United States Patent

Lewis et al.

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[54] **RETROFLECTOR DIPOLE ANTENNA ARRAY AND METHOD OF MAKING**

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[52] **U.S. Cl.** **343/817,** 343/755, 343/821, 29/600

[51] **Int. Cl.**.....**H01q 21/00**

[58] **Field of Search**.....343/753, 754, 755, 853, 854, 343/817, 821; 29/600, 601

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Attorney—Duckworth and Hobby

[57] **ABSTRACT**

A method of making an antenna array and an antenna array apparatus of a low-cost wide angle retroreflector is provided in which a printed circuit board has a plurality of antenna elements etched on one side thereof and a ground plane on the other separated by dielectric material of a predetermined thickness. Baluns are attached through the printed circuit board to each antenna element and to the ground plane and transmission lines of equal length connect spaced pairs of antenna elements utilizing the balun and matching the transmission line to the antenna element.

11 Claims, 5 Drawing Figures

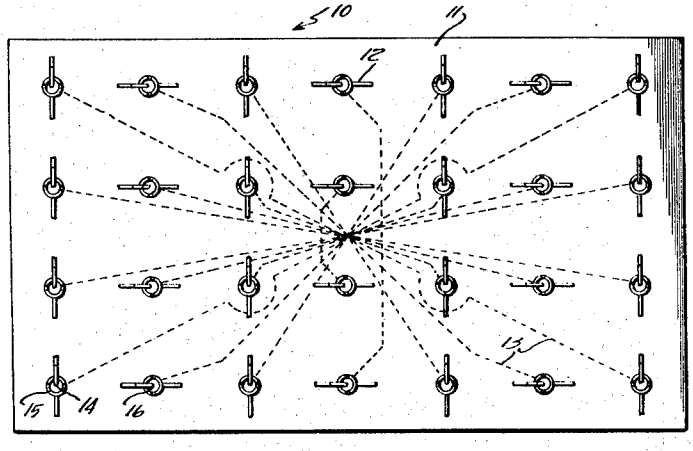


FIG. 1

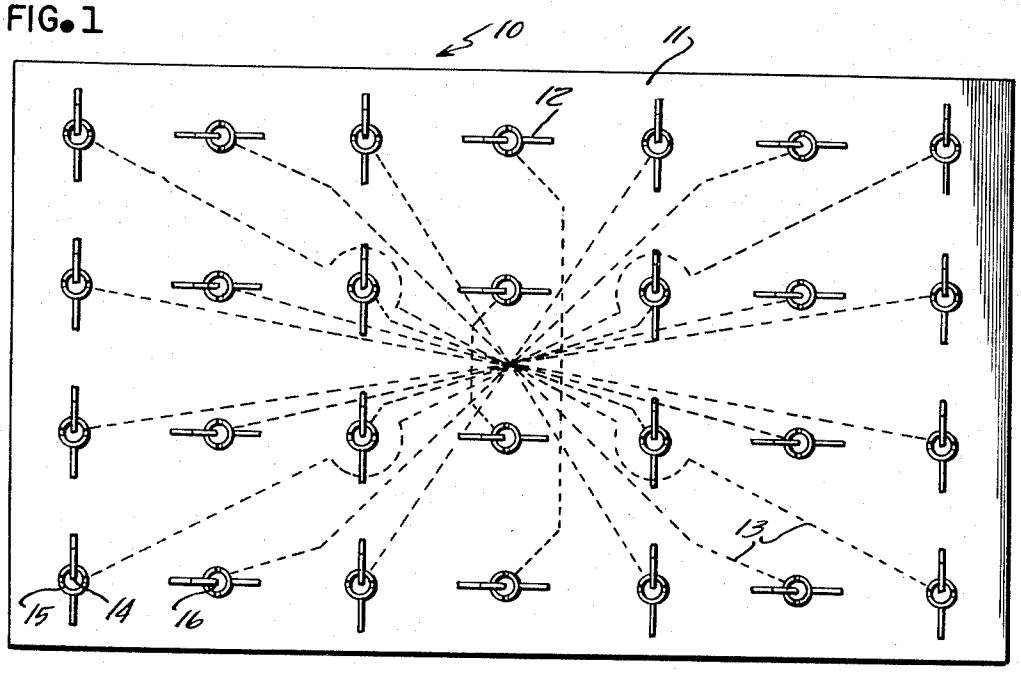


FIG. 2

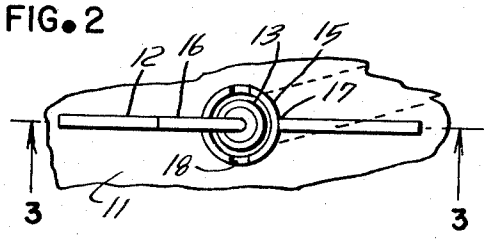


FIG. 3

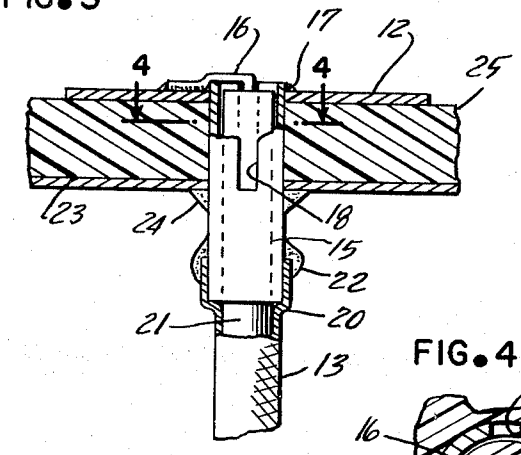


FIG. 4

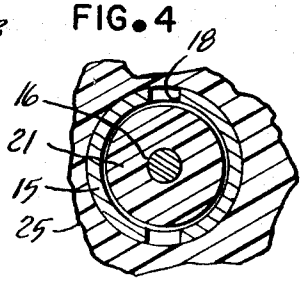
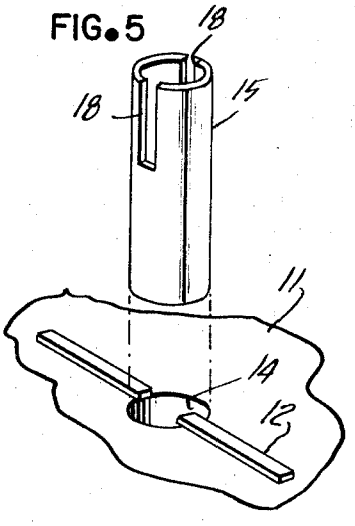


FIG. 5



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RETROFLECTOR DIPOLE ANTENNA ARRAY AND METHOD OF MAKING

BACKGROUND OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435, 42 U.S.C. 2457).

The present invention relates to a reflector composed of antenna elements so arranged and interconnected by transmission lines that when a signal is received on one set it is reradiated back in phase in the direction of incidence for all angles of incidence. Thus the present reflector is directed towards a replacement for dielectric reflectors such as Luneberg lenses and is a wide angle retroreflector utilizing individual dipoles tuned to a desired frequency.

