

May 28, 1957

W. SICHAK
ANTENNA SYSTEMS

2,794,185

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3 Sheets-Sheet 1

Fig. 1

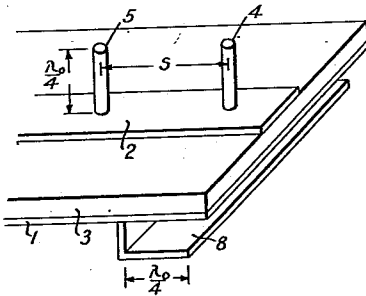


Fig. 2

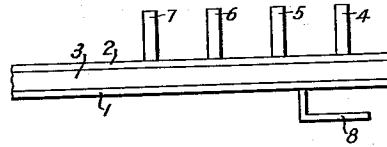
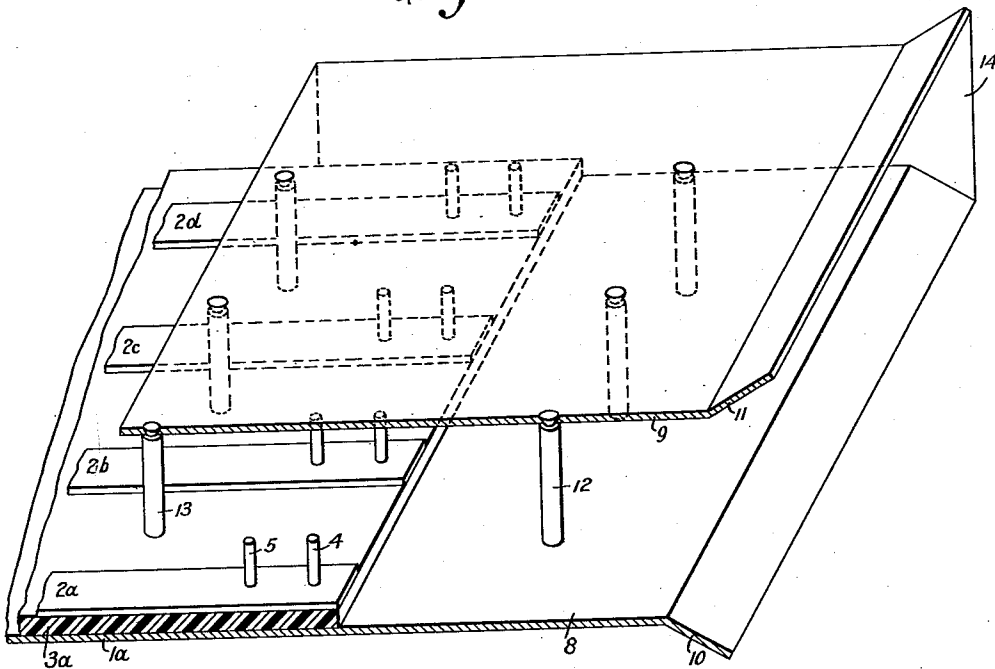


