

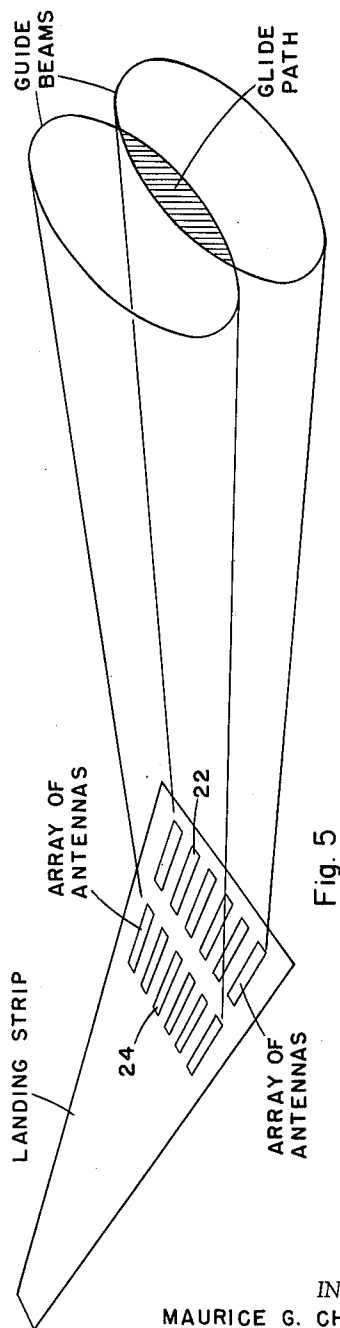
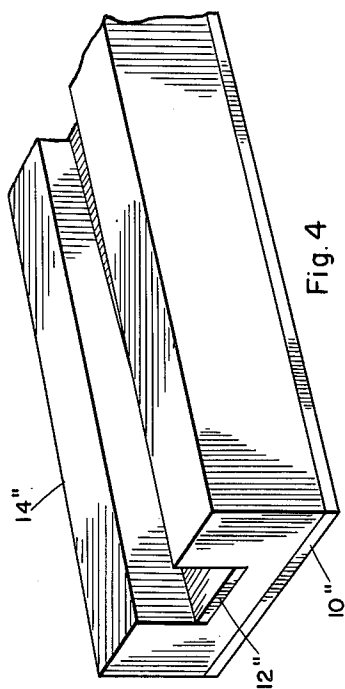
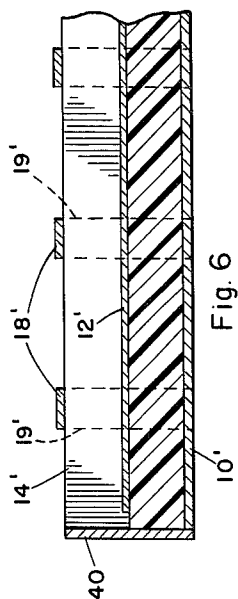
Dec. 21, 1965

M. G. CHATELAIN ETAL
VERTICALLY POLARIZED MICROSTRIP ANTENNA FOR
GLIDE PATH SYSTEM

3,225,351

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4 Sheets-Sheet 2



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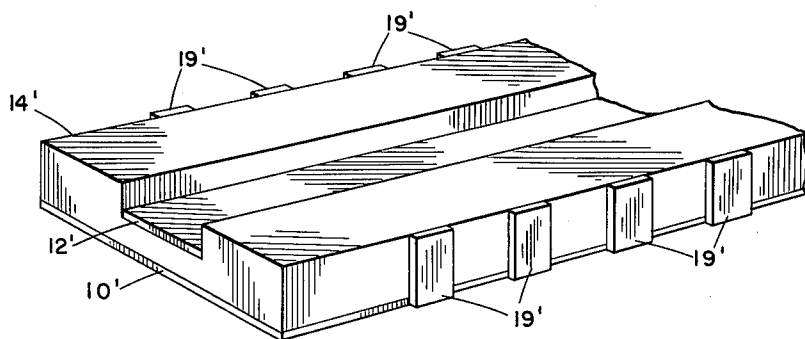