In the past it has been suggested to interconnect antenna elements with transmission lines to provide a new type of dielectric reflector. However, this type of reflector has not been widely used because of the lack of development of an operational array based on the overall general principle. The present invention is directed toward an operational array of this type and a method of manufacturing such an array while assuring uniformity of impedance match and ease of producing the array at a high volume and at a low cost. There have of course been a great number of other types of reflectors utilized in the past.

SUMMARY OF THE INVENTION

The present invention relates to retroreflectors and specifically to a method for making an antenna array and the antenna array apparatus. The manufacturing method includes steps of etching a printed circuit board with a plurality of antenna elements on one side such as omnidirectional dipoles while having the other side of the printed circuit board utilized as a ground plane. The conductor material on the printed circuit board may be copper separated by dielectric material with the thickness of dielectric material dependent upon the frequency to which the array is to be used. A machined balun, which may be made of brass and produced in an automatic screw machine, is attached through holes drilled through the printed circuit board and one balun is attached to each antenna element and also to the ground plane. Transmission lines having the same electrical length are cut and each end is inserted in a pair of spaced antenna elements with a balun attached, and each transmission line is attached to the antenna element and to the balun to provide a wide angle retroreflector apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages of this invention will be apparent from a study of the written description and the drawings in which:

FIG. 1 shows a top plan view of a preferred embodiment of the present invention, with dash lines illustrating the inter-connection of the antenna element;

FIG. 2 shows a top sectional view of one antenna element;

FIG. 3 is a view taken along line 3—3 of FIG. 2;

