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CROSS REFERENCE SEARCH ROC

Aug. 6, 1968 T. E. CHARLTON ET AL 3,396,396

AIRCRAFT NOSE RADOME WITH CERAMIC COVER MOUNTED ON METALLIC FRAMEWORK

Filed Nov. 30, 1965 4 Sheets-Sheet 1

Fig. 1

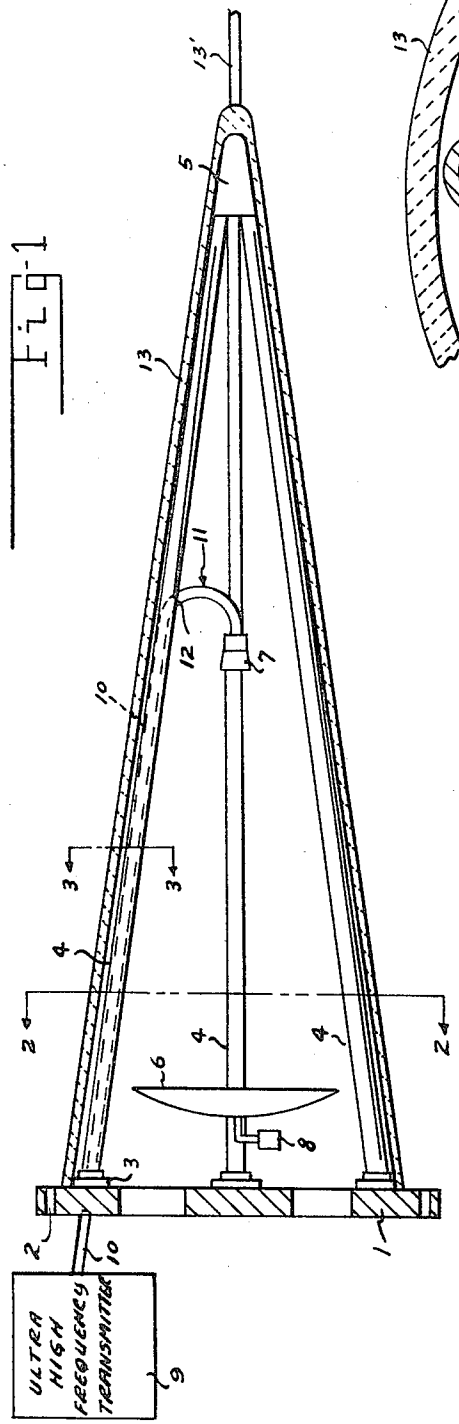


Fig. 3

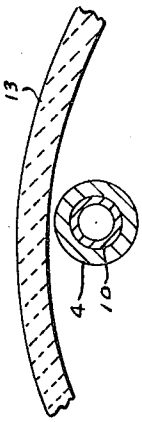


Fig. 4

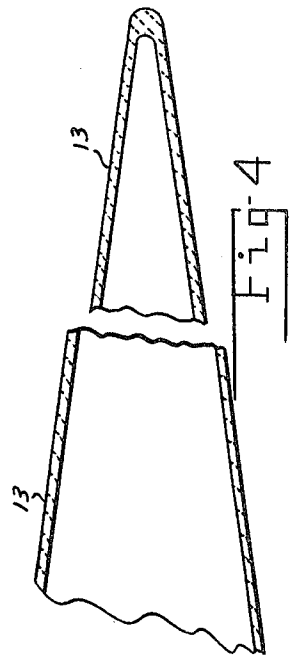
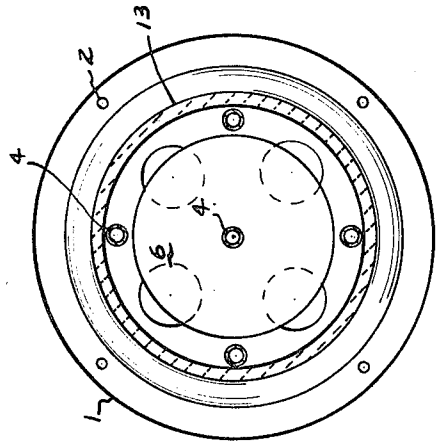


