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ANTENNA

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2 Sheets-Sheet 1

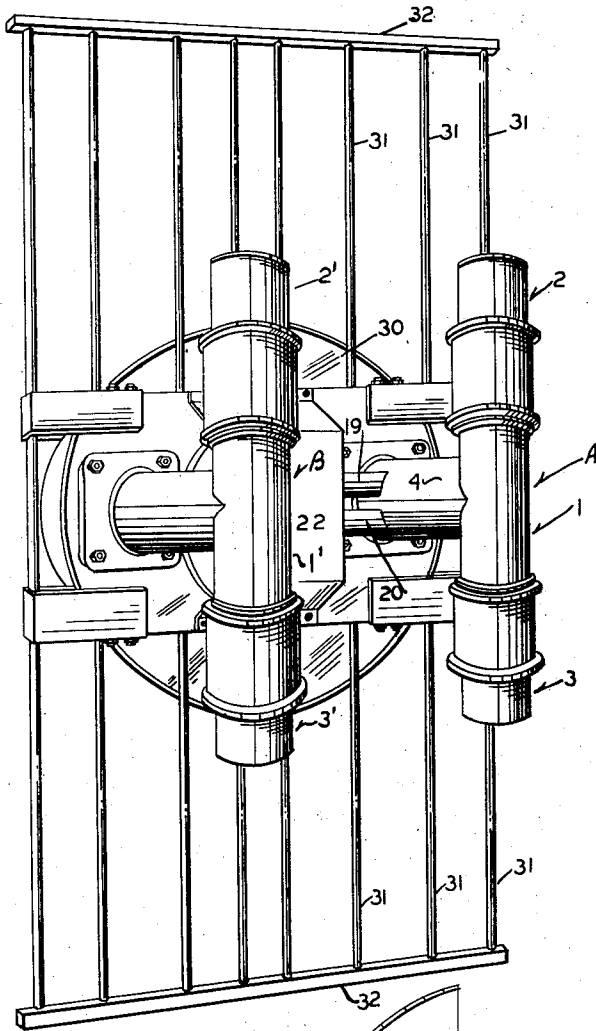


FIG. 1

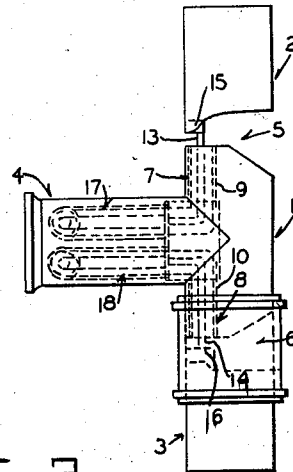
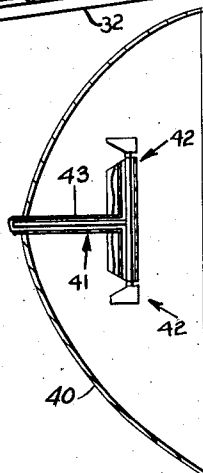


