Dec. 30, 1952 H. IAMS 2,624,003

DIELECTRIC ROD ANTENNA

Filed Jan. 7, 1948 2 SHEETS—SHEET 1

Fig. 1

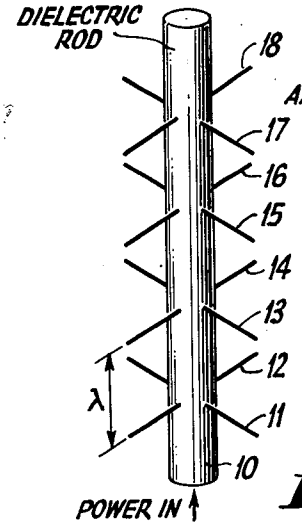


Fig. 2

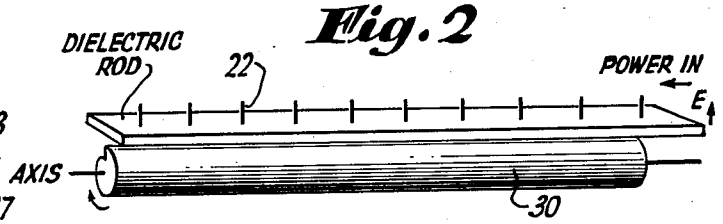


Fig. 3

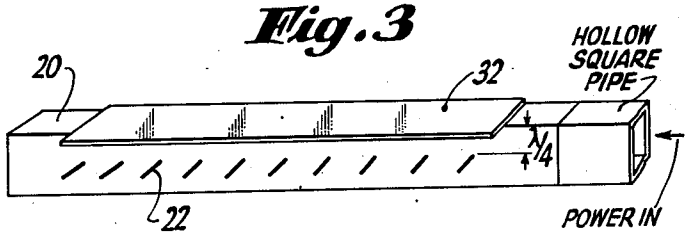


Fig. 4

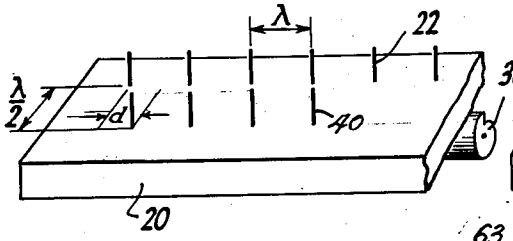


Fig. 5

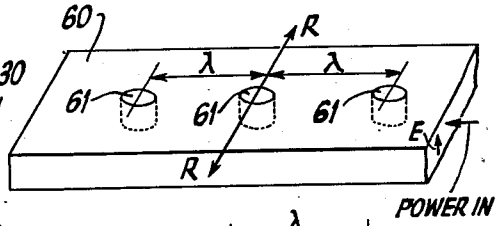


Fig. 6

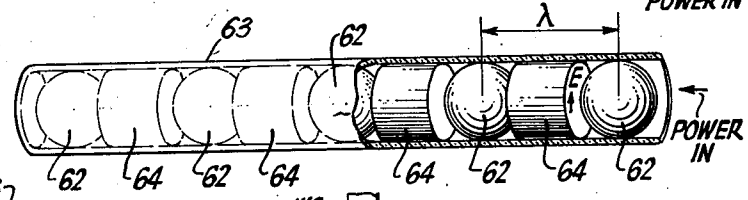


Fig. 7

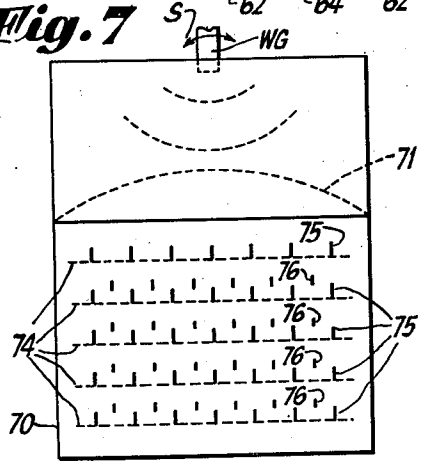
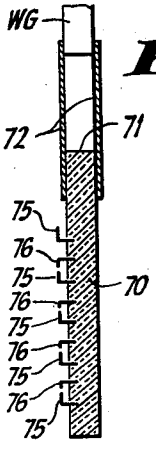


