

Oct. 26, 1965

J. YONKERS

3,214,760

DIRECTIONAL ANTENNA WITH A TWO DIMENSIONAL
LENS FORMED OF FLAT RESONANT DIPOLES
Filed April 28, 1960

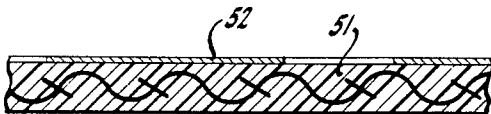
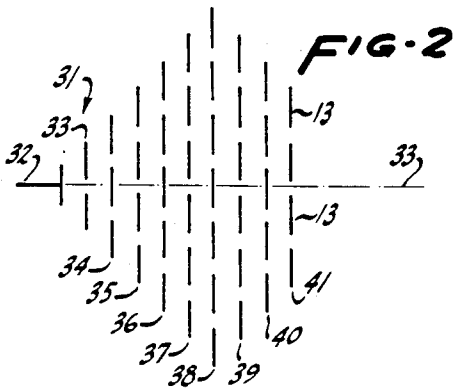
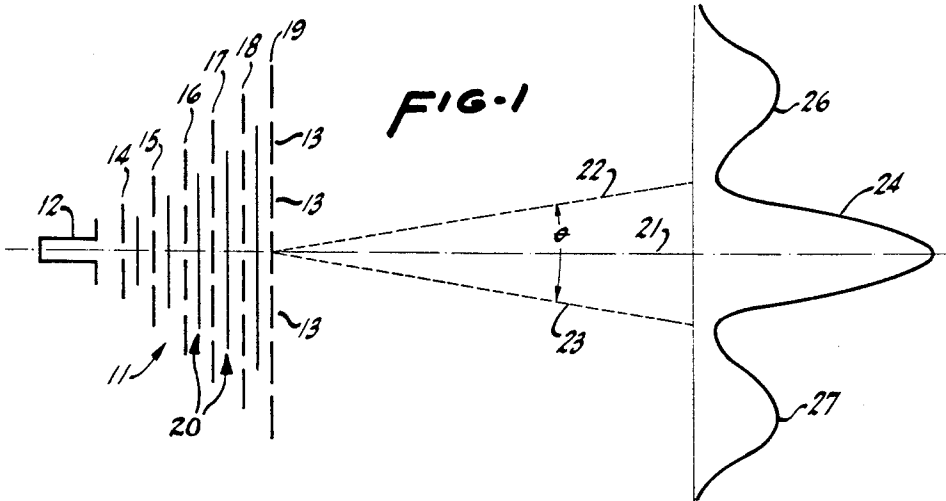


FIG. 4

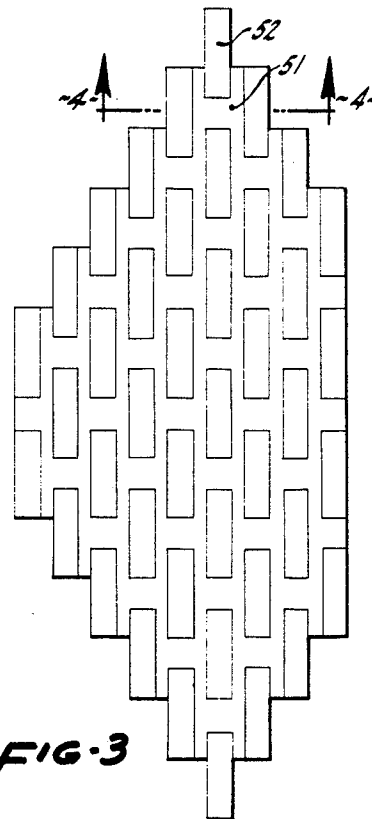


FIG. 3

INVENTOR.

JOHN YONKERS

BY

Lippincott, Ralls & Hendricson
ATTORNEYS

1

2

3,214,760

DIRECTIONAL ANTENNA WITH A TWO DIMENSIONAL LENS FORMED OF FLAT RESONANT DIPOLES

John Yonkers, San Bruno, Calif., assignor to Textron Inc., Providence, R.I., a corporation of Rhode Island
Filed Apr. 28, 1960, Ser. No. 25,416
8 Claims. (Cl. 343-753)

This application is a continuation-in-part of my prior filed application Serial No. 812,018, filed May 8, 1959, now abandoned.

