Oct. 19, 1954 W. E. KOCK 2,692,336

APERTURE ANTENNA

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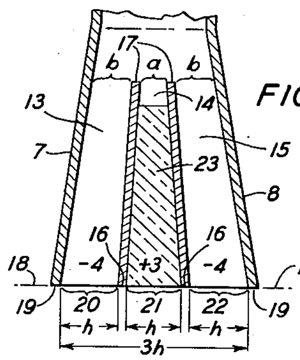

FIG. 2

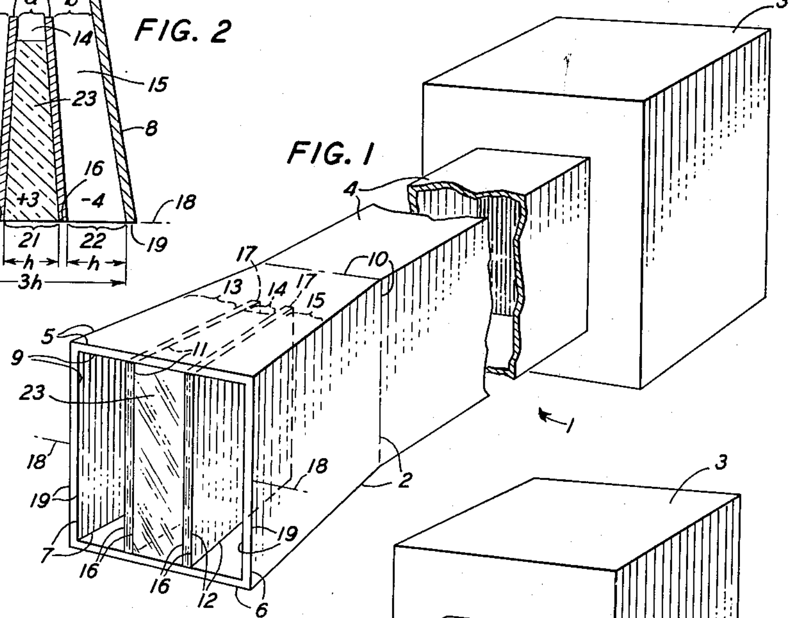

FIG. 1

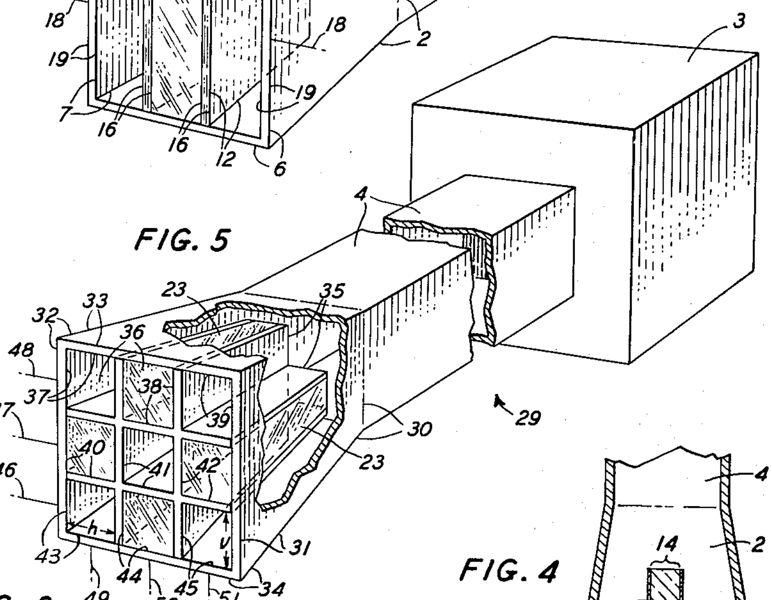

FIG. 5

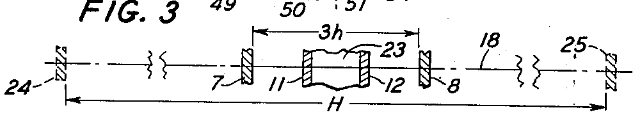

FIG. 3

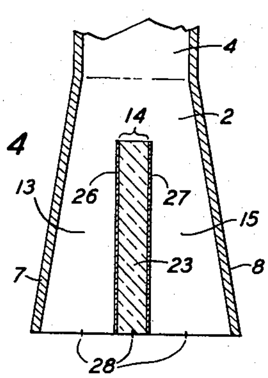

FIG. 4

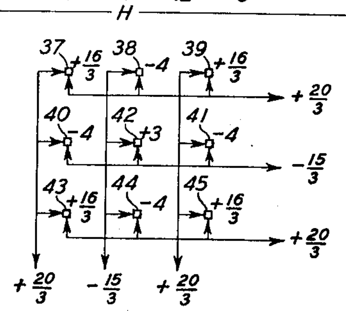

FIG. 6

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APERTURE ANTENNA

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3 Claims. (Cl. 250—33.63)

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This invention relates to directive antennas and more particularly to methods and means for improving the directive action of microwave antennas of the aperture type.

As is known, horns, wave guides, lens, reflectors and diffractors, each having a so-called antenna "aperture," have been widely used in the microwave art. In general, in this type of antenna the directivity or more specifically the half power width of the major directive lobe, in any given plane, is inversely proportional to the linear dimension of the aperture in the said given plane, and directly proportional to the wavelength. Also, considering for example, a horn having a single aperture of given area, it has heretofore been assumed that the sharpest beam, or stated differently, the minimum half power width for the major lobe, is obtainable only when the components of the wave in the aperture are cophasal and the amplitudes of the foresaid components are equal. Consequently, in the past, in order to secure an extremely narrow main beam, it has been found necessary in actual practice to utilize a large cumbersome antenna having an extremely large aperture, or at least an exceedingly large dimension or span in the selected plane of radio action, and in some systems, to employ structural means for securing the desired in-phase uniform energization of the aperture. Accordingly, it now appears desirable to secure, in an aperture type antenna, the exceedingly narrow main beam mentioned above, and in general an optimum directive pattern including a very narrow major lobe and negligible minor lobes, without utilizing a large antenna aperture. Conversely considered, it appears desirable to improve greatly the directive action of an antenna having a given small aperture. In particular, considering an antenna having an aperture of given area or linear span, it appears advantageous to obtain a beam which is considerably sharper, that is, a major lobe which is considerably more narrow, than the beam or lobe obtained when the aforesaid aperture is excited with cophasal wave components of uniform amplitude. In short, whereas in the prior art aperture antennas, the "effective" antenna area is always smaller than the actual or physical aperture area, it now appears advantageous to secure an effective aperture area which is larger than the actual aperture area.