FIG. 2

FIG. 3



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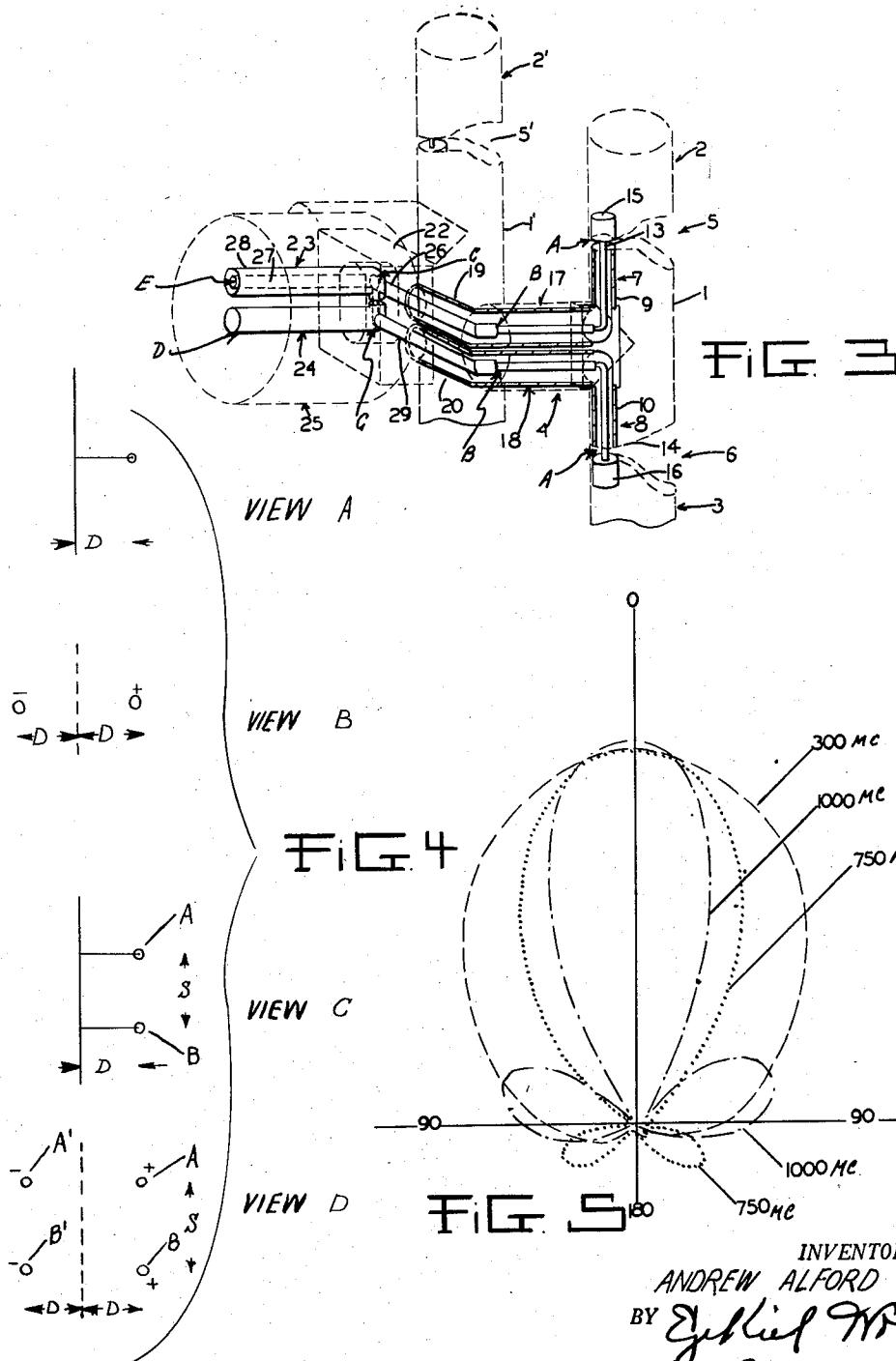
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The present invention relates to directional wide band antennas in ranges running approximately from 100 to 2500 megacycles. For many years past such directional antennas were used with many types of transmitters in connection with which attempts were made to establish as wide a frequency band as possible, so as to take in the desired frequencies at which the signals were to be transmitted. The frequency range of such antennas had ratios of approximately two to one, but efforts to increase this range were not very successful. For such purposes sleeve antennas with reflectors having 135° corners were used, but results were however, not promising for increased band range because the following limitations were encountered.

(a) The frequency range of the sleeve antenna appeared to be limited to approximately 2.3 to 1 without the reflector and 2.2 to 1 or less with the various types of reflectors which were tried.

(b) The radiation pattern split into two major lobes at about 2.3 times the lowest frequency at which the antenna impedance could be compensated.

The limitation under (a) has to do with the properties of the conventional sleeve antenna. The limitation under (b) is associated with phenomena of more fundamental character. A dipole antenna when placed in front of a reflector results in two signals being sent out in the direction of the desired beam, namely the direct signal and the signal sent back to the reflector. When the space between the antenna and the reflecting surface is not too different from ¼ wave length of the signal, then two signals are in the same phase with each other and therefore add. When the frequency is changed so that this space becomes one half wave length, the two signals tend to cancel one another and, therefore, produce a null in the direction normal to the reflector. At the lowest frequency within the operating band, the spacing between the antenna and a flat reflector cannot be made much less than about .22 wave length because even at those spacings there is an adverse effect on the antenna input impedance. This effect is difficult to compensate for. At a frequency about 2.3 times the lowest frequency, the spacing between the antenna and the reflector becomes equal to one half wave length and the reflected signal tends to cancel the direct signal from the antenna. Since the beam width is of the order of 35° to 60°, the reflector used is too small to make it possible for the reflected signal to overpower the direct signal. The two signals are then about equal so that a deep minimum in place of the peak of the major lobe is observed. The conventional sleeve, the double cone, the disc cone, the broad banded flat dipole, all behave in this same way and with all of these types of antennas the best frequency range ratio previously obtained was approximately 2.2 or 2.3 to 1.

