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Leahy

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[54] **DUAL FREQUENCY ARRAY**

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[52] **U.S. Cl.** **343/727,** 343/779, 343/786, 343/846

[51] **Int. Cl.** **H01q 21/00**

[58] **Field of Search** 343/725–730, 343/854, 786, 846

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Attorney, Agent, or Firm—J. B. Hinson

[57] **ABSTRACT**

An antenna array having two repetitive radiator systems in a single aperture, operating in two distinct frequency ranges. Each radiator system includes an open-ended, circular waveguide and a parallel plate waveguide. A monopole or a dipole is situated between the plates of the parallel plate waveguide and normal to them. The dimensions of the waveguides and the spacings between them are chosen to provide isolation between the frequency ranges.

5 Claims, 6 Drawing Figures

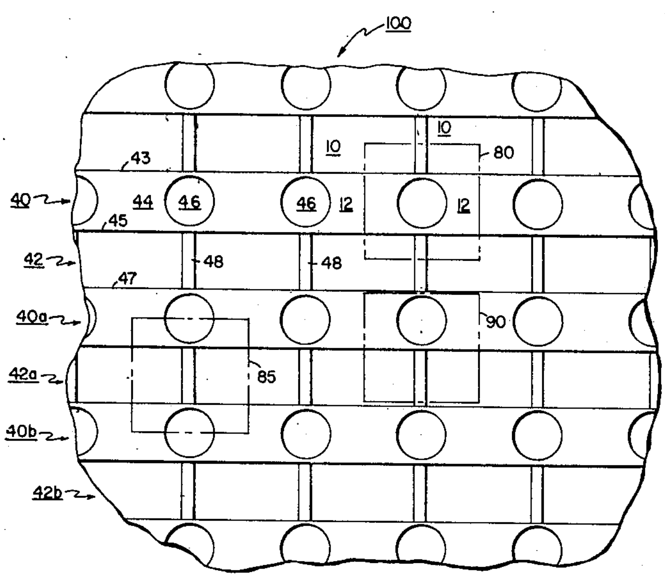
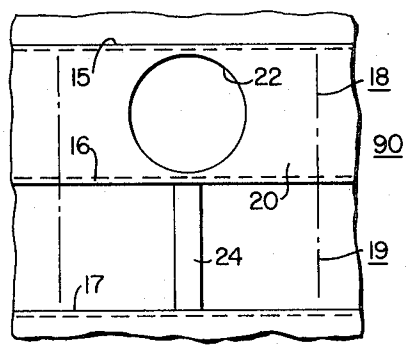