The present invention relates to an improved directional signal launcher and to an improved and simplified method of manufacturing such a launcher. The signal launcher hereof includes a plurality of individual radiators disposed in particular array to accommodate close coupling therebetween, somewhat resembling an espalier arrangement.

In the transmission of electromagnetic waves it has been found desirable to provide highly directional propagation and reception means, as for example, in radar and beamed radio communications. To this end, there have been developed a plurality of directional antenna arrangements, including sectoral horns. As regards the latter, it has been determined that the directivity of the horn is proportional to the horn aperture, and inversely proportional to the flare length of the horn. In accordance with these relationships, highly directional sectoral horns will be seen to require very substantial dimensions, so that same are consequently quite difficult and expensive to construct, as well as being quite unwieldy to employ. As an alternative to the sectoral horn, there have been developed highly-directional antenna arrays involving a large number of radiators in broadside array, end-fire array, or some other equivalent arrangement. These arrangements are uniformly complex, both as to structure and application, so that their applicability is somewhat limited.

The present invention is particularly directed to the simplification of highly directional antenna arrays, together with the achievement of very desirable antenna characteristics. In accordance with the present invention, there is provided a large plurality of simple radiator elements disposed in close coupling relationship for parasitic excitation from a feed end. It is possible in accordance herewith to accomplish substantial lateral coupling between parasitically-excited radiator elements of a single array to consequently attain a wide wavefront for propagation, and furthermore, to insure a uniform phase front at the propagating end of the array. The foregoing is accomplished by the particular distribution of the individual radiating elements of the espalier launcher hereof. Of particular note in connection with the present invention, is the extreme simplicity of the physical structure involved, for the entire directional signal launcher hereof lies in a single plane of minute thickness, and this plane may be defined by a flexible dielectric sheet, so that the array is readily adapted for mounting in substantially any location such as, for example, upon the various structural portions of an airplane.

Further to the present invention, there is herein provided a materially simplified and improved method of manufacturing directional signal launchers. Not only is the method of manufacture hereof quite simple and inexpensive, but furthermore, same is particularly adapted to the individual tailoring of specific arrays to achieve specifically desired propagation characteristics.

It is an object of the present invention to provide a directional signal launcher of improved and simplified structure.

It is another object of the present invention to provide an improved method of manufacturing directional signal launchers.

It is a further object of the present invention to provide a planar signal launcher formed of a plurality of small radiating elements disposed for lateral as well as longitudinal coupling to attain highly directional propagation characteristics.

It is yet another object of the present invention to provide a highly directional signal launcher of extended front width, wherein full phase control is achieved in a single plane without dielectric variations.

It is a still further object of the present invention to provide a signal launcher of dipole radiators arranged to laterally extend the wavefront for propagation to achieve highly directional launching and including a front configuration insuring a uniform phase front for propagation therefrom.

Various other objects and advantages of the present invention will become apparent to those skilled in the art from the following description of particular preferred embodiments of the present invention, and an exemplary illustration of the improved method of manufacture hereof. It is not, however, intended to limit the present invention by the terms of the following description, but instead, reference is made to the appended claims for a precise delineation of the true scope of this invention.

The invention is illustrated as to particular preferred embodiments thereof and certain steps of the method thereof in the accompanying drawings, wherein:

FIG. 1 is a schematic illustration in plan view of one embodiment of the present invention, and including a diagrammatic showing of propagation intensity as may be attained therefrom;

FIG. 2 is a schematic illustration in plan view of an alternative embodiment of the present invention;

FIG. 3 is a plan view of the actual structure of an espalier signal launcher, in accordance with the present invention; and

FIG. 4 is a magnified sectional view taken in the plane 4-4 of FIG. 3.