Fig. 8



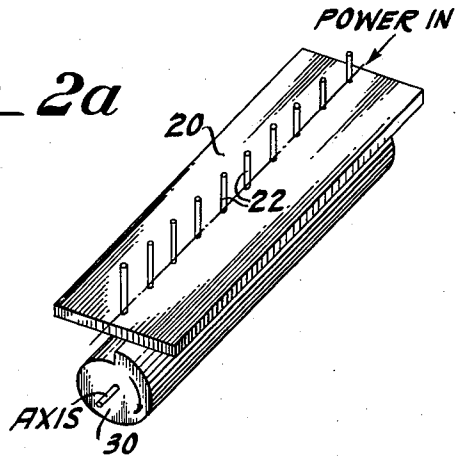
INVENTOR
HARLEY IAMS
BY Harry Tunick
ATTORNEY

Dec. 30, 1952 H. IAMS 2,624,003

DIELECTRIC ROD ANTENNA

Filed Jan. 7, 1948 2 SHEETS—SHEET 2

Fig_2a



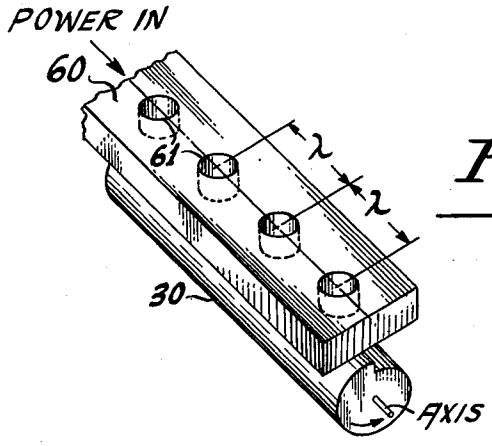


Fig_5a

INVENTOR.
HARLEY IAMS

BY Harry Tunick

ATTORNEY

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UNITED STATES PATENT OFFICE

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DIELECTRIC ROD ANTENNA

Harley Iams, Venice, Calif., assignor to Radio Corporation of America, a corporation of Delaware

Application January 7, 1948, Serial No. 951

24 Claims. (Cl. 250—33.63)

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The present invention relates to ultra high frequency antennas and more particularly to antenna arrays employing a dielectric rod feed.

An object of the present invention is the provision of a simple U. H. F. antenna requiring little space.

Another object of the present invention is the provision of a micro-wave antenna which is well suited for scanning a focused radio beam over a predetermined angle.

A further object of the present invention is the provision of a novel means for coupling wave energy between a confined field or wave guide and a free space field.

Another object of the present invention is the provision of a scanning antenna which is particularly suited for high scanning speeds.

Still another object of the present invention is the provision of a rapid scanning antenna which is relatively easy to build.

Still a further object of the present invention is the provision of a rapid scanning antenna which occupies but little space considering its effective length.

The foregoing objects and others which may appear from the following detailed description are attained by providing an antenna in the form of a dielectric rod along which the energy is guided. A series of spaced discontinuities in the rod causes energy to be radiated therefrom. By suitable arrangement of the discontinuities the radiated energy may be focused into a beam. Furthermore, in order to provide for scanning the focused beam radiating from said antenna over a suitable angle, means are provided for varying the speed of propagation of the radiant energy along the dielectric rod. This may be done by moving, in a predetermined path, a mass of conductive material along the rod.

The dielectric rod is preferably made of some low-loss material such as polystyrene. I have discovered that when the diameter is small compared with a wave length the loss of energy along such rods may be less than that encountered in the best metal wave guides. The reason for this effect is that much of the power is carried outside the dielectric, though guided by it. The rod can be round, rectangular, or of other shape as desired.

The present invention will be more fully understood by reference to the following detailed description which is accompanied by a drawing in which:

Figure 1 illustrates in a perspective view a non-directional antenna utilizing some of the principles of the present invention, while

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Figure 2 illustrates in perspective an antenna adapted to focus radio waves into a sharp beam with means for causing the beam to scan through a desired angle;

Fig. 2*a* illustrates an alternative arrangement of the antenna shown in Fig. 1;

Figure 3 illustrates a modification of the invention shown in Figure 2, and

Figure 4 illustrates a further modification;

Figures 5, 5*a* and 6 illustrate in perspective view further embodiments of the present invention, and

Figures 7 and 8 illustrate in plan and side view respectively a form of two-dimensional scanning array utilizing the principles of the present invention.

