March 25, 1947. P. S. CARTER 2,417,808

ANTENNA SYSTEM

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Fig. 1.

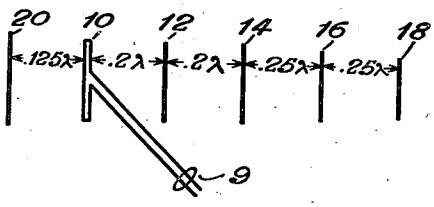



Fig. 2.

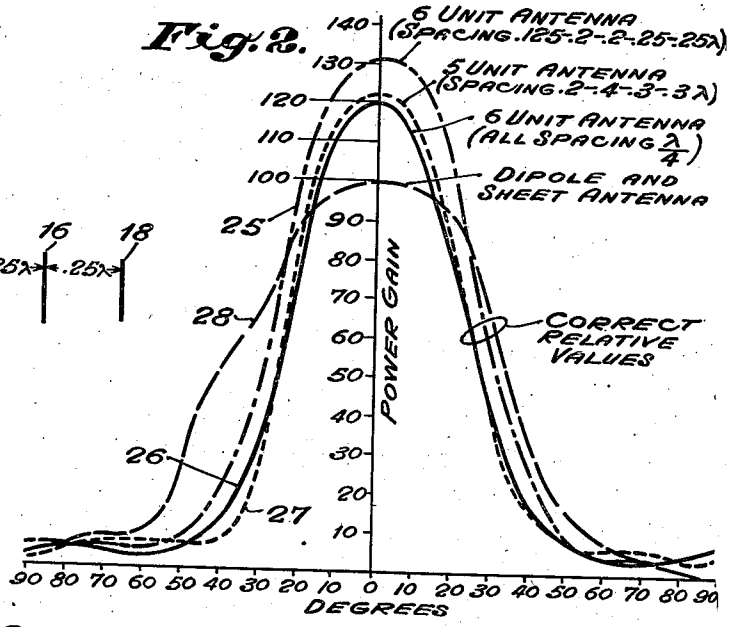



Fig. 3.

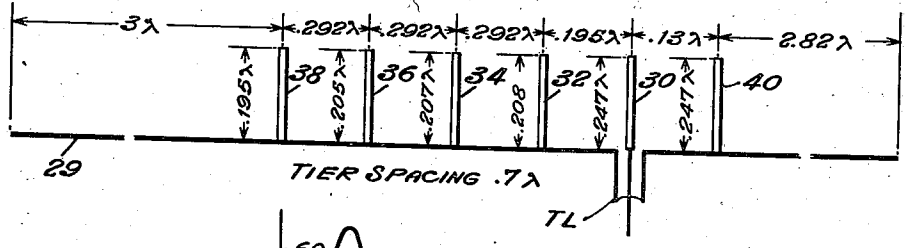
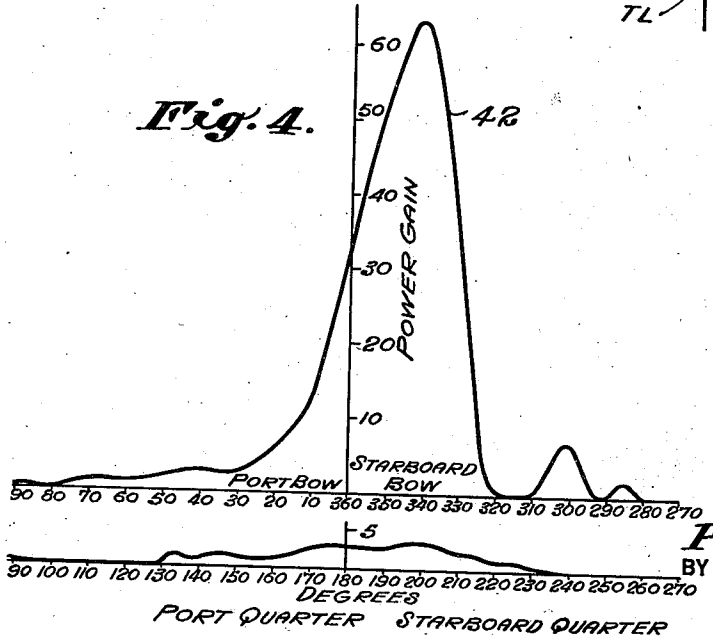



Fig. 4.