Fig. 3



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Fig. 4

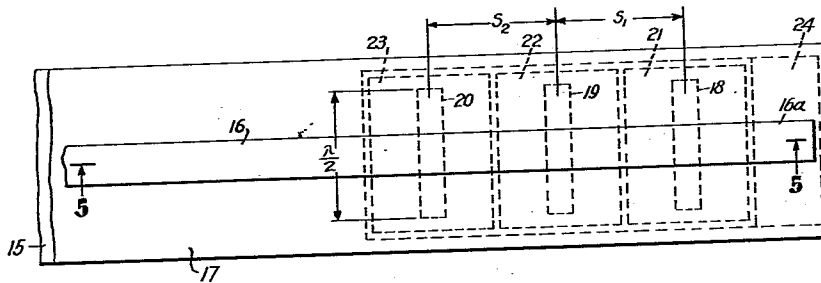


Fig. 5

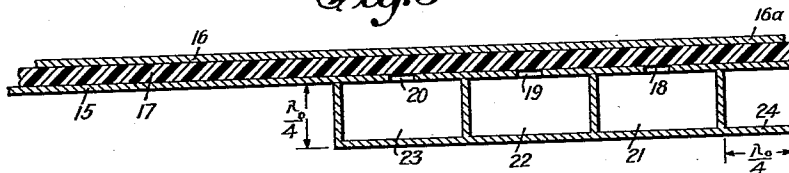
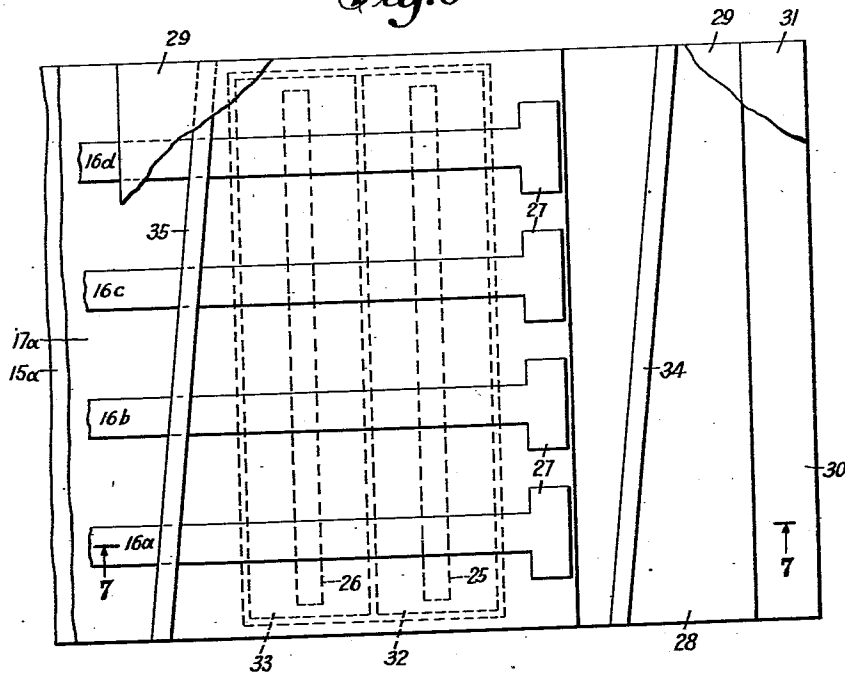


Fig. 6



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Fig. 7

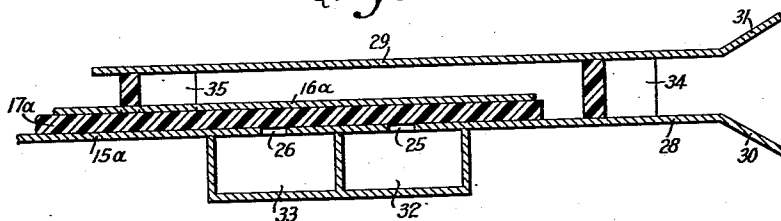


Fig. 8

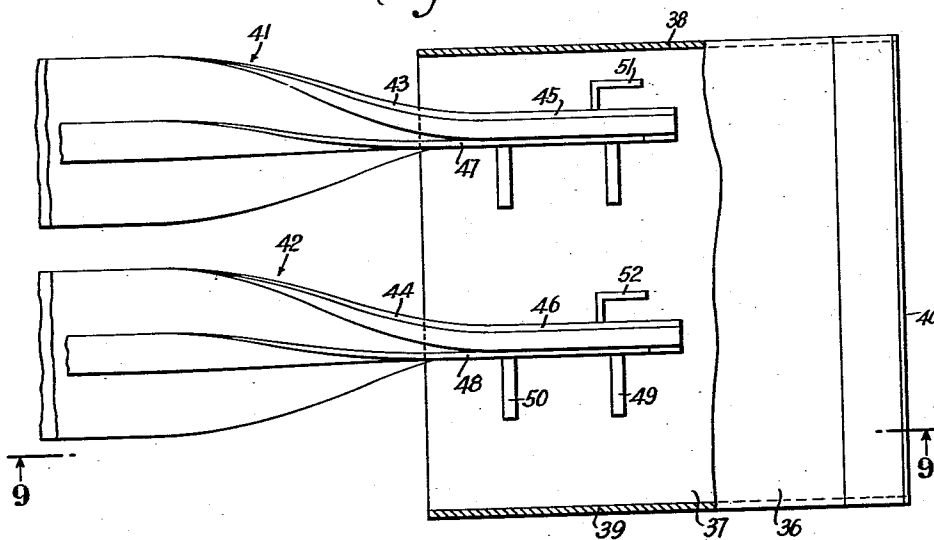
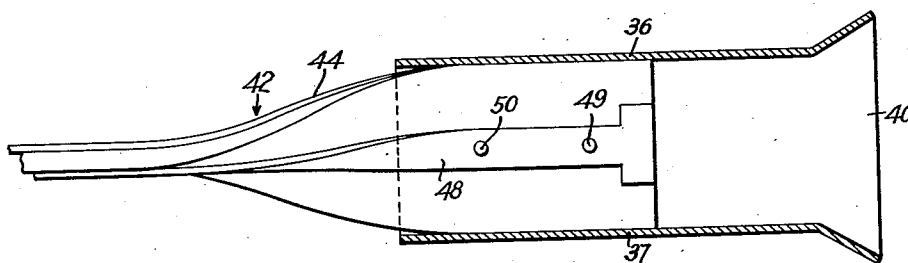