It is one object of this invention to increase the directivity of an aperture type antenna.

It is another object of the invention to produce a radio beam having an exceedingly narrow width,

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utilizing an antenna having an aperture which is small as compared to that of the prior art antenna heretofore employed to produce a beam having the aforesaid width.

It is another object of this invention to render, in an aperture type antenna, the effective aperture dimension in the given plane, or the effective aperture area, relatively large compared respectively to the actual aperture dimension in said plane or the actual aperture area.

It is still another object of this invention to obtain, in one or more planes of action, a sharper or more narrow major directive lobe, lower minor lobes and more satisfactorily positioned null points, for an aperture type antenna having an aperture of given area, than heretofore secured in aperture type antennas having said given aperture area and, in particular, in aperture antennas having said given aperture area and in which the so-called cophasal uniform type of energization is utilized in said aperture.

In accordance with one embodiment of the invention the mouth aperture of a microwave horn designed for a mean wavelength is divided by a pair of flat conductive members or partitions into three small cells each having a dimension or span in a given plane or radio action which is small, for example a quarter wavelength, relative to one-half of said wavelength. Preferably, but not necessarily, the spacing, in the horn mouth aperture, between the front edges of the flat partitions is such as to render the cell areas or more specifically the aforesaid cell dimensions equal. The partitions extend toward the horn throat aperture and the spacing between the back edges of the partitions is such as to secure a predetermined non-uniform amplitude distribution for the waves propagated through the three cells. Also, a dielectric phase reverser is positioned between the two partitions, that is, in the central channel or cell so that the waves in the adjacent cells are oppositely phased. More specifically, the relative amplitude distribution is 4, 3, 4 and the phase distribution −, +, −. By reason of the subdivision of the main horn aperture into three small cells, and the use of the above-described amplitude and phase distributions, the beam width produced is exceedingly narrow, as compared with that produced by the aforesaid horn, with the conductive members and the phase reverser omitted. Since the aperture antennas of the prior art are classified as highly directive devices, the aperture antenna of the invention may, for convenience, be classified as super-directive.