In overcoming the difficulties above set forth, the applicant has in general used two features by means of which a frequency range in the ratio of 3.3 to 1 or better has been obtained. Two elements particularly stand out

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in obtaining this broad band frequency range, first of which comprises proper antenna grouping, and secondly, the use of a so-called flared slot antenna which at the upper frequencies in the desired range has some directivity in and of itself. These features and other principles upon which the present invention is based will be more fully discussed in the rest of the specification set forth below when taken in connection with the drawings illustrating an embodiment of the same, in which:

Figure 1 shows a perspective view of an antenna group according to the present invention employing a reflector.

Figure 2 shows a single antenna unit with a portion removed to show a flat slot on one side.

Figure 3 shows a pair of antennas with connections partly in diagrammatical representation.

Figure 4 shows the development of the array of antennas of the present invention illustrating the principle upon which the present invention is based.

Figure 5 shows typical patterns of an array of the kind shown in Figures 1 and 4.

Figure 6 shows a modification of the arrangement of Figures 1 to 4 inclusive with a parabolic reflector and a dipole at the focus.

Referring more particularly to Figures 1, 2 and 3, each individual antenna comprises a central portion 1 and caps 2 and 3, each of which may be cylindrical in cross section or other suitable shape, such for instance as an ellipse, closed or partially closed, or some other regular or irregular shape having the same general purpose. The central portion 1 is connected to an electrically neutral supporting stem 4, which comprises an enclosing shell of conductive material such as a cylindrical conductor with internal conducting members which will be described later. The caps are separated from the central part by flat slots 5 and 6 respectively. These flat slots are comparatively narrow at the point of feed and widest at the side diametrically opposite the feed. The feeder for the caps or the feed across the slots 5 and 6 are the coaxial feed cables 7 and 8 which have outer conductors 9 and 10 respectively and inner conductors 13 and 14 respectively which cross the gap or slot at its narrowest point and which are conductively connected to the other side of the slot through conductive blocks 15 and 16 respectively.

The coaxial branch feeders 7 and 8 extend through the central arm portion 1 of the antenna and through the stem 4 as indicated by the sections 17 and 18 in the stem of the antenna. The antenna, therefore, is in the form of a T with slots or air gaps on each side of the arm branches of the T. While it is preferable to construct the antenna of cylindrical conductors, it is not necessary to confine the cross section of the antenna to this shape and as has been stated above, other equivalent shapes providing the same results however may be used for the T forming the antenna.

As indicated more clearly in Figures 2 and 3, the coaxial feeding sections 17 and 18 in the stem 4 are extended through the sides of the stem as at 19 and 20, Figure 1, into a junction box 22 where they connect to the balun or coupler 23, 24 within the shielded conductor 25. As will be seen, each coaxial branch 19, only one of which is shown in Figures 1 and 3, has its inner conductor 26 connected to the inner conductor 27 of the portion 23 of the balun; the outer conductor 28 of which forms the other half of the coaxial line. The inner conductor 29 of the coaxial branch cable 20 connects to the inner end of the conductor 24 which is similar to the external conductor 28. Each of the T-antennas, the second of which has the same numbers as the one previously mentioned, except that they are numbered with primes, and is of the same construction, shape and size, is connected to the balun in the same manner as the first antenna which has been

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described above. The power to the balun 23, 24 is fed through the coaxial cable comprising the inner conductor 27 and the outer conductor 28. The antennas of the pair, similar units of which are designated as A and B respectively, are mounted on a plate 30, which comprises part of the reflector, the rest of which is formed as a conductive frame having rods 31, 41, etc., tied together at the end by cross rods 32, 32, etc. Any other form of grill or full plate is satisfactory, providing the spacings between the conductors are small compared to a wave length so that no energy will be transmitted through the reflector but will be reflected back. Dimensions and spacings of the units from one another and from the reflector and also the relation and shape of the slot will be more fully explained in portions of the specification which follows below.

