

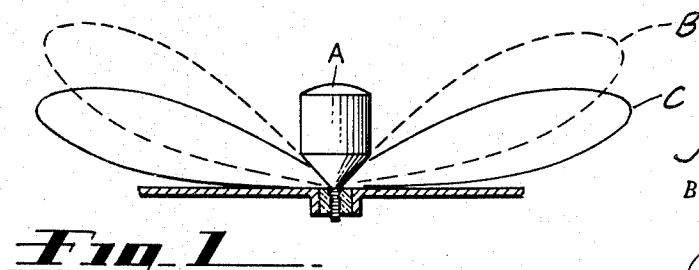
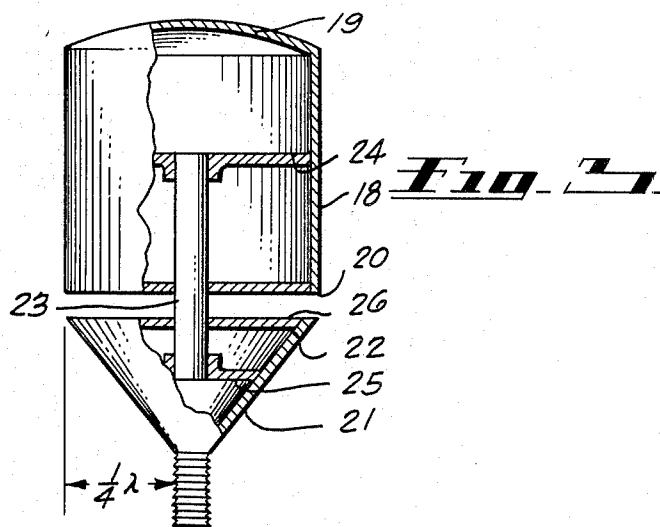
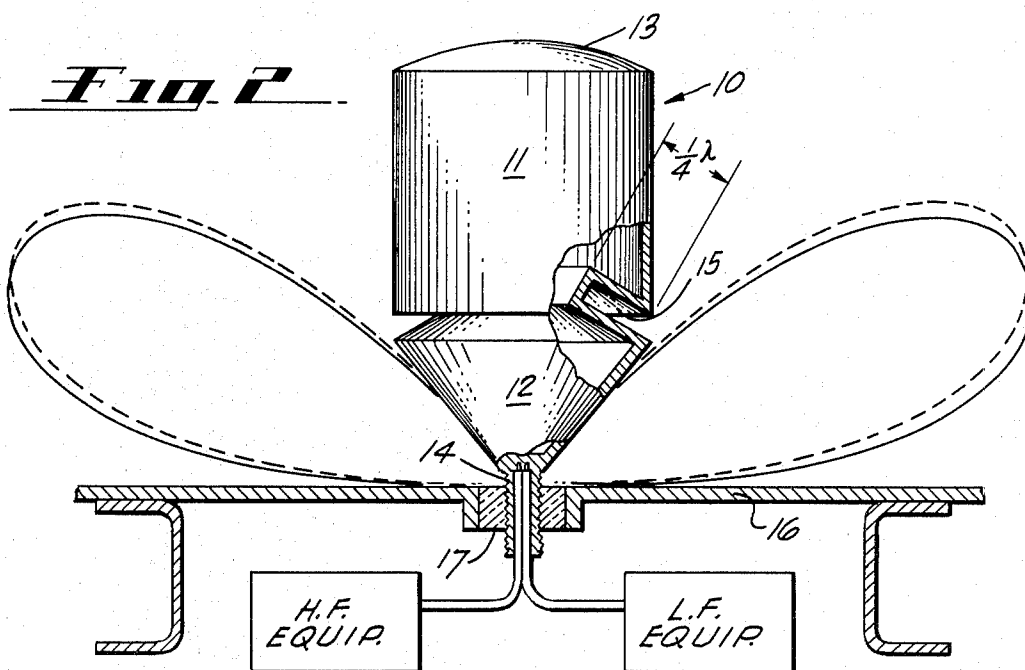
Nov. 15, 1955

