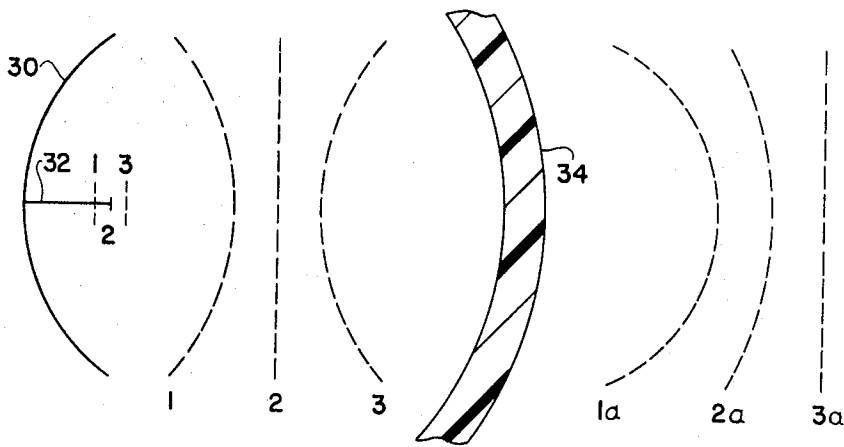
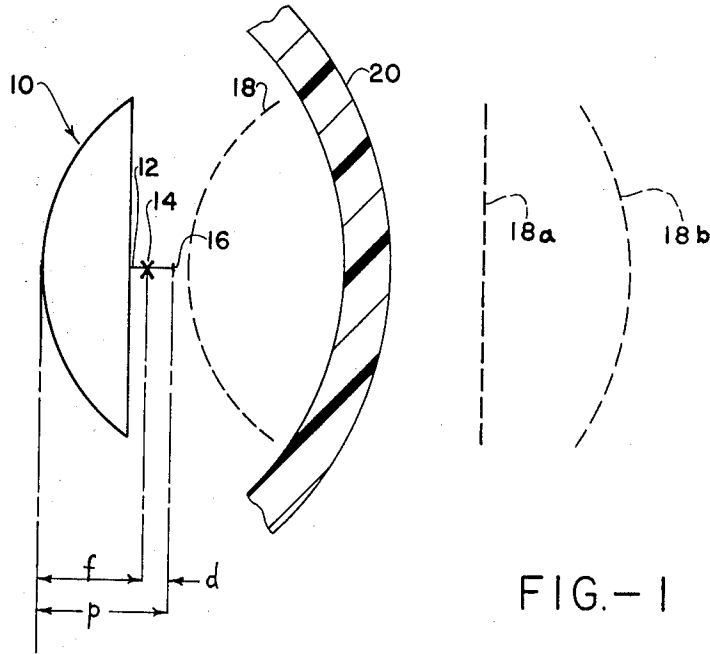




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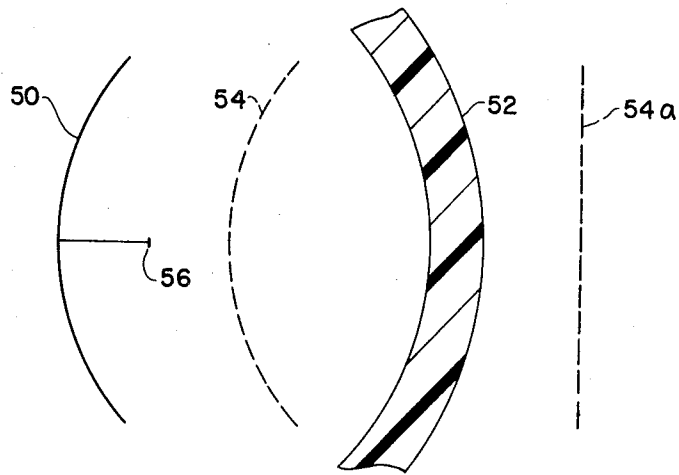