The invention will be more fully understood from the following specification taken in conjunction with the drawing on which like characters denote elements of similar function and on which:

Fig. 1 is a perspective view and Fig. 2 is a sectional partial plan view of one embodiment of the invention;

Fig. 3 is a diagram used for explaining the invention;

Fig. 4 is a sectional partial plan view of a slightly different embodiment of the invention;

Fig. 5 is a perspective view of still another embodiment of the invention, and

Fig. 6 is a diagram used in explaining the embodiment of Fig. 5.

Referring to Figs. 1 and 2, there is shown a microwave system 1 which comprises a sectoral horn 2 connected to a translation device 3 by means of a rectangular guide 4. The sectoral horn comprises the parallel wall members 5 and 6, the flared wall members 7 and 8. Numerals 9 and 10 denote respectively the mouth or main antenna aperture and the throat aperture. A pair of diverting conductive members or partitions 11 and 12 of negligible thickness are positioned perpendicular to the parallel walls 5 and 6 and form therewith the three passages or channels 13, 14 and 15. Numerals 16 and 17 denote respectively the front and back edges of partitions 11 and 12. In the plane 18 of radio action perpendicular to the flared horn walls 5 and 6, the front edges 16 of members 11 and 12 are spaced equal distances *h* from each other and from the flared horn walls 5 and 6, and form with the front elges 19 of the horn walls 5 and 6 the three antenna cells 20, 21 and 22 having equal areas. The back edges 17 of the partitions 11 and 12 are spaced apart a distance *a*; and each partition is spaced a distance *b* from the adjacent horn wall. The width or span *h* of each cell is small relative to one-half the operating wavelength as, for example, a quarter wavelength; and the spacings *a* and *b* are also each small relative to one-half the minimum operating wavelength. The spacing *a* determines the amplitude of the wave in the middle channel 14 relative to the equal amplitudes of the waves in the side channels 13 and 15 and, in the three-channel system of Figs. 1 and 2, the spacing *a* is smaller than the distance *b* and is selected so that the amplitude distribution in channels 13, 14 and 15 and, more particularly, in cells 20, 21 and 22 is respectively 4, 3, 4. If the electric polarization of the waves is perpendicular to the partitions 11 and 12 the dimensional ratio a/b is directly proportional to the amplitude ratio 3/4 for the adjacent cells 21, 20 or 21, 22, inasmuch as the amplitude distribution in the throat aperture 10 in the plane of the electric polarization is uniform. On the other hand if the electric polarization is parallel to partitions 11 and 12 the ratio a/b is not directly proportional to the aforesaid amplitude ratio 3/4, since in a plane perpendicular to the electric polarization the amplitude distribution in the throat aperture 10 is sinusoidal. Numeral 23 denotes a dielectric phase reverser positioned in channel 14 between and contacting the partitions 11 and 12. A dielectric phase reverser suitable for use in this system is disclosed in Patent 2,405,992 granted to E. Bruce. The reverser 23 has a critical length L such that the wave component, propagated through the middle channel 14 and having the mean or given operating wavelength, is delayed 180 degrees relative to the component propagated through either of the side channels 13 and 15, as indicated by the −, +, − signs associated respectively with channels 13, 14 and 15.

