elements each being oriented so that the principal axis of its radiation pattern is non-radial with respect to the radii of said arc of a circle, and means for energizing said elements in phase progression of such degree that the radiation pattern of the system is made uniform in an optimum degree for the intended sector radiation of the system.

5. A skew antenna system comprising at least three unidirectional radiating elements each having a center of radiation and a radiation pattern with a principal axis, said principal axes and centers of radiation being substantially in a common plane equidistant from a point therein, a reflector for each element, said reflectors and elements each being oriented to radiate unidirectionally at an angle to a line passing through said point in the plane and the center of radiation of the element, said elements cooperating to produce improved uniformity of the radiation pattern for the system wherein a progressive angular change of a receiver location about said point in said plane is accompanied by an inappreciable change in the phase relation of the energies received from said elements.

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