Before discussing this, it is however, well to discuss the principles underlying the structures described above. When a broad band antenna, such as for example, the antenna described in Figure 2 is placed near and parallel to the metal sheet, the field reflected signal from the sheet produces a change in the impedance of the antenna. An identical effect could be produced in the absence of the sheet by an image antenna in which the current is in opposite phase to the current in the primary antenna. These two equivalent arrangements are illustrated in views A and B, Figure 4. Consider now two identical primary antennas such as A and B placed in front of a metal sheet as illustrated in view C, Figure 4. This arrangement is equivalent to that shown in view D in Figure 4, in which the sheet has been replaced by images A' and B'. When the current in antenna B is equal to and in the same phase of the current in antenna A, the effect of the image A' on the impedance of the antenna A can be exactly neutralized by the opposite effect of antenna B, provided the distance S between A and B is made equal to 2D the distance between the antennas and their images. Under these conditions, the impedance of the antenna A is subject only to the effect of image B' which is $S\sqrt{2}$ or 1.41 times as far away from the antenna A as its own image A'. By the use of this expedient, the two antennas can be placed closer to a reflector. In fact, the distance S between the two antennas can be made .707 of the distance between a single antenna and its image before the effects of the reflected signal on antenna impedance is equalized by the position of the adjacent antenna.

As may be expected, the distance S need not be equal to 2D; but may be made considerably less this value before the beneficial effects of the antenna B on the impedance of antenna A and vice versa is lost. This possibility of varying distance S within the limits allows one to make this distance equal to one half of wave length at a frequency in the upper portion of the antenna range. The advantage of this arrangement is to decrease the radiation at right angles to the direction of the beam, thus simplifying the task to be performed by the reflector.

The following is given as an example of the dimensions of the antenna system in a range from approximately 300 megacycles to approximately 1080 megacycles which is a ratio of about 3.6 to 1. For such a construction, the overall length of such antenna was 13 $\frac{3}{4}$ inches; the spacing between the center lines of the two antennas was 9"; the spacing between the center line of each antenna and the center line of the reflector taken normally to the antennas was 6 $\frac{1}{16}$ inches, the diameter of each antenna was 2 $\frac{3}{4}$ inches. With these dimensions, the distance between the antennas and the reflector becomes $\frac{1}{4}$ wave length at approximately 440 megacycles and one half wave length at approximately 880 megacycles. Under such conditions, with ordinary dipoles of the prior art, the beam would split with frequency approaching $\frac{1}{2}\lambda$ at 880 megacycles. This difficulty can be avoided by making use of the slot dipole antenna of Figure 3, in which the coaxial feeders apply the energizing voltage not centrally but at one side of the slot. When a slot is ener-

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gized in this manner, the dipole itself can be made to have a directional pattern with the maximum directed away from the feeder connecting across the slot.

These experiments show that when the circumference of the dipole as measured around the slot is of the order of

$$\frac{\lambda}{4}$$

or less, the radiated pattern in the plane at right angles to the dipole is more or less omnidirectional but when the circumference becomes $\frac{1}{2}\lambda$ this pattern becomes directional with the maximum directed away from the point of feed.

In the example given above, the flared slot becomes one half wave length at 685 megacycles. It is quite directional at about 600 megacycles and remains directional at frequencies above 600 megacycles. At the lowest frequency in the operating range, the distance between the reflector and the antenna is equal to .17 λ and the space between antennas is .228 λ . At the highest frequency of the band, the distance between the reflector and the center line of each antenna is .628 λ the spacing between the antennas is .855 λ and the circumference of the slot becomes .78 λ . Overall dimensions of the reflector may be 30" x 17". If desired a larger reflector could be used.

The flaring of the slot increases the low impedance at the point of feed. The impedance increases to a more useful value at frequencies at which the circumference of the slot becomes half wave length. This follows because the voltage distribution along the slot increases in the flared slot further away from the point of feed and thereby maintains the impedance at a higher value than it would normally have over the frequency band with a slot of uniform dimensions. The flaring of the slot may be in the general relation as indicated by the drawing of about 3 or 4 to 1. It will be noted from Figure 2 and Figure 3, that the feed across the slot is placed on that side of the antenna nearest to the reflector so that when the radiation of the antenna becomes more directive in itself, as will be with higher frequencies, the beam will be directive away from the position of the reflector. It has been possible in the design herein described, to maintain a constant voltage standing wave ratio which for the most part, except at the very ends of the band, is in the vicinity of 1.5 or thereabouts; while at the ends of the bands, this voltage standing wave ratio may rise slightly higher, but can be held down to below 2 with a proper series section in the balun disturbing the characteristics of the antenna at other frequencies.

