FIG. 2
PHASED ARRAY ANTENNA WITH RAINFALL DRAINAGE CHANNELS

Fig. 3a

Fig. 3b

Fig. 3c

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FIG. 6

DIVERGENT BEAM

PROGRAMMER

SHIFTER

COLLIMATED & STEERED BEAMS

FIG. 5

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ABSTRACT OF THE DISCLOSURE

A phased array antenna being protected against rainfall, comprising an antenna support structure; a plurality of radiating elements each being raised away from said support structure a sufficient distance to permit the maximum projected rainfall to flow through the channels formed by raising the elements; and, means for connecting the array elements together at the front edges to simulate the existence of a continuous ground plane.

The invention herein described was made in the course of and under a contract or subcontract thereunder with the Department of the Army.

BACKGROUND OF THE INVENTION

This invention relates to antennas having a plurality of radiating elements, and more particularly, to the mounting of the radiating elements in a phased array antenna. An antenna array is composed of a plurality of radiating elements positioned in spaced-apart relationship. An example of such an antenna array is an S-band optically fed phased-array antenna with the array face being in the form of a circle of 14-foot diameter and containing five thousand radiating elements. Each of the radiating elements is constructed in the form of an open-ended cavity which is terminated and tuned by a flat beryllia window and contains a coupling loop of wire, commonly referred to as a "mode launcher," to transmit the microwave signal through said window. The input signal to each radiating element is obtained from a microwave phase shifter which is connected to the coupling loop and imparts the correct phase to the signal transmitted by each radiating element. Each phase shifter is provided with an input horn which intercepts a portion of the electromagnetic radiation of a primary transmitting horn.

The radiating elements are positioned in spaced-apart relationship by the antenna support structure which generally is in the form of a heavy mounting plate having apertures for receiving each element. With this type of mounting, the flat beryllia windows for receiving each element are flush with the front surface of the antenna support structure so as to provide a flat face for the array. In this configuration the antenna support structure also serves as a ground plane for the radiating elements.

In a typical installation, the antenna array forms a part of a wall or roof of the building which houses the transmitter and peripheral equipment. The face of the array is inclined at an angle of approximately 51.5° with the horizontal, as this orientation permits the beam of radiation to be scanned in elevation from low to high elevation angles.

An important advantage of this type of construction in the antenna array is its extreme rigidity and shock resistance. It is far more rigid and shock resistant than the typical radome, as is readily apparent from an examination of the radome support structure which usually comprises a series of widely spaced, relatively thin support members in comparison with the relatively heavy mounting structure of the antenna array. This antenna array is also blast resistant so that it may be located in the vicinity of a missile launch site.

A problem arises when the antenna array is operated in a rain environment. The large flat inclined face of the array intercepts a substantial quantity of rainfall. As the rainwater flows down the array face it combines with the raindrops falling on the lower portions of the face and thereby builds up a sheet of water whose depth increases with distance from the upper edge of the array face. The depth of the water sheet depends on the severity of the rainstorm and on the angle of inclination of the array face as well as the physical size of the array face. Since the dielectric constant of water is an order of magnitude greater than the metalized beryllia glass used in the beryllia windows, a thin sheet of water in contact with the beryllia windows detunes the radiating elements so that they no longer radiate effectively. The water depth near the lower edge of the array face during a moderate-to-heavy rainstorm is sufficient to present substantially a dead short to the radiant energy of the radiating elements near the lower edge of the array.

The rainwater problem exists independently of the type of feed structure supplying the input signals to the radiating elements so that the problem is also present with array antennas other than the optically fed, phased-array antenna. The windows of the elements near the lower edge of the array are covered with the sheet of water whether they are flat or in the form of a convex or concave lens, or whether they are constructed of beryllia or some other material. And furthermore, the rainwater problem is also present for array faces having a surface other than a flat plain surface, that is, a curved surface, and in particular, a cylindrical surface.

