April 7, 1964 D. H. LANCTOT 3,128,467

DIELECTRIC ROD RADIATING ANTENNA

Filed Feb. 19, 1960

2 Sheets-Sheet 1

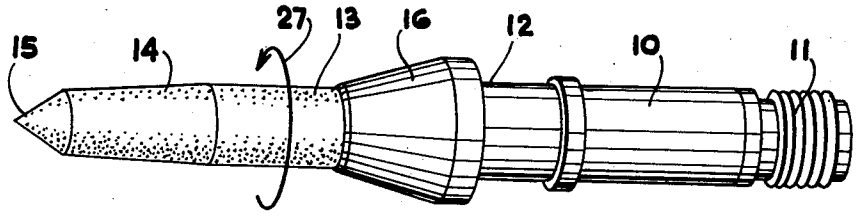


FIG. 1

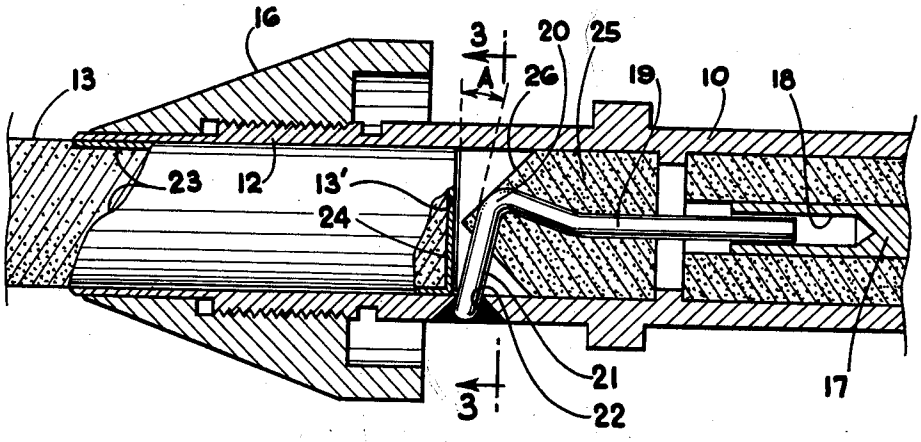


FIG. 2

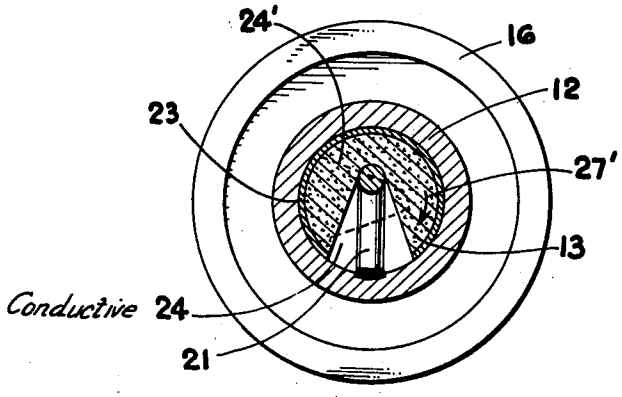


FIG. 3

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DIELECTRIC ROD RADIATING ANTENNA

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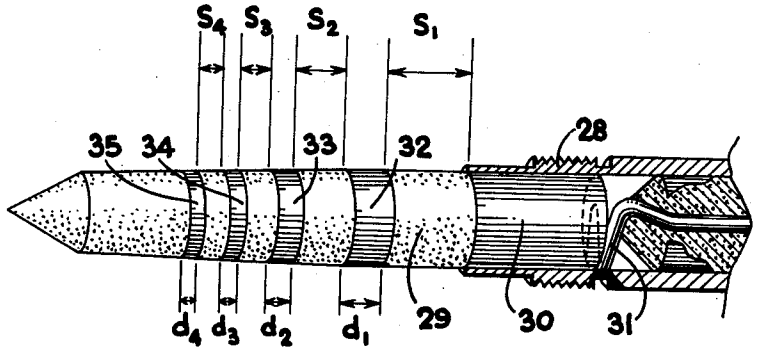