Fig. 2



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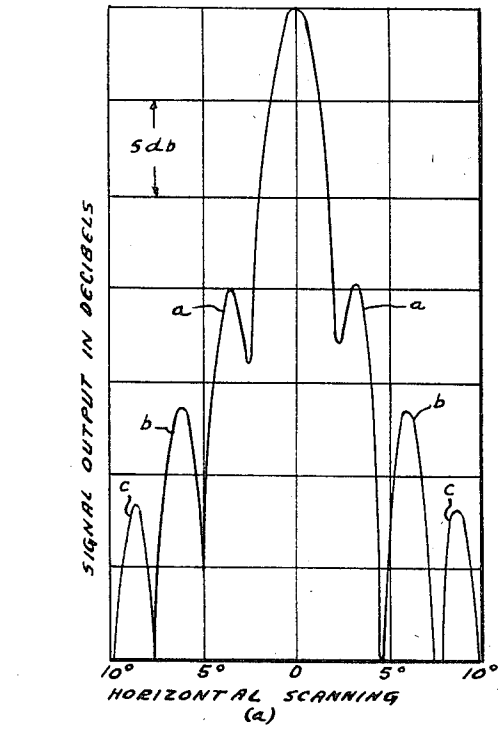


Fig-5

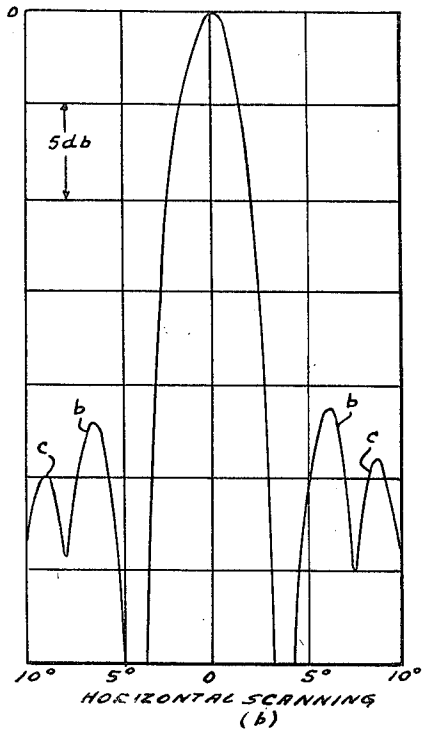


Fig-5a

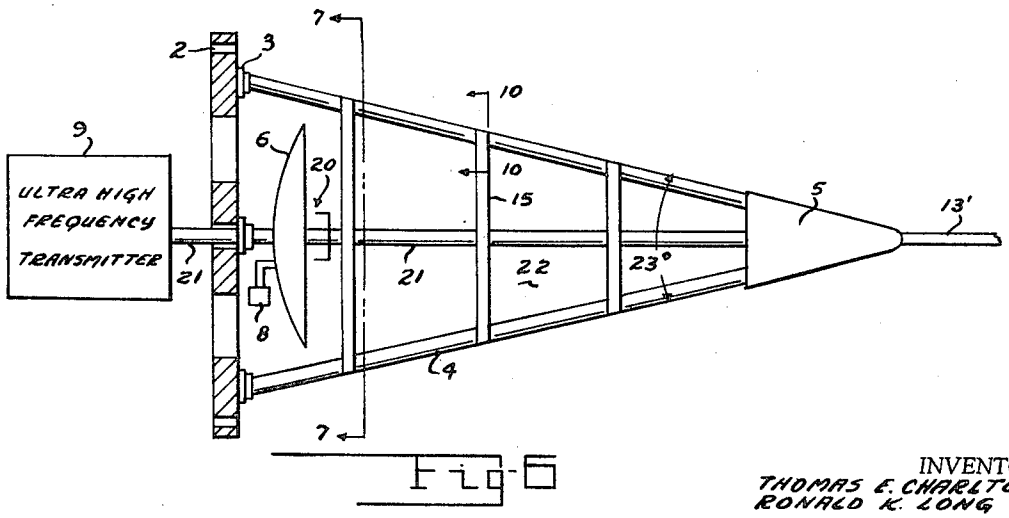


Fig-6

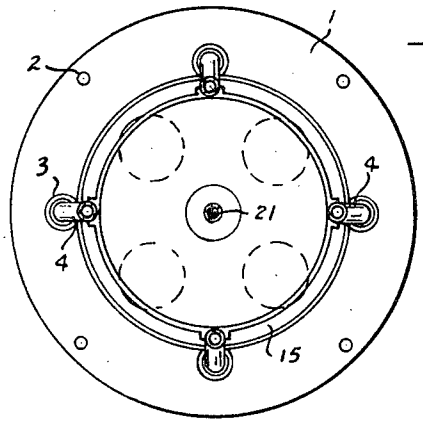
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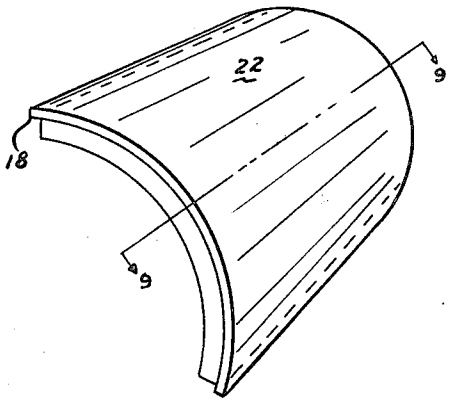
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Fig-7





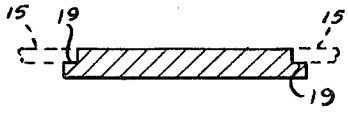