J. M. BOYER
RADIO ANTENNAS

2,724,052

Filed Nov. 30, 1950

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

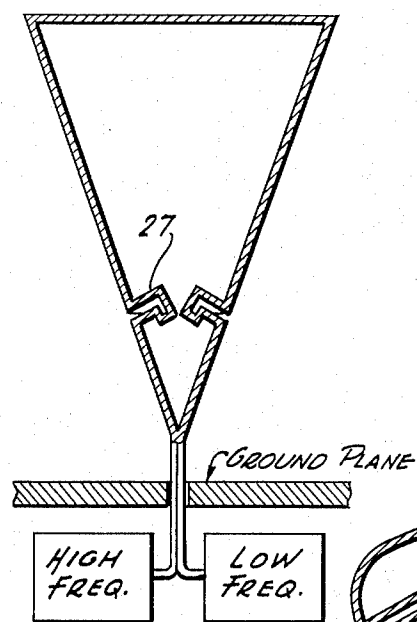


Fig. 4

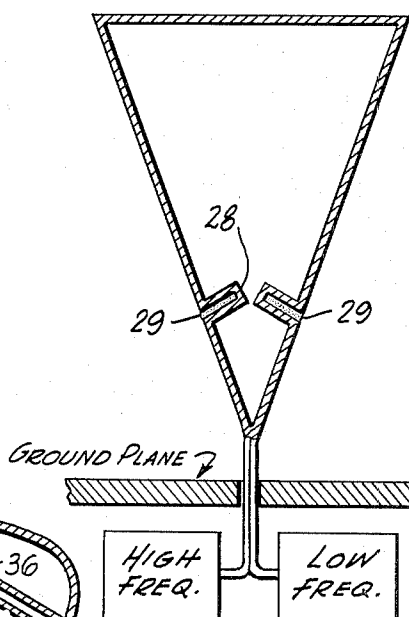


Fig. 5

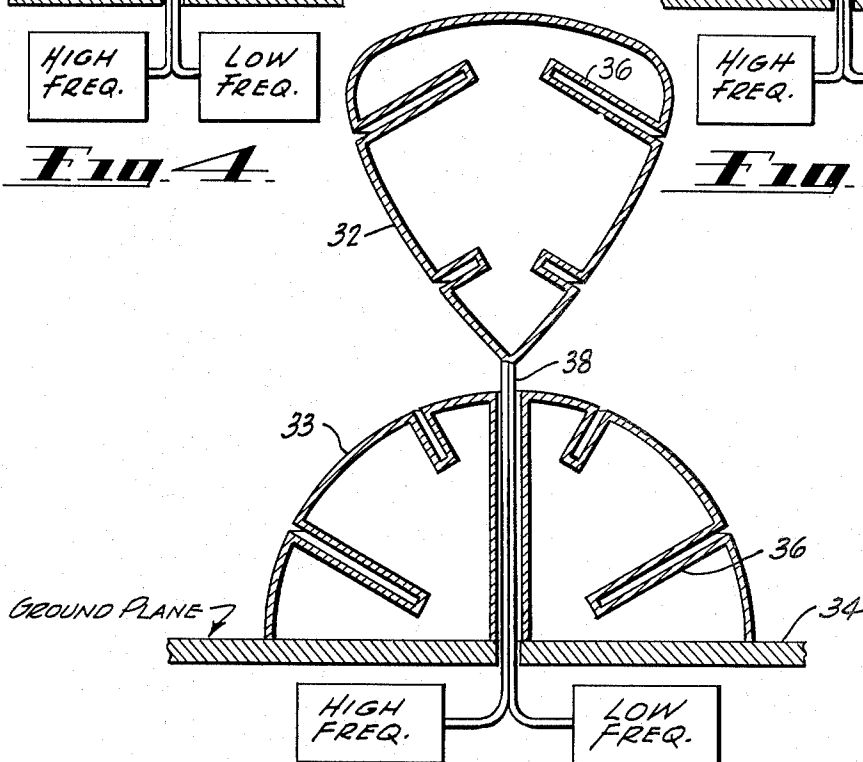


Fig. 6

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2,724,052

RADIO ANTENNAS

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Application November 30, 1950, Serial No. 198,410

11 Claims. (Cl. 250—33)

This invention relates to radio antennas and particularly to wide band antennas, especially those adapted for use in aircraft. Current advances in the art of antenna design make it possible to operate a single antenna over very wide bands of radio frequencies while at the same time achieving a very efficient transfer of energy from the transmission line to the antenna in the case of transmitting, or from the antenna to the transmission line in the case of receiving radio signals.