The present invention in general contemplates the provision of a plurality of antenna arrays disposed in espalier arrangement or "shoulder-like" configuration. The espalier arrangement may be limited to a single plane or, alternatively, the arrangement may be compounded into two planes normal to each other, for the purpose of deriving additional gain from the signal launcher. In the instance wherein the espalier arrangement is limited to a single plane, the signal launcher requires only a negligible, vertical aperture or opening for launching signals therefrom, inasmuch as transverse beam shaping is attained by end-fire effect. The espalier arrangement hereof includes the parallel alinement of a plurality of antenna arrays of successively increasing length, and of successively increasing number of radiators per array. The individual parasitic elements or radiators of the overall espalier arrangement hereof, are preferably formed as simple dipoles, and the individual radiators are herein disposed in closely adjacent proximity so that close coupling is attained. In this manner the espalier signal launcher of the present invention makes use of all types of coupling between conductive elements, including inductive and capacitive coupling, as well as more conventional radiation coupling. It is thus possible, in accordance herewith, to readily diverge the input energy in a lateral direction to energize a materially elongated array with a uniform phase front for attaining maximum directivity of the signal being launched.

With regard to the above-noted uniform phase front of the signal being launched, it is further noted that the present invention provides for the attainment of this necessary uniformity without the required inclusion of slow-wave elements, or excessively complicated structures. In distinction to more conventional antenna arrays wherein

materially elongated individual radiators are employed, the present invention includes only short radiating elements having, for example, half wavelength extensions, and it will be appreciated that in this instance it is necessary to overcome the apparent shorter path length axially of the launcher than appears to exist diagonally there-through. The individual radiating elements of the signal launcher are herein disposed in such a manner that no direct radiating path is available from a rear radiator to the front of the launcher, but instead, all of the energy coupled from the rear radiators must parasitically excite additional radiators disposed in front of same. This is herein accomplished by the alinement of individual radiators of the overall launcher in such a manner that no open path is available from any rear point of the launcher to the front thereof. There will thus be seen to be herein provided for the full exchange of input energy between successive rows of the launcher, and with the close coupling herein afforded, this energy is laterally propagated as well as longitudinally propagated through the launcher, so that the signal launched from the front of the unit has a materially increased lateral dimension to consequently achieve the desired directivity. Although it is possible to employ various means for insuring like electrical path lengths from the input end of the launcher to the front thereof, particular advantage is herein achieved by the utilization of an irregular front configuration wherein a materially simplified structure is attained. This particular structure may be quite simply and inexpensively manufactured, in accordance with the present invention, to thereby provide a further advancement over the art.

Considering now the details of one embodiment of the present invention and referring to FIG. 1 wherein same is illustrated, there will be seen to be provided an espalier signal launcher 11 disposed immediately in front of an energizing element 12, such as a simple dipole or horn. The signal launcher 11 has a generally triangular configuration with the narrow portion thereof comprising the back or input side of the launcher, and the elongated end of the triangle forming the front of the launcher from which signals are propagated. This triangular configuration is composed of a plurality of rows or arrays of individual radiators 13. In the embodiment illustrated in FIG. 1, there are shown some six rows 14 to 19, and each of these rows is symmetrically disposed about an axis 21 perpendicularly bisecting the energizing dipole 12. All of the rows of the launcher are disposed in a single, common plane, and the elongation of the rows is afforded by the addition of a radiating element to each row successively displaced forwardly of the energizing dipole. Thus, the embodiment illustrated includes a pair of radiators 13 in the first row 14 thereof, three radiators in the next adjacent row 15, and so on to the front row 19, wherein there are disposed some seven radiators. The individual radiators of each of the rows are disposed in end-on-end alinement in quite close proximity, and also, the individual rows are disposed in close proximity, so as to attain close coupling between adjacent radiators of the launcher. Furthermore, all of the rows of the launcher are disposed in parallelism, and the launcher axis 21 bisects each of the rows in the common plane of the launcher.

It will be seen that the above-described orientation of radiators in the espalier launcher configuration provides for a complete masking of the energizing dipole 12 from the front of the launcher. Consequently, energy radiated from the dipole or horn 12 can only reach the front of the signal launcher through the individual radiators of the separate rows thereof, and it is not possible for energy to be directly radiated from the dipole 12 forwardly of the launcher. It is further to be noted that the above-described orientation of individual radiators of the launcher does not include the alinement of radiators in the direction of signal propagation, i.e., there is not provided

stacks or rows of radiators extending from the rear to the front of the launcher. It is thus not possible for energy to be directly coupled from the rear to the front of the launcher through a single series of radiators, but instead, such energy is, in fact, coupled from each radiator of the launcher to a plurality of other radiators disposed in front of same, and consequently, there is herein attained a highly desirable lateral coupling of the energy through the launcher. It is well recognized that a broad wavefront is highly desirable in order to obtain directional propagation characteristics, and in accordance with the present invention, such a broad wavefront is accomplished by the lateral coupling of electromagnetic energy from a short row of radiators to a long row of radiators at the front of the signal launcher.