FIG. 4

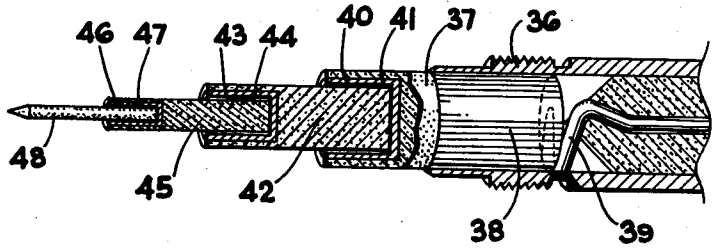


FIG. 5

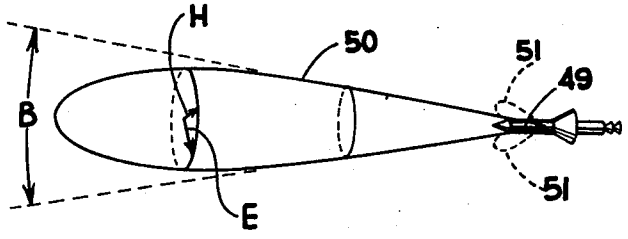


FIG. 6

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DIELECTRIC ROD RADIATING ANTENNA

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This invention relates generally to antennas and more particularly to an improved broad band high frequency antenna for airborne equipment.

In airborne antenna structures employed with radar equipment such as seeker, guidance, search or fire control systems for example, a single, symmetrical direction lobe or beam characteristic is desirable. Heretofore, a directional beam has been accomplished by exponential horns, parabolic reflectors, metallic lens arrays, and the like. Such structures, while providing a directive antenna, are oftentimes relatively large and bulky, particularly for lower frequency operations. Moreover, in exposed airborne antenna systems, radomes or equivalent aerodynamic streamlining structures have been required thus further increasing bulk and weight.

In addition to the foregoing, the use of specially designed horns, reflectors, or metallic lens type of structures for forming a desired beam, generally tends to limit the band width of the antenna to a considerable extent. This is because the directing structures are dimensioned in accordance with a contemplated wave length of operation, and large deviations from this wave length will result in similar deviations in the desired antenna pattern. Also, deviations in the wave length for these same reasons can result in serious mismatching of some of the components thus posing tuning problems.

In many installations, once a desired beam pattern is provided by any particular system, to change the beam width or lobe pattern symmetrically usually necessitates a major change in most of the directive elements of the system. Thus, there is a lack of versatility in the use of the system.

Finally, there is the ever present difficulty of side lobes in the directional beam pattern. Generally, side lobes can be attenuated, canceled, or otherwise eliminated by employing more sophisticated structures, but such solutions add further to inherent bulk and cost.

From the foregoing, it will be evident that antenna design for providing desirable lobe patterns for use in missiles becomes an important and serious problem. Any additional bulk or mass in an antenna system necessarily diminishes the pay load which the missile can carry by that extent. While theoretical and even structural solutions to most of the problems encountered in providing a broad band directive antenna system can be effected in the laboratory, as a practical matter, the resulting system is often prohibitive in size and weight for use on any high speed missile.

With all of the above in mind, it is a primary object of the present invention to provide a vastly improved general purpose broad band antenna in which extreme miniaturization is achieved thereby overcoming many of the foregoing problems encountered in airborne antennas.

More particularly, it is an object to provide a miniaturized broad band antenna for use in high speed missiles which is characterized by optimum electromagnetic radiation in a desired pattern and optimum aerodynamic streamlining to the end that radomes and other auxiliary structures are not necessary.

Another important object is to provide a broad band antenna which is simple in mechanical design and extremely rugged in construction thereby providing an ideal antenna system for use on rockets and missiles.

Another object is to provide a broad band miniature antenna having a directional beam pattern with substantially no side lobes and in which a given beam width may be maintained within an accuracy of $\pm 1°$.

Still another object is to provide an antenna in which the beam pattern may be varied by simple substitution of components in the system so that an extremely versatile antenna system results.

A particular object of the invention is to provide a miniaturized broad band high frequency antenna capable of withstanding high temperatures of the order of 2,000° F., and high speeds of the order of Mach 6 when used on the leading edge of a control surface or nose of a supersonic missile.

Briefly, these and many other objects and advantages of this invention are attained by the use of an extremely high dielectric material as a lens for the electromagnetic energy to be radiated or received. The high dielectric constant of the material enables a considerable scaling down of all of the antenna dimensions for effecting a desired pattern because of the effective decrease in electrical wave length of the energy in the material as compared to its wave length in air.

In a preferred embodiment, the antenna includes a hollow conducting body terminating at one end in a coaxial connector to receive input energy and at its other end in a sleeve for receiving the dielectric lens for radiating the energy. The dielectric lens itself is in the form of a solid rod having a cylindrical portion received in the sleeve and its remaining portion tapering towards a point.