This is possible primarily because ways have been discovered by which the portion of the antenna connected to the transmission line is tapered or contoured in such manner that a gradual change of wave impedance from the transmission line to the antenna proper is accomplished over broad bands of frequencies. Such techniques are prevalent particularly in aircraft antennas where aerodynamic requirements dictate the use of one antenna for a plurality of pieces of equipment of widely varying frequencies of operation.

The use of one antenna to cover wide bands of radio frequencies has one serious disadvantage, however. It has long been known to those skilled in the art that an antenna which is much longer than one half wave at the operating frequency will radiate its major energy lobe at a considerable angle from a plane normal to the antenna axis. In the case of a vertical radiator this would mean that most energy would radiate at relatively high angles above the horizon, thereby seriously limiting its usefulness in communicating with receiving stations located on the horizon. This effect is noticed in current wide band antennas which radiate well on the horizontal plane at the low frequency end of their band coverage because their physical dimensions place them in the quarter to half wave length category but tend to lift their energy lobe higher and higher above the horizon as they approach the high frequency end of their band coverage where they may now be as much as a full electrical wave length or more in height. This is especially true when operating in conjunction with small ground or base plane areas such as in aircraft or vehicle applications.

The invention herein described circumvents the above mentioned difficulties by providing a single antenna rendered capable of operating efficiently over wide bands of frequencies while at the same time maintaining a relatively constant low angle of radiation. This effect is accomplished by incorporating a frequency selective means within the outer surface of the antenna, which antenna consists of a single, dual-function article. The frequency selective means can be disposed at any desired location intermediate the ends of the antenna but preferably lies nearer the mounting end thereof than the opposite end to produce in effect, at said mounting end, a "high" frequency portion having an appropriate electrical length.

Broadly, the means at present preferred for achieving these and other ends essentially comprises a novel configuration of a peripheral portion of the outermost surface of the antenna which inhibits a portion of the antenna against radiation at the high frequency end of a

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given radio band while endowing the entire antenna with the power to radiate at the low frequency region of a given radio band. Electrically considered, this end is achieved by conferring upon the peripheral portion the effect of an impedance which, while negligible at the low end of the given radio band, offers an increasing impedance as the high frequency end of the band is approached, thereby forming a discrete electromagnetic break in the antenna surface at the high frequency region of the radio band covered. The break extends entirely around the periphery of the antenna and preferably has a radial depth of one-fourth of a wave length at some frequency intermediate between the ends of the radio band over which the antenna is employed. In the "low" frequency end of the radio band the effect of the inhibiting means is zero or substantially so, since no effective break in the antenna surface is presented to waves in the "low" frequency region which are moving over said surface. Thus the entire antenna surface then radiates, producing the horizontally directed pattern. This is preferably achieved by making the overall height of the antenna, at the "low" frequency end of its coverage, approximately one quarter of the low frequency wave length if operated above a metal surface or approximately one half of the low frequency wave length if operated in free space.

As the frequency value increases, the inhibiting means begins to have the effect on the surface charge of a reactance shunted across the break, and at a predetermined selective frequency within the high frequency region of the antenna coverage band, the inhibiting means, due to its special electrical nature, places a substantially non-conductive discontinuity across the longitudinal path of the charges moving out on the surface from the mounting end of the antenna towards the opposite end thereof. It thus gradually and effectively electrically decouples these longitudinally divided surfaces of the antenna and restricts the radiation and interception to the surface which lies near the mounting end of the antenna, in such manner that for all practical purposes this portion of the surface between the mounting end and inhibiting means is a separate antenna with an electrical length such that radiation is still directed substantially in the horizontal plane. The other, now electrically separated surface has a very secondary effect on the pattern while at the same time acting in no way to destroy the correct impedance relationship prevailing at the mounting end.