An example has been given for an antenna operating within the range from 300 to 1050 megacycles. Antennas have been designed which will operate over other frequency bands as an example from 600 mc. to 2140 mc. and it is possible using the features herein described, to design wide band antennas in other frequency ranges.

Distances from the antennas to the reflector have been measured from the center of the cylinder in which the air gap lies perpendicular to the reflector surface. This may be considered substantially the effective distance of the antenna from the reflector where the radiation of the antenna is uniform in the plane in which the air gap lies. Where the radiation pattern changes with the change in frequency, the radiation becomes directive away from the reflector. However in the present case, the effective distance of the antenna from the reflector is still considered the distance D.

It was found that a flat reflector of 35 λ long and .43 λ is satisfactory where λ corresponds to the lowest operating frequency. Larger reflections may be used.

Typical curves of radiation pattern for 300,700 and 1000 mc. in a horizontal plane when the reflector is perpendicular are shown in Figure 5. The radiation is directive through the axis and perpendicular to the plane of the reflector.

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In Figure 6 there is shown a parabolic reflector 40, in the focus of which is positioned a dipole 41 with slots 42, 42; symmetrically positioned on each side of the stem 43 of the T-shaped structure. The slots 42, 42 are flared outward towards the reflector and fed across the narrow points of the slot farthest away from the reflector. In this construction a very narrow beam pattern may be obtained since the maximum radiation from the antenna is directed into the reflector.

At the lower frequencies in the operating band where the antenna itself is non-directional, the reflector spacing is such that the direct and the reflected radiation add. At the higher frequencies in the operating band, the spacing becomes such as to result in potential cancellation of the reflected signal by the direct signal. The latter signal however is only a fraction of the former, and therefore can be overridden by it.

Having now described my invention, I claim:

1. A broad band high frequency directional antenna system comprising a pair of parallelly positioned T-shaped antennas, means forming air gaps in the cross bars of the T-shaped antennas symmetrically placed with respect to the stem of the T, said air gaps being in planes substantially perpendicular to the cross bars of the T's and extending all around their peripheries, a conductive reflector having a surface spaced at a distance D, from said cross bars and said cross bars spaced at a distance S from each other, said distance S being not greater than 2D and not less than $D\sqrt{2}$ where the distance D is equal to

$$\frac{\lambda}{4}$$

where λ is a wave length corresponding to a frequency within the transmitting band.

2. A broad band high frequency directional antenna system comprising a pair of circularly slotted antennas, a conductive reflecting surface positioned on one side of the antennas, means supporting said antennas in a fixed position with regard to said reflecting surface, the effective distance of the antennas from said surface being D, said antennas having an effective spacing from one another equal to S where S is not greater than 2D and substantially not less than $D\sqrt{2}$ with the distance D being equal to

$$\frac{\lambda}{4}$$

where λ is a wave length corresponding to a frequency within the transmitting band.

3. A broad band high frequency directional antenna system comprising a conductive reflecting surface, a pair of circularly slotted antennas having the plane of the slot substantially perpendicular to said conductive reflecting surface, means providing said conductive reflecting surface at a fixed distance from said slots, said conductive reflecting surface having an effective distance from said slots of D and said slots being spaced from one another at a distance S where S is not greater than 2D and substantially not less than $D\sqrt{2}$ with the distance D being equal to

$$\frac{\lambda}{4}$$

where λ is a wave length corresponding to a frequency within the transmitting band.

4. A broad band high frequency directional antenna system comprising, a conductive reflecting surface, a pair of circularly flared slotted antennas having the plane of the slot substantially perpendicular to said conductive reflecting surface, means providing said conductive reflecting surface at a fixed distance from said slots, said conductive reflecting surface having an effective distance from said slots of D and said slots being spaced from

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one another at a distance S where S is not greater than 2D and substantially not less than $D\sqrt{2}$ with the distance D being equal to

$$\frac{\lambda}{4}$$

where λ is a wave length corresponding to a frequency within the transmitting band.

5. A broad band high frequency directional antenna system comprising a conductive reflecting surface, a pair of circularly flared slotted antennas having the plane of the slot substantially perpendicular to said conductive reflecting surface with the narrowest part of the slot nearest to the reflective surface, means providing said conductive reflecting surface at a fixed distance from said slots, said conductive reflecting surface having an effective distance from said slots of D and said slots being spaced from one another at a distance S where S is not greater than 2D and substantially not less than $D\sqrt{2}$ with the distance D being equal to

$$\frac{\lambda}{4}$$

where λ is a wave length corresponding to a frequency within the transmitting band.