FIG.-3

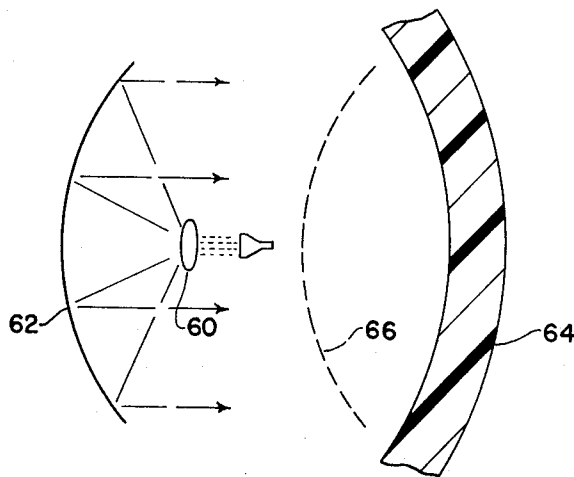


FIG.-4

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PHASE PATTERN CORRECTION FOR TRANSMITTER HAVING A RADOME

A monolithic foam construction for large spherical ground radomes has several desirable qualities over rival types. The radome does not require a structural frame of steel, aluminum, or even dielectric ribs that provide degrading blockage, reflection, and diffraction effects. The RF loss through the low density foam is small or nominal at the frequencies of use. Beam bending or boresight error through a radome of this kind can be maintained very low.

This kind of radome is, however, now without some of its own particular problems. When a large radome of reasonable foam thickness is placed over an antenna, edge rays of the antenna will impinge on the radome surface at a much higher angle of incidence than central rays. This causes a differential phase delay across the area of the aperture for rays emanating through the radome. This phase taper can, for high frequency radar antenna, and through thick foam sections become quite large and result in serious loss of gain and considerable distortion of the radiated antenna pattern.

The general object of the invention is to overcome this phase problem in radomes by the provision of a simple, yet highly efficient solution to the problem.

A further object of the invention is to provide for a phase correction in a radiating antenna associated with the radome by mechanically controlling the wave front of the emanating electromagnetic waves so they approach the radome out of phase and thus leave the radome in phase.

The aforesaid objects of the invention and other objects which will become apparent as the description proceeds are achieved in a radome phase pattern correction system which comprises a parabolic antenna reflector, a feed horn mounted to the center of the reflector and extending substantially perpendicularly from the surface thereof, and a radome surrounding and protecting the antenna and horn which is characterized by mechanically having the feed horn positioned slightly away from the focal point of the reflector or controlling the curvature of the reflector, or utilizing some type of lens, whereby the wave form propagated from the reflector is substantially parabolically shaped itself to an extent such that passage of the wave form through the radome emerges having a wave front of the desired characteristics.

For a better understanding of the invention reference should be had to the accompanying drawings wherein:

FIG. 1 is a schematic illustration of a reflector and radome incorporating the principles of the invention;

FIG. 2 is a schematic illustration showing the effect on the emanating electromagnetic wave forms dependent upon the position of the radiating end of the horn with respect to the focal point of the reflector; and

FIG. 3 illustrates schematically the mechanical reconstruction of the reflection to achieve the objects of the invention; and

FIG. 4 illustrates a modified embodiment of the invention which utilizes a lens to obtain the wave form correction prior to impingement on the radome.

The solution to the problem of phase error in a radome set forth by this invention relates to a parabolic reflector with a point-source feed. In essence, the system involves three separate mechanical embodiments to obtain wave form correction prior to impingement onto the radome. This provides a phase advance similar in magnitude and opposite in sign to the phase delay caused by the radome for the rays radiating through the radome. This correction can, in many cases, improve the antenna radiation pattern to almost the same characteristics as the original free space pattern.

With reference to the form of the invention illustrated in FIG. 1 of the drawings, the numeral 10 indicates generally a parabolic reflector having a feed horn 12 centrally positioned therein and extending substantially perpendicularly from such center position surface. The normal focal point of reflector 10 is at point 14 marked by the X, but to achieve the purposes of the invention, the actual radiating point of the horn is at the end 16. In essence, the radiation of electromagnetic energy

directed back towards reflector 10 from the radiating end 16 of the feed horn 12 will produce an electromagnetic wave form emanating in a wavefront looking like dotted line 18. The wave form 18 impinges against a radome 20, which normally is made from a thick, low density foam, all in a manner well understood by those skilled in the art. The waveform 18, upon passing through the radome 20, is phase corrected nonlinearly along its length depending upon increasing divergence from a normal entrance into the radome 20 so that in effect the wave front 18 flattens out to form a straight or planar front indicated by dotted front 18a. In the normal radiation, which would occur from focal point 14, the wave front transmitted would be planar, and would be bent back to the reverse paraboloid shape 18b because of the phase delay present in the radome 20.