In any form of the antenna, the axial length of the lower portion thereof, electrically considered, is determined as follows: a frequency midway between extremes of the frequency band is chosen. At this frequency, the physical height of the antenna between the slot and the lower end of the antenna is initially so chosen that, electrically considered, this height will be one-fourth of a wave length of the "midway wave length" of the frequency band being employed. Thus, although this height will vary electrically, its physical dimension will remain constant and may be chosen in keeping with the dimensions of the space and environment in which the antenna is installed.

Thus the single antenna dually serves continuously over the entire span of the relatively "low" and "high" frequency portions of the required radio band while automatically emitting or intercepting signal energy at substantially one and the same horizontal angle and without necessitating any manual attention.

When the antenna is employed as an interceptor the inventive construction will confine the interception of the maximum energy to that coming in the horizontal direction, regardless of its place in the spectrum of frequencies covered by the one antenna.

Thus the one antenna of the present invention serves at least equally well the same purposes as the previous

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plurality of antennas heretofore employed in the same circumstances. The plurality of transmission lines and switches previously necessitated for employment with these plural antennas are also obviated.

Hereinafter, when the terms "low" frequency and "high" frequency are employed, it is to be understood that by these terms is meant frequencies that are, compared to each other, relatively low or relatively high, respectively and that I do not use the term "low frequency" in its limited technical sense of having a value of 30-300 kc./s., nor do I employ the term "high frequency" in its limited technical sense of having a value of 3,000 to 30,000 kc./s.

Manifold ways of forming the aforescribed surface discontinuity and coupling it with the rest of the antenna are contemplated by the invention and some of the presently preferred embodiments thereof will be described hereinafter in conjunction with the accompanying drawing illustrating these embodiments.

In these drawings:

Figure 1 is a fragmentary side elevation of a conventional antenna system illustrated for purposes of providing a comparison of the shape and direction of the radiated pattern with the improved present radiated and intercepted pattern shape and direction;

Figure 2 is an elevational view of the antenna system of this invention;

Figure 3 is a fragmentary elevational view of a modification of the antenna of Figure 2;

Figure 4 is a diagrammatic vertical-sectional view of a modified form of the antenna incorporating return-bent, or angled, slots;

Figure 5 is a similar view of another form of the invention and showing the slots filled with a dielectric material; and

Figure 6 is a diagrammatic vertical sectional view of still another form of the invention, showing the invention applied to an "apple-core" type of antenna, both lobes of which incorporate a plurality of the present slots.

As shown in Figure 1, conventional antennas such as that designated A, when employed for high frequency transmission, radiate their transmission pattern B mainly above the horizontal, although their low frequency pattern C lies nearer the horizontal. Consequently, many ground stations, or stations lower in altitude than that of the airplane, would fail to intercept any of the high frequency emission and much power and many communication contacts are lost. Accordingly, it is prevalent practice to employ such type of antenna as is shown representationally in Figure 1 only for low frequency work, a separate antenna, of a different type, being necessitated for use in conjunction with the aforesaid antenna for the high frequency side of the work.

The single, uni-pole, unitary antenna shown in Figure 2 eliminates one of the aforesaid antennas from the system by a construction that enables the antenna of Figure 2 to serve both as a high frequency and a low frequency utilizer of radio energy, either for transmitting or for intercepting said energy.

Essentially, the antenna of this invention comprises a radio-energy radiative and interceptive member 10, at least the surface of which is electrically conductive. In this embodiment the antenna comprises a cylinder 11 based on a cone 12 and capped by a spheroidal head 13, the other end being integral with a coaxial combined input and output member and attaching means 14. The electrically conductive exterior surfaces of the body can consist of a metallic coating sprayed on a solid mass or may consist of the outer surface of a hollow elongate metallic body, as shown.