FIG.1



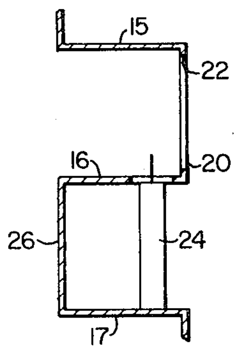


FIG.2

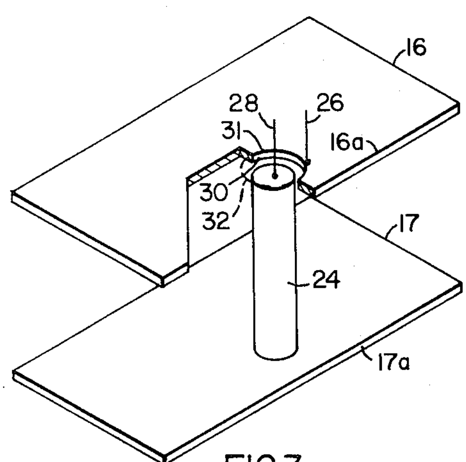


FIG.3

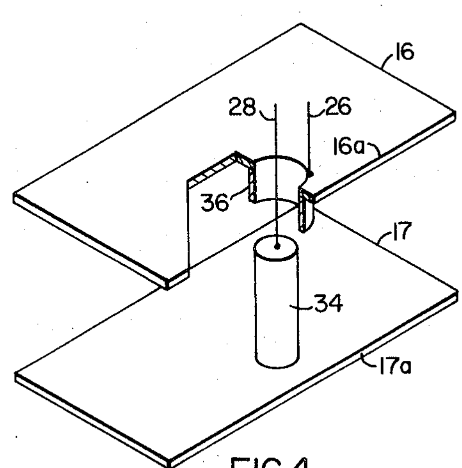
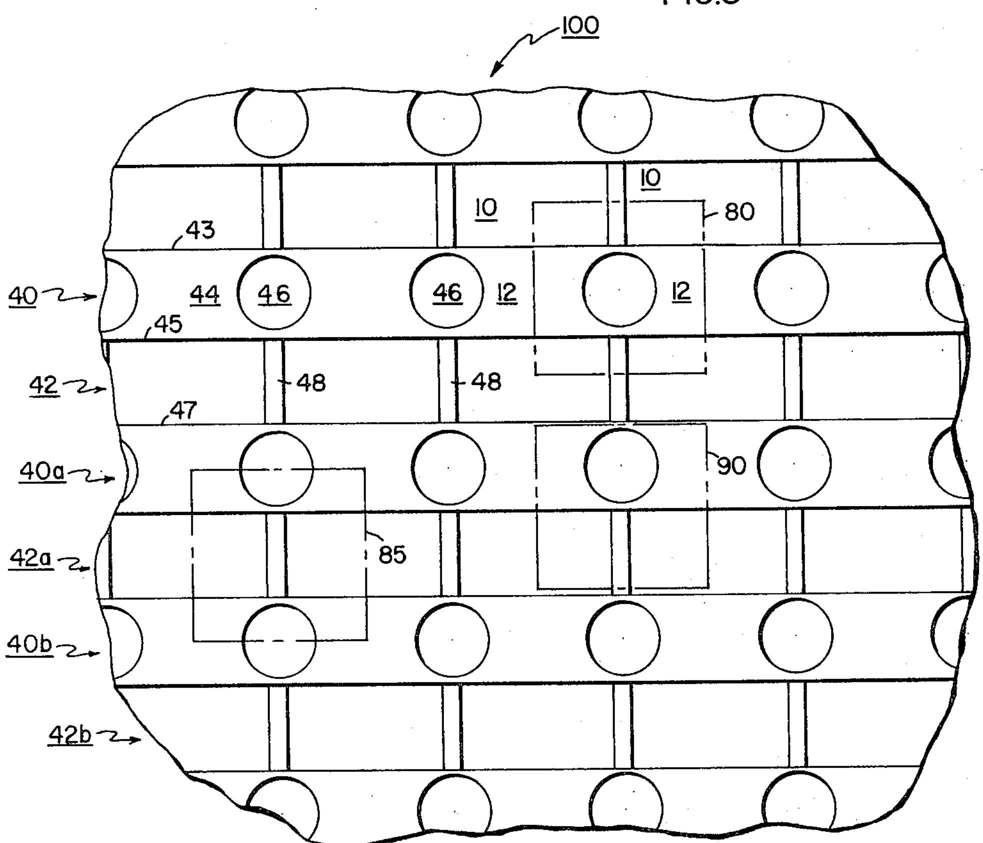


FIG.4

FIG.5


100
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85
40b
42b

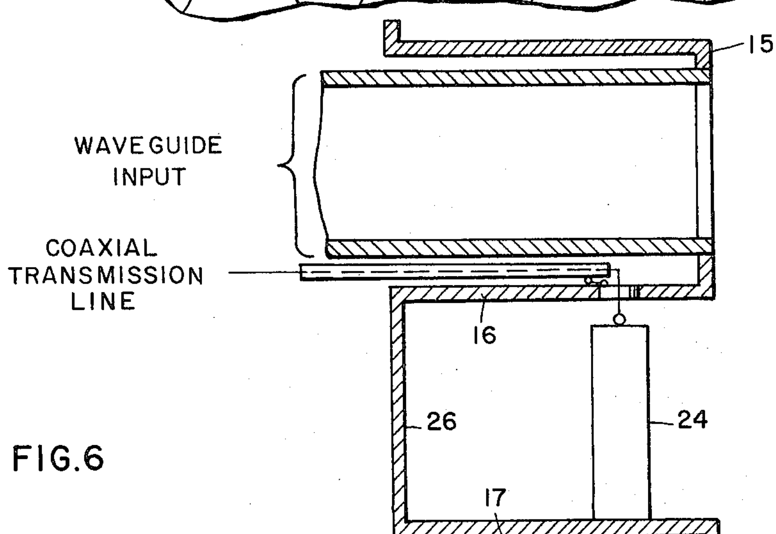
15
WAVE GUIDE
INPUT
COAXIAL
TRANSMISSION
LINE
16
26
24
17