INVENTOR
Philip S. Carter
BY
H. S. Grover
ATTORNEY

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*Fig. 5.*

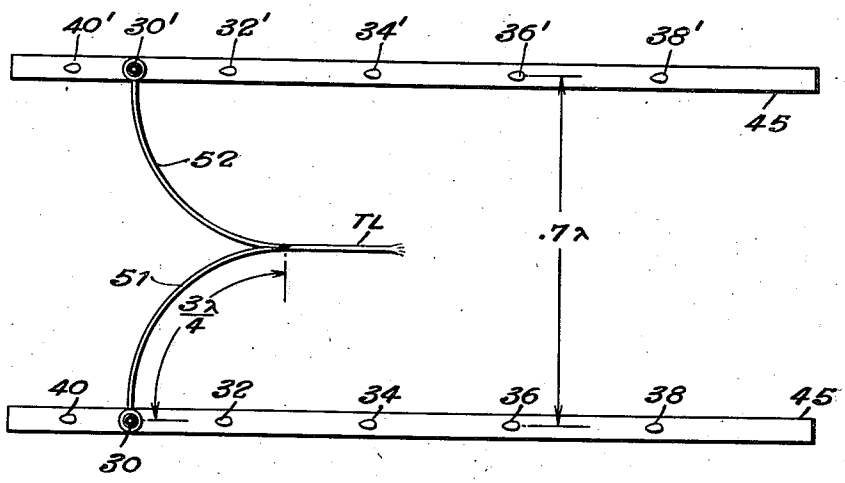
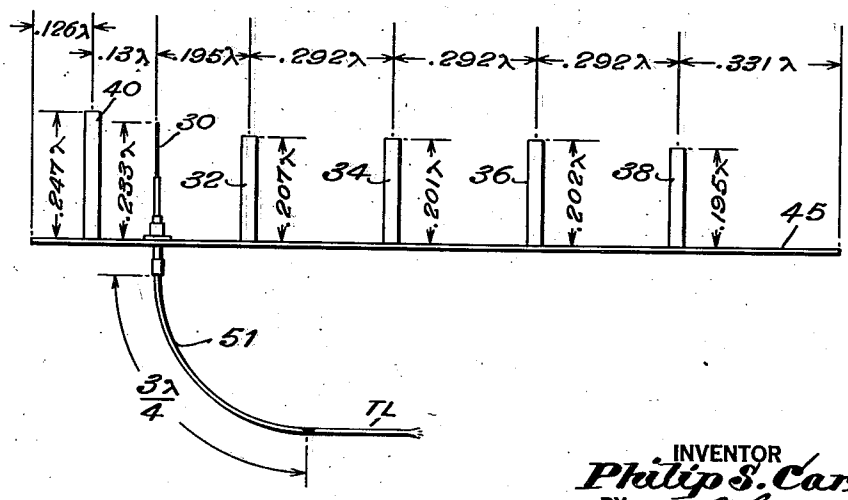



*Fig. 6.*




INVENTOR
Philip S. Carter
BY H. S. Grover
ATTORNEY

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Fig. 7.

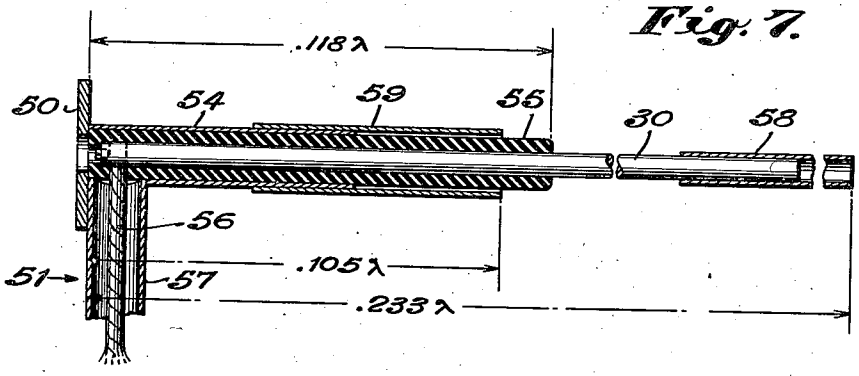



Fig. 8.