In accordance with the invention, high frequency energy flow inhibiting means 15 are formed or disposed in the exterior surface, being of such a nature as to electrically decouple the portions 11 and 12 of the exterior surface of the antenna that lie on each side of the frequency-

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selective inhibiting means but being effective only at high frequency use of the antenna. This configuration confines the high frequency area of use of the antenna to the conical portion of the surface lying between the inhibiting means and the attaching means, thereby to confine the maximum energy pattern emitted or intercepted by the antenna substantially to the horizontal.

The frequency selective inhibiting means in Figure 2 are shown as consisting of a peripherally extending interruption here taking the form of a radially inwardly and upwardly directed peripheral groove. The wall of the hollow body is of one piece and is mounted on a support 16 such as an airplane fuselage, by the dual function member 14 which serves as an attaching means and as combined input and output means for transmission and interception respectively. The attachment means is here shown as a coaxial line cable threaded into an insulating block 17 fixed in the fuselage frame. The radially inwardly and upwardly extending groove 15 may be rolled into the surface of the hollow body or otherwise suitably formed therein at the junction of the cone and the cylinder.

The high frequency energy travels mainly on the surface of the antenna and hence at the air gap 15 encounters an impedance that is sufficiently high, when the radial depth of the groove is $\frac{1}{4} \lambda$, of that frequency which lies intermediate the ends of the particular radio band over which the antenna is employed, to form a break in the electromagnetic continuity of the antenna. In the low frequency end of the radio band, the effect of the groove or indentation is zero or substantially so. Thus the entire antenna surface then radiates, producing the desired horizontally directed pattern. The accomplishment of this result is preferably assisted by making the overall height of the antenna, when operating at the low frequency end of its coverage, equal to approximately one quarter of the low frequency wave length, when the antenna is operated above a metallic surface. If the antenna is operated in a free space devoid of metal, the overall height of the antenna may be one-half of the low frequency wave length. In effect, at high frequency use, this gap shunts a peripheral reactance across the path of the high frequency energy. In any case, it effectively decouples the cylinder from the cone and restricts radiation and interception to the conical surface, thus compelling the pattern of emission or interception to lie close to the horizontal attitude. The cylindrical portion, now effectively isolated from the high frequency energy, is thus transformed into a mere mast.

Thus, the single piece article is utilizable for both high frequency and low frequency work, eliminating the necessity for another antenna in conjunction therewith as heretofore, essentially by virtue of confining the pattern of maximum emission and interception of energy substantially to the horizontal direction.

Since the frequency selective means are built into, or are integral with the antenna, no manual attention of any kind is required in shifting from low frequency to high frequency energies.

In Figure 3, the foregoing principle is embodied in a manner which, among other things, renders manufacture of the antenna simpler and cheaper. The antenna shown consists of a generally elongate body having at least its exterior surface rendered electrically conductive and may either be of hollow metallic construction, as shown, or consist of a solid coated exteriorly with a metallic surfacing.

In either case, the article comprises a cylinder 18 spheroidally capped at its upper or outer end 19 and closed planeally at its lower end 20. The exterior surface is, of course, electrically conductive. Spaced a suitable longitudinal distance from said lower end is a conical portion 21 arranged with its closed planeal base 22 confronting the closed base 20 of the cylinder. Uniting these two portions rigidly and conductively is an electrically conductive strut or post 23, screwed or otherwise at-

tached at each of its opposite ends in a rigid transversely extending conductive web, one web 24 being unitary with the cylinder and the other web 25 being unitary with the cone.

It is essential that the difference between the outside diameter of the tie member 23 and the outside diameter of the radially adjacent body portions, that is, the radial extent of the gap 26, be exactly $\frac{1}{4} \lambda$ of the wave length intermediate the ends of the band at which the antenna is employed so that high frequency energy cannot jump the gap 26 and is hence restricted to the cone both in emission and interception.