FIG.6

DUAL FREQUENCY ARRAY

BACKGROUND OF THE INVENTION

1. Field of the Invention

In general, the present invention pertains to a new antenna structure. More specifically, it pertains to an antenna array which couples to two distinct frequency ranges while using the same aperture. That is, it pertains to a situation where it would be necessary to have two systems operating on two different frequencies but where there is a shortage of space. In such a situation, it is highly desirable to minimize the antenna aperture — that is, the area of the antenna.

The invention described hereinafter is particularly useful in a phased array — that is, an antenna which has a large number of radiators which are individually controllable to some extent. In a phased array, the excitation of space is controlled by a large number of independent, point variables. Each of the independent point variables is an individual element of the phased array, the individual excitation of each element being adjustable. If desired, a phased array can be used for scanning purposes. That is, it is possible to steer the beam and change its shape by changing the excitation functions of each element. When the excitation functions of each element are changed very fast, scanning occurs very fast.

Because a phase array can operate very quickly, not retarded by mechanical inertia they are very desirable pieces of equipment. However, they are also very expensive. Therefore, it is very desirable to make the most efficient use of the antenna aperture and the electronics equipment required to operate the antenna. For example, it is desirable to have the antenna perform two distinct functions substantially simultaneously.

For example, it might be desirable for an airplane to carry an antenna system both for the purpose of mapping the terrain below it and, simultaneously, keeping track of all other aircraft in the immediate vicinity in order to avoid a mid-air collision. While performing a mapping function, angular resolution is extremely important in order to determine exactly where the antenna is pointing within predetermined tolerances. A narrower beam width is necessarily a requirement of increased angular resolution. Because higher frequencies provide narrower beam widths, the greater the angular resolution required for the particular mapping function, the higher the frequency required.

In providing a search function, one of the main objectives is detection of objects of interest at larger and larger ranges. In order to increase the range of detection, the antenna must be operated at a lower frequency as range increases. When an antenna is operated at lower frequencies, its energy is more easily able to penetrate clouds, water, and water vapor. The difficulty of penetrating such atmospheric disturbances increases as frequency increases. Therefore, a search radar uses frequencies in a relatively lower frequency range in order to increase its range capabilities.

As discussed above, the present invention pertains to a system which permits a single antenna aperture to perform two functions. For example, the antenna to be described hereinafter could provide both the above described mapping function and search function because each requires a different, distinct frequency range of operation. However, the invention to be described

could be used for any two functions which can be performed by using two distinct frequency ranges and which are separated by a sufficiently large frequency range.

2. Description of the Prior Art

A commonly considered method of designing the transmitter electronics of an active antenna array is the use of a transmitter amplifier cascaded with a varactor multiplier. Because an antenna array utilizes large numbers of radiators, construction of such an array has posed a problem of combining large numbers of low powered sources with minimal loss. An excellent solution to this problem has been to associate a system having individual array elemental radiators with individual transmitters. In a system thus configured, the varactor multipliers constitute the major source of inefficiency in converting raw power into usable radiated energy. Nevertheless, their use is mandatory in most of such systems where the radiated frequencies lie above the capabilities of existing transistors.

As explained above, there are situations in multimode radars where high frequencies are required for some functions but not for others. In such cases, one approach is to use the amplifier output as the directly radiated signal thereby eliminating the necessity of transmission through the varactor multipliers. The varactor multipliers often reduce radiated energy by 50 percent to 80 percent. However, this new approach has led to problems in other areas of design, one of which, radiation structure, is a subject of this invention.

BRIEF SUMMARY OF INVENTION

The antenna to be described hereinafter in detail is made up of a plurality of juxtaposed basic radiator structures. Each of the radiator structures is, in turn, made up of a plurality of first radiator elements and a plurality of second radiator elements. The first and second radiator elements are each capable of coupling only to their respective frequency ranges. When the basic radiator structures are arranged in a predetermined manner, the result is a first repetitive radiator system and a second repetitive radiator system which, together, form an antenna array.