Accordingly, it is an object of this invention to improve the performance of an array antenna during precipitation by substantially reducing the amount of water on the windows of the radiating elements of the antenna array.

SUMMARY OF THE INVENTION

In accordance with the invention an antenna array is provided comprising a plurality of radiating elements, a support structure which supports and positions the radiating elements in spaced relationship, said support structure being positioned behind the array face to form channels which act as a drainage region between the radiating elements to receive such fluid as may from time to time contact the array face.

An electrically-conducting structure interconnecting said radiating elements preferably is positioned adjacent to the array face and forms a ground plane for the radiating elements and is in contact with only a portion of each radiating element so as to form openings which are the entrance to the drainage region.

It is preferable that the structure forming the ground plane and the supporting structure be spaced apart a sufficient distance to present with the outer surface of the radiating elements a cavity which serves as a drainage region and with the openings formed by the interconnecting structure provides that the radiation characteristics of the antenna array remain substantially constant even with a change in the depth of the water in the drainage region.

It should be understood that in the present embodiment each of said radiating elements have the form of a cylindrical open-ended cavity terminated with a window or lens. However, solid or dipole-type elements of either metal or dielectric or a combination thereof can be used. Also an exit port in one embodiment is provided from which said fluid can flow out of the drainage region.
3 BRIEF DESCRIPTION OF THE DRAWINGS

Other objects and advantages of this invention will become apparent from the following specification taken in connection with the accompanying drawings wherein:

FIG. 1 shows an enlarged pictorial view of a portion of an array of radiating elements in accordance with the present invention;

FIG. 2 shows a vertical sectional view of the face of an array along with metallic spacers for connection with adjacent elements and exposing the array drainage channels for disposing collected fluid;

FIG. 3a is a diagrammatic representation of an antenna with drainage structure;

FIGS. 3b and 3c show diagrammatic representations of the antenna with a drainage structure;

FIG. 4a shows an equivalent circuit representation for the impedance presented to a single radiating element in the case of a flush mounting of the radiating elements in which there are no drainage channels, and no apertures in the ground plane;

FIG. 4b shows an equivalent circuit representation for the impedance presented to a single radiating element for the situation in which a portion of the ground plane is recessed a small fraction of a wavelength;

FIG. 5 shows an equivalent circuit representation for the situation in which there is a connecting means bridging a portion of the spaces between the radiating elements so that apertures or perforations are formed in the ground plane;

FIG. 4d shows an equivalent circuit representation for the situation in which there is the combination of recessed connecting means, apertures in the ground plane, and enclosed drainage channels;

FIG. 5 shows in diagrammatic form a typical installation of the array antenna; and

FIG. 6 shows in diagrammatic form a lens-type, optically fed array antenna incorporating features of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, there is shown a portion 10 of an antenna array 12, as shown in FIGS. 5 and 6, having radiating elements 14 disposed in spaced-apart relation. Each of these radiating elements is supported and positioned by means of an antenna support structure 16 in the form of an electrically conducting plate having apertures to receive the radiating elements 14, said antenna support structure being located behind the face of the array. Each radiating element 14 is affixed to the support structure 16 by means of mounting lugs 18 and bolts 20 which secure the mounting lugs 18 to the support structure 16. Referring to FIGS. 1 and 2, there are shown spring-loaded, metallic, electrically conducting spacers in the form of shoes 22 which are attached to the radiating elements 14. Each shoe 22 is positioned with the aid of a spring 24 and guide pin 26. In this embodiment, the radiating element 14 has a metallic cylindrical wall of sufficient depth to support the guide pins 26 which are mounted in said wall such that the inner end of a guide pin 26 is flush with the inner surface of said wall. The front or transmitting end of each radiating element 14 has a metallized beryllia ceramic window 28 brazed to the inner surface of the cylindrical wall of the radiating element 14, such that said beryllia window is flush with the front surface of said radiating element. Integral with and protruding radially from the cylindrical wall of each radiating element 14 is a lip 30 which is flush with the front surface of said radiating element to facilitate the discharge of fluid from the front surface of the beryllia window 28. As is shown in FIG. 1, drainage apertures 32 are provided in the face of the array to drain the fluid from the front faces of the radiating elements 14, each of said apertures having a boundary comprised of the lips 30 of three adjacent radiating elements 14 and the corresponding three pairs of shoes 22. The shoes 22 are located below the lips 30 to form a recession in the face of the array, and thereby facilitate the entry of fluid from the front surfaces of the radiating elements 14 into the drainage apertures 32. An electrical ground plane is formed for the array of radiating elements 14 by the combination of lips 30 and shoes 22 lying in or adjacent to the face of the array, said ground plane being perforated by the drainage apertures 32.