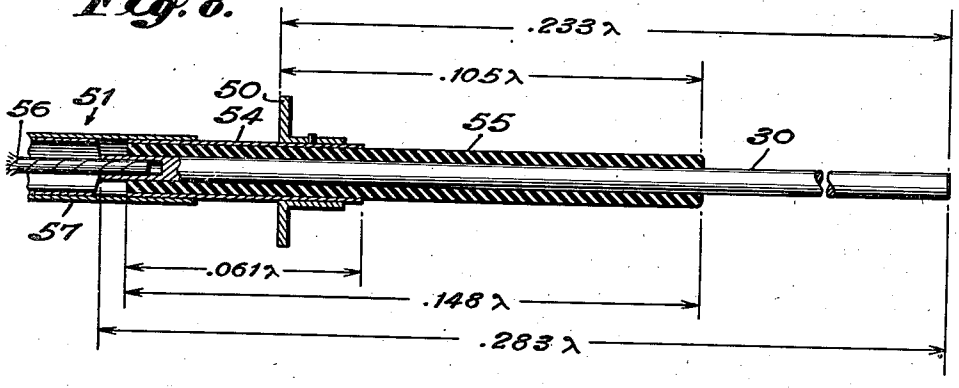
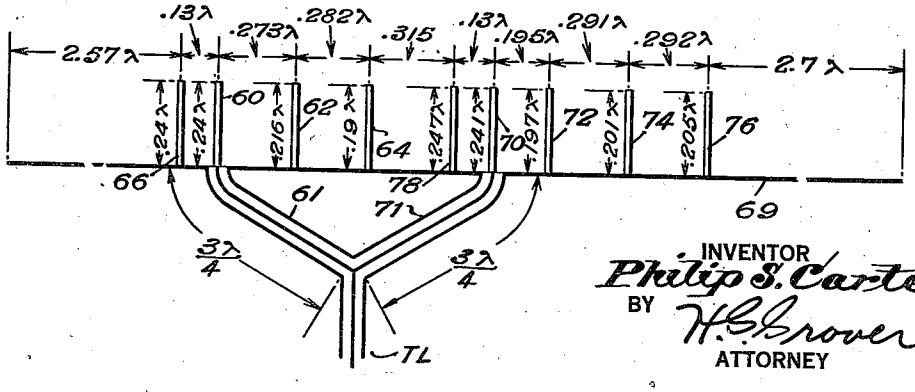



Fig. 9.




INVENTOR
Philip S. Carter
BY
H. S. Grover
ATTORNEY

Patented Mar. 25, 1947

2,417,80-

# UNITED STATES PATENT OFFICE

2,417,808

## ANTENNA SYSTEM

Philip S. Carter, Rocky Point, N. Y., assignor to Radio Corporation of America, a corporation of Delaware

Application June 30, 1942, Serial No. 449,103

12 Claims. (Cl. 250—11)

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The present invention relates to antenna systems and, more particularly, to ultra short wave directive antenna arrays.

An object of the present invention is the provision of an antenna array for use on airplanes.

Another object of the present invention is the provision of an ultra short wave antenna array to be used on airplanes for direction finding.

Still another object of the present invention is the provision of an antenna array for detecting the direction of arrival of ultra short wave radio impulses.

A further object is the provision of an antenna array for radiating pulses of ultra short wave radio energy in a sharply directive beam, and for receiving said pulses as they return from a reflecting object.

A further object of the present invention is the provision of a multi-unit antenna array, in which impedance changes in the antenna array have substantially no effect on the directivity pattern of the antenna.

Still a further object of the present invention is the provision of an antenna array which is compact in size, so that it does not adversely affect the aerodynamics of a plane on which it may be mounted, which is mechanically sturdy, so that it will be unaffected by the conditions under which it is to be used, and which is, furthermore, adapted to be conveniently mounted on an airplane.