The first radiator system is made up of a plurality of rows of a certain type of radiator elements. Interspersed between the rows of these elements are rows of a second kind of radiator element. For each element in the first system there is a corresponding element in the second system. Each row of the first system has a conductive strip which helps to form the first radiator elements. The second system is made up of a plurality of parallel plate waveguides with either a monopole or a dipole situated between the plates of the waveguides and normal to the plates.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention, reference may be had to the preferred embodiment, exemplary of the invention, shown in the accompanying drawings, in which:

FIG. 1 is a normal view of the basic radiator structure of the antenna array;

FIG. 2 is an end view of the basic radiator structure;

FIG. 3 is a perspective view of the parallel plate waveguide section of the basic radiator structure;

FIG. 4 is a perspective view of an alternative embodiment of the parallel plate waveguide portion of the basic radiator structure;

FIG. 5 is a normal view of a portion of an antenna array comprising a plurality of basic radiator structures; and

FIG. 6 is an end view of the basic radiator showing the R.F. energy coupling lines.

DETAILED DESCRIPTION OF THE INVENTION

The antenna described herein is composed of a plurality of basic radiator structures. When these basic radiator structures are juxtaposed in such a manner that each basic structure is in physical contact with a least one other basic radiator structure, the totality of these structures form an antenna array. Referring briefly to FIG. **5**, an antenna **100** is shown as being composed of a plurality of radiator elements **10** and **12.** For analysis purposes, in order to break down the array **100** into a basic radiator structure, an elemental, repetitive component has been chosen. Examples of such a component are indicated in FIG. **5** as dashed blocks **80, 85,** and **90.** Each of these dashed blocks represent a predetermined portion of the antenna aperture — that is, a predetermined portion of the antenna area. Each of the blocks covers an equal area. For purposes of explanation herein, block **90** is the easiest to explain.

Referring to FIG. **1,** block **90** is shown as the basic radiator structure. It will be understood, however, that any component of like size could be chosen to explain the structure and operation of the present invention. As explained above, block **80** or block **85** could have been chosen.

Referring to FIG. **1,** the basic radiator structure **90** is enclosed by and includes three parallel plates **15, 16,** and **17.** Plates **15** and **16** are part of and enclose a first radiator element **18** which is operable to couple to a first frequency range — a high frequency range such as 9–10 GHz. Plates **16** and **17** are part of, and enclose, a second radiator element **19** which is operable to couple to a second frequency range — a low frequency range such as 1.8–2.0 GHz.

A fundamental problem which is solved by the present invention is isolation of the two radiation systems. Isolation is quite essential if two plane scan is to be accomplished with maintenance of element drive point impedance and/or more than trivial bandwidth is to be realized. Isolation is accomplished by the present invention which uses crossed linear polarizations and cut off phenomena.

The first radiator element **18,** hereinafter referred to as the high frequency radiator, includes a conductive strip **20** composed of metals, copper, brass, aluminum or silver, for example. An aperture **22** is made in the conductive strip **20** in order to couple to the high frequency energy. Because most antennas are reciprocal — that is, they can be used either to transmit or receive energy, the function of the present invention is not to be construed as being limited to either of these functions. Accordingly, the term "couple" will be used throughout the present application to connote both transmitting and receiving functions.

The aperture **22** in the conductive strip **20** can be referred to as a small horn or as an open ended waveguide. While it is recognized that some people skilled in the antenna arts might make definite distinctions between what they call a "waveguide" and a "horn", it is difficult to determine exactly when a radiator becomes so small that the terminology used to describe it can be changed from horn to waveguide. Therefore, even though the two terms can be used interchangeably in the present application, no significance is intended to be attached to one term over the other.

In the embodiment shown in FIG. **1,** the aperture **22** of the high frequency radiator **18** has a circular cross-section — that is, it can be said to be X and Y symmetric. It excites, in space, a far field TEM wave with a horizontal E field. Because of the technique of cross-polarization, the horizontal E field coupled to the high frequency radiator **18** cannot couple to the low frequency radiator **19** as will be described in more detail below.

