

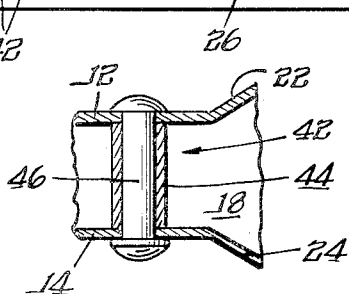
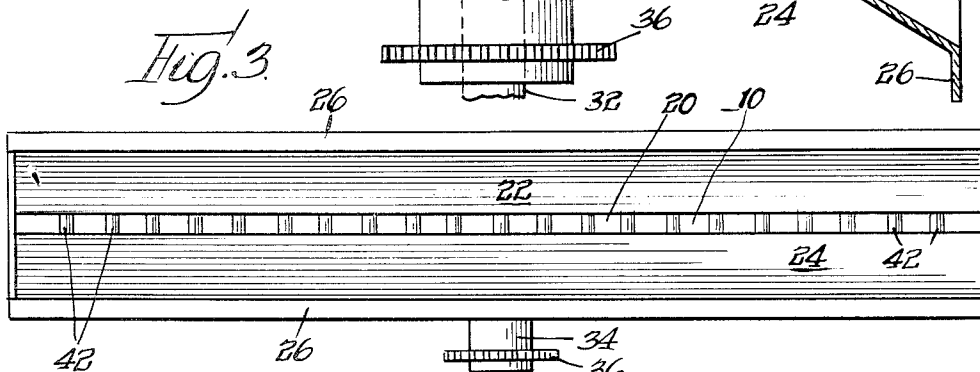
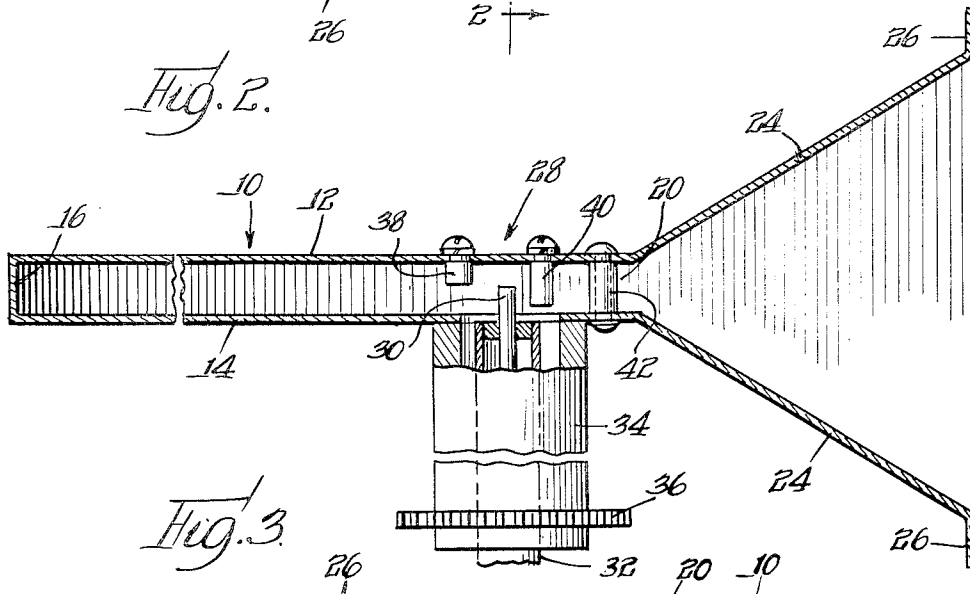
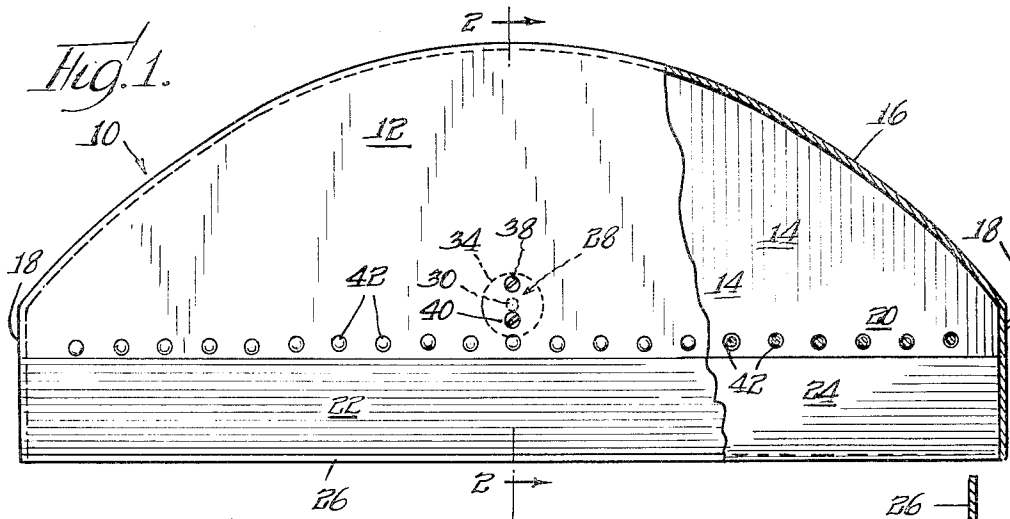
Dec. 28, 1965