FIG. 2 is a cross-sectional view taken through three radiating elements 14, as indicated in FIG. 1, and illustrates in detail the spring loading of a shoe 22 and the interior of a radiating element 14. The springs 24 are fitted into recessions in the outer surfaces of the cylindrical walls of the radiating elements 14 and maintain the necessary pressure to urge the shoes 22 radially outward from the cylindrical walls of said radiating elements so that contact is made between pairs of shoes 22 of adjacent radiating elements 14 with sufficient pressure to provide good electrical conduction. Each radiating element 14 has a base 34 which closes off one end of the cylinder formed by the walls of said element to form an open-ended cavity 36 which in combination with the coupling loop 38, mode suppressing rod 40, and beryllia window 28 comprises the microwave structure for transmitting microwave radiation. The microwave energy enters the radiating element 14 by means of a coaxial connection, not shown, and the coupling loop 38. Provision is made for the coaxial connector 42 in the base 34 of the radiating element 14 which opening has a diameter larger than the diameter of the wire of loop 38 such that said wire can pass through said opening with the necessary clearance between said wire and the boundary of said opening, said clearance being similar to the clearance between the inner and outer conductors of said coaxial connector, not shown, so that the microwave energy can be readily coupled through said coaxial connector into said radiating element. Coupling loop 38 is constructed of a rigid large diameter wire bent with two ninety degree bends to form two parallel arms one of which connects with the aforementioned coaxial connector and the second arm being affixed by means of screw 44 to the base 34. The diameter of the wire of coupling loop 38 is sufficiently large to present an adequate radiating surface on the wire and, as is well known, to effect the necessary capacitance to the wire. Cavity 36 also contains a well-known, mode-suppressing rod 40 which is affixed, by brazing, to the center of the beryllia window 28. The diameter of the mode-suppressing rod 40 is approximately two-thirds the diameter of the wire of the coupling loop 38, the length of the mode-suppressing rod 40 is approximately twenty percent greater than the overall length of the top portion of the coupling loop 38 where said top portion is the portion of the coupling loop 38 which is parallel to the beryllia window 28. The two ends of the mode-suppressing rod 40 are bent away slightly, approximately twelve degrees, from the surface of the beryllia window 28, and said tuning rod is so mounted that the plane containing the center line of said rod is perpendicular to the plane containing the center line of the coupling loop 38. The overall diameter of said radiating element is approximately two inches at 5 band.

In operation, therefore, the drainage apertures 32, as shown in FIG. 1, admit fluid such as rainwater which from time to time contacts the beryllia windows 28, the lips 30 and the shoes 22 of the radiating elements 14 and the fluid then flows upon the support structure 16 and between the radiating elements 14 in enclosed drainage channels 46 and thereby drains away from the face of the array. The enclosed drainage channels 46 form a microwave-cavity-type structure which in combination with the drainage apertures 32 exhibits the necessary surface wave resonances which would significantly disturb the performance of the antenna array 12.
FIGS. 3a, 3b, and 3c illustrate, with the aid of diagrammatic representations of antenna arrays, the operation of this embodiment of the invention in the removal of fluid from the face of the array and the resulting improvement obtained therefrom. FIG. 3a shows a flush mounted antenna array of the prior art in which the radiating element 54 and the support structure 56 support a sheet of water 48 of the face of the array. The sheet of water 48 alters the impedance presented to the radiating elements of the prior art and thereby detunes the elements. The sheet of water 48 does not appear on the face of the array in the line drawing of FIG. 3c because the water has been withdrawn from the face of the array by means of the enclosed drainage channels 50. An intermediate solution shown in FIG. 3b utilizes open drainage channels 52.