Although FIG. **1** shows a circular aperture **22,** the shape of the aperture need not be circular. For example, the shape could be square or rectangular. In the case of the circular aperture **22,** shown in FIG. **1,** the diameter of the aperture must be greater than one-half the wavelength of the highest frequency in the high frequency range. If it is desired to make the basic radiator structure **90** as small as possible, the actual physical diameter of the aperture **22** can be made to be less than one-half of the wavelength but electrically, the effective width must be greater than one-half of the wavelength. Such an effective width is essential to obtain propagation of the high frequency energy through the high frequency radiator **18** — that is, through the aperture **22** and the waveguide connected to it. In order to increase the effective cross-section or width of the aperture **22,** the aperture must be filled with a suitable, low loss dielectric material. An example of such material is polystyrene ($\epsilon_r = 2.6$) or Teflon ($\epsilon_r = 2.07$). When such a dielectric material is used, the effective diameter of the aperture **22** is determined by the relationship $D_{eff} = D_{act} \sqrt{\epsilon_r}$.

If a shape other than circular is used for the aperture **22,** one effective dimension can be arbitrary but the other effective dimension must be determined by other considerations. One consideration is the cross polarization effect to prevent coupling of the low frequency energy into the high frequency radiator. Accordingly, the dimension of the aperture which is perpendicular to the direction of the E field of the low frequency radiator (that is, parallel to the direction of the E field of the high frequency radiator) must be less than $\frac{1}{2}\lambda_l/\sqrt{\epsilon_r}$ where λ_l is the wavelength of the lowest frequency of the high frequency range. In one embodiment, the E field of the low frequency radiator will be vertical and the E field of the high frequency radiator will be horizontal the E field of the high frequency. As explained previously, propagation cannot occur unless the effective electrical width is greater than one-half of the wave-length of the frequency being propagated. Because wavelength increases as frequency decreases, the dimension of the aperture perpendicular to the E field, must be greater $\frac{1}{2}\lambda/\sqrt{\epsilon_r}$ for the greatest usable wavelength. In the present invention, the largest wavelength in the high frequency range will therefore occur at the lowest frequency in that range.

In addition to the consideration of cross polarization, the high frequency range must be chosen so that it cannot couple into the low frequency radiator. That is, the high frequency being propagated must be well beyond the cut off of the lower frequency parallel plate waveguide. Stated another way, the lowest frequency in the high frequency range must be substantially greater than the highest frequency of the low frequency range.

Referring briefly to FIG. 2, it can be seen that the aperture 22 extends for an arbitrary distance in depth. It need only be extended far enough so that the energy can be coupled from the high frequency generator (not shown) by any convenient means such for example a mixer or a transmitter.

Referring again to FIG. 1, the second radiator element 19, hereinafter referred to as the low frequency radiator, is shown juxtaposed to and touching the high frequency radiator 18. It can be said to be touching the high frequency radiator 18 because of the common plate 16 which is common to both the high frequency radiator and the low frequency radiator. In describing the low frequency radiator 19, reference will be made to both FIG. 1 and FIG. 2.

The low frequency radiator 19 includes two parallel plates 16 and 17 which make up a parallel plate waveguide. The spacing between the plates is determined by the high frequency range. That is, the cut off frequency of the parallel plate waveguide is determined by the high frequency range. The cut off frequency is then set by proper spacing between the plates.

The spacing between the plates 16 and 17 of the parallel plate waveguide is made small compared to the wavelengths of both frequency ranges. Specifically, the spacing between the plates 16 and 17 is made less than one-half of the wavelength of the highest frequency of the high frequency range. Consequently, the parallel plate waveguide will be able to propagate TE waves with the E field normal to the plates at all frequencies. TE modes with the E field parallel to the planes of the plates (or any other modes) can propagate only at frequencies above the cut-off frequency of the appropriate mode. The lowest cut-off frequency is defined by the relationship $c/\sqrt{\epsilon_r}$, where c is the free space velocity of light, L is the spacing between the plates and ϵ_r is the free space normalized dielectric constant of the material between the plates. L and ϵ are chosen to yield a cut-off frequency above the highest frequency of the high frequency operating band. Therefore, there will not be any frequencies which can couple to the high frequency radiator which will also be under the cut-off frequency of the low frequency radiator. To summarize, to prevent cross coupling between high and low frequency radiators, the field coupled to the low frequency radiator has an E field which is normal to the plates of the parallel plate waveguide. On the other hand, the E field of the high frequency radiator 18 is parallel to the plates 15 and 16 and, consequently, parallel to the plates of the parallel plate waveguide 16 and 17. Partially as a result of this cross polarization and because of the above described cut-off features of each radiator segment, the energy of the high frequency radiator cannot be coupled into the low frequency radiator and vice versa.