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PROBE FED PILLBOX ANTENNA WITH PATTERN
SHAPING PINS AT APERTURE

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2 Sheets-Sheet 1



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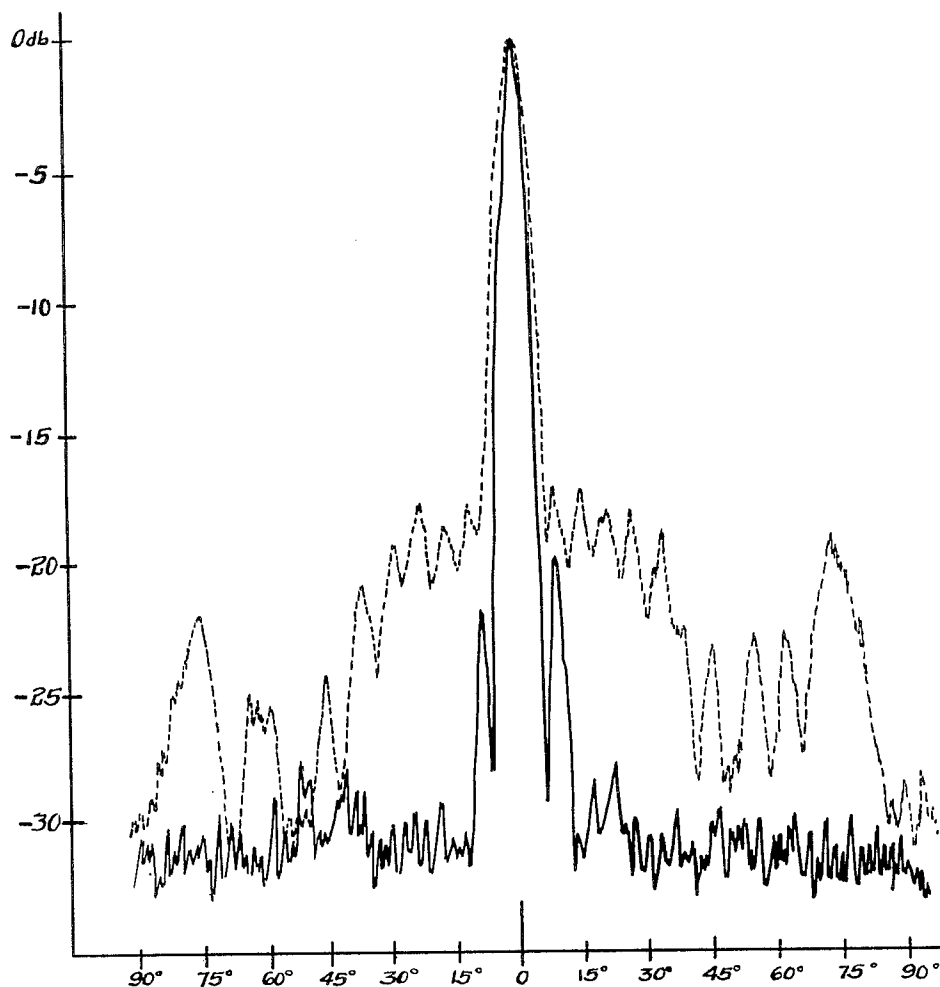