Referring specifically to FIG. 3b, the open drainage channels 52 can be formed by raising the radiating elements 54 away from the support structure 56 of FIG. 3a, or equivalently, by removing material from said support structure between said radiating elements. The resultant support structure 58 is shown in both FIGS. 3b and 3c. In FIG. 3b, the water drains into the open drainage channels 52 and does not build up inside the portion of the antenna to cover the radiating elements 54. In some applications where this intermediate solution can be used, the support structure 58 with the water 48 aid in forming the ground plane. However, for optimum operation of the antenna array, the radiating elements 54 are tuned to resonate with the impedance presented by the drainage channels. The effective depth of the open drainage channels 52, and hence their impedance, varies with the quantity of the water in the channel. This variation of impedance with water depth in the drainage channel is virtually eliminated, as shown in FIG. 3c, by connecting the front edges of the radiating elements with shoes 60, thereby forming the enclosed drainage channel 50. In this configuration, the impedance presented to the radiating elements 54 remains essentially constant with changing water depth so that the radiating elements 54 can be tuned, and remain tuned whether or not the water is present.

The operation of the enclosed drainage channels 50 can be further explained in terms of the electrical resonances introduced by the various components of the embodiment shown in FIG. 1. One possible explanation for the effects on the array impedance which are introduced by the perforated and recessed portions of the ground plane is hereby presented. These effects are directly related to the dimensions of the perforated and recessed portions of the ground plane and to the depth of the enclosed drainage channels 46. The depth of the enclosed drainage channels 46 are less than a half wavelength, to avoid resonances within the band of interest. For optimum performance, the depth is approximately a quarter wavelength. Six equally spaced areas of contact around the circumference of each element are provided by the location of the shoes to permit proper current flow between the elements and to avoid "ring" resonances.

The effects on the array impedance which are introduced by the perforated and recessed portions of the ground plane can be determined with the aid of a representation of the enclosed drainage channels, the perforations or apertures in the ground plane, and the recessed connecting means in the form of an equivalent circuit in which the circuit parameters are related to the physical dimensions of the individual elements of FIG. 1. The height of the recessed portion of the unit cell 62 is taken as the region enclosed by the right cylinder coaxial with the radiating element 14 and extending from the support structure to the face of the array, and having a cross section in the form of a hexagon of which each side is the perpendicular bisector of a line segment extending from the center of said radiating element to the center of an immediately adjacent radiating element 14. The equivalent circuit is developed with the aid of FIGS. 4a, 4b, 4c, and 4d. The circuit impedances are normalized to the intrinsic impedance of free space. The impedance, normalized, of a radiating element 14 at the face of the array is taken as unity.

Referring specifically to FIG. 4a, there is shown a simplified diagram of the face of the antenna array which for illustrative purposes has been modified so that there are no recessed and no perforated portions in the ground plane and no drainage channels, said portion comprising one unit cell 62. The area 64 within the unit cell 62 and without the periphery of the beryllium window 28 is electrically conducting and functions as the ground plane. The impedance presented to the radiating element 14 is given by $S$, the normalized characteristic impedance of free space, where the terminal pair 66 represents the connection to the radiating element 14. The expression for the impedance $S$ includes the effects of scan angle $\theta$, thus, $S=1/\cos \theta$ for H-plane scan and $S=\cos \theta$ for E-plane scan. The equivalent circuit, therefore, consists of simply a resistor $68$ of value $S$.