A unique coupling means is provided within the conducting body between the connector and the base of the cylindrical section of the rod member. This coupling structure enables desired tuning to be achieved to provide perfect impedance matching by simply rotating the rod member itself within the sleeve through small angles.

The tapered front end portion of the rod not only provides a directing lens structure for electromagnetic energy, but also provides the desired aerodynamic streamlining necessary to minimize drag when the antenna is employed on a missile.

A better understanding of the invention will be had by referring to the accompanying drawings, in which:

FIGURE 1 is a perspective view of a preferred embodiment of the antenna of this invention;

FIGURE 2 is an enlarged view partly in cross section of the central portion of the antenna illustrated in FIGURE 1;

FIGURE 3 is a cross section taken in the direction of the arrows 3—3 of FIGURE 2;

FIGURE 4 is a fragmentary perspective view partly cut-away of a modified antenna;

FIGURE 5 is a view similar to FIGURE 4 of still another modified antenna; and,

FIGURE 6 is a simple schematic diagram illustrating a beam pattern typical of the antenna of this invention.

Referring first to FIGURE 1, the antenna comprises a hollow conducting body **10** terminating at one end in a co-axial input connector **11** and at its other end in a sleeve **12**. A rod member of high dielectric material includes at its rearward end a cylindrical section **13** partially received within the sleeve **12** and at its forward end a tapered portion **14** and front end portion **15**. A gland nut **16** of exterior conical shape for aerodynamic streamlining is provided for securing the antenna in a desired position.

Input electromagnetic energy is fed to the antenna through the connector **11** and radiated from the dielectric rod member which serves as a lens for providing a highly effective lobe pattern with substantitally no side lobes present.

It will be evident from the appearance as illustrated in FIGURE 1 that the structure is aerodynamically con-

toured for minimum drag, and in actual practice, will operate under speeds as high as Mach 6 and at temperatures of 2,000° F.

The dielectric material itself may comprise, for example, sintered zirconium oxide. Alternatively, aluminum oxide or titanium oxide may be used to provide the desired high dielectric constant. In some instances, the material may constitute a sintered mixture of these oxides. The resulting material is extremely strong mechanically and has a dielectric constant of from 10 to 22. Thus electrical lengths within the material are reduced by a considerable factor enabling the desired miniaturization to be effected over a broad band of frequencies.

Referring to the cross-section of FIGURE 2, there is illustrated the unique coupling means in accordance with the invention for transferring electromagnetic energy from the input connector **11** to the cylindrical section **13** of the dielectric lens. As shown, the conducting body **10** forms a continuation of the outer conductor of the connector **11** and the inner conductor **17** thereof extends in co-axial alignment with the body **10**, sleeve portion **12** and the rod member. The extreme end of the inner conductor **17** terminates in a cylindrical cavity **18** telescopically receiving one end of a co-axially disposed probe **19**. By this arrangement a thermal expansion joint is provided. The other end of the probe **19** extends towards the base of the cylindrical portion **13** of the lens rod member and is curved at **20** to form a laterally bent portion **21** juxtaposed the base and connected at **22** to the body **10**. The bend itself is less than 90 degrees with respect to the longitudinal axis of the body and probe so that the lateral bent portion **21** forms an acute angle A with respect to the plane of the base of the rod member.

The cylindrical section **13** of the rod member is provided with a conductive coating **23** surrounding only that portion of the cylindrical section within the sleeve **12**. This coating may be silver and as shown best in FIGURE 3 extends over a circumferential edge portion of the base to provide a sector shaped coating **24**. This sector shaped coating is defined by the edge of the coating on the base converging from the circumferential edge portion of the base towards the central axis of the body.

The probe itself is held in co-axial relationship and properly matched for transfer of electromagnetic energy to the laterally bent portion **21** by dielectric material **25** filling a portion of the annular space between the probe and the interior of the body **10**. As shown, the dielectric material **25** terminates in a conical surface **26** adjacent to the exit point of the laterally bent portion **21** of the probe.

With the foregoing described coupling arrangement, a variable inductive coupling is effected between the sector shaped coating **24** and laterally bent portion **21**. Tuning of this coupling for maximum power transfer from the probe to the rod member can be effected by slight rotations of the rod member within the sleeve **12** as indicated by the arrow **27** in FIGURE 1 or **27'** in FIGURE 3. For example, small rotations through angles less than the angle of convergence of the sector shaped coating will provide a fine tuning for transfer of energy for a given mode of excitation in the rod member. On the other hand, a rotation of the dielectric rod member **13** through ninety degrees to reposition the sector shaped coating **24** to the position illustrated at **24'** in dotted lines in FIGURE 3, for example, will alter the mode of excitation to provide circular polarization.