Referring now to Figure 1, there is shown a dielectric rod 10 having a diameter such that a transverse electromagnetic wave may be guided by it. For polystyrene a diameter between one-eighth and one-half of the free space wavelength is desirable. A series of discontinuities is provided along the length of rod 10 causing energy to be radiated from the spaced points along which the discontinuities exist. In the form of the invention shown in Figure 1, the discontinuities consist of crossed pairs of dipoles 11—12, 13—14, 15—16 and 17—18 inserted through transverse holes drilled in the rod 10. The vertical spacing between adjacent pairs of crossed dipoles is, as indicated by the dimension mark between dipoles 12 and 14, preferably of the order of one wavelength along the dielectric rod. Now, if circularly polarized energy is fed into the feed end of dielectric rod 10 as indicated by the arrow labeled "Power In," the first pair of crossed dipoles 11 and 12 will be energized in phase quadrature by the energy in rod 10 and radiate a horizontally polarized non-directional wave in a manner similar to the way a conventional turnstile antenna radiates. The additional pairs of crossed dipoles 13, 14; 15, 16 and 17, 18 are so spaced along the length of the dielectric rod 10 that their radiation reinforces that from the first pair of dipoles 11, 12. If a non-circular radiation pattern is desired a plane polarized transverse wave may be applied to the bottom of rod 10, either in the plane of dipoles 12, 14, 16 and 18 or 11, 13, 15 and 17. It should be noted that thus a steerable antenna pattern is provided without requiring electrical switching or moving current carrying structures.

In accordance with another aspect of the present invention shown in Fig. 2, the antenna may consist of an elongated rectangular dielectric rod 20 having along one of the flat faces thereof a

series of discontinuities which cause radiation to occur along the rod to ambient space. These discontinuities are preferably in the form of small conducting strips or short wires **22** inserted along one face of rod **20**. They are preferably somewhat less than a half wavelength long and spaced a distance along the rod a distance of the order of one wavelength. If all of the radiation elements **22** are of the same length, it is preferable to place them at different distances from the central axis of the rod so that each picks up and radiates the same amount of power. Alternatively, as shown in Fig. 2*a* the lengths of metal strips **22**, may vary with the shortest near the source of power, as indicated by the arrow labeled "Power In," so as to couple like amounts of power between the free space field and the energy within the rod. The speed of propagation of the radiant energy along dielectric rod **20** may be controlled by bringing a conductive surface near the rod. I have found, for example, that when the free space wavelength is 1¼ cm., in a polystyrene rod having transverse dimensions of .150'' x .500'' the wavelength is about 1.17 cm. When a metal strip ½ inch wide is brought against one side of the rod, the wavelength within the rod is equal to .95 cm. It will thus be seen that the wavelength along the rod may be varied by about 20% by moving a metal surface near it. In order to vary the wavelength of the energy guided by the rod in a regular manner, or cyclically, to provide scanning over a predetermined pattern, a metal cylinder **30** having a non-circular outer surface is provided. That is, the outer surface is so shaped that in cross section the cylinder has a cam formation, or stated otherwise, the axis about which the cylinder **30** is rotated is asymmetrically located with respect to the outermost surface. Now, as the metal cylinder is rotated, the effective spacing between the metal comprising the cylinder and the dielectric rod is varied in accordance with the formation of the cam surface. Thus the beam of radiant energy radiated broadside to the array of metal strips or wires **22** may be swung over a comparatively wide angle. An angle of scanning of some 9 degrees has been obtained without difficulty.

It will be seen that a scanning antenna employing this construction is relatively easy to build and occupies little space, considering its effective length. Furthermore, the arrangement is suited for high scanning speeds since there are no unbalanced couples to be rotated about the axis of the scanning device. It will be seen that such a structure may easily be fitted into the wing of an airplane or it may be used on the ground if an unusually narrow beam is required.

If it is desired to direct all of the energy in the beam to one side of the rod, the modified form of invention shown in Figure 3 may be used. Here the dielectric rod **20** carries along one side a flat sheet of metal **32** which is parallel to the plane in which the conductive strips **22** lie and a quarter wave away from said plane. Such an arrangement directs all of the energy in the beam to one side of the rod. The same scanning arrangement as shown in Figure 2 may be used with the rod arrangement of Figure 3, though not so shown. Two or more rows of strips or wires **22** may be used to improve the beam quality.