Fig-9

Fig-8

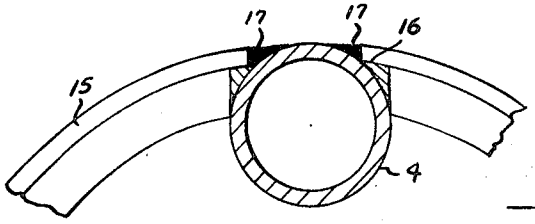
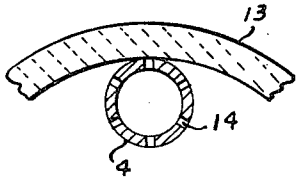


Fig-10

Fig-11



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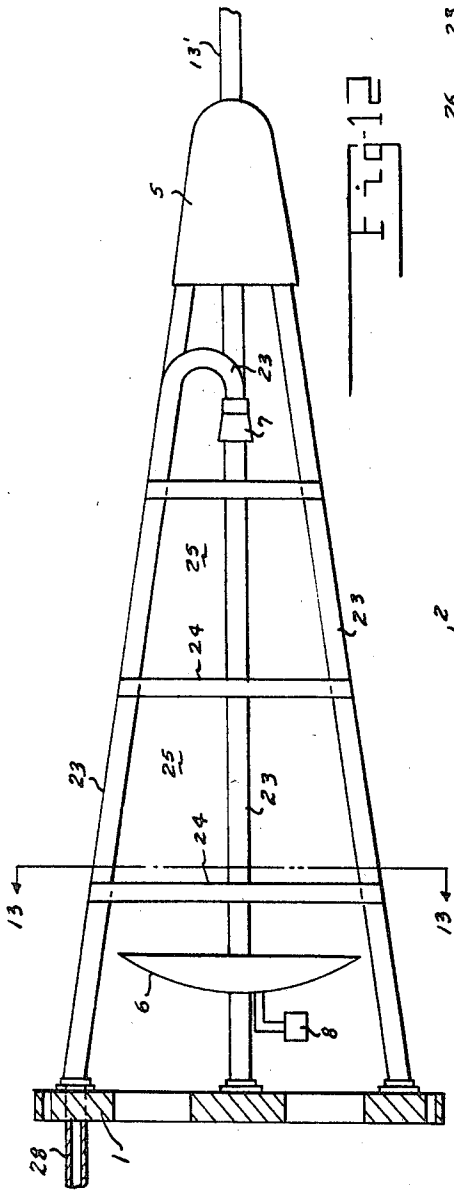


Fig 12

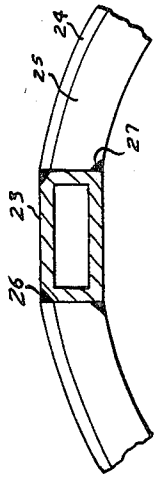


Fig 14

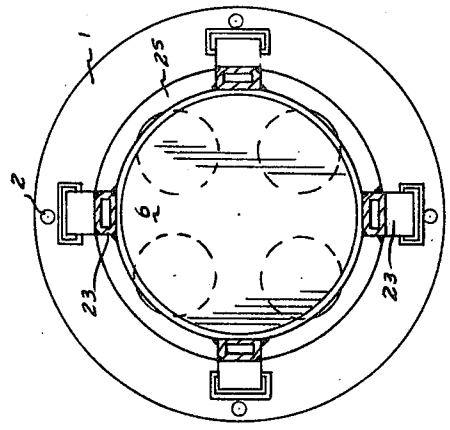


Fig 13

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AIRCRAFT NOSE RADOME WITH CERAMIC COVER MOUNTED ON METALLIC FRAMEWORK