Fig. 5.

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PROBE FED PILLBOX ANTENNA WITH PATTERN SHAPING PINS AT APERTURE

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This invention relates to directive antennas, and more specifically to the type of antenna having a radiating feed at the focus of a parabolic reflector. The invention is of particular utility in connection with the so-called "pill-box" antenna, characterized by a cavity having two parallel walls with a rear wall extending perpendicularly to, and connecting, the parallel walls, and describing a parabola having its focus on the front portion of this axis, the front portion being substantially open and forming the mouth. In such antennas, the feed is disposed at the focus, and the spacing between the parallel plane walls is normally sufficiently small so as to permit the propagation of only a single mode with the polarization direction of the feed.

One important use of highly directional antennas is in connection with radar, and the horizontally oriented pill-box antenna, suitably mounted for rotation is frequently used in marine radar, the relation of the sharpness of the directivity in the horizontal plane compared to that in the vertical plane being particularly advantageous in obtaining the radar intelligence there desired, azimuth and distance being essentially the only important requirement in such a system, and this type of antenna being accordingly well-suited for the purpose, requiring only rotation about a vertical axis and being compact and convenient, particularly in the small sizes with which very high directivity may be obtained at frequencies of the order of thousands of megacycles. At such frequencies, parabolas of very large aperture (in terms of wavelength) may be employed in the very shallow cavities thus required, forming a relatively plate-like overall structure except for the horn flaring in the vertical plane, which is provided to give reasonable directionality in that plane to prevent waste of the radiated energy at large upward and downward angles.

One limitation on the use of high-frequency radar in relatively inexpensive systems suitable for use on small ships, and particularly on pleasure craft, is the precision of fabrication required where fully reliable sharp horizontal patterns are to be obtained. In theory, it would appear that the ability to employ an aperture of a width of many wavelengths should make the achievement of high horizontal directivity relatively simple. In practice, however, although a sharp main beam may be obtained without too much difficulty, the employment of designs and construction practices of a cost compatible with such uses has, prior to the present invention, encountered great difficulty with the additional production of unwanted and spurious sidelobes in the radiation pattern, which, although of substantially smaller magnitude than the main beam, create serious ambiguities in the radar information, particularly in view of the vast differences in reflectivity of various kinds of objects which must be detected by the system, simple and easily fabricated types of construction of such antennas heretofore available having sidelobes of such amplitude that a single detected object might appear in the radar pattern with a multitude of "ghosts" in which second and third objects of lesser reflectivity might be completely obscured. This problem of spurious sidelobes can well render the entire marine radar system useless for its intended purpose, irrespective of sharpness of the main beam, particularly in the simple

types of manners in which the reflected signals must be handled in the electronic systems which are economically practical for such uses, computational features of the type designed to distinguish between sidelobe and true images by storing and using information from the entire radar sweep to distinguish between spurious and desired images being completely impractical in general.