In operation, the signal launcher of FIG. 1 is energized by suitable energization of the horn or dipole 12, whereby same radiates energy forwardly thereof, generally axially of the launcher. This energy radiated from the dipole 12 will parasitically excite the radiators of the first row 14 which, in turn, are closely coupled to the three radiators of the next adjacent row 15. As a consequence of this close coupling, the individual elements or radiators 13 of this row 15 will each be excited, and will, in turn, energize the elements of the next adjacent row 16, etc. until the front row 19 of the launcher is energized. The close coupling afforded between the radiators of adjacent rows will be seen to cause a lateral transmission of wave energy, as well as an axial transmission, so that each of the radiators of the elongated row 19 is, in fact, energized to radiate energy therefrom into space for accomplishing a broad wavefront propagation.

It will be appreciated that a uniform phase front for the propagated wave is required across the radiating surface of the launcher, in this instance the end row 19 thereof, and such is herein accomplished by the maintenance of the same electrical path length from the energizing dipole 12 to the ends and center of the longest row of radiators. It is possible in this respect to employ a variation in dielectric between the rows of radiators, and in the embodiment illustrated in FIG. 1 this will be seen to call for more dielectric along the axis thereof than along the outer edges of the launcher. Dielectric strips 20 are schematically illustrated as providing requisite variation in electrical path lengths. Such dielectric variation will be seen to provide a lower wave propagation velocity axially of the launcher than along the edges thereof, so that the wave to be launched reaches and energizes each of the individual radiators of the longest row 19 at the same time.

It is well known that the beam angle of the radiated energy is inversely proportional to the width of the radiating aperture from a horn or antenna array. This is schematically illustrated in FIG. 1 of the drawing, wherein the beam angle θ is shown to be included between the dotted lines 22 and 23 indicating the extremities of the main lobe of a transmitted electromagnetic wave. As shown at the right of FIG. 1, the wave radiated from the signal launcher hereof may have a sharply peaked main lobe 24 with secondary or side lobes 26 and 27 displaced laterally therefrom. Calculations of the wave patterns may be made from conventional relationships for antennas to be found in standard text, and may even be determined from optical principles.

With regard to the attainment of a uniform phase front for energy propagated from the signal launcher of the present invention, attention is invited to FIG. 2 for an illustration of a different embodiment of the present invention. As noted above, it is necessary for the energy launched from the present invention to have a uniform phase front across the width of the launcher, and this is attained by maintaining the electrical path length to the extremities of the launcher, the same as the electrical path length to the center thereof. While it is possible to accomplish this result by the establish-

5

ment of different wave propagation velocities in different parts of the launcher, or by the separate tuning of different wave paths through the utilization of individual radiators of different lengths, particularly advantage lies in the embodiment of the invention illustrated in FIG. 2 wherein no tuning is required, and furthermore, no dielectric variations are necessary. The signal launcher 31, illustrated in FIG. 2, is adapted for energization from a conventional dipole, or the like 32, disposed at the back side of the launcher and bisected by the axis 30 of the launcher. This espalier launcher configuration is identical to that illustrated in FIG. 1, insofar as the establishment of an expanded wavefront is concerned. The launcher will thus be seen to include a plurality of parallel rows of radiators 13, and there is illustrated some six of such rows identified by the numerals 33 to 38. The rear row 33 is formed of two dipole radiators disposed in end-on-end alinement with the launcher axis passing between same, and each of the succeeding rows toward the front of the launcher is provided with one more radiator than the preceding row, in the manner described above. Here again in this embodiment, the launcher is formed in a single plane, and the individual radiators of each row are closely spaced from each other in end-on-end alinement and the separate rows are closely spaced from each other in parallelism so as to attain close coupling between adjacent radiators.