Although in Figures 2 and 3 the antenna has been shown as incorporating a slot or surface discontinuity that is rectilinear in section, for situations where it is impossible to secure the necessary quarter-wave depth into the antenna without impairing the structural strength thereof, as shown in Figure 4, a return bent or folded, slot 27 may be employed. This slot has a total length conferring the desired quarter-wave depth thereon, but leaves the cross-sectional area of the antenna larger than if the slot were rectilinear and of the desired depth.

As shown in Figure 5, the same results may be obtained by forming a slot 28 to a depth considerably less than the desired quarter-wave length and filling it with a suitable dielectric material 29 which is of a nature to adhere to the material of which the antenna is constructed. The length of this slot varies inversely with the known dielectric constant of the dielectric material.

It is to be understood that the foregoing description is based on the assumption that the antenna is disposed over a "ground-plane," which acts in place of a mirror-image thereof. When the antenna is disposed on metal-free space, that is, when it is employed as a mast mounted on but spaced well above the earth, it is preferable that an identical, but inverted, body (not shown) be employed with it, and arranged base to base and acting, according to the well-known radio-energy "theory of images" and replacing said "ground-plane."

In Figure 6, the invention is shown applied to the well-known "apple-core" type of antenna. This antenna comprises an upper body 32 which, as may all the bodies in all the embodiments of the present antenna, may take the form of any "closed geometrical solid." That is, it is not essential that it be a symmetrical surface of revolution, all horizontal sections of which are circular, such as a cone. It hence may be a vertical ellipsoid, an oblate spheroid, or any vertical solid with a compound curved exterior surface.

The same is true of the lower body 33, which is preferably mounted on a base, or ground, plane 34. The upper body or lobe is mounted to the same base-plane by a rigid coaxial line 38.

Both bodies incorporate a plurality of rectilinear, empty slots 36, for the purpose of handling extremely broad bands of frequencies. The slots are shown as rectilinear in section and not reflective, but may, of course, take the latter form or, if desired, they may be made shorter than as shown and be filled with a dielectric material, as before. In any case, each of the additional slots is so proportioned in depth as to offer a high impedance at some specific portion of the "extremely broad" band coverage. Thus, by utilizing a number of such breaks or discontinuities in the surface of an antenna, radiation or interception can be confined to the horizontal by the single antenna over a band of frequencies of any extent.

Although certain definite structural members and specific geometrical shapes have been mentioned hereinabove, it is to be definitely understood that the invention is not limited in the forms it can take to these particulars but instead resides in any of the forms and configurations lying within the scope of the annexed claims.

I claim:

1. A uni-pole dual nature antenna operable with

a unit utilizing both high frequency and low frequency radio energy, thereby to obviate one antenna in dual service systems, comprising: a radio energy radiative and interceptive member having an input-output end and an electrically conductive exterior surface which is conductively-continuous from end-to-end of the antenna; electrically conductive means at said input-output end for entraining said energy into and out of said radiative and interceptive member; means connecting said electrically conductive means to a unit utilizing both high frequency and low frequency radio energy; and means for inhibiting high frequency radio energy flow peripherally disposed in said conductively-continuous exterior surface intermediate the ends thereof, thereby to electrically decouple the portions of said exterior surface lying on each side of said flow inhibiting means at high frequency operation of the antenna; whereby to confine the maximum radiation pattern emitted and received by the antenna substantially to the horizontal direction at all frequencies of operation of the antenna.

2. A uni-pole dual nature antenna operable with a unit utilizing both high frequency and low frequency radio energy, thereby to obviate one antenna in dual service systems, comprising: a radio energy radiative and interceptive member having an input-output end and an electrically conductive exterior surface which is conductively-continuous from end-to-end of the antenna; electrically conductive means at said input-output end for entraining said energy into and out of said radiative and interceptive member and adapted for attaching said member to a support; means connecting said electrically conductive means to a unit utilizing both high frequency and low frequency radio energy; and means for inhibiting high frequency radio energy flow peripherally disposed in said exterior surface intermediate the ends thereof, said peripherally disposed means lying sufficiently nearer the input end of said radiative and interceptive member than the opposite end thereof as to divide said conductively-continuous exterior surface into a major segment and a minor segment, thereby restricting a portion of the length of the antenna to such value as compared to the total length of the antenna as to confine high-frequency radiation to said minor segment thereby to electrically decouple the portions of said exterior surface lying on each side of said flow inhibiting means at high frequency operation of the antenna; whereby to confine the maximum radiation pattern emitted and received by the antenna substantially to the horizontal direction at all frequencies of operation of the antenna.