FIG. 4 is a view taken along line 4—4 of FIG. 3; and

FIG. 5 shows an exploded view with a balun separated from the printed circuit board.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1 a wide angle retroreflector 10 can be seen having a printed circuit board 11 with dipoles 12 etched on one surface thereof, which dipoles are tuned to a desired frequency. Pairs of dipoles 12 are interconnected by transmission line 13 shown as dotted lines which run beneath the printed circuit board 11. All the transmission lines 13 will have the same electrical lengths and the opposite side of the printed circuit board 11 from the dipoles 12 will have a ground plane separated from the dipoles by dielectric material. The ground plane could for instance be the copper coating on the other side of the printed circuit 11 not having any material etched away. The thickness of the dielectric material will be dependent upon the frequency to which the array is to be used and a double copper-clad baseplate printed circuit board material is used having a predetermined thickness and dielectric constant. The printed circuit board 11 has holes 14 drilled in it at each dipole 12 with a balun 15 attached to each dipole 12 and extending below the printed circuit board 11. Each transmission line 13 is inserted through the drilled holes 14 and attached to the balun 15 with the center wire 16 being attached to one side of the dipole 12.

Balun in this application is defined as an acronym for "balanced-to-unbalanced" and includes matching an unbalanced transmission line such as a coaxial cable to a balanced line or system such as a two wire line in which the terminals have equal impedances to ground.

Turning now to FIG. 2, the dipole section of the printed circuit board 10 is illustrated in the portion of the circuit board 11 having a dipole 12 being connected such as by soldering a center line 16 of the coaxial line 13 which has been inserted up through the balun 15. It can also be seen that the dipole 12 is soldered at 17 to the balun 15, and that the balun 15 has a slotted area 18, as will be described in more detail.

FIG. 3 shows a sectional view more clearly illustrating the transmission line 13 having an outer conductive braid 20 enclosing a dielectric material such as teflon 21 and being attached to the balun 15 with solder at 22. The balun can be seen attached to the ground plate 23 at 24 and having a dielectric material 25 separated from the dipole antenna element 12. The center line conductor 16 is shown soldered to the dipole 12 and the dipole element 12 is also soldered to the balun 15.

It should be noted at this point that the braid 20 has a very close and tight fit on the balun 15 and that the slot 18 is slotted to a point just about even with the bottom surface of the ground plane 23 and that the center line conductor 16 forms a very tight and smooth bend to one dipole element 12, where it is soldered to the dipole element and to the balun 15. These techniques are mentioned since providing an efficient reflector requires many techniques which may seem small but which the sum total can produce desired results.

FIG. 4 is taken along line 4—4 and shows a balun 15 having slot 18 passing through insulating material 25 with the transmission line 13 having the teflon insulating material 21 passing through the balun 15 along with the center conductor 16 passing through the teflon material 21.

FIG. 5 shows an exploded view with balun 15 being removed from the printed circuit board 11 and having the slot 18 therein. This balun 15 is machined to the desired length as required by the mechanical and electrical characteristics of the cable used and is slotted so that the slot length is one-quarter wavelength of the frequency to which the array will be resonant. The slot length is critical in that the required length to provide an impedance match to the cable is necessary. This particular balun is especially desirable because it may be easily mass-produced by machinery such as an automatic screw machine which assures impedance matching due to the uniformity in the balun. The hole 14 is drilled so as to center on the two one-quarter wave dipoles 12.

The method for producing the present antenna ray requires that a printed circuit board clad on both sides with copper and having the desired thickness and dielectric constance be selected and cut to the proper size. The printed circuit board may then be coated with a material such as wax utilizing a process such as silk-screening so that the ground plane will not be touched by the acid in which the etching is performed, and the plane having the dipoles will etch away all the copper except the dipoles at the desired location. The board can then be drilled either singularly or preferably multiple drillings in a jig fixture for drilling in the center of each of the two one-quarter wave dipoles. The baluns may be made of a material such as a brass tubing which may be produced in an automatic screw machine, or the like, and having the desired length and slot for a one-quarter wavelength of the frequency the antenna wave is to have. The baluns are then inserted in the drilled holes in the printed circuit board and adjusted for depth and then soldered to the ground plane which soldering may desirably be performed in a flow soldering machine making connections with all the baluns and the ground plane. Next, the transmission lines or cables are selected in accordance with the desired frequency of operation and are cut to the desired length. Cables are then inserted into the baluns with the cable shield slipped over the end of the baluns and soldered at that point. The center conductor of the coaxial cable is then left sticking above the balun where it is bent over the appropriate dipole and soldered. As with the baluns, the center conductors may all be soldered in a flow soldering machine making the connection not only of the center conductor to the appropriate dipole, but also the balun to the dipole.