Fig. 7

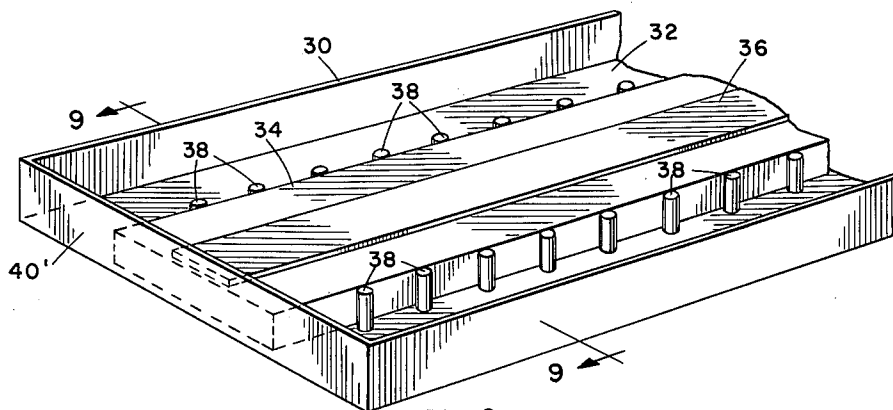


Fig. 8

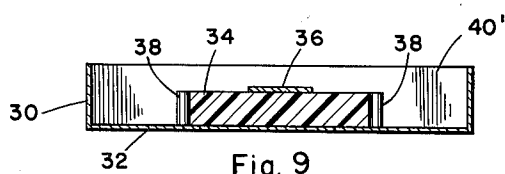


Fig. 9

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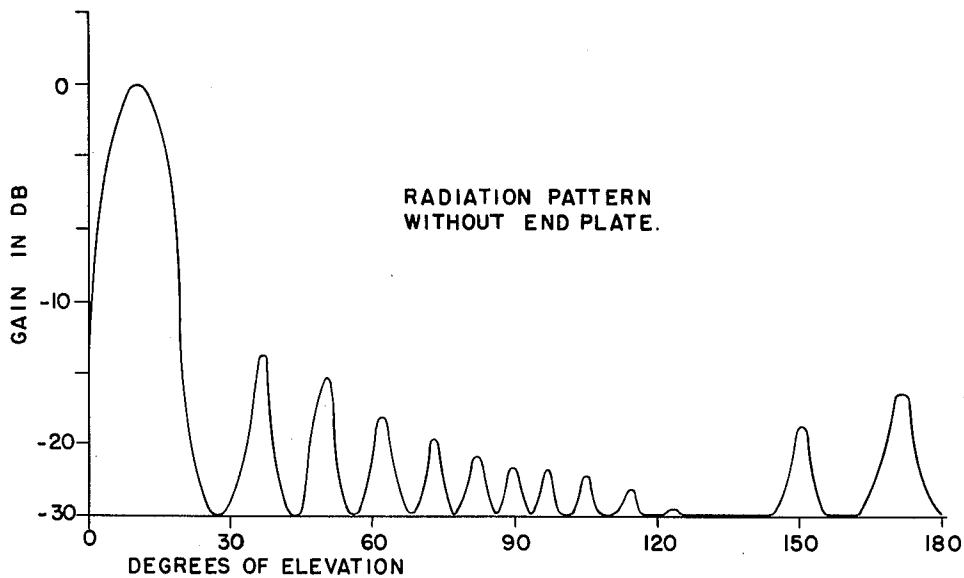