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ABSTRACT OF THE DISCLOSURE

A radome is disclosed formed of thin alumina and having a hollow cone-like configuration. The radome is supported on a metal frame formed of longitudinally extending pipes spaced about a support plate and converging down to a pointed hollow metal member. Circumferential straps of metal are equidistantly spaced along the pipes at a considerable distance apart and crossing the pipes in a rectilinear fashion to provide optimum "open window" space between the metal parts. The alumina covering can be molded in one piece but in the case of large radomes are constituted of arcuate slabs fitted together over the framework and provided with interfitting ledges and undercuts which hold them in place. The pipes are hollow and can be cooled by circulating water therethrough without affecting the efficiency of the radome.

The present invention relates to radomes or inclosures used for the protection of radio antennas and structures from the atmospheric elements. These radomes are carried by planes which may travel at various speeds, including supersonic.

It is well known that the optimum thickness of a radome is dependent on the wave length of the radio beam which passes through the radome as well as the dielectric constant of the radome material. This optimum wall thickness of the radome is set preferably at no greater than ½ wave length of the transmitted signals, usually about ¼" to ⅜". The radome is generally made of a ceramic such as fused silica or alumina which has been found to offer little or no obstruction to the propagation of ultra-high-frequency radiation. A radome is usually designed as a self-supporting casing of conical shape, molded from a wet powder mass and fired to a hard finish. The element may approach considerable size in length and diameter depending upon the dimensions of the transmitting or receiving structure. Often the need for structural strength and ruggedness to withstand the excessive stress set up by a plane maneuvering at supersonic speeds has required that the radome be constituted of a thickness greater than the optimum dimension referred to hereinbefore. Radomes as now manufactured have a thickness as high as ¾" or even 1". Thus the element is much heavier, more difficult to mold and certainly more expensive than is necessary in providing a protective housing for an antenna system.

The primary object of the invention is to provide an improved radome which shall conform to the optimum dimension determined by the transmitted or received wave length, without regard to the encumbrance of heavy weight, size and thickness heretofore required to withstand the severe stresses to which radomes are subjected.

Still another object is to provide a radome which has the minimum thickness and yet is able to withstand the rigorous stress imparted by airplanes maneuvering at high speeds.

A further object is to reduce the thickness of a radome wall, thereby lightening the weight and size without detracting in any degree from its ability to withstand weather

and wind loading. Furthermore, there is the necessity of making them larger and still larger due to the expanded size of the contained reflector and the associated antenna structure. It is becoming more difficult to make a self-supporting radome which conforms to these enormous specifications, on account of the complexity of the molding operations and the difficulty of handling. Moreover, as the size increases, the thickness of the radome is normally increased to carry its own increased weight and stresses brought about by heavy weight.

Accordingly, another object of the invention is to provide a radome designed and constructed which has practically no limitation as to size, particularly as to thickness based on size, and can be made as thin as is compatible with frequency considerations to permit passage of radio signals without interference or attenuation.

The above objects are obtained in brief by providing within the radome or forming a part thereof, a support structure which conforms to the shape of the radome but which masks or shades only a minimal part of the radiated energy. Thus, the radome covering itself, need not be self-supporting and can be made to any size or thickness that is feasible, without danger of collapse under stress. Instead of forming the radome housing as a single integral unit, we may, as a modified form of the invention, construct the radome of a number of readily moldable sections fitted and secured onto a metal framework which has been found to detract very little from the electrical transparency of the radome as a whole.

The invention will be better understood when reference is made to the following description and the accompanying drawings in which:

FIG. 1 is a diagrammatic representation, partly in section and partly in elevation, of a typical transmitting system, contained in the improved radome;

FIG. 2 represents a cross-section taken along line 2—2 in FIG. 1;

FIG. 3 is an enlarged cross-section taken along line 3—3 in FIG. 1;

FIG. 4 shows in section, as a miniature, the ceramic covering of the radome illustrated in FIG. 1;

FIGS. 5 and 5a represent comparison charts showing the side lobe frequency reduction obtained by using our improved radome;

FIG. 6 illustrates a modified form of the improved structure, partly in section and partly in elevation, by which the radome covering is sectionalized and assembled together to complete the radome as a unit;