It has been found that by employing a coupling means as described, a near perfect impedance match from the input connector to the radiating medium can be achieved over a very broad frequency range. In this respect, the acute angle A formed by the laterally bent portion **21** with respect to the sector shaped coating is important and in a preferred embodiment is approximately two and one-half degrees. Thus, the capacitance between different portions of the laterally bent part of the probe and the sector shaped conductive coating varies along the length of the laterally bent portion, not only as a consequence of the variable spacing because of the angle A but also because of the convergence of the sector shaped coating itself. The equivalent "tuned circuit" provided by the coupling structure is thus very broad to enable broad band operation with excellent power transfer throughout the band range.

Generally the type of pattern or lobe can be controlled by the diameter of the dielectric rod member or lens. This in turn is determined by the frequency mode of the energy in the lens. For example, the rod may function as a circular wave guide supporting the TE–11 mode. With this type of operation, the beam width of the lobe can be controlled by varying the length of the dielectric member. Because of the telescoped connection of the section **13** in the sleeve **12**, it is a simple matter to remove the rod member itself and insert another rod member of different length in accordance with a desired beam width.

In instances requiring an extremely narrow beam width such as in fire control or tracking operations, modifications other than a change in length of the antenna lens structure may be effected.

Referring to FIGURE 4, for example, there is shown a modified antenna structure comprising a conducting body having a sleeve **28** for receiving a cylindrical portion **29** of a dielectric rod. This cylindrical portion is partially coated with a highly conductive material as indicated at **30** and is coupled to a laterally bent probe portion **31** all as described in detail in connection with FIGURES 1, 2, and 3.

In FIGURE 4, the remaining portion of the dielectric rod member extending from the sleeve **28** is provided with a plurality of conductive bands **32**, **33**, **34**, and **35**. These bands are of progressively decreasing axial spacing, as indicated by the successive dimensions d_1, d_2, d_3 and d_4, and of progressively decreasing width, as indicated by S_1, S_2, S_3, and S_4 in a direction away from the sleeve towards the extreme end of the rod member. Essentially, these conductive bands serve as directors in a manner analogous to the directors employed in a Yagi array.

An even narrower beam width may be achieved in yet another manner as illustrated in FIGURE 5. In this modification, there is shown a body member having a sleeve portion **36** receiving a cylindrical section **37** of a rod member provided with a conductive coating **38** for coupling to the lateral bent portion **39** of a probe all as described heretofore in connection with FIGURES 1, 2, and 3. The remaining portion of the dielectric rod member **37** however terminates in a front cylindrical cavity **40** provided with a metallic coating or lining **41**. This cavity is arranged to receive a cylindrical section of an additional rod member **42** of decreased diameter. Similarly, the rod member **42** is provided with a front cylindrical cavity **43** and conductive lining **44** for receiving the cylindrical section or rear portion of another dielectric rod **45** of further reduced diameter. The rod **45** in turn may be provided with a front cylindrical cavity **46** and liner **47** for receiving an end rod **48** terminating in a front point.

There is thus provided a plurality of additional rod members of progressively decreasing diameter telescoped in end to end relationship. The operation is analogous to a plurality of optical lens axially aligned and dimensioned to provide a pencil like beam of light. By this method, the resulting electromagnetic beam width can be reduced to substantially four degrees.

FIGURE 6 illustrates by way of example, an antenna **49** in which the principal lobe pattern **50** is outlined schematically. The beam width angle is indicated by the letter B. As shown, any side lobes **51** are virtually eliminated. Further, for the TE–11 mode, the E and H field patterns are substantially identical.

From the foregoing description, it will be evident that the present invention has provided a greatly improved broad band antenna. The features of streamlining and miniaturization renders the antenna extremely useful for missile applications wherein weight and space are at a premium. Not only is tuning extremely simplified by the simple expedient of rotating the dielectric lens or rod member within the cylindrical sleeve, but this construction also enables substitution of different lenses to be effected in a simple manner thereby providing greater versatility. Moreover, the feeding is linear throughout thereby again facilitating aerodynamic design and minimizing overall dimensions.

Modifications that fall clearly within the scope and spirit of this invention will occur to those skilled in the art. The broad band antenna is therefore not to be thought of as limited solely to the particular embodiments set forth merely for illustrative purposes.