Fig. 10

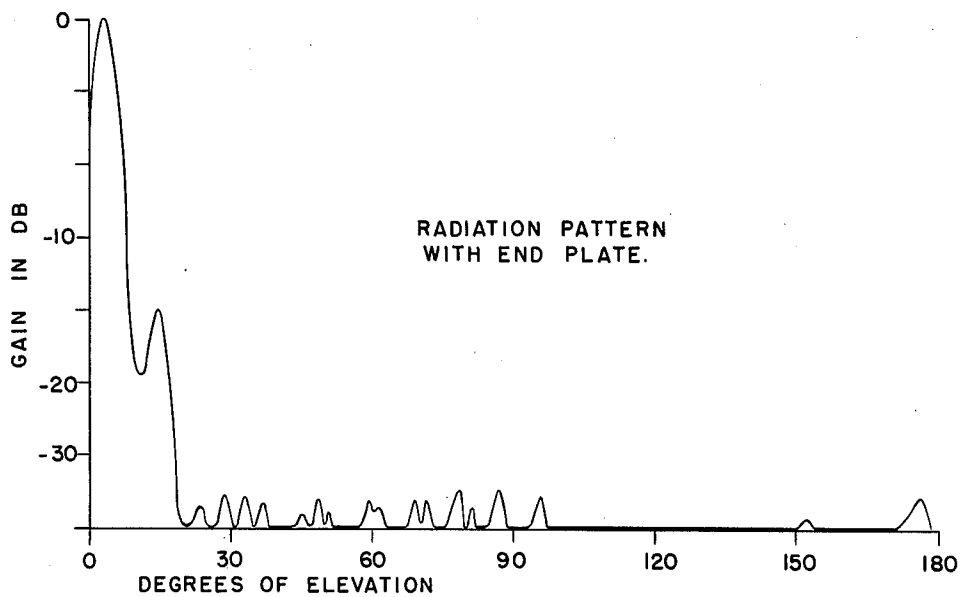


Fig. 11

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3,225,351

**VERTICALLY POLARIZED MICROSTRIP
ANTENNA FOR GLIDE PATH SYSTEM**

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9 Claims. (Cl. 343—731)

This invention relates to a glide path system for guiding aircraft to a landing strip and more particularly to a vertically polarized glide path antenna, and is a continuation-in-part of my application for Glide Path System, Serial No. 54,897, filed September 9, 1960, now abandoned.

There is an increasing need for aircraft to be able to make blind landings under conditions of poor visibility. This need has given rise to the concept of having a transmitting antenna at the airport to produce guide beams that are sensed by receivers in an aircraft, and are used by the pilot to guide the plane along a predetermined path to a landing strip.

Existing glide path systems utilize horizontal polarization of signals and the receivers carried in aircraft use a phase shift detection system to determine proper glide path. With horizontal polarization part of the beam is reflected from the ground and becomes reversed in phase, while the antennas are often located on elevated supports at the side of the aircraft runway, resulting in off center alignment and phasing errors in addition to being a collision hazard. Also, at the small angle of elevation of the glide path beam, the reflections from the ground interfere with the beam and may cause cancellation under certain conditions. In addition, horizontally polarized beams are rarely effective much below an angle of elevation of about 15 degrees, which is too steep for a good glide approach, particularly with high speed aircraft.

The primary object of this invention, therefore, is to provide an antenna which will transmit a signal in the form of a glide path beam at a very low angle of elevation, on the order of 3 degrees, and which is vertically polarized to avoid phase changes and errors.

Another object of this invention is to provide a glide path antenna which can be mounted flush with the surface of an aircraft landing strip without affecting the low beam angle.

Another object of this invention is to provide a glide path antenna having an endfire radiation in the direction of glide approach with virtually non-existent broadside or back radiation.

A further object of this invention is to provide a glide path antenna which is not unduly affected by changes in weather or ground conditions, such as snow, ice, or rain.

The final object of this invention is to provide a glide path antenna which is adaptable to a variety of sizes and frequencies, yet is simple in structure and easily fabricated.

The attainment of these and other objects will be realized from the following specification, in conjunction with the drawings, in which:

FIGURE 1 is an exploded cross section of a basic element of our invention;

FIGURE 2 is a fragmentary perspective view of one form of our invention;

FIGURE 3 depicts the operation of our invention;

FIGURE 4 is a fragmentary perspective view of another embodiment;

FIGURE 5 illustrates the use of several of our antennas in the form of arrays in an aircraft landing strip;

FIGURE 6 is a longitudinal sectional view of the structure of FIGURE 2 and incorporating an end plate;

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FIGURE 7 is a fragmentary perspective view of a modified form of the antenna;

FIGURE 8 is a fragmentary perspective view of a further modified form of the antenna;

FIGURE 9 is a sectional view taken on line 9—9 of FIGURE 8; and

FIGURES 10 and 11 are graphs of the radiation patterns of the antenna.

Broadly speaking, our invention contemplates a novel transmitting antenna that is flush mounted at the end of a landing strip of an airport, and the use of vertically polarized radio waves for forming guide beams, so that no disturbing reflections are produced.