The phase delay increases in magnitude for rays further away from the center of the reflector 10. By moving the feed point 16 away from the focal point 14, the rays traveling from the feed to points on the dish further from its centerline are provided an increasing phase advance. This effect is opposite to but not necessarily equal to the phase delay caused by the radome 20.

The calculation of the distance of displacement making a total feed distance from the reflector 10 equal to distance p , as contrasted to the focal distance f , is critical to the proper operation of the invention. Calculation of this distance reveals that the following relationship should be present:

$$\Delta \Phi_{(F.D.)} = (p-f) - (p-f) \cos \Psi \\ = (p-f)(1 - \cos \Psi)$$

where $\Delta \Phi_{(F.D.)}$ = phase advance for the i th ray due to the feed displacement

f = distance from the vertex to the focal point

p = distance from the vertex to the new feed point; and

Ψ = angle from the antenna centerline to the i th ray from the feed.

Thus, for example where a 4-foot diameter parabolic reflector with a conical feed horn having a focal point 14 inches from the vertex of the parabola, an increase in distance of 0.085 inches would be optimum with an antenna feed horn aperture of 0.72 inches in diameter with about -12.5 and -14.5 decibels of energy at the edge of the reflector in the H-plane and E-planes, respectively.

FIG. 2 illustrates the theory of this embodiment of the invention in more readily understood detail. Specifically, a parabolic reflector 30 having a feed horn 32 is mounted and surrounded by a radome 34. The radiating end of the horn is indicated at positions 1, 2, and 3, with position 2 being the optimum normal focal point of the reflector 30. Radiation of the feed horn 32 with the radiating element at point 1 will result in a phase front indicated by dotted line 1 in front of the radome 34. Similarly, the wave fronts for positions 2 and 3 are illustrated by dotted lines. However, note the phase fronts indicated by dotted curves 1a, 2a, and 3a differ considerably because of the phase distortion present in the radome 34 upon the transmission of the waves therethrough. It should thus be understood that the optimum condition is for wave form 3a to be the resultant emanating wave form, and hence movement of the radiating point away from the reflector 30 according to the formula above to achieve proper defocusing provides the solution to the corrections required.

This correction or compensation technique is considered here particularly for a thick foam radome at a high microwave frequency. The compensation is, however, applicable to other frequencies, kinds, and sizes of radomes (including fiberglass laminate and honeycomb sandwich) and antenna where phase distortion of the RF signal transmitted through the radome, due to its contour and thickness, becomes a problem.

FIG. 3 illustrated a modified embodiment of the invention where the contour of a reflector 50 is conformed to provide a wave front indicated by dotted line 54, which upon passage through radome 52 take the flat planar shape indicated by dotted line 54a. Here the horn 56 is positioned at an optimum focus condition but the contour of the reflector 50 gives the

appropriate predetermined correction necessary to wavefront 54.

FIG. 4 illustrates another mechanical embodiment of the invention which is a lens 60 positioned between a reflector 62 and a radome 64 so as to provide the desired wavefront configuration indicated by dotted line 66. Preferably, the lens 60 will be made of a suitable material such as the same material as the radome 64 so as to delay those waves at the center for longer times than those waves nearer to the edges. This proportional delay will provide the wavefront 66, as indicated.

While in accordance with the patent statutes only the best known embodiment of the invention has been illustrated and described in detail, it is to be particularly understood that the invention is not limited thereto or thereby, but that the inventive scope is defined in the appended claims.

I claim:

1. Electromagnetic wave phase-changing apparatus comprising:
 - a. a radome;
 - b. first means transmitting electromagnetic wave energy; and
 - c. second means operatively mounted relative to the

radome and said first means to alter the wave phase to a nonplanar configuration to compensate for radome phase distortion and produce an exiting wave having a predetermined phase front, and characterized in that the second means comprises an antenna reflector, and the first means comprises an electromagnetic wave feed means operatively positioned out of the focal point of the reflector to alter the wave phase configuration to a nonplanar front, whereby the waveform exiting from the radome has a predetermined phase front.

2. A system according to claim 1 where the distance the feed horn should be from the reflector is determined by the formula

$$\Delta \Phi_{(F.D.)} = (p-f) 1 - \cos \Psi \text{ where}$$

$\Delta \Phi_{(F.D.)}$ = phase advance for the *i*th ray due to the feed horn displacement

f = distance from vertex to the focal point for the reflector

p = distance from the vertex to the new feed point

Ψ = angle from the antenna centerline to the *i*th ray from the feed.

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