The low frequency radiator 19 also includes a monopole 24 which is disposed between the plates 16 and 17 essentially in the same plane as the conductive strip 20 of the high frequency radiator 18. The specific structure and location of the monopole 24 will be described in greater detail below.

Referring to FIG. 2, it can be seen that the parallel plates 16 and 17 are short circuited by a conductive strip 26. The short circuit 26 is located at a distance which is measured from the center of the monopole 24. The specific distance is one quarter of the wavelength of the midband frequency of the low frequency range. If the monopole 24 is placed sufficiently close to the plane of the conductive strip 20, the parallel plate waveguide appears as an open circuit or of small reactance at the plane of the conductive strip 20 for TE waves with the E field normal to the plates. As a result, during transmission, all of the transmitted energy will radiate out from the front of the waveguide instead of only half of the energy. That is, the monopole will radiate into half-space. All other x polarized waves impinging on this structure impinge on a waveguide beyond cut-off and the surface appears as an inductive surface with evanescent fields existing in the space between the plates.

FIG. 3 is a cut-away, perspective view of the parallel plate waveguide previously discussed in FIGS. 1 and 2. FIG. 3 shows the monopole placed across the open end of the waveguide and normal to the waveguide plates 16 and 17. The waveguide is open circuited for the fields the monopole can excite and the free space on the other side of the monopole has a real impedance into which energy is radiated. The radiation resistance of the monopole is the impedance of free space multiplied by the ratio of the unit cell dimensions. The unit cell can be defined by the unit vectors describing the monopole location.

The precise location fore and aft of the monopole is not important. However, it is desirable to locate it as close as possible to the edges 16*a* and 17*a* of the plates 16 and 17 — that is, so that it is essentially in the same plane as the conductive strip 20 which was described in FIG. 1 and FIG. 2. It is desirable to place the monopole in such a position because the driving point impedance of the parallel plate waveguide becomes increasingly frequency sensitive as the monopole is moved away from the edges 16*a* and 17*a* of the parallel plates.

The monopole 24, in an operative embodiment, is constructed of the inner cable of a coaxial cable. However, it could just as well be constructed of any wire conductor. It is not necessary to physically connect the monopole 24 to the plate 17. However, it is preferable to have the monopole 24 physically and electrically connected to said plate. The connection can be made by a simple soldering operation. If the monopole is not physically connected to the plate 17, a high capacitance electrical connection between the lower end of the monopole and the plate 17 is required. The diameter of the monopole 24 is significant only insofar as its physical strength is concerned. That is, it should not be so thin that it is unable to remain in its preset position without falling over or that it breaks easily.

In order to connect low frequency energy to the low frequency radiator 19, the low frequency generator (not shown) is connected to two parts of the low frequency radiator by means of two wires 26 and 28, which may form the inner and outer conductors of a coaxial cable.

In order to connect the wires 26 and 28 to the appropriate places of the low frequency radiator 19, a small hole is cut into the plate 16. In order to more easily illustrate the structure, FIG. 3 shows only a cut-away view of the upper plate. However, it will be understood that FIG. 3 only shows half of the hole 30 as illustrated by solid line 31. In fact, the hole is complete as illustrated by dotted line 32. The dimension of the hole does not matter as long as it is significantly smaller than the aperture **22** associated with the high frequency radiator **18** described in FIG. **1.** Furthermore, it does not matter if the monopole **24** is thin enough so that it can extend up into the hole **30.** Or, if desired, the length of the monopole **24** can stop just short of the underside of the plate **16.** A wire **28** is attached to the upper end of the monopole **24** and is extended through the hole **30** for connection to one terminal of the low frequency generator. The other wire, **26,** is connected to the other terminal of the low frequency generator and is connected to the edge **31** of the hole **30.**