Referring specifically to FIG. 4b, there is shown a portion of the face of the antenna array, said portion being the same portion as is shown in FIG. 4a. However, in FIG. 4b, this portion has been modified to show the recessed portion 60 and to cover the radiating elements 54 and the impedance presented by the drainage channels. The effective depth of the open drainage channels 52, and hence their impedance, varies with the quantity of the water in the channel. This variation of impedance with water depth in the drainage channel is virtually eliminated, as shown in FIG. 3c, by connecting the front edges of the radiating elements with shoes 60, thereby forming the enclosed drainage channel 50. In this configuration, the impedance presented to the radiating elements 54 remains essentially constant with changing water depth so that the radiating elements 54 can be tuned, and remain tuned whether or not the water is present.

The operation of the enclosed drainage channels 50 can be further explained in terms of the electrical resonances introduced by the various components of the embodiment shown in FIG. 1. One possible explanation for the effects on the array impedance which are introduced by the perforated and recessed portions of the ground plane is hereby presented. These effects are directly related to the dimensions of the perforated and recessed portions of the ground plane and to the depth of the enclosed drainage channels 46. The depth of the enclosed drainage channels 46 are less than a half wavelength, to avoid resonances within the band of interest. For optimum performance, the depth is approximately a quarter wavelength. Six equally spaced areas of contact around the circumference of each element are provided by the location of the shoes to permit proper current flow between the elements and to avoid "ring" resonances.

The effects on the array impedance which are introduced by the perforated and recessed portions of the ground plane can be determined with the aid of a representation of the enclosed drainage channels, the perforations or apertures in the ground plane, and the recessed connecting means in the form of an equivalent circuit in which the circuit parameters are related to the physical dimensions of the individual elements of FIG. 1. The height of the recessed portion of the unit cell 62 is taken as the region enclosed by the right cylinder coaxial with the radiating element 14 and extending from the support structure to the face of the array, and having a cross section in the form of a hexagon of which each side is the perpendicular bisector of a line segment extending from the center of said radiating element to the center of an immediately adjacent radiating element 14. The equivalent circuit is developed with the aid of FIGS.
and perforated portions of the ground plane, and the enclosed drainage channels 46 shown in FIG. 1. The impedance presented by the enclosed drainage channels 46 is conveniently represented by a shorted line where the length of the line y is related to the depth of the enclosed drainage channels 46. As is shown in the electrical schematic of FIG. 6d, the channel impedance 80 appears in parallel with the aperture reactance 76 of value $X_p$. The optimum value

$$y = \lambda/4$$

for the length of the shorted line of the channel impedance 80 is indicated in FIG. 4d. When the fluid in the enclosed drainage channel 46 is of such a depth that the equivalent length of the shorted line of the channel impedance 80 is a quarter wavelength, the channel impedance 80 is essentially infinite so that the combination of aperture reactance 76 and channel impedance 80 is essentially equal to the value $X_p$. In the electrical schematic representation the aperture reactance 76 appears at the end of the transmission line representation of the recession impedance 72. The combination of aperture reactance 76 and the recession impedance 72 is the value $X_p$ reflected to the beginning of the line representing the recession impedance 72, and similarly, the combination of the channel impedance 80 with the aperture reactance 76 and the recession impedance 72 is the parallel combination of the channel impedance 80 and the aperture reactance 76 reflected to the beginning of the line representing the recession impedance 72. The total impedance presented to the radiating element 14 at terminal pair 66 is the combination of the resistor 68 in series with the parallel combination of the aperture reactance 76 and the channel impedance 80 reflected through the line representing the recession impedance 72. With an appropriate value for $X_p$, a considerable variation in the fluid depth and a corresponding variation in the channel impedance 80 does not significantly alter the value of the total impedance appearing at terminal pair 66. In other words, the impedance presented to the radiating element 14 at terminal pair 66 is substantially constant with variations in the depth of the fluid in the enclosed resonant drainage structure. It is also evident that for values of $X_p$, which are substantially smaller than the value $S$ of the resistor 68, and for values of the recession in the ground plane which is small compared to a wavelength, the total impedance presented to the radiating element 14 at terminal pair 66 is substantially the same as that shown in FIG. 4a which depicts a situation analogous to a flush-mounted antenna array. It is also evident that since the impedance is essentially constant with the depth of the fluid in the enclosed drainage channel 46, the radiating elements 14 may be tuned for the impedance $S + X_p$ and that the radiating elements 14 will remain substantially tuned with variations in the fluid depth. Also, the radiation characteristic of the antenna array is substantially the same as that of a flush-mounted array. It is thus evident that the invention of the enclosed resonant drainage structure with apertures in the face of the array provides a ground plane and a wide-band electrically resonant structure whose electrical characteristics approximate that of a flush-mounted array.