Fig. 9



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ANTENNA SYSTEMS

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Application January 6, 1953, Serial No. 329,775

12 Claims. (Cl. 343—786)

This invention relates to antenna systems and more particularly to microwave directional antennas and linear arrays of relatively high resolution.

One of the objects of this invention is to provide a simplified end-fire type of microwave antenna.

Another object is to provide a microwave antenna array system of high resolution, that is, one capable of an exceptionally narrow beamwidth, and which may be either vertically or horizontally polarized.

Still another object of the invention is the provision of a novel transducer arrangement for use between a line-above-ground type of transmission line and a waveguide of the parallel conductor form commonly associated with horn radiators.

A feature of the invention is the use of a line-above-ground type of transmission line as a feeder or receiver for an antenna radiator or other radiator structures arranged in combination with the conductors of such a line. Another feature comprises the formation of an antenna array in conjunction with the conductors of the line-above-ground type of transmission line by mounting two or more dipoles in proper spaced relation along and in coupled relation to the so called "line" conductor. Another radiator form of this invention comprises the provision of slots in the "ground" or planar conductor of the transmission line with proper spacing therebetween and provided with traps to effect a desired directivity of radiation.

Still another feature of the invention is the addition of a cover plate to form in conjunction with one of the conductors of the transmission line a horn type of radiator structure. In such arrangements the dipoles or slots, as the case may be, comprise a transducer coupling between the conductors of the transmission line and the parallel conductor plates forming the horn configuration.

The above-mentioned and other features and objects of this invention and the manner of attaining them will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a view in perspective of a combination line-above-ground transmission line and dipole antenna arrangement for end-fire radiation;

Fig. 2 is a view in side elevation showing the form of antenna illustrated in Fig. 1 with four dipoles;

Fig. 3 is a view in perspective with parts broken away illustrating a parallel plate, horn-dipole array for producing a vertically polarized radiation beam of high resolution;

Fig. 4 is a view in plan of a combination line-above-ground type of transmission line and slot array for producing end-fire radiation;

Fig. 5 is a longitudinal sectional view taken along line 5—5 of Fig. 4;

Fig. 6 shows in plan view, with the cover plate removed, of a slot radiator array which with the cover plate in position comprises a horn radiator system of high resolution;

Fig. 7 is a longitudinal sectional view taken substantially

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along line 7—7 of Fig. 6 showing the cover plate in position.

Fig. 8 is a plan view of an array similar to the embodiment shown in Fig. 3 for producing a horizontally polarized beam; and

Fig. 9 is a cross-sectional view taken along line 9—9 of Fig. 8.

Referring to Fig. 1, the line-above-ground type of transmission line employed as the feeder for the antenna array comprises a first or planar conductor 1, and a second or line conductor 2 spaced apart by a thin strip or layer of dielectric 3. The conductor may be at ground or any other desired reference potential. The two conductors 1 and 2 are preferably of flat strip form, the planar conductor being wider than the line conductor so that propagation of microwave energy therealong is in a TEM mode. The line conductor however may be round or otherwise shaped if be desired. The parameters of importance are the width of the line conductor 2 and the thickness of the spacing dielectric 3. The dielectric material should be of high dielectric quality, materials experimented with are polystyrene, polyethylene, "Teflon," fiberglass and combinations thereof. Quartz may also be used. The transmission line may be made up of strip material or made in accordance with printed circuit technique. For additional information regarding the characteristics of this form of transmission line reference may be had to the copending applications of D. D. Grieg and H. F. Englemann, Serial No. 227,896, filed May 23, 1951, and M. Arditi and P. Parzen, Serial No. 286,764, filed May 8, 1952.