In the same manner as described above, there is herein attained propagation of electromagnetic energy axially through the launcher and also laterally of the axis thereof, so that the longest launcher row 38 is fully energized as to each of the radiators thereof. This longest row 38 is formed of the desired total length of the wavefront to be launched from the device. In the embodiment of FIG. 2 the required uniform wavefront of propagated energy is attained by the provision of additional rows of radiators in front of the longest row 38. There will be seen to be illustrated the rows 39, 40 and 41, disposed in front of the row 38. Each of the additional rows 39, 40 and 41 is formed of individual dipole radiators 13 disposed in end-on-end alinement in each row, and the separate rows are disposed in parallelism with each other and with the longest row 38. Furthermore, the row 39 is formed of a lesser length than the longest row 38 by the inclusion of one less radiator therein, and in like manner the row 40 is formed with one less radiator than the row 39, and the row 41 with one less radiator than the row 40. Each of the rows 39, 40 and 41 is bisected by the launcher axis 30, and it will be seen that the electrical path length from the energizing dipole 32 to the front of the launcher at row 41 on the axis of the launcher is substantially equal to the distance from the dipole 32 to the outermost radiator of the longest row 38. With an equality of physical distances to the points of radiation from the front of the launcher, it will be appreciated that with like electrical materials provided in the paths there is consequently achieved a substantial identity of electrical path lengths. In this embodiment of the invention it will be seen that signals launched therefrom are radiated from the outermost points of the longest row or array 38 thereof, and also, from the outermost points of the rows 39 and 40, as well as from the entire length of the front row 41.

In accordance with the present invention, a variation in the number of additional or front rows of the launcher disposed in front of the longest row or array thereof is contemplated in order that the desired uniformity of phase front may be attained for individual applications of the invention. Thus, the number of rows of decreasing length disposed in front of the longest row or array may be varied between applications of the invention; however, the illustrated embodiment employing three front rows has been found to be wholly satisfactory for the launching of signals under a variety of circumstances.

The signal propagated from the launcher illustrated in FIG. 2 may have a propagation intensity somewhat as il-

6

lustrated in FIG. 1. However, the addition of shorter rows or arrays of radiating elements in front of the row of maximum length provides in this embodiment for a material simplification in the actual physical structure of the invention. In this respect it is noted that individual, planar, signal launchers, in accordance with the present invention, may be compounded in a variety of manners to attain particular propagation characteristics. It is possible to place two espalier launchers one above the other, and to energize same from a common source so as to materially narrow the vertical beam width. It is also possible to dispose two signal launchers, in accordance with the present invention, in a single, horizontal plane wherein the launchers are disposed in side-by-side relationship. Energization of such a launcher combination with signals of equal phase as, for example, through a T-junction from a common source, will produce a very narrow beam width in the horizontal or common plane of the launchers.

It is particularly noted that the signal launcher of the present invention has a planar configuration, and furthermore, that the thickness of same need only be very minute. As a consequence of this physical configuration, the present invention is particularly well adapted for mounting in positions wherein only very small vertical spacings are available. In this respect, it is noted that the espalier signal launcher is highly advantageous for integration into a rotodome-type antenna housing.

With regard to the physical structure of the espalier signal launcher of the present invention, attention is invited to FIGS. 3 and 4 of the drawings. The launcher therein illustrated includes a planar sheet 51 of dielectric material. This sheet 51 may be formed of a plastic or other suitable material such as, for example, an impregnated cloth, as illustrated. Upon the surface of this sheet 51 there are disposed a plurality of conducting elements 52. These elements 52 are preferably formed as metal tabs, which may, for example, be plated upon the upper side of the sheet in the form of rectangles, preferably having a length substantially equal to one-half wavelength of energy to be propagated from the particular launcher. The width of the individual metallic elements 52 may be made somewhere around one-quarter of the length thereof. With regard to the orientation of the separate elements 52 upon the sheet 51, it will be seen that these elements are disposed in rows transversely of the sheet, and furthermore, that the individual elements of adjacent rows are offset with respect to each other. Thus, the elements of an individual row are disposed in longitudinal alinement across the sheet in spaced relation to each other, and the individual elements of the next adjacent row in parallel therewith are disposed in centered relationship with the space between the elements of the first-mentioned row.