FIGURE 1 shows an "exploded" view of a cross section of one basic embodiment of our antenna. As may be seen, it comprises a first conductive plate or ground plane 10, and a second conductive plate or microstrip 12 which is the driven element of the antenna and between which the radio energy is propagated into the plane of the paper. In order to maintain the desired spatial relation between ground plane 10 and microstrip 12, they are secured to a unitary lower member 14, of dielectric material, such as "Teflon-Fiberglas" or "Styrofoam," for example. These are commercially available insulating materials having the desired electrical and mechanical properties. Conductive elements 10 and 12 may take the form of conductive layers deposited onto or embedded in the dielectric, or may be actual plates attached to the material. Electrical connection is made by a coaxial cable, the center conductor 13 of which is connected to microstrip 12 and the shield or outer conductor 15 connected to ground plane 10, as indicated diagrammatically. Since our antenna is to be flush-mounted into the landing strip, we cover it with another unitary upper member 16, shown separated for clarity.

This may be formed of the same materials, or of any other material of sufficient strength and thickness to protect the antenna. Cover 16 has on its lower surface, a series of conductive radiators 18, whose function will be hereinafter described, said radiators being substantially of inverted U-shape and having side plates 19 which extend to make electrical contact with ground plane 10 when assembled. Members 14 and 16 may be molded, extruded, or formed in any desired manner that produces the desired cross section and length.

FIGURE 2 shows another embodiment of our invention, cover 16 having been omitted for clarity. Here ground plane 10' and microstrip 12' are parallel, and a series of spaced radiators 18', having side plates 19', are secured to dielectric member 14', which is illustrated as generally rectangular in cross section. Radiators 18' introduce periodic discontinuities that disturb the propagation of the radio energy along the strips. The result is that radio waves emerge from the antenna, and move upwards at a "radiation" angle. Since the landing aircraft should ideally approach the ground at an angle of about three degrees, the radiation angle of our antenna is preferably the same, so that the conical beam of radiated energy may be used as the guide beam.

Since the phase velocity along the line is the same as the phase velocity of the radiated wave, the radiation is "endfire" along the longitudinal axis of the antenna. However, each radiating element brings in a slight disturbance in the phase of the radiated wave, resulting in a slight displacement of the radiation angle. This phase difference can be either corrected or utilized to obtain the desired radiation angle.

The beamwidth of the radiated radio waves is a function of the number of radiating elements, decreasing when the number of elements is increased and when radiators 18 are close to microstrip 12, the effect of the disturbance

is markedly increased. Thus, a closer spacing between radiators 18 and microstrip 12 produces a stronger radiation.

Radiators 18 may take the forms of strips, zig-zags or sinuous configurations, or bands that extend approximately three quarters of the way around lower member 14, as in FIGURES 1 and 2. The radiators themselves may be on the lower surface of cover 16, as shown in FIGURE 1, on the lower structure 14, or in any other convenient place.

Since the radiation is produced by the periodically positioned radiators 18, this embodiment of our invention is designated as a "periodic radiator."

FIGURE 3 symbolically illustrates the operation of our invention. The length of the antenna is preferably an integral multiple of the wavelength of the radio energy. Thus in FIGURE 3, the antenna comprises a ground plane 10, a microstrip 12 and radiators 18 on dielectric member 14 which serves as the supporting structure. The protective cover has been omitted for clarity. The radiated beam takes a conical form that has a radiation angle 20 with respect to ground.

Another embodiment of our invention is shown in FIGURE 4. Here ground plane 10'' and microstrip 12'', mounted on dielectric member 14'', are not parallel, but are at an angle to each other. The progressively varying distance between the plates acts as a continuous disturbance. Thus, radiation takes place along the entire antenna, which we have therefore designated as a "continuous radiator." In this embodiment, the radiation angle is a function of the rate of change of the disturbance, or in other words, of the angle between conductor and ground plane. The beamwidth is a function of the length of the antenna, decreasing when the length is increased.

The modified form of the antenna illustrated in FIGURE 7 is basically similar to that of FIGURE 2, except that the bridge portions of the radiators are omitted, leaving only the side plates 19'.

A further modified structure illustrated in FIGURES 8 and 9 is constructed in a shallow metal tray 30, the bottom of which serves as a ground plane 32. Extending longitudinally along the center of the tray 30 is a dielectric member 34 which supports a microstrip 36. Along both sides of member 34 and extending upwardly from ground plane 32 are spaced cylindrical monopoles 38 arranged in opposed pairs, the monopoles being the equivalent of previously described side plates 19 and 19'. This particular structure is especially suitable for installation in a runway surface since the tray 30 serves as a combined mounting and protective element.