What is claimed is:

1. A broad band high frequency antenna comprising, in combination: a hollow conducting body terminaing at one end in a co-axial connector and at its other end in a sleeve in co-axial alignment with said connector; a rod member of high dielectric material having a cylindrical section received within said sleeve and rotatable therein, the remaining portion of said rod extending from the end of said sleeve in axial alignment therewith; a probe co-axially disposed within said body having one end connected to the inner conductor of said connector and its other end terminating in a laterally bent portion in juxtaposed relationship to the base of said cylindrical section, said laterally bent portion being bent less than 90 degrees with respect to the axis of said body to form an acute angle with the plane of said base, the extreme end of said bent portion being connected to said body; and a conductive coating surrounding the exterior cylindrical surface of that portion of said cylindrical section of said rod within said sleeve, said coating extending over a circumferential edge portion of said base at the end of said cylindrical section to provide a sector shaped coating on said base, said sector shaped coating being defined by converging edges of said coating extending from said circumferential edge portion towards the central axis of said rod, said laterally bent portion and said sector shaped coating constituting a coupling for transferring electromagnetic energy passed into said connector to said rod member, said rod member serving as a directive lens for said electromagnetic energy, rotation of said rod member through small angles less than the angle of convergence of said sector shaped coating serving to vary the position of said sector shaped coating with respect to said laterally bent portion of said probe to tune said coupling for maximum power transfer, and rotation of said rod member over ninety degrees serving to alter the mode of excitation of said electromagnetic energy in said rod member transferred from said connector to said rod member.

2. The subject matter of claim 1, in which the inner conductor of said connector terminates in a front cavity telescopically recieving said one end of said probe to provide a thermal expansion joint; and dielectric material filling at least a portion of the annular space between said probe and the interior walls of said body, said dielectric material supporting said probe in co-axial relationship in said body and terminating in a conical surface at said laterally bent portion to provide an impedance match between said connector and said laterally bent portion.

3. The subject matter of claim 2, in which the remaining portion of said rod member tapers towards a point in a direction away from said sleeve and includes a plurality of conducting bands of decreasing axial spacing and decreasing width in said direction to provide director elements for said electromagnetic energy.

4. The subject matter of claim 2, in which the remaining portion of said rod member terminates in a plurality of additional rod members having cylindrical sections of successively decreased diameter respectively, the forward ends of said additional rod members having cylindrical cavities for receiving the cylindrical sections of the next successive rod members respectively to hold said rods in partially telescoped, co-axial, end to end relationship, the last of said additional rods terminating at its free end in a point; and conductive linings in said cavities respectively surrounding those portions of said cylindrical sections received therein.

5. A broad band high frequency antenna comprising, in combination:

a hollow conducting body terminating at one end in a co-axial connector and at its other end in a sleeve;

a rod member having a cylindrical section within said sleeve, the remaining portion of said rod extending from the end of said sleeve, said connector, sleeve, and rod member all being co-axially aligned;

coupling means within said body between said connector and cylindrical section of said rod member for transferring electromagnetic energy passed into said connector to said rod member, said rod member functioning as a wave guide for radiating said electromagnetic energy, said coupling means including a probe telescopically coupled at one end to the inner conductor of said co-axial connector to provide a thermal expansion joint and terminating at its other end in a laterally bent portion in juxtaposed relationship to the base of said cylindrical section of said rod member and connected at its end to said sleeve; and

a conductive coating over a portion of said base in spaced relationship to said laterally bent portion, whereby the degree of coupling of electromagnetic energy from said laterally bent portion to said conductive coating can be varied by rotating said cylindrical section about its longitudinal axis within said sleeve.

6. The subject matter of claim 5, in which said conductive coating is sector shaped with the edges of said sector converging from a circumferential edge portion of said base towards the longitudinal axis of said cylindrical section, said laterally bent portion of said probe forming an acute angle with the plane of said base.

7. The subject matter of claim 5, in which the remaining portion of said rod member tapers towards a point in a direction away from said sleeve and includes a plurality of conducting bands of decreasing axial spacing and decreasing width in said direction to provide director elements for said electromagnetic energy.

8. The subject matter of claim 5, in which the remaining portion of said rod terminates in a plurality of additional rod members having cylindrical sections of successively decreased diameter respectively, the forward ends of said additional rod members having cylindrical cavities for receiving the cylindrical sections of the next successive rod members respectively to hold said rods in partially telescoped, co-axial, end to end relationship, the last of said additional rods terminating at its free end in a point; and conductive linings in said cavities respectively surrounding those portions of said cylindrical sections received therein.

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