The foregoing objects, and others which may appear from the following detailed description, are attained in accordance with the principles of the present invention, by providing a multi-tiered antenna, each tier comprising one or more energized radiators and parasitic directors and reflectors aligned along a desired line of directivity. The radiators are mounted perpendicular to a conductive sheet, which may be the side wall of the fuselage or body of an airplane, one on each side of the plane and near the front of the plane. Thus arranged, each antenna has its direction of maximum response directed about 12° away from dead ahead on the plane.

The antennas are so arranged that the directivity directly ahead of the plane at a point when patterns cross the signal strength is down about 1.5 decibels from the maximum response. It is contemplated that structure may be provided for alternately connecting first one, and then the other antenna, to a transmitter and receiver. Equal amplitude output pulses from the receiver then indicate that the plane is travelling directly toward the signal source, thus providing a "homing" indication. Furthermore, the antennas may be used for transmitting pulses which, when reflected from a conductive object, are received by the same antennas and are applied to a receiver as mentioned above and thus indicate its distance and its direction from the plane.

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The present invention will be more fully understood by reference to the following detailed description, which is accompanied by a drawing in which Figure 1 illustrates diagrammatically, for the purpose of explaining the principles of the present invention, an end fire antenna utilizing an energized radiator and parasitic reflector and director radiator, and Figure 2 is a family of curves representing the effect on the directivity of the antenna, of a variation in the number of units of the antenna of Figure 1 and their spacing; while Figure 3 illustrates a side view of an embodiment of the present invention shown in Figure 1; and Figure 4 is a curve showing the directivity pattern of the antenna of Figure 3; Figures 5 and 6 are plan and elevational views of a modification of the form of the invention shown in Figure 3, particularly designed for use on airplanes; Figures 7 and 8 illustrate an enlarged cross-sectional view of the details of construction of two modifications of the energized radiator elements of the antenna of Figures 5 and 6; and Figure 9 is a side view of a further modification of the invention.

In Figure 1 I have shown a multi-unit end fire directive antenna, including an energized radiator 10, parasitic directive radiators 12, 14, 16 and 18, and a parasitic reflector radiator 20. The antenna 10 in this embodiment is shown as a folded half wave dipole. The folded construction is used so that an impedance match between the two-wire transmission line 9 and radiator 10 is obtained. This form of construction has been fully described in my prior application No. 155,385, filed July 24, 1937, now Patent #2,283,914, granted May 26, 1942, to which reference may be had for a more detailed description as to the theory of operation.

The antenna of Figure 1 has a directivity pattern having a decided maximum of response along a common axis normal to each of the radiators 10, 12, 14, 16, 18 and 20. The effect on the directivity pattern of a variation in the number of radiator elements and their spacing is shown in Figure 2. For example, curve 25 of Figure 2 shows the directivity in a plane normal to the plane of the radiators of an antenna such as shown in Figure 1, comprising six radiator units, that is, one energized dipole, one reflector di-

pole and four director dipoles. The spacing between the various elements is as shown in Figure 1. Now, if the antenna is as constructed in Figure 1, except that all units are spaced apart a distance equal to one-quarter of the operating wavelength, a directivity pattern is obtained, as shown by curve **26**. It will be noted that a considerable drop in the power gain along the axis of the antenna is encountered. If a five-unit antenna is used, that is, one energized dipole, one reflector and three directors, having relative spacings of .2, .4, .3, .3 wavelength, a directivity pattern is obtained as shown by curve **27** of Figure 2. It will be noted that this directivity is somewhat better than that obtained by the use of a six-unit antenna, with all spacings equal, though it is less than the optimum obtainable with a six-unit antenna. Curve **28** shows the directivity obtained by a single dipole in front of a reflective sheet and may be used for comparison since all curves in Figure 2 have been drawn to their correct relative values.