The illustration of FIG. 3 is substantially a full-scale representation of a highly directional espalier signal launcher, in accordance with the present invention, and in this particular illustration the individual metallic elements may, for example, have a length of about $\frac{11}{16}$ inch and a longitudinal separation between elements in an individual row of about one-quarter of an inch. The width of the individual elements 52 is herein about $\frac{3}{16}$ inch, and the spacing between parallel rows of elements is about $\frac{3}{32}$ of an inch. It will be appreciated that the foregoing dimensions of a single espalier launcher are hereinset forth merely as exemplary, and without intent to limit the present invention thereby.

The sheet 51, upon which the metallic elements 52 are disposed, is preferably formed of a flexible material, such as in impregnated cloth, as noted above. The desired rigidity of this backing sheet 51 may vary between individual applications of the invention, and normally, the sheet will be formed of sufficient rigidity to adequately maintain shape so as to thus provide full and complete support for the radiating elements thereon. In an alterna-

tive circumstance however, the sheet 51 may be bent to conform to the curvature of particular mounting surfaces, such as those found on an airplane, for example, and inasmuch as the sheet 51 is an electrical insulator, it is possible to directly attach the sheet to any desired metallic mounting means or structural element by direct contact of the under side of the sheet with such element. It is only necessary for the metallic elements 52 to have a very minute thickness transversely of the sheet, and consequently, the overall thickness of the signal launcher may be maintained of the order of the thickness of a few sheets of paper. This highly simplified physical structure as illustrated in FIGS. 3 and 4, has been found to be the full equivalent of a sectoral horn of substantial dimensions and weight. Furthermore, this particular signal launcher is likewise the full electrical equivalent of highly complex and bulky antenna arrays of the type well known in the prior art. The total weight of the espalier signal launcher of the present invention, and in particular the one illustrated in FIGS. 3 and 4, may be of the order of an ounce or so, as compared to the conventional weight of many pounds for sectoral horns producing similar electrical propagation characteristics.

The present invention is furthermore highly advantageous in providing a material simplification in the process of manufacturing directional signal launchers. In accordance with the present invention, the espalier signal launcher may be quite readily produced by the deposition of metal strips on a single surface of an insulating sheet. This deposition may be accomplished in a variety of ways, including many conventional deposition procedures, such as plating, and the like. With a single enlarged insulating sheet having a large plurality of metal strips 52 disposed thereon in firm attachment to a single surface thereof in the orientation illustrated in FIG. 3, it will be appreciated that it only remains for the outline of the desired espalier signal launcher to be marked upon the sheet, and the launcher then cut therefrom. This cutting operation may be quite simply and rapidly performed as by means of cutting machinery or, alternatively, by the application of hand shears. Of particular advantage in connection with the present invention is the ability of the one forming the signal launcher to vary the characteristics thereof by cutting additional portions from same. The final signal launcher is quite readily operated upon with means such as scissors or shears, to remove additional electrical elements therefrom at will. Thus, for any particular application, it is possible for the one installing and operating same to vary the propagation characteristics by quite simple and readily accessible means. It is furthermore possible, in accordance with the improved manufacturing process hereof, to provide the user of signal launchers with sheets of the basic material from which he may readily form particular launchers to conform to the requisites of his application.

What is claimed is:

1. An improved signal launcher comprising a flexible dielectric sheet, and a plurality of parallel rows of closely spaced like metal tabs upon a single side of said sheet with the tabs of each row being disposed in end-on-end alinement and the tabs of adjacent rows being offset with respect to each other, said sheet having a triangular configuration extending laterally outward from an input end to encompass an additional tab per row toward the front of the launcher.

2. A planar directional signal launcher comprising a plurality of like dipole radiators disposed in a plurality of parallel rows in end-on-end relationship in each row, said rows lying in a single plane and having a progressively increasing length from the rear of the launcher to a maximum launcher width, the radiators of each row being offset with respect to the radiators of adjacent rows to aline the radiators of each row upon openings between radiators of adjacent rows, the radiators of each

row and the rows of radiators being closely spaced apart whereby energy fed into the rear of the launcher is coupled laterally as well as axially therethrough to energize all of the radiators of the launcher and thereby propagate such energy from an elongated wavefront for maximized directivity.