Such an arrangement is shown in Figure 4 in perspective. Here the radiation from the first row of radiating wires **22** is reinforced by that from a second row of radiating wires **40**. As is apparent from an inspection of the drawing, the rows of radiators **22** and **40** are parallel with each other and with the axis of the dielectric rod **20**. The rows are spaced a half wavelength apart, whereby the radiation from the two rows adds in a broadside direction. The wires in the two rows are preferably staggered a distance "*d*" equal to a half wavelength in the dielectric to make the energy from all of the wires arrive at the common wave front in the same phase relationship.

The shaped metal scanning cylinder **30** of Figure 4 operates in the same way as described with reference to Figure 2. The contour of the surface of the scanning cylinder **30** determines the relationship between the beam position and the angular position of the cylinder. It should be noted that in this figure, the scanning cylinder **30** is shown in a reduced scale with respect to the dielectric rod **20**. For a maximum scanning effect as shown in Figure 2, the diameter of the scanning cylinder should be of the order of or somewhat greater than the width of the dielectric rod.

Referring to Fig. 5, there is shown another form of radiating arrangement which may be used consisting of elongated dielectric rod **60** having holes **61** drilled through the rod at approximately one wavelength spacing. The diameter of the holes **61** are such as to provide optimum coupling between the space within the dielectric rod **60** and free space. It should be noted that the antenna of Figure 5 is a broadside antenna and not an end-fire type. The radiation takes place in the directions indicated by arrows R. The manner of feeding dielectric rod antenna of Figure 5 is indicated by the arrows "Power In" and "E," the arrow "E" denoting the direction of the electric field within the dielectric rod. If scanning of the radiated beam is desired a scanning cylinder such as cylinder **30** of Figures 2 and 4 may be used as shown in Fig. 5*a*.

Another example of a dielectric antenna is that shown in Figure 6. This embodiment includes a dielectric tube **63** containing localized volumes of different dielectric properties therein in the form of alternate conducting spheres **62** and dielectric spacer plugs **64**. As indicated by the dimension marks in the figure, the metal spheres **62** are preferably so arranged that their center-to-center spacing is approximately a wavelength. Then, when the antenna is energized as indicated by the arrow labeled "Power In," the arrangement radiates energy in a direction normal to the axis of the tube **63** with a maximum amplitude in a direction transverse to the direction of the electric field "E." If a circularly polarized wave is applied to one end of the antenna, a circularly polarized field will be radiated.

A two-dimensional scanning array is shown in Figures 7 and 8. Here a dielectric sheet **70** having a curved edge **71** supports a large number of radiating wires **75** in holes drilled in one flat surface of the sheet. The curved edge of the dielectric sheet is placed between a pair of flat parallel metal sheets **72** constituting a wide thin wave guide section for coupling between the main wave guide WG and the dielectric sheet radiating elements. The curved edge **71** of the dielectric sheet acts like a lens to make the wavefront originating at the mount of the wave guide WG approximately straight as it enters the body of the dielectric **70**. An appropriate radius of curvature is $R=f(\sqrt{K}-1)$, where f is the focal length or distance from the lens to WG and K is the dielectric constant of the material **70**. Thus the lines of equal phase **74** are straight lines across

the entire width of sheet 70. The radiating wires 75 are inserted in the sheet at points which are in the same instantaneous phase relationship; that is, along lines 74. As indicated, the wires may be bent at right angles after emerging from the surface of the sheet to radiate in a direction at right angles to the plane of the sheet. If desired, a second set of radiating wires 76 may be inserted in the dielectric sheet at points which differ in phase by 180 degrees from the points where wires 75 are inserted. The ends of the wires 76 are, therefore, oriented in opposite direction to the ends of wires 75, thus insuring that the resultant radiation in free space is additive. Scanning in one direction may be provided by swinging the wave guide WG in a direction as indicated by the curved arrow S.

While I have illustrated a particular embodiment of the present invention, it should be clearly understood that it is not limited thereto since many modification may be made in the several elements employed and in their arrangement and without departing from the spirit and scope of the invention.

What I claim is:

1. An antenna including an elongated rod of solid dielectric material having transverse dimensions at which transmission of radiant energy waves is facilitated along the length thereof, said rod having holes therethrough to effect radiation between the rod and ambient space at spaced points along said rod said rod being adapted to have radio frequency transducer apparatus coupled thereto.

2. An antenna including an elongated rod of solid dielectric material having transverse dimensions at which radiant energy waves are propagated along the length thereof, means for causing radiation to be translated between said rod and surrounding space at spaced points along said rod, said means including a number of short conductive members inserted in said rod with the axes of said members normal to the axis of the rod, said members having a spacing and a length at which the field radiated therefrom is concentrated along lines normal to the axis of said rod.