The embodiment of my invention shown in Figure 3 utilizes quarter-wave radiators **30**, **32**, **34**, **36**, **38** and **40**, mounted on a conductive sheet **29**, which extends at least three wavelengths beyond radiator **38** in the forward direction, and 2.82 wavelengths in a rearward direction behind radiator **40**. The radiator **30** is in this modification energized at one end by coaxial transmission line TL. This manner of energization is possible where quarter-wave radiators are used, since the base impedance of a quarter-wave radiator may be made substantially equal to the characteristic impedance of transmission line TL. It should be understood that the transducer means, such as a transmitter or receiver, may be substituted for line TL, or connected to the other end of line TL as desired.

Director radiators **32**, **34**, **36** and **38**, and the reflector radiator **40**, perform the same functions as their corresponding elements in Figure 1. An array of two antennas such as shown in Figure 3, spaced apart a distance equal to .7 wavelength, results in a directivity in a plane parallel to the planes of the antennas, such as shown by curve **42** of Figure 4. It will be noted that the maximum of this radiation pattern does not occur along the axis of the antenna, but is displaced therefrom a matter of 18° or so. This effect is obtained because of the limited extent of conducting sheet **29** in front of the first director **38**. If conducting sheet **29** were infinite in extent, of course, the maximum would occur along the axis of the antenna. However, this deflection of the maximum is highly desirable when a pair of antennas is used for "homing" purposes.

As a matter of interest, it may be noted that the equivalent gain obtained by a single dipole and sheet reflector antenna would fall at about 20 on the vertical scale of Figure 4, which may be compared with the maximum gain of over 60 for the antenna of Figure 3.

Figure 5 is a plan view of a modification of Figure 3, which because of structural modifications is particularly designed for use on airplanes. It will be apparent that since each of the director radiators **32**, **34**, **36** and **38**, as well as the reflector radiator **40**, are streamlined in form, as little aerodynamic disturbance as possible is created. The energized radiator **30** shown here in end view, will be further described with reference to Figures 7 and 8.

The tier of radiators so far described is duplicated by a second tier exactly similar to the ones just described and given the same reference numerals primed. The second tier is spaced from the first a distance equal to .7 wavelength. Each tier of radiators is securely mounted, as by silver soldering or welding to a mounting strip **45**, which may be provided with suitable bolt holes for attaching the array to the side wall of an airplane fuselage.

The two tiers of the antenna are energized from a single coaxial transmission line TL, through a pair of branch circuits **51** and **52**, each having an electrical length equal to an odd multiple, including unity, of a quarter of a wavelength. With tier spacings of .7 wavelength, ¾ wavelength branch circuits may conveniently be used. The quarter wavelength distance is very important, since it results in the currents in radiator **30** and **30'** being of correct amplitude and phase, regardless of any possible changes of impedance of any of the radiators of either of the two tiers. The current amplitudes in radiators **30** and **30'** are determined solely by the impedance of line sections **51** and **52**. The reasons for this have been more fully described in my copending application #445,560, filed June 3, 1942.

The elevation of the antenna shown in Figure 6 indicates the relative lengths of radiators and their spacing which I have found to result in the most desirable directivity pattern. It will be noted that each of the director radiators are shorter than the energized radiator, and become progressively shorter with increasing distance from the energized radiator while at the same time their spacing increases. The reflector radiator **40** is somewhat longer than the energized radiator, and is quite closely spaced therefrom. A spacing of .13 wavelength has been found satisfactory.

In Figures 7 and 8 are shown two modifications of energized radiator **30** of Figures 5 and 6. The modification shown in Figure 7 is so designed that the transmission line may lie on the same side of the conducting sheet as that to which the radiators are attached. The antenna is attached to the conducting sheet or supporting strip by means of a mounting flange **50** carrying thereon an extending tube portion **54** within which the radiator **30** is maintained in position by insulating sleeve **55**. Inner conductor **56** of transmission line **51** is connected to the inner end of radiator **30**. The outer sheath **57** of the transmission line **51** is conductively connected to tubular portion **54** by silver soldering or brazing it thereto. Means are provided in the structure so that both the effective length of the antenna and the effective position of feed on the antenna may be adjusted so as to present the desired impedance to the transmission line. The effective length is changed by moving the sliding tube **58** while the effective feed point is shifted by sliding the tube **59** along the tube **54**. The insulation material **55** also has a very considerable effect on the impedance presented by the antenna. The dimension of $0.105\lambda$ shown in the figure for the distance from base to end of tube **59** and the dimension of $0.233\lambda$ to the outer end of the radiator were both found experimentally to result in a perfect match of the main transmission line at the junction. Under such a condition the impedance presented by the antenna at its base is 25 ohms. This value is transformed by the ¾ wavelength branch transmission line having a surge impedance of approximately 50 ohms to a value of 100 ohms at the junction. The total value of impedance for the two branch lines in parallel then becomes 50

ohms at the junction and perfectly matches the main line.