3. A directional signal launcher as set forth in claim 2, further defined by an additional plurality of rows of like radiators disposed in parallel relationship in front of the longest row of radiators and having progressively decreasing lengths toward the front of the launcher for establishing a uniform phase relationship across the propagation wavefront.

4. A wave transmitter and receiver comprising a plurality of parallel rows of dipole radiators, the radiators of each of said rows being alined end-on-end in spaced relationship and there being provided one more radiating element in each row toward the front of said transmitter and receiver than in the row to the rear thereof, said rows being disposed in a single plane and each extending equally from opposite sides of an axis normal to the rows and the rows being closely spaced for maximized energy coupling therebetween, one of said rows of antenna radiators being adapted for energization by electromagnetic waves coupled thereto for successive coupling between rows of radiators whereby energy is coupled laterally as well as axially of the array of rows.

5. A signal launcher comprising a single dipole radiator having an axis extending normally thereto through the center thereof, a plurality of parallel rows of dipole antenna radiators disposed in parallel relationship transversely to said axis with said axis extending through the center of each of said rows, each of said rows having a greater number of radiators than the preceding row on the side thereof toward said first radiator and extending farther from said axis than the next preceding row on the side thereof toward said radiator, said rows of dipole radiators forming a planar triangle with said axis extending through the center thereof, and means establishing substantially the same electrical path length from said first single radiator to all portions of each of the rows of radiators whereby energy coupled from said first radiator to said rows of radiators passes through said launcher with the same phase relationship along each row thereof for transmission from the longest row of radiators at the front of said launcher in a highly directional beam.

6. A signal launcher comprising a single radiator adapted for energization to propagate electromagnetic waves directionally therefrom along an axis, an array of a plurality of parallel rows of parasitic radiators with successive rows having an increasing number of radiators to define a triangular configuration, said array being disposed with the axis of said single radiator extending through the center thereof whereby waves from the latter are coupled through said array both along said axis and laterally therefrom to each of the radiators of the longest row of radiators, and means varying the rate of wave propagation through said array from a minimum along said axis to a maximum along row ends for providing in-phase wave propagation from said longest row of radiators.

7. A directional signal launcher comprising a plurality of individual metallic radiators mounted upon a sheet of dielectric material, said radiators being disposed in a plurality of parallel rows in longitudinal alinement in each row, said rows each having one more radiator per row in succession from a short input row to a longest row defining the wavefront extension of the launcher and each of the rows being disposed symmetrically with respect to a single perpendicularly bisecting launcher axis, the successive rows being closely spaced from each other and in offset relation to adjacent rows so that each radiator is equidistant from two radiators of each adjacent row for close coupling of energy between the radiators

9

in a direction axially of the launcher and longitudinally of the rows for full energization of all radiators of the longest row, and means establishing a substantially equal electrical path length from each of the radiators at the front of the launcher to an input point behind the input row of the launcher.

8. A directional signal launcher as set forth in claim 7, further defined by said last means consisting of an additional plurality of parallel rows of radiators of successively decreasing length disposed in front of the longest row of radiators for establishing a substantially equal distance from an input point behind the launcher to each of the front radiators propagating energy from the launcher.

References Cited by the Examiner

UNITED STATES PATENTS

2,192,532	3/40	Katzin	343—908
2,538,035	1/51	Pickles	343—18

10

2,577,619	12/51	Kock	343—753
2,579,324	12/51	Kock	343—911
2,624,003	12/52	Iams	343—785 X
2,644,091	6/53	Middlemark	343—833
2,663,797	12/53	Kock	343—781 X
2,921,312	1/60	Wickersham	343—756 X
2,929,065	3/60	Kreinhelder	343—785
3,016,536	1/62	Fubini	343—847 X
3,096,520	7/63	Ehrenspeck	343—819 X

FOREIGN PATENTS

903,474	2/54	Germany.
332,677	10/58	Switzerland.

OTHER REFERENCES

15 Pub. I, McDonough and Malech, "Printed Microwave Antennas," Electronic Design, Feb. 15, 1956, page 32 relied on.

HERMAN KARL SAALBACH, *Primary Examiner.*