FIG. 7 represents a section taken along line 7—7 in FIG. 6;

FIG. 8 depicts in perspective, a typical section of the radome covering;

FIG. 9 shows a section taken along line 9—9 in FIG. 8;

FIG. 10 is a fragmentary view, somewhat enlarged and partly in section, showing the manner in which sections of the covering illustrated in FIG. 6 and the encircling straps can be fitted to the longitudinal pipes and secured in position;

FIG. 11 shows in section, a modified form of the longitudinal pipes or spars;

FIG. 12 shows still another modification of the improved radome structure. This view is partly in section and partly in elevation;

FIG. 13 depicts a section taken along line 13—13 in FIG. 12; and

FIG. 14 is an enlarged fragmentary view of one of the joints between the pipes or spars, the hoop lengths and the ceramic sections of the structure shown in FIG. 12.

Referring to FIG. 1, reference character 1 represents an apertured metal plate having bolt holes 2 for secur-

ing the radome to the nose portion of a plane or any other support. At four equidistantly spaced positions about the plate, there are a series of flanged holding members **3** for receiving adjacent ends of four metal pipes or spars **4** of about 1" outside diameter. These pipes extend along tapered lines to take on a general conical shape and at the ends opposite from the plate **1** are contained within a pointed hollow metal member **5** to which they are secured in any suitable manner. The framework is quite rugged since it is supported at both ends.

Within the framework, there is located a typical antenna system formed of a reflector **6** for directing the radio waves, and a sectoral horn **7** of any suitable and well-known type to which the energy to be transmitted is fed. The reflector is supported on a gimbal structure (not shown) to allow tilting in at least two directions as is usual, and is actuated by a suitable mechanism indicated at **8** through a servomotor. The horn **7** is suitably supported within the framework and is rectilinearly positioned with respect to the center axis of the reflector.

The energy from the transmitter **9** is propagated to the horn **7** by means of a wave guide **10** of suitable size and shape and which may extend through one of the metal pipes. This wave guide is connected to the farthest end to the horn, as indicated at **11**. The wave guide portion **11** passes through an opening, indicated at **12**, in the pipe because the latter is maintained continuous to impart ruggedness to the structure as a whole.

The radome covering **13** as shown in FIG. 4 is constituted of a cone-shaped monolith body of an aluminous-silicous material, such as a suitable form of alumina or a fused silicate. It is open at the larger end, closed at the front or smaller end which is thicker than the main portion and rounded. A covering of this type is molded from a liquid-powder mix, and then fired under fusing temperature to form a ceramic. The internal size and shape of the body is such that it will fit snugly over the pipes as seen more clearly in FIG. 2. The larger end of the ceramic body abuts the plate **1** while the smaller end fits over the cone **5**. The covering can be secured to portions of the underneath pipe frame by high temperature adhesive material so as to hold it securely in place. It is evident that due to the sung fit only the minimum fastening effect need be applied.

The usual Pitot boom **13'** for use in determining the speed of the plane can be secured to the metal framework and carried through the nose of the member **13**. Connections, either electrical or tubing may be taken through one of the pipes to the cockpit instrumentation.

Prior to our invention, it had been the practice to determine the thickness of the ceramic radome mainly on the basis of being self-supporting, both during manufacture and during use, and, therefore, particularly on the largest sizes of radomes, requiring excessive thickness, wasted material and added expense. We have found that, contrary to expectation and belief, that the judicious use of metal employed at the surface of the radome does not detract from the "window effect" presented by a reasonable thickness of the ceramic. When the metal is properly positioned as by the use of a quadripod frame, the latter actually enhances the propagation of the radio waves. Referring to FIG. 5, a graph is shown depicting the absence of metal from an unimproved radome while FIG. 5*a* shows the effect of the metal supporting frame together with the relatively thin radome wall disclosed herein. In both figures, the abscissa is depicted in degrees of scanning, and the signal output in decibels is shown as the ordinate. The measurements were made in the horizontal plane. In FIG. 5 it will be noted that the side lobe effect *a*, i.e., the spreading out of the radiant energy beam is quite noticeable whereas in FIG. 5*a*, this spread is substantially absent. Moreover, the interference brought about by the side lobes *b* and *c* in FIG. 5 is removed from the main portion of the beam in FIG. 5*a* so that the latter is somewhat isolated from the inevitable side lobes, in spite of the presence of the metal framework. We have therefore concluded that the latter does not have any appreciable deleterious effect on the transmission of signals; but quite to the contrary, it would appear to offer some improvement, at least from the side lobe interfering effect.