The pattern difficulties just mentioned are found to flow from a number of sources, in general connected with the required limits imposed by economics, prior to the present invention. At frequencies of the order of a number of gigacycles, with wavelengths of the order of an inch or so, small dimensional irregularities anywhere in the cavity, of an absolute magnitude which would be negligible at lower frequencies, become of sufficient magnitude with respect to the wavelength that there result departures from theoretical operation produced by interference patterns and similar phenomena due to variations of phase relations and axial symmetry in the emitted wave-front from the theoretical ideal, due to differences in phase velocity within the cavity and reflections at the mouth resulting from deviations from complete flat parallelism of the walls and similar phenomena. Such difficulties are multiplied where, for economic reasons, the cavity and its associated horn are formed from materials of sufficient thinness and flexibility to permit fabrication of the parabolic surface and the horn by bending and similar techniques, the employment of such techniques as machining from solid blocks being clearly prohibitive. The use of a large aperture for purposes of narrowing the main beam involves, in such an antenna, the employment of large sheets for the top and bottom parallel cavity surfaces, with consequent dimensional instability in constructions heretofore used.

Another source of difficulty which has heretofore been encountered in economically practical constructions is the matter of direct radiation from the feed, which of course does not have the benefit of the focusing effect of the reflector. For economic reasons, the feed employed must be of a very simple type. The use of such complexities as a horn waveguide termination disposed within the cavity for illumination of the parabolic reflector wall is economically impractical, the difficulties of construction of such a feed for uniform illumination, coupled with the necessity of rotating waveguide joints, etc., thus required, being prohibitive, so that the cavity is normally excited by a simple probe-type radiator at the focus, such a probe in itself inherently producing a circularly symmetrical pattern, and the pill-box being rotated about the focus as an axis in the radar sweep. In order to reduce the forward radiation directly from the probe, which is of course unfocused, a reflector element may be secured immediately forward of the radiating probe in the cavity. It is found, however, that if such a reflector is made of sufficient width to attempt to shield the direct radiation from the entire forward solid angle, whether straight or curved, the theoretical pattern is again destroyed by the improper phase and directional properties of reflections to the parabolic surface which come from the lateral portions of the reflector.

It has been found that simple and expensive marine radar antennas of the pill-box type were not completely practical as regards freedom from objectionable sidelobes, and particularly in the region of the main beam, prior to the present invention, for one or more of the reasons stated above. The present invention flows from a study of the possible or probable causes of inadequate sidelobe performance in this type of antenna, and the present invention provides a simple and inexpensive, but highly effective, construction for such antennas as regards desirable pattern characteristics. (It will be understood that the patterns and structural features herein

discussed, including terms such as "radiate," "exciter", etc., include both transmission and reception, in accordance with the usual practice flowing from reciprocity.) It is experimentally found that the construction herein-after to be described produces a great reduction in side-lobe amplitude as compared with previously known constructions, with no reduction in sharpness or amplitude of the main forward beam. In the present construction, there are disposed across the mouth of the cavity, inwardly adjacent to the commencement of the flaring which forms the horn, a large number of parallel mutually spaced conducting pins or posts extending perpendicularly between the parallel walls and spaced by a distance of from one-half to one wavelength, the lateral dimension being very short compared to a wavelength, i.e., substantially less than a quarter wavelength. This linear array of posts or pins (what is known of the exact theory of operation would indicate that thin plates extending in the direction of focus might be equally good electrically, although much more expensive for comparable performance, for reasons which will later be seen) extends across the entire mouth and is only very slightly (less than a wavelength) forward of the parabolic focus at which the exciting probe is located, so that the spacing between the pins, although appearing as of the order of magnitude of a wavelength in the desired direction of propagation, i.e., in the direction in which radiations from the omnidirectionally radiating exciting conductor are reflected by the parabolic surface, appear effectively as a solid wall of conductor for radiations from the position of the exciting conductor at angles beyond the angles subtended by a simple screw-type reflector immediately forward of the exciting conductor, thus shielding against direct radiations and radiations reflected from the side-walls of the horn portion. The pins or posts so spaced produce no observable adverse effect on the main forward beam, the primary effect of their presence beyond the desired one of substantially eliminating sidelobes of greatly troublesome magnitude, particularly close to the main lobe, being a slight change of impedance which is readily accommodated by the impedance-matching construction which must in any event be used, where, as is common, the exciter probe is itself excited from a stationary waveguide.