FIG. **4** shows an alternative embodiment to the use of a monopole — a dipole. The dipole location is to the monopole location which was described in FIG. **3.** That is, it is located as close as possible to the edges **16***a* and **17***a* of the plates **16** and **17.** In an operative embodiment, the dipole consists of a solid conductor **34** and a hollow metal sleeve **36** which extends downwardly from the plate **16** toward the plate **17.** The sleeve **36** has a circular cross section and has an aperture in its center. The sleeve **36** forms the upper half or arm of the dipole and the solid conductor **34** forms the other of the dipole. Although sleeve **36** is shown in FIG. **4** in a cross sectional view, it will be understood that it forms a complete cylinder. Wire **28** is connected to the top of the solid conductor **34** and the other end of conductor **28** is connected to one terminal of the low frequency generator (not shown). The other terminal of the low frequency generator is connected to the wire **26** which, in turn, is connected to the inside face of the sleeve **36.**

In order to construct the antenna array **100** shown in FIG. **5,** a plurality of the above-described basic radiator structures are juxtaposed to one another. It will be noted, however, as discussed previously, that the basic radiator structure could have been considered to be block **80** or block **85** of FIG. **5.** If either of those blocks were used, the basic radiator structure would have had portions of more than one low frequency radiator such as shown by block **80** or it would have had portions of more than one high frequency radiator as shown by block **85.** Irrespective of which type of basic radiator structure is used in the analysis, the antenna array **100** shown in FIG. **5** is composed of a plurality of them.

FIG. **5** shows only a portion **100** of the entire antenna array aperture. The array includes two repetitive systems. A portion of the first repetitive system is shown as row **40** which includes and is enclosed by plates **43** and **45** each of which extend, as shown in FIG. **5,** in a horizontal direction to their respective ends of the antenna array. The first repetitive radiator system is adapted to operate in the first or high frequency range. Its structure consists of a plurality of high frequency radiators each of which is similar to the high frequency radiator **18** of FIG. **1.** That is, it includes a conductive strip **44** and a plurality of apertures **46** located in the conductive strip. The dimensions of the apertures **46** are chosen in the same manner as explained with respect to aperture **22** of the high frequency radiator **18** in FIG. **1.** Each such radiator is connected to a different high frequency generator.

The antenna array **100** also has a second repetitive radiator system which is adapted to operate in the second or low frequency range. One portion of the second repetitive radiator system is indicated as row **42** which includes and is enclosed by the plates **45** and **47.** These plates also extend in a horizontal direction to their respective ends of the antenna array. These plates, **45** and **47,** form a parallel plate waveguide the dimensions of which are determined by the same considerations which were explained above with respect to low frequency radiator **19** shown in FIGS. **1** and **2.** At predetermined locations throughout the parallel plate waveguide are located a plutality of monopoles or dipoles for the same reasons and of the same dimensions and installed into the parallel plate waveguide in the same manner as was explained in FIGS. **1, 2,** and **3.** Each such radiator may be connected to a different low frequency generator. For every aperture **46** there is a corresponding monopole or dipole **48.** That is, the two are present in their respective repetitive systems on a one to one basis.

As explained above, the row **40** is part of a first repetitive radiator system and the row **42** is part of a second repetitive radiator system. Each row is substantially repeated in alternate rows. That is, the structure of row **40** occurs both above and below row **42.** The row occurring after row **42** has been designated as **40***a*. Likewise, a row substantially identical to row **42** occurs both above and below row **40***a*. The row below row **40***a* has been designated row **42***a*. Similarly, row **40***b* is substantially the same as row **40** and occurs after row **42***a*; and row **42***b* is substantially the same as row **42** and occurs after row **40***b*.