In addition, the quadripod frame permits the ceramic covering to be made thinner without regard to any self-supporting consideration so that the optimum thickness, resolved solely on the basis of wave length of the transmitted energy, can be employed. The "window" effect of the ceramic body is in nowise affected. Greater lengths of the radome and larger diameters can successfully be employed due to the improved supporting structure.

As a modification, we may employ the structure shown in FIGS. 6–10. The pipes or spars **4** are formed in a tapered or conical configuration as in FIG. 1, supported at one end from the apertured plate **1** and they merge together at the metal cone **5** to which they are secured. However, in this modification, we employ metal straps or hoops **15** equidistantly spaced along the pipes so that the framework constitutes a cage with horizontal and vertical portions. These portions extend at right angles to one another. In order to support the straps on each pipe, we secure to the latter wedge-shaped pieces of metal **16** which provide a ledge at both sides of each pipe (FIG. 10) and the straps are sectionalized so as to rest on the ledges. A bonding material **17**, which can withstand high temperatures, is applied in any suitable manner within the triangular spaces at the ends of the straps so as to make the junction of the straps and pipes as smooth as possible. A suitable bonding material could be a resin constituted of boron fiber reinforced polybenzidamide-azole, readily procurable on the market and can be fused in place. It will be noted that the pipes are integral throughout their length but the arcuate straps span only one quadrant each. The spaces between the pipes and the straps are filled in with pieces or slabs of suitable ceramic material having a general rectangular shape but curved in the circumferential direction as shown in FIG. 8. The exact shape can be determined by template. In order to secure the ceramic elements to the metal framework, we may provide over-hanging edges **18** (FIG. 18) which lie next to the straps so as to be supported by the ledges **16**. Undercuts **19** (FIG. 9) can also be employed along the edges which abut the side edges of the quadrantal strap sections. Thus, the ceramic sections are locked in place by the longitudinal ledges and the circumferential undercuts.

It is apparent that the radome as a whole, is built up, beginning from one end, after the pipe **4** has been placed in position between the plate **1** and the cone element **5**. The ceramic sections and the straps are applied on a piece-by-piece basis, and when completely assembled, the bonding material **17** is laid down, fused solid, and smoothed out.

The antenna system, as illustrated, comprises the reflector **6** mounted on a tiltable platform and actuated by the servomotor **8**. The reflector or scanning device is fed from a "Cutler Feed" device **20** of well-known type which is tiltable with the reflector. The wave guide **21** carries the ultrahigh-frequency energy to the feed member **20**. As in the case of the structure described in connection with FIG. 1, the pipes **4** are integral throughout their length, and in view of the solid support offered at the plate **1** and cone **5**, the framework and the interfitted ceramic slabs present a rigid structure, well able to withstand the stress involved in planes traveling at supersonic speed. The ceramic segments are relatively light, easy to handle, and do not require heavy and cumbersome molds.

The ceramic segments can be made of any desired thickness for optimum results in transmitting or receiving ultrahigh-frequency waves, and regardless of the thinness of the material, the radome as a whole is strong and will

not deform on account of the supporting framework into which the segments are fitted and secured. As a typical example, prior to our invention, it was usual for radomes to be made of solid fused silica or alumina ¾" to 1" thick. This extreme thickness of the material is not conducive to the highest degree of transparency to ultrahigh-frequency radiation and the weight of these radomes on account of this thickness becomes almost exorbitant. But by supporting the radome by the interior framework, we are able to employ radomes of considerable diameter and height with a wall thickness of not much over ¼" to ⅜" thick, which is compatible with the usual wave lengths (approximately 1 cm.) used in ultrahigh-frequency radio transmission and reception.

It has been found that the presence of the straps and pipes or spars offer little, if any, impediment to the radiation because the "window" area of the ceramic is more than ample to allow complete access over a wide band of frequencies. Moreover, the presence of the metal, particularly the pipes, appear to give some operational improvement from the standpoint of reducing side lobe interference as shown in FIG. 5*a*.

Since none of the pipes **4** in FIG. 6 contain a wave guide, it may be feasible to provide the pipes with radially extending openings, indicated at **14** in FIG. 11. Suitable gas under pressure can be introduced into the pipes for cooling the interior of the radome.