To produce an end-fire radiation, I find that two or more dipoles, such as indicated at 4, 5, 6, and 7, Figs. 1 and 2, may be mounted in spaced relation along the line conductor. The length of the dipoles is approximately a quarter air wavelength and the spacing between adjacent dipoles is approximately a half air wavelength or preferably as expressed by the following formula:

$$S = \frac{1}{2 \left(\frac{1}{\lambda_0} + \frac{1}{\lambda_g} \right)}$$

where λ_0 is the air wavelength and λ_g is the guide wavelength of the line. For two dipoles, such as 4 and 5, this spacing relationship provides for a minimum back lobe. Where more than two such dipoles are employed, as indicated by the additional dipoles 6 and 7 in Fig. 2, the forward pattern can be improved in resolution together with the cancellation of radiation in directions other than the forward direction. To obtain desired cancellations of such radiations in directions other than the forward direction, the spacing between dipoles 5 and 6 and 6 and 7 may have to be varied slightly from the value of the above mentioned formula.

In order to eliminate the presence of currents on the bottom side of the planar conductor 1, a quarter wave trap, as indicated at 8, Figs. 1 and 2, may be provided adjacent the end of the conductor 1.

Where a lateral linear array of dipoles is desired, the planar conductor 1 may be extended laterally as indicated by conductor 1a in Fig. 3 and with additional line conductors suitably spaced thereacross depending upon the number of radiators desired. As shown in Fig. 3, four such line conductor strips are shown as indicated at 2a, 2b, 2c and 2d. The line conductors are spaced above the planar conductor 1a by a thin strip of dielectric 3a. The planar conductor 1a is extended forward beyond the ends of the line conductors and forms a lower plate conductor of a parallel plate transmission line which is here shown terminated into a flared horn-like radiator structure. The parallel plates comprise extension 8 of planar conductor 1a and a plate 9 disposed in spaced parallel relation above the line conductors. The forward

ends of these two plates are flared as indicated by the angular portions 10 and 11 which may be at any desired angle depending upon the radiation pattern desired. The two plates may be supported in spaced relation by forward and rearward spacing posts 12 and 13, respectively. The forward posts are preferably of dielectric material and are located out of alignment with respect to the line conductors 2a—2d. The rear post 13 may be of either dielectric material or conductive material, whichever is desired, these posts also being located in the space between adjacent line conductors. In the place of posts 12 and 13 or in conjunction therewith, side walls of either dielectric or conductive material may be provided at the lateral edges of the plates 8 and 9 as indicated at 14. Where the array is wide the walls 14 may be insufficient to maintain the plates 8 and 9 truly parallel throughout the width of the array and for that reason it may be preferable, particularly where the plates are of thin material, to provide intermediate supporting posts such as indicated at 12 and 13. Insofar as the radiation pattern is concerned, the walls 14 may be dispensed with. Where walls 14 are desired for structural or other reasons, the spacing between the wall 14 and the adjacent line conductor should be approximately one quarter wavelength. The spacing of adjacent line conductors should be about, or slightly less than, one guide wavelength apart. The spacing of the conductor plates 8 and 9 should be slightly less than a half guide wavelength.

The dipoles 4 and 5 of each of the line conductors provides a transducer coupling between the transmission line, formed by planar conductor 1a and line conductor 2, and the parallel plate guides 8, 9.

The plural transmission lines feeding the array of dipoles may be fed from a single main transmission line by means of a suitable power divider network between such single line and the plural lines 2a—2d. Such a feeder construction is disclosed in my copending application Serial No. 332,424, filed January 21, 1953, to which reference may be had.

Referring to Figs. 4 and 5, another end-fire antenna system is shown also comprising a planar conductor 15, a line conductor 16 and a strip of spacing dielectric 17. In this embodiment the planar conductor 15 is provided with an array of radiator slots 18, 19 and 20, it being understood, of course, that such array may comprise two or more slots depending on the beam pattern desired. Each of these slots are approximately a half guide wavelength in length and the spacing S1 and S2 correspond substantially with the formula given for spacing S in connection with the embodiment illustrated in Fig. 1. To prevent radiation from the bottom side of the planar conductor 15, closed traps 21, 22, and 23 are provided each being of a quarter air wavelength in depth. Also to eliminate the presence of currents on the underside of the planar conductor 15 a quarter air wavelength trap 24 is provided adjacent the end of the antenna. To provide for impedance matching, the line conductor may be extended as a "stub" beyond the foremost slot 18 as indicated by the portion 16a. The length of this stub may be varied in length or breadth or both to obtain optimum matching.