Each of the structures illustrated can be mounted in the surface of a runway or landing strip and covered by a protective slab or layer of dielectric material, the thickness of which depends on the type of material and the degree of protection required.

In vertically polarized antennas of the type described, the magnetic vector is in a horizontal plane. As long as the horizontal dimension of the antenna is greater than one-half wavelength, the vertical dimension may be very small, the antenna behaving in the manner of a flat waveguide wherein the vertical dimension determines impedance. It has been found that the vertical dimension may be as small as one-hundredth of the wavelength when the radiation pattern is not critical. For glide path application, however, where the radiation pattern is important, a vertical dimension of one-twentieth of a wavelength has been found to be practical. Thus for a frequency of 332 megacycles, the complete antenna could be approximately 5 centimeters deep and 50 centimeters wide, the length being variable according to the number of radiators used.

In this type of antenna, wherein linear endfire arrays of radiator elements are coupled to a microstrip line, the radiators are fed individually and continuously from the microstrip rather than being merely parasitic, as in some

types of endfire arrays. The antenna is preferably several wavelengths long, six wavelengths being a practical size, and, to obtain most effective coupling, the phase velocity in the endfire array must be the same as that in the microstrip. This is controlled by proper selection of dielectric material and the dimension and spacing of the radiators. Since each radiator receives only a portion of the energy in the microstrip line, there is usually some residual energy and this is normally absorbed by a load.

To avoid unnecessary energy loss the residual energy can be reflected back into the line with such a phase relationship that it radiates at the same phase and same angle as the main lobe. This is accomplished by means of a vertically disposed end plate 40 positioned in front of the microstrip as in FIGURES 3 and 6, the actual spacing being dependent on the particular antenna and the frequency involved. A back plate 42 may also be fitted at the rear of the microstrip line, as in FIGURE 3. In the configuration of FIGURES 8 and 9, the end wall of tray 30 conveniently acts as an end plate 40' in the same manner. The feedback of energy into the line in this manner also reduces back and side lobes, resulting in a narrower beamwidth and a lower beam angle.

FIGURE 10 illustrates the radiation pattern of an antenna of the type described, as measured in actual tests, without an end plate. The main lobe is at approximately 9 degrees elevation and substantial back and side lobes are present, but the radiation pattern is still satisfactory for glide path use. The pattern is for a specific antenna and could be improved somewhat by different dimensioning and proportioning of the antenna structure. However, by the addition of an end plate to this same antenna to reflect energy back into the line with the proper phase relationship, the radiation pattern of FIGURE 11 was obtained. In this pattern the main lobe has an elevation angle of 3 degrees, ideal for glide path use, and side and back lobes are virtually non-existent.

While it is theoretically possible for an aircraft to find the guide beam and "ride" it down to the landing strip, it is preferred that the guide beam cover a large area, and incorporate a sharply defined glide path therein. This is accomplished by using two of our antennas so that their conical beams emerge one above the other. Thus the axes of the beams are parallel to each other, and form the same radiation angle with respect to the ground, but the lower edge of the upper beam overlaps the upper edge of the lower beam. The overlap area takes the form of a horizontal double-convex configuration that forms a sharply defined glide path that slopes up from the ground at a predetermined angle of about three degrees. By the use of suitably circuitry, the glide path may be devoid of signals, or may contain especially strong signals. This beam arrangement may be obtained by placing two of our antennas one behind the other, as in FIGURE 5, wherein a first array 22 of antennas is flush-mounted in the landing strip so they are parallel. Their coating effect produces a long narrow beam at the common radiation angle. A second similar array 24, is placed behind the first, so that the second array also produces a long narrow beam at the same radiation angle. The two beams overlap as described, to produce the desired glide path.

Our invention has the advantage that it does not make obsolete existing receiving equipment already installed in aircraft but merely requires an antenna for receiving the vertically polarized radio waves. During the transition period while both vertical and horizontally polarized radio waves will be used, it would only be necessary to equip the aircraft with either a second receiving antenna for receiving vertically polarized signals, or with a type of antenna that is sensitive to both horizontal and vertical polarizations. Another expedient would be to reserve a particular frequency for vertically polarized beams, and to have the receiver switched to this antenna when approaching a landing strip using vertical polarization.