In the construction to be described, the posts or pins just mentioned are formed in such a way as to serve the additional function of strengthening the entire structure mechanically and providing accurate spacing across the vertical dimension of the cavity, the rigidity and accuracy of spacing produced at the mouth cooperating with the rigid parabolic back wall to make the entire cavity interior completely stable dimensionally as compared with the stability and dimensional uniformity which can be maintained with the same thickness of material of the parallel walls of the cavity without the reinforcement and spacing function provided by the pins or posts across the mouth.

Although the invention is of particular utility in the pill-box type of construction, of which an embodiment is illustrated in the drawing and described below in accordance with the provisions of the patent laws, certain of the features will be adaptable to use with antennas of somewhat different construction, as will be observed by persons skilled in the art. The invention will best be understood in both its narrower and broader aspects from the description of the embodiment illustrated in the drawing annexed, in which:

FIGURE 1 is a top plan view, partially broken away in section, of an antenna constructed in accordance with the invention;

FIGURE 2 is a vertical sectional view taken along the line 2—2 of FIGURE 1 in the direction indicated by arrows, the hub portion employed for rotation of the antenna being shown in elevation;

FIGURE 3 is a front elevational view of the antenna; FIGURE 4 is a fragmentary enlarged sectional view showing the details of a post or pin construction employed in the illustrated embodiment; and

FIGURE 5 is a comparative pattern plot illustrating the improvement in pattern characteristics obtained by the improvement of the invention.

In the illustrated embodiment, the pill-box cavity 10 is formed by a top plate 12 and a bottom plate 14 connected by a back wall 16 extending perpendicular to the parallel plates 12 and 14 and shaped in the form of a plane parabola having its focus at the intersection of the parabolic axis and the line connecting the opposite edges of the parabola. The parabola as illustrated is symmetrical with respect to the axis, as is common in antennas of this type. The top and bottom walls or plates 12 and 14 are carried slightly forward of the parabolic portion of the cavity, and side plates 18, parallel with each other and with the parabolic axis, cooperate with this forward extension of the top and bottom plates to form an open mouth 20 projecting from the parabolic portion, the plates 12 and 14 being bent respectively upward and downward from this point out to form horn flare portions 22 and 24, with further bends forming flanges 26, the sidewalls 18 being formed with appropriate taper of vertical dimensions to produce the enclosed horn form commonly used to produce the desired vertical plane pattern and impedance transformation of the coupling from the interior to the exterior of the antenna cavity.

The feed, generally designated by the numeral 28, has an exciting conductor 30 extending vertically in the cavity at the focus point of the parabola, this conductor being the protruding center conductor of a rigid coaxial line 32 which is fixedly mounted at its bottom end (not shown), where it is coupled by a suitable transistion and impedance match to the waveguide which is conventionally employed in such systems. The region of the cavity exterior surrounding the coaxial line 32 is provided with a hub 34 mounted on suitable bearings isolated electrically from the cavity by the usual grooving, etc., employed in such rotating joints (not shown) and is provided with a drive gear 36 for rotation.

The exciting conductor or probe 30 is thus on the rotational axis of the antenna so that its orientation relative to all parts of the rotating cavity 10 remains constant throughout. Respectively disposed rearward and forward of the probe 30 are a director 38 and reflector 40 consisting of screw-posts of the relative lengths and spacings from the probe which are normally used in such directive elements.