A lateral linear array of radiators may be provided employing the slot feature as a transducer. Such an array is illustrated in Figs. 6 and 7. The planar conductor is provided of desired width to accommodate the desired group of feeders and to provide the necessary slot length. As shown, the planar conductor 15a is provided with two slots 25 and 26 which extend transversely of the four feeders. The four feeders which comprise line conductors 16a—16d in conjunction with planar conductor 15a overlie the slots 25 and 26. Adjacent line conductors are spaced apart slightly less than a guide wavelength. The ends of the line conductors are terminated into stubs as indicated at 27 for impedance matching purposes. As in Fig. 3 the lateral array may be disposed between parallel

plates by extending the planar conductor 15a as indicated at 28 and placing a second plate conductor 29 in spaced relation above the line conductors 16a—16d. The forward ends of the plate conductors 28 and 29 are preferably flared at an angle as indicated at 30 and 31 to provide the desired beam pattern.

Underlying the planar conductor 15a are closed traps 32 and 33 to eliminate radiation from the bottom side of the planar conductor adjacent the slots 25 and 26. Where parallel plates for producing a horn radiator structure are provided, as illustrated in Figs. 3 and 7, there is no need for traps to eliminate currents on the bottom side of the planar conductor since the slot radiators or dipole radiators, as the case may be, provide a transducer coupling between the transmission line and the parallel plate waveguide.

The parallel plates 28 and 29, Figs. 6 and 7, may be supported in spaced relation by either posts or side plates or by strips of dielectric, whichever is desired. If a strip of dielectric is employed crosswise of the horn, as indicated at 34, it is preferable to angle the dielectric strip so that reflections therefrom are out of phase with respect to the transducer elements, that is, dipoles or slots.

In the antenna illustrations of Figs. 1 to 7, the polarization is vertical in accordance with the TEM mode of propagation for which the line-above-ground transmission system is most readily adapted. It follows that by severing the planar conductor between adjacent line-above-ground transmission portions, Fig. 3 and Figs. 6 and 7, and rotating these severed lines 90° about their longitudinal axes before entering the parallel plate waveguide, horizontal polarization of the radiated beam will be obtained.

Figs. 8 and 9 show an antenna array wherein the transducer elements are disposed to propagate microwave energy into the parallel plate waveguide so as to obtain horizontal polarization of the radiated beam. As shown, the slot array comprises parallel plates 36 and 37 having a spacing therebetween which may be between a half air wavelength and about one air wavelength. These plates as shown in this embodiment are provided with side walls 38 and 39 and a flared radiating horn-like structure 40. Two feeders are shown comprising line-above-ground transmission lines 41 and 42. While these two transmission lines may have a common planar conductor they are shown to be separate. The transmission lines before entering the parallel plate waveguide are revolved 90° as indicated at 43 and 44 so that the plane of the ground conductors 45 and 46 thereof are at right angles to the plates 36 and 37. Radiators are carried by the line conductors 47 and 48, as indicated at 49 and 50, to produce an end-fire propagation of the microwave energy. While the radiators 49 and 50 are shown to be dipoles, they may, of course, be slots formed in the ground conductors 45 and 46 similarly as illustrated in Figs. 4 and 5. Chokes as indicated at 51 and 52 are provided to minimize currents on the backsides of the ground conductors. While two feeders are shown in Figs. 8 and 9, it will be understood that one feeder may be employed or a much greater number than two, as may be desired.

While parallel plates have been shown in combination with a plurality of feeders and transducer elements such as dipoles and slots, it should be understood that such parallel plate or horn configuration is also contemplated for single feeder, end-fire antennas, whether or not the transducer comprises a strip line-dipole or a strip line-slot arrangement.

While I have described above the principles of my invention in connection with specific apparatus, it is to be clearly understood that this description is made by way of example only and not as a limitation to the scope of my invention as set forth in the objects thereof and in the accompanying claims.

I claim:

1. In combination, a planar conductor, a plate con-

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ductor disposed in spaced parallel relation to one portion of said planar conductor forming therewith a parallel plate waveguide for microwave energy, a line conductor narrower than said planar conductor disposed in spaced parallel relation to said planar conductor also forming a waveguide for microwave energy, and radiators disposed in energy coupling relation to said line-planar conductor waveguide adjacent the end of the line conductor thereof, the end portion of said line conductor including said radiators being disposed within the space between the conductor portions forming said planar-plate waveguide as a transducer for coupling of microwave energy from one to the other of said two waveguides.

2. The combination according to claim 1, wherein said radiators each comprises a dipole disposed normal to the longitudinal axis of the line conductor.