6. A broad band high frequency directional antenna system comprising a conductive reflecting surface, a pair of circularly flared slotted antennas having the plane of the slot substantially perpendicular to said conductive reflecting surface with the narrowest part of the slot nearest to the reflective surface, means for feeding the slot across its narrowest point, means providing said conductive reflecting surface at a fixed distance from said slots, said conductive reflecting surface having an effective distance from said slots of D and said slots being spaced from one another at a distance S where S is not greater than 2D and substantially not less than $D\sqrt{2}$ with the distance D being equal to

$$\frac{\lambda}{4}$$

where λ is a wave length corresponding to a frequency within the transmitting band.

7. A broad band high frequency directional antenna system comprising a pair of parallelly positioned T-shaped cylindrical tube antennas each having a cylindrical air gap on each side of the cross bar of the T symmetrically positioned in substantially parallel planes transverse to the axis of the cross bar, means for feeding said antennas through the stem of the T across the cylindrical gap, a conductive reflector for said antennas, said conductive reflector being substantially perpendicular to the plane of said air gap and spaced at a distance D therefrom, said antennas being effectively spaced at a distance S from one another where S is not greater than 2D and substantially not less than $D\sqrt{2}$ with the distance D being equal to

$$\frac{\lambda}{4}$$

where λ is a wave length corresponding to a frequency within the transmitting band.

8. A system as in claim 7 wherein said feed across the air gap is at a point nearest the reflecting surface.

9. A broad high frequency directional antenna system comprising a reflecting surface, a pair of circularly flared slotted antennas having the planes of the slot substantially perpendicular to said reflecting surface, means for feeding said slot across its narrowest point said narrowest point being positioned nearest to said reflecting surface and flaring out to a widest point at a diametrically opposite position across the slot, the effective distance of the antennas from said surface being D, said antennas having an effective spacing from one another equal to S

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where S is not greater than 2D and substantially not less than $D\sqrt{2}$ with the distance D being equal to

$$\frac{\lambda}{4}$$

where λ is a wave length corresponding to a frequency within the transmitting band.

10. A broad antenna comprising a pair of parallel dipoles and a substantially flat reflector parallel to said dipoles, said dipole being spaced apart a distance S from one another and a distance D from the reflector where S is not more than 2D and substantially not less than $D\sqrt{2}$ where D is equal to

$$\frac{\lambda}{4}$$

where λ is a wave length corresponding to a frequency within the transmitting band.

11. A broad band cylindrical conductive antenna having a slot substantially transverse to its axis, said slot extending all around the periphery of the cylinder, means feeding the slot across one point of its periphery, said slot having peripheral length not less than $.4\lambda$ where λ corresponds to a frequency within the operating band whereby the radiation from said slot is substantially directional away from the point of feed in the plane of the slot.

12. A broad band antenna structure as in claim 11, wherein said slot has a peripheral length between $.4\lambda$ and $.8\lambda$.

13. A broad band directive antenna comprising a conductive reflector and a dipole radiator having a pair of flared slots in substantially parallel planes normal to the reflector and means for feeding said slots at a point where the slot is narrowest.

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14. A broad band directive antenna comprising a conductive reflector and a dipole radiator having a pair of flared slots in substantially parallel planes normal to the reflector and means for feeding said slots at a point where the slot is narrowest, said slots being flared in the direction of the reflector.

15. A broad band directive antenna comprising a conductive reflector and a dipole radiator having a pair of flared slots in substantially parallel planes normal to the reflector and means for feeding said slots at a point where the slot is narrowest, said slots being flared in a direction away from the reflector.

16. A broad band directive antenna comprising a conductive reflector and a dipole radiator having a pair of flared slots in substantially parallel planes normal to the reflector and means for feeding said slots at a point where the slot is narrowest, said slots being flared in the direction of the reflector, said slots being spaced from the reflector substantially one-quarter of a wave length in the lower frequency band range whereby the direct and reflected signal add, and greater in the higher frequencies of the band range whereby the maximum energy is directed towards the reflector and reflected.

17. A device as in claim 16, wherein the reflector is substantially a parabola.

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