3. A dual service antenna for use with a unit utilizing both low and high frequency radio energy, comprising: an elongate member having an exterior surface which is conductively continuous from end-to-end of the elongate member and including a base portion of electrically conductive material disposed coaxially adjacent a radially coextensive and longitudinally more extensive portion of electrically conductive material; means for mounting said elongate member on a support; electrically conductive means connecting the inner end of said base portion to a unit utilizing both high frequency and low frequency radio energy; and a frequency-selective, peripherally extending groove in the conductively-continuous exterior surface of said elongate member, and disposed in the region of adjacency of said portions whereby to electrically decouple the base portion from said more extensive portion at high frequency energization of the antenna and confine the reception and radiation pattern of the aforementioned high frequency energy to said base portion; thereby to constrain the maximum energy pattern received and transmitted by the antenna substantially to the horizontal direction at all frequencies of operation of said antenna.

4. A dual service antenna for use with a unit utiliz-

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ing low and high frequency radio energy, comprising: electrically conductive material in the form of an elongate, generally cylindrical solid of revolution which is conical at the input end thereof and hemispherical at the opposite end; means for mounting the conical end to a support; electrically conductive means connecting said end to a unit utilizing both high frequency and low frequency energy; and a corrugation in the outer surface of said material located at the junction of the conical portion and the cylindrical portion of said material, said corrugation having its major axis directed inwardly and upwardly of the cylindrical portion and having a depth substantially equal to one-fourth of the length of that wave-length which lies intermediate the highest and lowest frequencies for which the antenna is adapted; thereby to interrupt the exterior surface of said article and electrically decouple the exterior surface of the conical portion from the exterior surface of the cylindrical portion while physically uniting the cone and the cylinder.

5. A dual service antenna for use with a unit utilizing both low and high frequency radio energy, comprising: a conical member having an electrically conductive exterior surface; a cylindrical member having the same diameter as that of the base of the cone and having an electrically conductive exterior surface; said cylinder member being arranged coaxially in longitudinally spaced relationship to said conical member to provide an electrical discontinuity between the surfaces of the two members unbridgeable by high frequency energy; electrically conductive means for low frequency energy conduction longitudinally extending into union at opposite ends with said cone and said cylinder and uniting them into a single article; said conductive means having an exterior diameter so related to the outside diameter of the cone and the cylinder as to provide a radially extending groove therebetween having a depth substantially equal to one-fourth of the length of that wave-length which lies intermediate the highest and lowest frequencies for which the antenna is adapted; means for mounting said conical member on a support; and electrically conductive means connecting the outer end of said conical portion to a unit utilizing high frequency and low frequency energy.

6. A dual service antenna for use with a unit utilizing both low frequency and high frequency radio energy, comprising: an elongate electrically conductive body adapted to be connected to units utilizing both high and low frequency electrical energy; a peripheral indentation of the body disposed generally adjacent the one end of said body and having the one portion of its inward extent directed inwardly and upwardly with respect to the longitudinal axis of said body, the other portion of the inward extent of said indentation being directed still farther inwardly of said body, from the inner end of the first-said portion and reflexed with respect to the first-said portion to form a return-bend, said indentation, constituting an electrical discontinuity unbridgeable by high frequency radio energy; and means for mounting said body to a support.

7. An antenna according to claim 3, in which said peripheral indentation extends insufficiently deeply into said elongate member to effect electrical decoupling of said base portion from said more extensive portion of said body at high frequency energization of the antenna; and dielectric material substantially filling said indentation and electrically increasing its effective depth sufficiently to decouple said portions at high frequency energization of the antenna; the slot having a depth inversely proportioned to the dielectric constant of said dielectric material.