The proper dimensions having been determined by means of the structure shown in Figure 7, in the final installation of the antenna on the plane, the form of construction shown in Figure 8 may be more desirable. Here the transmission line 51 is arranged to lie within the body of the plane, and conductors 56 and 57 thereof are connected to tube 54 and radiator 30 in coaxial alignment. The projecting length of tube 54, together with insulation material 55, is such as to obtain an impedance of 25 ohms pure resistance at the base of radiator 30. The ¾λ transmission line 51 having a characteristic impedance of 50 ohms transforms this to 100 ohms at the junction of the two lines 51 and 52. The two branch lines in parallel then present an impedance of 50 ohms to the main line TL, thus matching the same. In this arrangement the effective length of the antenna is adjusted by sliding the complete unit in or out through flange 59. This type of antenna is very sensitive to overall length but relatively insensitive to moderate changes in the position of the effective feed point. The impedance presented depends, in addition to the effective length of the antenna, considerably upon the length of the insulation material extended along the exposed portion. The dimensions shown in the figure were arrived at experimentally and resulted in a perfect match at the transmission line junction. The adjustment may be maintained by flowing solder between flange 59 and tube 59.

The further modification of the present invention shown in Figure 9 constitutes a nine-element antenna. This particular form of construction is desirable where a large number of radiating elements must be used, since it has been discovered that where more than five parasitic elements are used with a single energized element the currents in the most remote elements are relatively low so that the optimum gain is not obtained. Therefore, two elements are energized, while the remainder are parasitic. With two or more energized radiator elements, it is desirable that they be arranged to be energized in an in-phase relationship, since this relationship may be more conveniently maintained than any fractional relationship. The two directly energized units 60 and 70 are so arranged that they are exactly a wavelength apart. They are energized in the same phase through branch coaxial lines 61 and 71, having lengths equal to an odd multiple of a quarter wavelength. Thus, the amplitude and phase relationships of currents in radiators 60 and 70 are not affected by the dimensions of the radiators themselves, but only by the constants of lines 61 and 71, respectively. The currents must thus always remain in the correct amplitude and phase relationship, regardless of any see-sawing of the impedance, such as may be caused by ice deposits on the radiators themselves, or by undesired mutual impedance effects from the associated reflectors and directors. Three parasitic director radiators 72, 74 and 76, and one parasitic reflector radiator 78, obtain most of their excitation from radiator 70, while energized radiator 60 supplies energy to parasitic director 62 and 64 and parasitic reflector radiator 66.

The conducting sheet 69 has the same function as conducting sheet 29 of Figure 3, and its dimensions at each end of the array should be of the same magnitude as they are in Figure 3, in order that the directivity pattern will have its maximum in the proper direction.

While the foregoing detailed description has been predicated, for convenience, upon the assumption that the antenna is to be used for the radiation of short wave energy, it is to be understood that the antenna may equally well be employed for the reception of short wave energy or for both in alternation.

Furthermore, while I have particularly shown and described several modifications of the present invention, it should be clearly understood that the invention is not limited to these forms alone, but that modifications may be made.

I claim:

1. A directive antenna array including an energized antenna coupled to a high frequency transducer means, a plurality of parasitic director antennas and a parasitic reflector antenna, all of said antennas being arranged perpendicularly to a common axis of directivity and in a single plane, the spacing of said director antennas varying directly and their lengths varying inversely as their distance from said energized antenna.

2. A directive antenna array including an energized antenna coupled to a high frequency means, a plurality of parasitic director antennas and a parasitic reflector antenna, all of said antennas being arranged perpendicular to a common conducting sheet and along a common line of directivity on said sheet, the spacing of said director antennas varying directly and their length varying inversely as their distance from said energized antenna.