FIG. 5 illustrates one method of providing hemispherical coverage with more than one antenna array 12. Here one array 12 is mounted on each of the four inclined roofs of the square-shaped building 82. The voids between the lowest row of radiating elements 14 in each array 12 serve as exit ports 84 out of which the rainwater flows.

It should be understood that more than one form of connecting means is applicable to bridge the drainage channels. While the present embodiment utilizes a connecting means in the form of the aforementioned shoes 22 affixed to the radiating elements 14, the connecting means could alternatively have the form of metallic electrically conducting spacers adapted to make electrically conducting contacts with the radiating elements at or adjacent to the front of the radiating elements, said connecting means being a part of the antenna array 12. The connecting means could alternatively be formed by a perforated metallic plate, screen or wire mesh with openings of sufficient size to admit the rainwater from the face of the array. Other forms of connecting means will be apparent to those skilled in the art.

It should also be understood that more than one form of the radiating element 14 is applicable for the antenna array 12. For example, radiating element 14 or other type source of radiation can be terminated in a window, lens or other suitable transparent termination. Radiating element 14 can alternatively be constructed in the form of a horn. It may contain a solid or fluid dielectric though air is usually employed for the dielectric. If the dielectric were solid, no window would be required insofar as the shedding of rainwater is concerned. However, a window or lens might still be required for tuning the radiating element 14.

FIG. 6 shows a phased array antenna system 86 including antenna array 12. Details of such a typical system are described, for example, in U.S. Pat. No. 3,305,867, entitled “Antenna Array System,” issued to A. R. Miccioli et al., Feb. 21, 1967. In particular, a transmitting horn 88 in spaced-apart relationship from a microwave lens 90 generates a divergent beam of microwave electromagnetic radiation whose rays 92 and wave fronts 94 are directed towards the microwave lenses 90. The microwave lens 90 is comprised of a plurality of horns 96, a corresponding set of phase shifters 98, and a corresponding set of radiating elements 14 of the antenna array 12 raised or extending outward from support structure 16 to shed water. Each phase shifter 98 directed by signals 100 from a programmer 102 imparts the requisite phase shift to the signal transmitted by each radiating element 14 so that the antenna output signals 104 are collimated and steered in the requisite directions 106.

It is understood that the above-described embodiments of the invention are illustrative only and modifications thereof will occur to those skilled in the art. For example, the concept of a tuned structure forming a part of a radiating element or an array of radiating elements is not limited to electromagnetic radiation. The concept can be applied, for example, to acoustic radiators. Accordingly, it is desired that this invention is not to be limited to the embodiments disclosed herein but is to be limited only as defined by the appended claims.

1. An antenna array comprising a plurality of radiating elements, an electrically conductive support structure adapted to position the radiating elements, said support structure being positioned behind the face of the array a sufficient distance to provide channels between the radiating elements permitting drainage of fluid from the face of the array, and means for providing a ground plane at the face of said array, said means cooperating with the side surfaces of said radiating elements and said support structure to permit resonant modes of radiant energy within said channels.