In operation, assuming device 3 is a transmitter, waves are supplied by device 3 over guide 4 to the throat aperture 10 of the horn and thence through the distinct channels 13, 14 and 15 to the radiating cells 20, 21 and 22. As explained above, the waves emitted by cells 21, 22 and 23 have a non-uniform amplitude distribution, namely, 4, 3, 4 and the wave components emitted by cell 21 are phased opposite to the waves emitted by cells 20 and 22. By reason of the aforesaid amplitude and phase distributions, and especially by reason of the fact that the dimension *h* of each cell is small compared to one-half of the given or mean wavelength, an optimum directive pattern in the plane 18 is obtained. More specifically, as compared to the directive pattern of the horn 2 obtained when the partitions 11 and 12 and the phase reverser 23 are omitted and the amplitude distribution across the horn mouth aperture is uniform, the pattern of the structure shown in Figs. 1 and 2 is more satisfactory in that it contains an exceedingly narrow major lobe and low minor lobes, the minor lobe level being one ninth of the major lobe. Stated differently, the beam or major lobe obtained for the sectionalized horn of Figs. 1 and 2 corresponds to that secured for a non-sectionalized horn having a mouth aperture area much greater than the area of the actual mouth aperture 9 of horn 2. Thus, as illustrated schematically in Fig. 3, the effect of inserting the partitions 11 and 12 and the phase reverser 23 in the horn 2, and judiciously selecting the amplitude distribution, is to increase the horn aperture span, in the plane 18, from the relatively small actual dimension of 3 *h*, neglecting the thickness of the partitions 11 and 12, to the relatively large dimension H, for the hypothetical horn comprising the walls 24 and 25.

In reception, the converse operation is obtained by reason of the theorem of reciprocity. While the sectionalized horn 2 comprises a "one-dimension" linear array of only three cells spaced along a direction in the plane 18, any practical number of cells as, for example, several hundred may be utilized in the one-dimension array. For a five-cell linear array the phase and amplitude distributions should be +0.43, −0.57, +1.0, −0.57, +0.43, the amplitude distribution being symmetrical about the center cell. While the five-cell amplitude distribution just given and the three-cell amplitude distribution 4, 3, 4 were determined experimentally, it may be pointed out that these distributions are in substantial agreement with the coefficients of expression

$$a_0+a_1x+a_2(2x^2-1)+a_3(4x^3-3x)$$

given by H. J. Riblet on page 491 in a discussion of the article "A Current Distribution for Broad Side Arrays Which Optimizes the Relationship Between Beam Widths and Side Lobe Level" by C. L. Dolph, Proceedings I. R. E., May 1947, page 489, for the righthand half of a hypothetical linear array of spaced elements, the term a_0 representing the center antenna element. Thus, for a three-element linear array having elements spaced a quarter wavelength apart corresponding to the cell spacing in the horn 2 of Figs. 1 and 2, the amplitude distribution obtained from the above expression, namely 5.5, 1.0 and 5.5 is comparable to the 4, 3, 4 distribution employed in the horn of Figs. 1 and 2. Assuming now that the cell spacing h in the horn 2 is an eighth of a wavelength, the distribution, as determined experimentally, should be 0.63, 1.0, and 0.63, and this distribution is substantially the same as the distribution 0.68, 1.0, 0.68 obtained from the above-mentioned expression for an array using one-eighth wavelength spacing. It may be noted that both of the amplitude distributions given above, for the eighth wavelength spacing array, are substantially the same as the distribution 0.645, 1, 0.645 corresponding to the distribution 1, 1.55, 1 given in Fig. 1 of Patent 2,066,874 to O. Bohm et al.

The embodiment illustrated by Fig. 4 is similar to that illustrated by Figs. 1 and 2, the main difference being that the metallic partition members in Fig. 4 are parallel instead of diverging. Numerals **26** and **27** denote copper foil members corresponding to the rigid metallic partitions **11** and **12** and attached to the parallel flat surfaces of the dielectric phase reverser **23**. The thickness of the assembly comprising the dielectric reverser and copper foil members is chosen so as to obtain the correct dimensions a and b and for securing the desired amplitude distribution 4, 3, 4. As shown on the drawing the spacings between the centers **28** of the cells **20**, **21** and **22** are equal, as is the case in the horn of Figs. 1 and 2. In operation, the sectionalized horn of Fig. 4 emits or receives waves in substantially the same optimum manner as the sectionalized horn of Figs. 1 and 2.