3. An antenna system including a plurality of arrays, as set forth in claim 1, said arrays being arranged in parallel planes and spaced apart a distance substantially equal to .7 wavelengths and each of said energized antennas being coupled to said transducer means through equal length transmission line sections.

4. A directive antenna array including an energized antenna coupled to a high frequency means, a plurality of parasitic director antennas and a parasitic reflector antenna, all of said antennas being arranged perpendicular to a common conducting sheet and along a common line of directivity on said sheet, the spacing of said director antennas varying directly and their length varying inversely as their distance from said energized antenna, the said conducting sheet extending beyond said antennas along said line of directivity a distance such that a radiation maximum takes place at an angle to the plane of said sheet of from 10 to 20 degrees.

5. A directive antenna array including an energized antenna coupled to a high frequency transducer means, a plurality of parasitic director antennas and a parasitic reflector antenna, all of said antennas being arranged perpendicular to a common axis of directivity and in a single plane, the spacing of said director antennas varying directly and their lengths varying inversely as their distance from said energized antenna, the spacing of said reflector antenna from said energized antenna being of the order of one-eighth of the operating wavelength and its length substantially equal to the length of said energized antenna.

6. A directive antenna array including an energized antenna coupled to high frequency transducer means, a plurality of parasitic director antennas and a parasitic reflector antenna, all of said antennas being arranged perpendicular to a common conducting sheet and along a common

line of directivity on said sheet, the spacing of said director antennas varying directly and their length varying inversely as their distance from said energized antenna, the spacing of said reflector antenna from said energized antenna being of the order of one-eighth of an operating wavelength and its length substantially equal to said energized antenna.

7. An antenna system including a plurality of arrays, as set forth in claim 6, said arrays being arranged in parallel planes spaced apart a distance substantially equal to .7 wavelengths and each of said energized antennas being coupled to said transducer means through equal length transmission line sections, said transmission line sections having lengths equal to an odd multiple, including unity, of a quarter wavelength.

8. In a directive antenna array including a plurality of radiators arranged along a desired line of directivity, some of said radiators being connected to a source of high frequency energy and others adapted to be parasitically energized from said energized radiators, said connected radiators being so spaced that they may be energized in an in phase relationship, and equal length transmission lines for connecting said energized radiators to said source of high frequency energy, each having a length equal to an odd multiple of a quarter of the operating wavelength whereby the current in each of said energized radiators is independent of the impedance of said radiators.

9. A directive antenna system including a plurality of radiators arranged one behind another along a desired line of directivity, some of said radiators being connected to transducer means by equal length transmission lines whereby the energy in said connected radiators is in an inphase relationship, said connected radiators being spaced apart a distance equal to the operating wavelength, the lengths of said transmission lines being equal to an odd multiple including unity of one quarter of the operating wavelength whereby the relative currents in said connected radiators are determined solely by the relative impedances of the transmission lines.



10. An antenna array including a plurality of radiators connected to a source of high frequency energy, said radiators being so spaced that they may be energized in an inphase relationship, and equal length transmission lines for connecting said radiators to said source of high frequency energy, the length of said transmission lines being equal to an odd multiple, including unity of one quarter of the operating wavelength whereby the current in each of said radiators is independent of the impedance of said radiators.

11. A directive antenna system including a plurality of parallel antennas lying in a plane perpendicular to a conductive sheet and so arranged that the direction of maximum response of said system lies along said plane, said conductive sheet extending beyond said antennas in the direction of maximum response of said system a distance such that the direction of maximum response along said plane is elevated with respect to said conductive sheet.

12. A directive antenna array including an energized antenna coupled to a high frequency means, a plurality of parasitic director antennas and a parasitic reflector antenna, all of said antennas being arranged perpendicular to a common conducting sheet and along a common line of directivity on said sheet, said director antenas being shorter than said energized antennas, the said conducting sheet extending beyond said antennas along said line of directivity a distance such that a radiation maximum takes place at an angle to the plane of said sheet of from 10 to 20 degrees.

PHILIP S. CARTER.

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