8. An antenna according to claim 3 for use with extremely broad band frequencies and in which there are a plurality of said formations spaced longitudinally of said elongate member, each of said formations, in suc-

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cessions from the base of said member towards the opposite end thereof being so proportioned in depth to the immediately preceding formation as to offer an effectively high impedance to said increasingly broad band of high frequency energization at a predetermined portion of said extremely broad band coverage.

9. An "apple-core" type antenna, for utilization with high frequency and low frequency radio-energy, comprising: a base plane; a first radiating body having its radiating surface disposed spacedly from said plane; electrically conductive means connected at its outer end to that portion of said body which lies adjacent to said plane, said means being connected at its opposite end to high frequency and low radio-energy means; means defining at least one peripheral gap in the exterior surface of said body at the distal boundary of said portion of said body, said gap having a depth sufficient to electrically decouple said portion lying adjacent said plane from the rest of the body at high frequency radio-energization of said body, said decoupling confining high frequency radiation from said body to said portion of said body and directing it horizontally therefrom, substantially the entire exterior surface of said body radiating low frequency energy horizontally therefrom; a second radiative body supported on said base plane in coaxially spaced relationship to said first body and disposed in sufficiently close proximity thereto to be radiatively energized by said first body; means defining in the exterior surface of said second body a peripheral gap in the portion of said body that lies adjacent said first body, said gap having a depth sufficient to electrically decouple the portion of said second body that lies outwardly of said gap from the rest of said body to confine high frequency radiation from said second body to said portion and to direct it horizontally therefrom, substantially the entire exterior surface of said body radiating low frequency energy horizontally therefrom; whereby to confine both high frequency and low frequency radiation from said antenna to the horizontal direction.

10. An "apple-core" type antenna for utilization with extremely broad bands of high frequency and low frequency energy, comprising: a base plane; a first radiating body disposed in spaced relation to said base plane and having a portion substantially proximal thereto; electrically conductive means connected at its one end to said proximal portion, said means being connected at its opposite end to extremely broad band high frequency and low frequency energy means; means defining in the exterior surface of said proximal portion a plurality of peripheral gaps spaced longitudinally of said proximal portion, each gap successively outwardly of said body from said proximal end having a depth increased in proportion to the increasing frequency in said broad band so as to electrically decouple increasingly larger areas of said proximal portion from the rest of the body and confine only high frequency radiation from said body to said areas while directing same horizontally; a second radiating body supported on said base plane and coaxially spaced from the first said body closely enough to be radiatively energized by the first said body; means defining a plurality of longitudinally spaced peripheral gaps in the exterior surface of the second said body adjacent the first body, each gap successively towards said ground plane having a depth increased in predetermined proportion to the increasing frequency in said broad band energization of the first said body so as to electrically decouple increasingly larger areas in said adjacent portion of the second said body and confine only high frequency radiation from said body to said areas while directing it horizontally; whereby to direct all radiation from said antenna substantially horizontally at substantially all frequencies of energization thereof.

11. An antenna for utilization with high frequency and low frequency radio-energy, comprising: a substantially upright electrically conductive body disposed over a metal base plane and having the shape of a geometrical

solid elongate along the upright axis thereof and having a conductively continuous exterior surface curved through 360° at least in all planes lying at right angles to said axis; electrically conductive means connected at its outer end to the lower end of said body and connected at its opposite end to high frequency and low frequency radio-energy means; the height of said body being equal to one-fourth of a wave length of the low frequency radio-energization of said body; and means disposed in said conductively continuous exterior surface of said body and defining at least one peripheral gap in said conductively-continuous exterior surface of said body nearer the lower end thereof than the upper end thereof, said gap having a depth inwardly of said body equal to one-fourth of a wave length of the low frequency energization of said body thereby to electrically decouple the portion of said body lying below said gap from the portion

thereof lying above said gap at high frequency energization of said body, thereby to confine high frequency radiation from said body to said portion below said gap and to direct said radiation substantially horizontally outwardly therefrom, substantially the entire exterior surface of said body radiating low frequency energy substantially horizontally.

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