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In summary, the antenna is compact, extremely simple in structure and economical to manufacture by existing techniques. The endfire configuration produces a low angle, narrow beam, even with the antenna slightly below the ground surface. Full use of available energy is made by feeding back residual energy into the line to reinforce the desired portion of the radiation pattern, while subduing the unwanted radiation. The antenna may be readily flush-mounted, and is not affected by environmental effects such as contact with aircraft wheels during landing, takeoff, or taxiing; jet blast; dirt, oil, or rubber deposits; or weather conditions such as rain, snow or ice.

It is understood that minor variation from the form of the invention disclosed herein may be made without departing from the spirit and scope of the invention, and that the specification and drawing are to be considered as merely illustrative rather than limiting.

We claim:

1. A vertically polarized glide path antenna, comprising:

an elongated, conductive ground plane;
an elongated, conductive, driven microstrip element vertically spaced from said ground plane, whereby radio frequency energy may be transmitted longitudinally therethrough;

a pair of endfire arrays of longitudinally spaced radiator elements spaced on opposite sides of said microstrip element;

said radiator elements causing periodic disturbances in the passage of radio frequency energy to produce a vertically polarized endfire radiation from the antenna.

2. An antenna according to claim 1 wherein said radiator elements are substantially vertical flat plates aligned in opposed pairs.

3. An antenna according to claim 1 wherein said radiator elements are substantially vertical cylindrical monopoles arranged in opposed pairs.

4. A vertically polarized glide path antenna, comprising:

an elongated, conductive ground plane;
an elongated, conductive, driven microstrip element vertically spaced from said ground plane, whereby radio frequency energy may be transmitted longitudinally therethrough;

a pair of endfire arrays of longitudinally spaced radiator elements spaced on opposite sides of said microstrip element;

said radiator elements causing periodic disturbances in the passage of radio frequency energy to produce a vertically polarized endfire radiation from the antenna;

and an end plate spaced from at least one end of said microstrip element to reflect radio frequency energy back to the antenna in such a phase relationship as to reinforce the primary endfire radiation.

5. A vertically polarized glide path antenna, comprising:

an elongated, conductive ground plane;
a dielectric member above and attached to said ground plane;

an elongated, conductive, driven microstrip element on said dielectric member and being vertically spaced from said ground plane, whereby radio frequency energy may be transmitted longitudinally through the microstrip element;

a plurality of radiator elements longitudinally spaced along said dielectric member and being spaced on opposite sides of said microstrip element;

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said radiator elements causing periodic disturbances in the passage of radio frequency energy to produce a vertically polarized endfire radiation from the antenna.

6. An antenna according to claim 5 wherein said dielectric member is substantially wider than said microstrip element, and said radiator elements are attached to the sides of the dielectric member.

7. An antenna according to claim 5 and including a dielectric protective cover mounted above and covering said microstrip element and said radiator elements.

8. A vertically polarized glide path antenna, comprising:

a shallow elongated conductive tray, the lower portion of said tray constituting a ground plane;

an elongated, conductive, driven microstrip element parallel to and spaced from said ground plane, whereby radio frequency energy may be transmitted longitudinally through the microstrip element;

a pair of endfire arrays of upright radiator elements spaced longitudinally along opposite sides of and horizontally spaced from said microstrip element and being connected to said ground plane;

said radiator elements causing periodic disturbances in the radio frequency energy to produce a vertically polarized endfire radiation from the antenna;

and said tray having an upright end wall spaced from the end of said microstrip element to reflect radio frequency energy back to the antenna in such a phase relationship as to reinforce the primary endfire radiation.

9. The combination comprising:

a lower structure including a first conductive plate having a longitudinal axis and

a second conductive plate having a longitudinal axis positioned in the same vertical plane as said other axis;

said plates being parallel to each other; means for maintaining said plates in a fixed spaced apart relation;

said means comprising a dielectric material;

a cover of dielectric material for said lower structure;

said lower structure being mounted with the plates parallel to the surface of the ground of a landing strip, whereby radio energy may be transmitted between said plates in one direction of said axis;

and radiation means for producing disturbances in the passage of said radio energy to cause said radio energy to be radiated from said plates in the form of vertically polarized radio waves;

said means comprising conductive bands of material positioned on the lower surface of said cover transverse to the direction of passage of said radio energy, and extending partially around said lower structure.

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