Arranged in a straight line across the entire mouth 20 of the cavity are pins or posts 42. The horizontal dimensions of the cavity 10 are very large relative to the wavelength at the frequency of operation, the parabolic aperture or the width of the mouth 20 thus being a large number of wavelengths. The pins or posts 42 are formed by conducting tubes 44 secured by rivets 46 extending through suitable apertures in the top and bottom plates 12 and 14.

The transverse dimension of the pin or post structures 42 is so selected as to be very small compared to a wavelength. However, the diameter of round conductors such as here illustrated is preferably sufficient to perform the mechanical support and spacing function mentioned, although thin wires can of course be used in instances where this aspect of the advantages of the construction can be sacrificed.

To meet the requirements that the conductors 42 must not, by their dimensions and spacing, interfere substantially with main lobe or beam transmission, but must provide substantially complete shielding of direct radiations from the probe 30 at angles at which the reflector 40 is ineffective, it is of course possible to use more complex forms of construction such as thin plates. However, by proper selection of spacing and pin diameter, the same

effect is produced with round conductors without the complexity of fabrication and assembly required for the use of plates or vanes, and with simple installation in a manner assuring proper cavity dimensioning. A spacing between adjacent conductors of at least a half wavelength and at most slightly more than a wavelength is satisfactory, but reduction of the openings between pins to less than a half wavelength impairs the entire operation. As earlier indicated, the pin diameter should be less than a quarter wavelength; with the latter limitation, center-to-center pin spacings greater than one-and-one-half wavelengths, corresponding to openings much wider than a wavelength, commence to seriously impair the sidelobe reduction characteristics achieved by the construction illustrated. Where round pins or posts are used for producing rigidity and accuracy of cavity dimensions, a diameter of about one-eighth wavelength is desirable, the preferred dimensioning employing pins of from two to three sixteenths wavelength diameter spaced by somewhat less than one wavelength.

In addition to the shielding function just discussed, the pin construction serves an important purpose in providing rigidity and dimensional stability. With the use of the tubes 44, secured by external fasteners such as the illustrated rivets, or bolts, the height at the mouth is accurately controlled by the tube length, thus giving a dimensional stability and constancy across the width which is otherwise unobtainable in any comparably simple fashion.

One construction of the illustrated device was designed for operation at a frequency of 9.4 gc. An aperture of approximately 22 inches was employed with pins (tubes) of three-sixteenths inch outer diameter with equal center-to-center spacing of 10½ inches between the central and each of the outermost of the ten pins illustrated on each side thereof in the drawing, other constructional features being more or less conventional (reflector one-quarter wave forward of the radiator probe, etc.). The line of pins was located slightly less than three-quarters of an inch forward of the probe. The forward pattern in the horizontal plane obtained at this frequency is shown in FIGURE 5, the dotted curve indicating the results obtained before installation of the pins, and the solid curve showing the pattern as obtained with the pin construction just described. In this graph or plot, as is conventional, the maximum of the radiation is shown as the 0 db level, with the other ordinate values being related thereto as a function of angle with respect to the axis. It will be observed that the improvement effected by the addition of the pins is extremely great. The first sidelobe (at about seven or eight degrees from the main beam peak) is reduced by almost three db, while all further sidelobe structure is reduced by ten db or more, the improvement in the entire sidelobe structure outside of the first sidelobe region being extreme, as will be observed.

It will of course be understood that the theory underlying the experimental finding of vast improvement typified by FIGURE 5, as discussed above, cannot be easily experimentally verified. The extent to which the improvement is obtained by the shielding effect, and the extent to which it is obtained by the exactness of dimensioning produced at the mouth, cannot readily be determined. It is believed that it is the combined effects that produce the remarkable improvement experimentally found, but the protection to be afforded the invention should not be impaired by lack of present knowledge as to the exact theory of operation of the construction experimentally found to be advantageous, nor should the protection be limited to the particular embodiment illustrated in the drawing and described above, many variants being readily obvious, and others being observable by those skilled in the art after study. The structure of the invention is described in the appended claims.