3. An antenna including an elongated body of solid dielectric material, means for causing radiation to be propagated between said rod and ambient space at spaced points along said body, a conductive member, and means to vary the speed of propagation of radiant energy along said body.

4. An antenna including an elongated body of solid dielectric material having transverse dimensions at which transmission of radiant energy waves is facilitated along the length thereof, means for causing radiation to be propagated between said rod and ambient space at spaced points along said body, a conductive member, and means cyclically to vary the spacing of said conductive member from said body to vary the speed of propagation of radiant energy along said body.

5. An antenna including an elongated body of solid dielectric material having transverse dimensions at which transmission of radiant energy waves is facilitated along the length thereof, means for causing radiation to be propagated between said rod and ambient space at spaced points along said body, said means including discontinuities in said dielectric body, a conductive member, and means cyclically to vary the spacing of said conductive member from said body to vary the speed of propagation of radiant energy along said body.

6. An antenna including an elongated prismatic body of solid dielectric material having transverse dimensions at which radiant energy waves are propagated along the length thereof and having holes therethrough, for causing radiation to be propagated between said rod and ambient space at spaced points along said body, a conductive member, and means cyclically to vary the spacing of said conductive member from said body to vary the speed of propagation of radiant energy along said body.

7. An antenna including an elongated prismatic body of solid dielectric material having transverse dimensions at which transmission of radiant energy waves is effected along the length thereof, means for causing radiation to be propagated between said rod and ambient space at spaced points along said body, said means including localized volumes of different dielectrical properties than those of said body, a conductive member, and means cyclically to vary the spacing of said conductive member from said body to vary the speed of propagation of radiant energy along said body.

8. An antenna including an elongated prismatic body of solid dielectric material having transverse dimensions at which transmission of radiant energy waves is facilitated along the length thereof, means for causing radiation to take place between said rod and ambient space at spaced points along said body, said means including a number of short conductive members inserted in said body, said members having lengths and being spaced apart to provide concentration of the field radiated therefrom along lines normal to the axis of said body, a conductive member arranged in parallel relationship to said body, and means cyclically to vary the spacing of said conductive member from said body to vary the speed of propagation of radiant energy along said body.

9. An antenna including an elongated prismatic body of solid dielectric material having transverse dimensions at which radiant energy waves are propagated along the length thereof, means for causing said energy to be translated between said rod and ambient space at spaced points along said body, an elongated conductive member having an axis arranged in parallel relationship to the axis of said body, said member having a non-uniform configuration in a plane normal to its axis, and means to move said member with respect to said body cyclically to vary the velocity of propagation of said radiant energy.

10. An antenna including an elongated prismatic body of solid dielectric material having transverse dimensions at which radiant energy waves are propagated along the length thereof, means for causing said energy to be translated between said rod and ambient space at spaced points along said body, an elongated conductive member having an axis arranged in parallel relationship to the axis of said body, the axis of said member being located at a varying distance from its outermost surface, and means to rotate said member about its axis cyclically to vary the velocity of propagation of said radiant energy.

11. An antenna including an elongated prismatic body of solid dielectric material having transverse dimensions at which radiant energy waves are propagated along the length thereof, a plurality of radiator elements inserted in line in said body at intervals of a wavelength at the operating frequency, an elongated conductive member having an axis arranged in parallel relation-

ship to the axis of said body, said member having a varying dimension from its axis to its outermost surface, and means to rotate said member about its axis cyclically to vary the velocity of propagation of said radiant energy.

12. An antenna including an elongated prismatic body of solid dielectric material having transverse dimensions at which radiant energy waves are propagated along the length thereof, a plurality of rows of radiator elements inserted in line in said body, the elements of each row being spaced apart at intervals of a wavelength at the operating frequency, an elongated conductive member having an axis arranged in parallel relationship to the axes of said rows of elements inserted in said body, the axis of said member being asymmetrically arranged with respect to its outermost surface, and means to rotate said member about its axis cyclically to vary the velocity of propagation of said radiant energy.

13. An antenna including an elongated prismatic body of solid dielectric material having transverse dimensions at which radiant energy waves are propagated along the length thereof, a plurality of rows of radiator elements inserted in line in said body at intervals of a wave length at the operating frequency, the individual elements of one row being staggered with respect to the elements of another row, an elongated conductive member having an axis arranged in parallel relationship to the axis of said body and of said elements, said member having a cam shaped configuration in the plane normal to its axis, and means to rotate said member about said axis cyclically to vary the velocity of propagation of said radiant energy.