Applicant of course does not wish to be limited to any particular design or shape, but one embodiment of the present invention which has been successfully operated utilizes a dielectric printed circuit board having a thickness of 0.375 inch of Rexolite or a polystyrene with a copper coating on either side of 0.010 inch, having a balun which is 0.880 inch in length with a slot extending from one end into the balun 0.375 inch and having an inside diameter of 0.118 and an outside diameter of 0.15512. The coaxial cable may have a teflon inner insulator with the braid portion removed to expose a 0.630 inch length of teflon with the center conductor extending another 0.250 inch above the teflon. The coaxial cable will have a length of an even number of wavelengths.

It should be made clear at this point that while dipoles are commonly used in these arrays because of their omnidirectional characteristics which gives the array the broadest wide angle coverage, it is anticipated that the use of spirals, helixes, horns, and the like, could also be used as desired without departing from the spirit and scope of the present invention. It should also be noted that the configuration illustrated has a circular polarization but that horizontally polarized dipoles and other variations are anticipated as being within the scope of the present invention, and while a group of dipoles on a square planed surface has been illustrated, it should be realized that this is one example where the same principles could be constructed on a cylindrical, spherical, rectangular or circular surface, without departing from the scope of the invention. Accordingly this invention is not to be construed as limited to the particular forms disclosed herein since these are to be regarded as illustrative rather than restrictive.

We claim:

1. A method of making a retroreflector apparatus comprising the steps of:
   a. etching a printed circuit board with a plurality of antenna elements at predetermined locations on one side; said printed circuit board having a ground plane on a second side thereof;
   b. attaching a balun to each said antenna element on one side of said printed circuit board;
   c. attaching each said balun to said ground plane on said second side of said printed circuit board;
   d. cutting a plurality of transmission lines to the approximate same electrical length for connection between spaced baluns;
   e. attaching each of said plurality of transmission lines between spaced pairs of baluns one end of each said transmission line being attached to only one balun and said baluns being located in predetermined spaced relationship to each other whereby a wide angle retroreflector apparatus is produced.

2. The method in accordance with claim 1 but including the step of drilling holes in said printed circuit board at predetermined locations for inserting said balun in prior to attaching each said balun to each side of said printed circuit board.

3. The method in accordance with claim 2 but including the step of attaching said baluns to said printed circuit board by positioning each balun in a hole in said printed circuit board and flow soldering said balun to a ground plane of said printed circuit board on the opposite side from said antenna elements.

4. The method in accordance with claim 3 in which said baluns are attached to each antenna element by flow soldering said baluns following attaching said baluns to said ground plane.

5. The method in accordance with claim 4 which includes attaching the center conductor of said transmission line to one said antenna element.

6. The method in accordance with claim 5 but including the step of machining baluns from tubing prior to attaching a balun to each said antenna element.

7. A retroreflector apparatus comprising in combination:
   a. a printed circuit board having antenna elements etched on one side thereof and a ground plane on the other side thereof;

b. said printed circuit board having tubular shaped baluns with parallel slots in the walls of one end thereof, said slots being of a length corresponding to approximately one quarter of the frequency of said retroreflector and each said balun being attached to said ground plane and to one said antenna element; and

c. a plurality of transmission lines of approximately equal lengths; each said transmission line being connected between a pair of spaced baluns and each end of each said transmission line being attached to only one spaced balun whereby a wide angle retroreflector array is provided with pairs of spaced interconnected antenna elements.

8. The apparatus according to claim **7** in which each said transmission line is a coaxial cable having each end thereof of said transmission line braid attached to one said balun and each end of each center conductor attached to one said antenna element.

9. The apparatus according to claim **8** in which said antenna elements are dipoles.

10. The apparatus according to claim **9** in which said printed circuit board has a copper clad ground plane and copper clad antenna elements.

11. The apparatus according to claim **10** in which said dipoles are aligned in intermittent rows with said elements in each row running perpendicular to the elements in each preceding row.

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