What is claimed is:

1. In a directive antenna having:

(a) a radiator cavity having a pair of plane parallel

conducting walls and a rear wall extending perpendicularly to, and connecting, said parallel walls, the rear wall being in the general form of a parabola having its focus in the front portion of the cavity, the front portion of the cavity being substantially open and forming the radiator mouth, and

(b) a feed in the cavity at the focus of the parabolic back wall comprising a substantially omnidirectional radiating probe element and a reflector conductor adjacently forward thereof to impede direct external radiation from the feed in the directly forward direction, the improved construction having:

(c) parallel mutually spaced conductors of rearward-to-forward dimension smaller than the spacing extending perpendicularly between and connecting the parallel walls at the open mouth portion of the cavity slightly forward of the feed to impede direct external radiation from the feed in the laterally forward directions.

2. The antenna of claim 1 wherein said spaced conductors are round pins.

3. The antenna of claim 1 wherein said spaced conductors are equally spaced in a straight line across the entire mouth, the spacing between adjacent conductors being at least a half wavelength and at most slightly more than a wavelength.

4. The antenna of claim 3 wherein said spaced conductors are round and of less than a quarter wavelength diameter.

5. The antenna of claim 1 wherein the parallel walls are formed by metal plates, said spaced conductors being of equal length and having the adjacent portions of the parallel walls supported and spaced thereby to hold the spacing of the walls rigidly uniform.

6. The antenna of claim 5 wherein the conductors are metal tubes, in register with apertures in the parallel plates and secured by fasteners extending through the apertures and plates to clamp the inner surfaces of the plates against the ends of the tubes.

7. In a directive antenna having:

(a) a radiator cavity having a pair of plane parallel conducting walls and a rear wall extending perpendicularly to, and connecting, said parallel walls, the rear wall being in the general form of a parabola having focus in the front portion of the cavity, the front portion of the cavity being substantially open and forming the radiator mouth, and

(b) a feed in the cavity at the focus of the parabolic back wall comprising a substantially omnidirectional radiating probe element and a reflector conductor adjacently forward thereof to impede direct external radiation from the feed in the directly forward direction, the improved construction having:

(c) conductors dispersed along the mouth and connecting the parallel walls and of a spacing and shape producing substantially complete shielding of the exterior from direct radiations from the feed in the large-angle forward directions in which the reflecting means is least effective while having substantially no effect on the parallel forward transmissions from the parabolic wall.

8. The antenna of claim 7 having a horn portion forward of the mouth of the cavity, the horn portion having side-webs shielded from the direct radiation from the feed by the conductors.

9. The antenna of claim 7 wherein the latter conductors are round pins of a diameter less than a quarter wavelength and of equal spacing between a half and one-and-one half wavelengths, and said conductors being in a straight line extending across the mouth of the cavity, the perpendicular distance from the feed to the line defined by the conductors being substantially less than a wavelength.

10. In a directive antenna having:

(a) a parabolic reflecting element, and

- (b) a feed at the focus of the parabolic element comprising a radiating conductor of essentially non-directional radiating characteristics in the plane perpendicular to its direction of orientation and a reflector conductor adjacently forward of the radiating element to reflect radiation directly from the element in the forward direction, the improved construction comprising:
- (c) conductors dispersed across the front of the parabolic element parallel with the radiating conductor and forward thereof and mutually spaced in the direction perpendicular to their extension and of a spacing and shape producing substantially complete shielding of direct radiations from the feed in the large-angle forward directions in which the reflecting means is least effective while having substantially no effect on the parallel forward transmissions from the parabolic element.
11. The antenna of claim 10 wherein the latter conductors are round with equal spacings of between one-half and one-and-one half wavelength, the diameter be-

ing substantially less than a quarter wavelength and the conductors being arranged in a straight line, the perpendicular distance from the feed to the line defined by the conductors being less than a wavelength.

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