2. Apparatus as defined in claim 1 wherein each of said radiating elements is an open-ended cavity.

3. An antenna array comprising a plurality of radiating elements, a support structure adapted to position the radiating elements, said support structure being positioned behind the face of the array a sufficient distance to provide spaces between the radiating elements permitting drainage of fluid from the face of the array, and means for providing a ground plane for said array, said ground plane including means for bridging the spaces between the radiating elements, said connecting means cooperating with said support structure to provide substantially the same electrical characteristics as that of a ground plane located adjacent to the face of the array.

4. Apparatus as defined in claim 3 wherein said connecting means bridges only a portion of the space between
the radiating elements thereby providing apertures between individual elements to permit the drainage of fluid from the face of the array through said apertures.

5. Apparatus as defined in claim 4 wherein the support structure is an electrically conducting plate located a specific distance behind the connecting means to provide in conjunction with said radiating elements a microwave cavity-type-structure.

6. Apparatus as defined in claim 5 wherein each of said radiating elements is an open-ended cavity.

7. An antenna array comprising a plurality of radiating elements, each of said radiating elements being an open-ended cavity, a support structure adapted to support and position the radiating elements, said support structure being positioned behind the face of the array, means for providing a ground plane for said antenna array wherein said ground plane includes connecting means for bridging the spaces between the radiating elements, said connecting means cooperating with said support structure to provide substantially the same electrical characteristics as that of a ground plane located adjacent to the face of the array; said support structure comprising an electrically conducting plate located a specific distance behind the connecting means to provide in conjunction with said radiating elements a microwave cavity-type structure; said connecting means bridging only a portion of the space between the radiating elements thereby providing apertures between the individual radiating elements to permit the drainage of fluid from the face of the array through said apertures into the microwave cavity-type-structure; said microwave cavity-type-structure being adapted to serve as a drainage region to receive and drain fluid from the face of the array.

8. Apparatus as defined in claim 7 wherein the dimensions of the apertures and the dimensions of the microwave cavity-type-structure are such that the impedance characteristics of said apertures and structure and their effect on the radiation characteristics of the antenna array are essentially constant even with a changing depth of fluid in the drainage region, the magnitude of the reactance of said apertures being sufficiently small to permit the radiating elements to be tuned to provide a radiation characteristic of the antenna array substantially the same as that of a similar antenna array wherein the radiating elements are flush mounted.

9. Apparatus as defined in claim 8 wherein an exit port is provided to permit fluid to flow from the drainage region.

10. A phased array antenna including a plurality of cylindrical radiating elements and an electrically conductive support structure adapted to position the cylindrical radiating elements, said support structure being positioned behind the face of the array a sufficient distance to provide channels between the cylindrical radiating elements permitting drainage of fluid from the face of the array, said channels extending in depth from the face of the array to said support structure and having a mean width which is sufficiently smaller than the depth such that the cross sectional form of the channels permits a uniform mode of radiant energy within the channels even with a changing depth of fluid in the drainage region.

11. A phased array antenna including a plurality of radiating elements, a support structure adapted to position said radiating elements, said support structure being positioned behind the face of the array a sufficient distance to provide spaces between the radiating elements permitting drainage of fluid from the face of the array, and connecting means for bridging the spaces between the radiating elements, said connecting means cooperating with said support structure to provide substantially the same electrical characteristics as that of a ground plane located adjacent to the face of the array.

12. Apparatus as defined in claim 11 wherein said support structure and said connecting means in conjunction with said radiating elements provide a microwave cavity-type-structure, said connecting means bridging only a portion of the space between the radiating elements to permit the drainage of fluid from the face of the array through said apertures into said microwave cavity-type-structure, the dimensions of said apertures and the dimensions of said microwave cavity-type-structure providing essentially constant radiation characteristics for said antenna array even with a changing depth of fluid in the drainage region.

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