FIGS. 12, 13 and 14 show still another form that the improved radome may take. In this case, the pipes **23** are of hollow rectangular configuration, of which six in number have been provided equidistantly spaced, and are supported between the plate **1** and the cone element. The strap portions **24** and ceramic segments **25** can squarely abut the sides of the pipe to which they can be secured by a suitable high-temperature bonding compound. The bonding effect can be enhanced by machining the two corners off from each pipe as indicated at **26** and the inside corners can be ground from each ceramic section, as indicated at **27**, to leave triangularly shaped grooves. The latter may be filled with a high-temperature bonding material which can be fused to a solid mass and then smoothed out.

It will be noted that the pipes **23** not only lend rigidity to the frame and fitted portions, but can, if desired, serve as a wave guide to the ultrahigh-frequency energy. For this purpose, one of the pipes is carried through the plate as indicated at **28** to make connection with the usual form of transmitter (not shown). The radome illustrated in FIG. 12 encloses the usual form of tilting reflector **6** and sectoral horn **7** to which the wave guide is connected, as indicated at **23**.

The strap and ceramic sections can readily be fitted and secured within the circumferential spaces between the rectangular pipes **23** and the straps **24** to provide a smooth outer surface for the radome as a whole. Very little consideration need be given to the thickness of the ceramic covering from the self-supporting standpoint because the associated framework provides all the rigidity necessary, without detracting in substantial degree from the electrical transmission properties of the radome as a whole.

From the foregoing, it is evident that we have disclosed a radome construction that can be made as large or small as necessary and can use either a monolith formation of fused silica or alumina, or can be formed of smaller sections of these materials as a built-up structure. In each case, the radome covering can be made as thin as desired to derive its optimum electrical transmission properties, and yet the structure as a whole, is rugged and can withstand severe stress, and also heavy wind loading. Expensive, heavy, or complicated molding apparatus need not be employed and the cost of manufacturing the improved radome is accordingly decreased without any sacrifice in its ability to withstand severe handling or when subjected to loads introduced by weather and speed conditions.

While certain specific embodiments have been described in detail, it is obvious that numerous changes may be made without departing from the general principle and scope of the invention.

We claim:

1. A radome for housing ultrahigh-frequency antenna apparatus, said radome comprising: a conically shaped hollow member of an aluminous-silicous material supported on a metal framework, the parts of which crisscross one another at right angles in circumferential and longitudinal directions and are shaped to conform to the interior of said member.

2. A radome for housing ultrahigh-frequency antenna apparatus, said radome being constituted of a framework formed of a plurality of longitudinally extending members spaced from one another and conforming to a circular configuration, a plurality of transversely extending members spaced from one another and crossing the longitudinal members at approximately right angles, the spaces between the longitudinal and transverse members being filled with slabs of material having rectangularly shaped edges but are curvilinear at the inner and outer surfaces, said slabs being permeable to ultrahigh-frequency energy and secured in position between the longitudinal and transverse members of the framework, the outer surface of the built-up housing being smooth, and closed at one end.

3. A radome for housing ultrahigh-frequency antenna apparatus, said radome being constituted of a plurality of equidistantly spaced pipes arranged in a cone-shaped configuration, means for securing said pipes in a fixed relation, said means including a plurality of strap elements spaced along the length of the pipes, and separately molded sections of ceramic material filling up the spaces between the pipes and strap elements and secured thereto to form a continuous conical surface.

4. A radome for housing ultrahigh-frequency antenna apparatus, said radome being constituted of a plurality of equidistantly spaced pipes extending longitudinally in a converging manner to form a cone-shaped configuration, a plurality of circumferentially extending strap elements equidistantly spaced along the length of the pipes for securing the pipes in a fixed relation, separately molded sections of ceramic material secured within the spaces between the pipes and the strap elements to form a continuous conical surface, and at least one of said pipes containing a wave guide for the antenna contained within the radome.

5. A radome for housing ultrahigh-frequency antenna apparatus, said radome being constituted of a plurality of equidistantly spaced pipes arranged in a cone-shaped configuration, means for securing said pipes in a fixed relation, said means including a plurality of strap elements spaced along the length of the pipes, sections of ceramic material interposed within the spaces between the pipes and the strap elements to form a continuous conical surface, said pipes being perforated and adapted to receive a cooling fluid for maintaining the temperature of the ceramic member relatively cool during operation.

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