Referring to Fig. 5, there is shown a microwave system **29** comprising a pyramidal horn **30** having a pair of walls **31** and **32** flared in the vertical plane and the pair of walls **33** and **34** flared in a plane perpendicular to the first-mentioned plane. As shown on the drawing, the horn is sectionalized to form a two-dimension array of cells. Thus, the metallic members **35** divide the horn into nine shielded channels **36** and the horn mouth aperture **9** into nine square cells **37**, **38**, **39**, **40**, **41**, **42**, **43**, **44** and **45** arranged in three horizontal tiers **46**, **47** and **48** and in three vertical stacks **49**, **50** and **51**. The horizontal dimension h and the vertical dimension v of each cell are small compared to a half wavelength. Considering any pair of channels in each horizontal tier, or in each vertical stack, a phase reverser **23** is included in only one of the two adjacent channels. The metallic partition members **35** diverge from back to front in both planes, the front edges of these members being spaced equally in both planes and the back edges being spaced so as to produce the two-dimensional amplitude distribution shown in Fig. 6. Thus, the center cell **41** has a relative amplitude of 3 and a positive phase, the corner cells **37**, **39**, **43** and **45** each have a relative amplitude of 16/3 and a positive phase, and the remaining intermediate side cells **38**, **40**, **42** and **44** each have a relative amplitude of 4 and a negative phase. With this distribution, in the horizontal plane, the effective amplitude distribution is 20/3, 15/3, 20/3, that is 4, 3, 4 which is the algebraic addition of the amplitudes in each horizontal tier. Similarly in the vertical plane, the effective amplitude distribution is 20/3, 15/3, 20/3, that is, 4, 3, 4 obtained by the algebraic addition of the amplitudes in each vertical stack. Hence the amplitude and phase distributions are optimum for both planes and the resulting directive patterns in the two planes, and in general the directive characteristic considered in the solid, are the optimum.

While the invention has been specifically described in connection with aperture antennas of the horn type it may be utilized in connection with other types of aperture antennas such as lenses, reflectors and diffractors. Also, if desired, in horn systems utilizing a relatively large number of cells compared to the number employed in the embodiments described herein, the four horn walls may be omitted and a cellular structure comprising open channels or cells and phase shifting channels or cells may be positioned at an appreciable distance in front of the actual horn aperture. Similarly, in the other types of aperture antennas mentioned above, a cellular structure corresponding to the cells **37**—**45** and comprising antiphased adjacent cells may be spaced from the opening of the reflector or the face of the lens or diffractor.

Although the invention has been explained in connection with certain embodiments, it is to be understood that it is not to be limited to the embodiments described inasmuch as other apparatus may be successfully employed in practicing the invention. In particular, in place of the dielectric phase changer, other types of phase changers, such as metallic delay or metallic advance shifters may be employed in practicing applicant's invention.

What is claimed is:

1. An aperture antenna having a given linear aperture dimension, and means for increasing for a given wavelength the effective value of said given dimension, comprising a pair of conductive members positioned in said aperture and forming with the aperture boundary at least three parallel cells having collinear dimensions, each of said collinear dimensions being small relative to one-half of said wavelength, said pair of conductive members being at one end contiguous to and extending inwardly from the energy delivering aperture of said antenna, said conductive members being positioned with respect to said aperture to direct more energy to each of the outer cells than to the central cell, and a phase reverser positioned in the central cell, only.

2. A sectionalized aperture antenna for waves having a given wavelength comprising a plurality of conductive members positioned in the aperture of said antenna and forming a plurality of antenna cells, including a central cell and a plurality of outer cells, the dimensions of each cell in a given plane being small relative to one-half of said wavelength, and a phase changer positioned in one only of each pair of adjacent cells said antenna cells being formed contiguous to and extending inwardly from the energy delivering aperture of said antenna, said conductive elements being positioned within said aperture to direct more energy to each of the outer cells than to the central cell.

3. In combination, a pyramidal horn for a wave of a given wavelength having four similarly flared walls and a square mouth aperture, a first set of flat metallic members positioned perpendicularly to one pair of opposite horn walls and a second set of flat metallic members positioned perpendicularly to the other set of opposite horn walls, each of said flat members having front and back edges, said four horn walls and the front edges of all of said members forming a square array of square antenna cells, including a central cell and a plurality of outer cells, the side dimension of each cell being small relative to one-half of said wavelength, a plurality of phasing reversers, one of said reversers

being positioned in one only of each pair of adjacent cells said partitions being positioned with respect to the mouth aperture of said horn to direct more energy to each of said outer cells than to the central cell of said array.

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