3. The combination according to claim 1, wherein the radiators each comprises portions of said planar conductor having a slot crosswise therein in symmetrical relation with respect to said line conductor, and closed wave traps on the side thereof opposite said line conductor.

4. In combination, a first plate conductor, a second plate conductor disposed in spaced parallel relation to said first plate conductor as a parallel plate waveguide for microwave energy, a transmission line comprising a planar conductor and a line conductor disposed in spaced parallel relation to form a waveguide for microwave energy, said transmission line extending into the space between said first and second plates with the planar conductor thereof disposed at right angles to said plates, and radiators disposed in energy coupling relation with respect to the portion of said line-planar conductor waveguide disposed between said plates whereby microwave energy propagated along said transmission line is coupled to said parallel plate waveguide in horizontally polarized relation.

5. In combination, a pair of plate conductors disposed in spaced parallel relation to comprise a waveguide for microwave energy, the forward edges of said plates comprising a horn radiator, a plurality of transmission lines comprising a common planar conductor and individual line conductors disposed in spaced parallel relation to said planar conductor, said planar conductor being connected to one of said plate conductors, the ends of said line conductors being extended into the space between said parallel plate conductors, and radiators disposed in energy coupling relation to said transmission lines for coaction therewith as transducers for flow of microwave energy between said plurality of transmission lines on the one hand and said parallel plate waveguide on the other hand.

6. The combination according to claim 5, wherein said radiators each comprises a dipole disposed normal to the longitudinal axis of the line conductor.

7. The combination according to claim 5, wherein the radiators each comprises portions of said planar conductor having a slot crosswise therein in symmetrical relation with respect to said line conductor, and closed wave traps on the side thereof opposite said line conductor.

8. The combination according to claim 5, wherein said pair of plate conductors are provided with a strip of dielectric material to maintain them in spaced parallel relation, said strip of dielectric being disposed at an acute angle to a plane passed containing the radiating edges of said plate conductors.

9. The combination according to claim 5, wherein said plate conductors are supported in spaced relation by posts disposed out of alignment with respect to the radiators of said transmission line.

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10. In combination, a pair of plate conductors disposed in spaced parallel relation to comprise a waveguide for microwave energy, the forward edges of said plates comprising a horn radiator, a plurality of transmission lines each comprising a planar conductor and a line conductor disposed in spaced parallel relation for propagation of microwave energy, the planar conductors of said transmission lines being disposed at right angles to said plate conductors, and radiators disposed in energy coupling relation to said transmission lines for coaction therewith as transducers for flow of microwave energy between said plurality of transmission lines on the one hand and said parallel plate waveguide on the other hand.

11. A directional antenna comprising a first conductor, a second conductor, dielectric means spacing said conductors in substantially parallel relation as a transmission line for transmission of microwave energy therealong, radiators in the form of dipoles carried by one of said conductors adjacent the end thereof and at points spaced apart longitudinally of said conductors approximately a half air wavelength apart, each of said dipoles being disposed normal to the longitudinal axis of one of said conductors, said first conductor comprising a planar conductor and the second conductor comprising a line conductor narrower in width than said planar conductor, with the dipoles being disposed in conductive relation to said line conductor, and a plate conductor disposed in spaced parallel relation to said planar conductor forming therewith a parallel plate waveguide, said dipole radiators being located within the confines of said plate waveguide as a transducer coupling between the transmission line comprising said first and second conductors and said parallel plate waveguide, the forward edges of said parallel plate waveguide comprising a horn radiator.

12. A directional antenna comprising a first conductor, a second conductor, dielectric means spacing said conductors in substantially parallel relation as a transmission line for transmission of microwave energy therealong, radiators carried by one of said conductors adjacent the end thereof and at points spaced apart longitudinally of said conductors approximately a half air wavelength apart, said first conductor comprising a planar conductor and the second conductor comprising a line conductor narrower in width than said planar conductor, the radiators each comprising portions of said planar conductor having a slot disposed crosswise thereof in symmetrical relation with respect to said line conductor, said planar conductor having a wave trap closure underlying said slots by a depth of substantially one quarter air wavelength, and a plate conductor disposed in spaced parallel relation to said planar conductor forming therewith a parallel plate waveguide, said slot radiators being located within the confines of said parallel plate waveguide as a transducer coupling between the transmission line comprising said first and second conductors and said parallel plate waveguide, the forward edges of said parallel plate waveguide comprising a horn radiator.

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