In order to insure that the array operates properly, a number of constraints are necessary. Although it is not necessary that the monopoles **48** be located exactly as shown in FIG. **5** with respect to the apertures **46,** once a particular location has been chosen for each, relative to one another, that relative position must be maintained throughout the array. For example, if the longitudinal axis of the monopole **48** is exactly aligned with the vertical diameter of the aperture **46** in one particular one to one relationship, the same relative position must be maintained between all of the monopoles **48** and apertures **46.**

In the following discussion of the antenna array, it is easier if we define the high frequency radiator elements to be the apertures **46** and the low frequency radiating elements to be the monopoles **48.** However, it will be understood that whenever the term "high frequency radiator" is used that it is also describing all of the structure and factors considered with respect to FIGS. **1, 2,** and **3.** In addition, whenever the term "low frequency radiator" is used it will incorporate by reference all of the information discussed above with respect to FIGS. **1, 2,** and **3.**

The space between each of the high frequency radiators **46** must be on the order of one-half of the wavelength of the highest frequency of the high frequency range. That is, the spacing between the apertures **46** cannot be greater than said distance. The spacing between the monopoles **48** is the same as the spacing between the high frequency apertures **46.** This is done partially in order to more easily obtain the basic radiator structures described above. It is also done to prevent coupling of energy from the high frequency radiators into the low frequency radiators and vice versa. Moreover, at the frequency at which it is operating, that is, at a low frequency, the spacing of the low frequency radiators cannot be greater than one-eighth of a wavelength. This latter constraint, then, partly determines the low frequency range. The maximum frequency of the low frequency range cannot be greater than one-quarter of the minimum frequency of the high frequency range because the drive point impedance of the low frequency radiators becomes highly reactive for wider spacings. The spacing between the low frequency radiators has been chosen to be not greater than one-eighth of a wavelength of the lowest frequency of the low frequency range because at low frequencies, the Q (the ratio of reactance to resistance) gets better — that is, the Q gets lower. When designed in such a manner, the low frequency repetitive system is equivalent to a current sheet. The current can be controlled as a function of position in the sheet.

The only coupling possibilities are monopole (dipole) and/or waveguide to near field vertically polarized waves. Since these waves do not exist in the high frequency far field, the total contribution to such waves of each elemental high frequency radiators near field must be zero.

Typical frequency ranges for the high frequency radiator is 9 to 10 GHz, and 1.8 to 2 GHz for the low frequency radiators.

I claim:

1. An antenna adapted to operate in first and second frequency ranges comprising:

a. a plurality of radiating horns for radiating energy within said first frequency range;

b. a plurality of dipole radiating elements transversely mounted in a plurality of sections of open waveguide, each of said dipoles being designed to radiate energy in said second frequency range;

e. means for mounting said horns and said sections of open waveguide to form a unitary antenna aperture comprising rows of radiating elements, the type of radiating element comprising the rows alternating between horns and dipoles in a direction substantially ninety degrees with respect to said waveguides, with said first and second frequency ranges, the dimension of said horns, the dimension of said dipole elements and the dimension of said open waveguide being selected to reduce the coupling between said horns and dipoles.

2. An antenna adapted to operate in first and second frequency ranges, said antenna comprising a plurality of array elements assembled to form a unitary aperture structure with each element being substantially identical and including a first horn radiating element comprising an opening in a conductive strip for radiating energy within a first selected frequency band and a dipole element for radiating energy within a second selected frequency band, said dipole element being mounted substantially parallel to said strip and transverse across and near the open side of a section of open waveguide, the dimensions of said openings in said conductive strip, said dipole and said open waveguide being selected such that coupling between said horns and dipole is minimized, said elements being assembled such that said dipoles and horns form rows with the type of radiating element alternating between rows.

3. An antenna array in accordance with claim 1 in which the spacing between adjacent radiating horns is less than one half of the wavelength of the highest frequency within said first frequency range.

4. An antenna in accordance with claim 1 in which the mechanical spacing of said dipoles is the same as the spacing of said radiating horns.

5. An antenna adapted to operate in first and second frequency ranges, said antenna comprising a plurality of array elements assembled to form a unitary aperture structure with each element of said array being substantially identical and including, a first radiating element comprising an opening in a conductive strip to form a horn for radiating energy within a first selected frequency band and a second dipole radiating element mounted transversely across and near the open edge of a section of open waveguide for radiating energy within a second selected frequency band, the dimension of said opening in said conductive strip, said second radiating element and said waveguide being selected such that coupling between said first and second radiating elements is minimized said elements being assembled to form said aperture such that said first and second radiating elements form rows with the type of radiating element alternating between adjacent rows.

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