14. An antenna including an elongated prismatic body of solid dielectric material having transverse dimensions at which radiant energy waves are propagated along the length thereof, two rows of radiator elements inserted in line in said body at intervals of a wavelength at the operating frequency, said rows being parallel to each other and spaced a half wave apart at the operating frequency, the individual elements of one row being staggered a half wave from the elements of the other row, an elongated conductive member having an axis arranged in parallel relationship to the axes of the rows of said elements, said member having an axis asymmetrically arranged with respect to its outermost surface, and means to rotate said member about said axis cyclically to vary the velocity of propagation of said radiant energy.

15. An antenna including an elongated rod of solid dielectric material having transverse dimensions at which radiant energy waves are propagated along the length thereof and having holes therethrough for effecting radiation between ambient space and said rod, said holes being spaced along said rod at intervals of a multiple including unity of a wavelength at the operating frequency.

16. An antenna including an elongated rod of dielectric material having transverse dimensions at which radiant energy waves are propagated along the length thereof, and means for effecting radiation between ambient space and said rod, said means comprising conductive spheres entirely contained within said rod and spaced along said rod at intervals of integral multiples including unity of a wavelength at the operating frequency.

17. An antenna including an elongated rod of dielectric material having transverse dimensions at which radiant energy waves are propagated along the length thereof, said dielectric rod being exposed to ambient space along the length thereof and means for translating said radiant energy waves between said rod and ambient space at spaced points along said rod, said means comprising conductive members entirely contained within said rod at spaced intervals therealong.

18. An antenna including an elongated rod of dielectric material having transverse dimensions at which radiant energy waves are propagated along the length thereof, and means for translating said radiant energy between ambient space and said rod, said means comprising conductive spheres arranged within said rod at intervals of a multiple including unity of wavelengths at the operating frequency.

19. An antenna including an elongated rod of solid dielectric material having transverse dimensions at which radiant energy waves are propagated along the length thereof, and means for translating said radiant energy waves between said rod and ambient space at spaced points along said rod, said means comprising a plurality of elongated conductive members inserted along said rod at intervals of a multiple including unity of a wavelength at the operating frequency, the longitudinal axis of said members being normal to the axis of said rod and at least some of said members being spaced from the axis of said rod.

20. An antenna including an elongated rod of solid dielectric material having transverse dimensions at which radiant energy waves are propagated along the length thereof, and means for translating said radiant energy waves between said rod and ambient space at spaced points along said rod, said means comprising a plurality of elongated conductive members inserted along the axis of said rod at intervals of a wavelength at the operating frequency, said members protruding from one surface only of said rod, said members being arranged in rows spaced a half-wave apart at the operating frequency, the longitudinal axis of said members being normal to the axis of said rod.

21. An antenna including an elongated rod of solid dielectric material having transverse dimensions at which radiant energy waves are propagated along the length thereof, and means for translating said radiant energy waves between said rod and ambient space at spaced points along said rod, said means comprising a plurality of elongated conductive members inserted along the axis of said rod at intervals of a wavelength at the operating frequency, said members protruding from one surface only of said rod, said members being arranged in rows spaced a half-wave apart at the operating frequency, the members in alternate rows being staggered by a half-wavelength at the operating frequency, the longitudinal axis of said members being normal to the axis of said rod.

22. An antenna including an elongated rod of solid dielectric material having transverse dimensions at which radiant energy waves are propagated along the length thereof, and means for translating said radiant energy waves between said rod and ambient space at spaced points along said rod, said means comprising elongated conductors inserted in said rod at intervals of a wavelength at the operating frequency, said conductors being located at varying distances from the axis of the rod and being arranged in groups, the axes of the conductors of one group being parallel to the axes of those of another group,

and the axes of the conductors of all groups being normal to the axis of said rod.

23. An antenna as claimed in claim 18 having the dielectric rod exposed to ambient space along the length thereof.

24. An antenna including an elongated rod of dielectric material having transverse dimensions at which radiant energy waves are propagated along the length thereof, said dielectric rod being exposed to ambient space along the length thereof, and means for causing radiation to be propagated between the rod and ambient space at spaced points along said rod, said means including localized volumes having different dielectric properties than those of said rod and being entirely surrounded by said dielectric material, said rod being adapted to have radio frequency transducer apparatus coupled thereto.

HARLEY IAMS.

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