

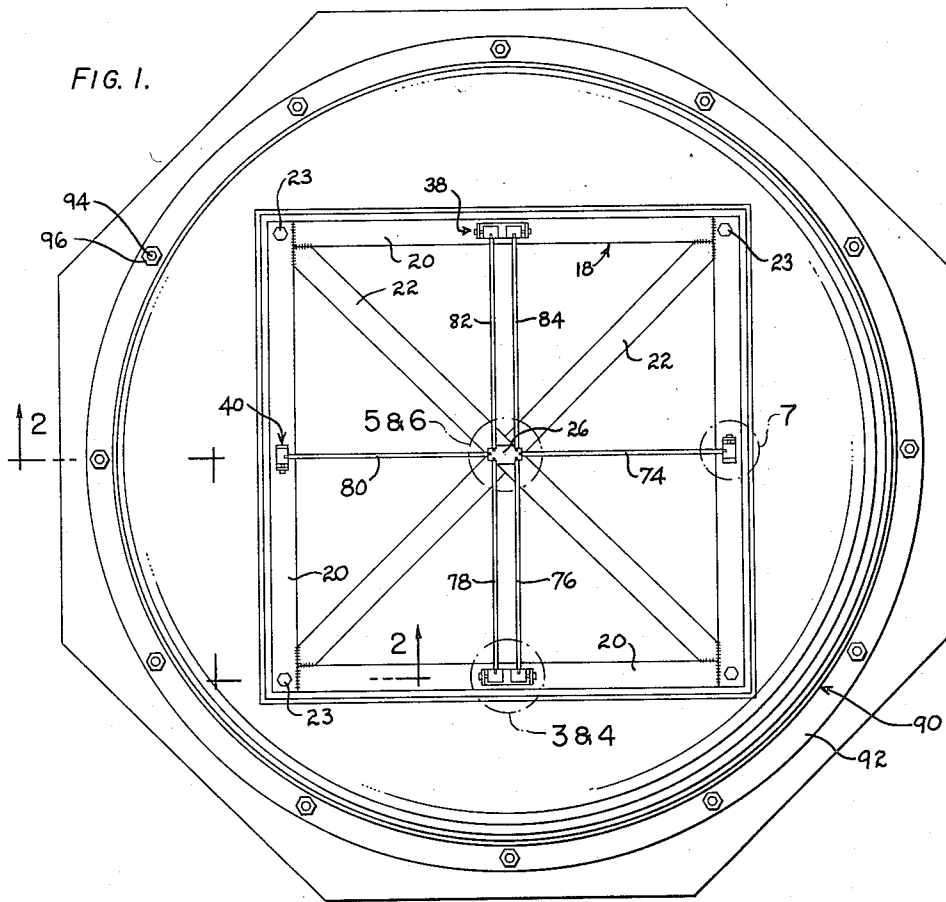
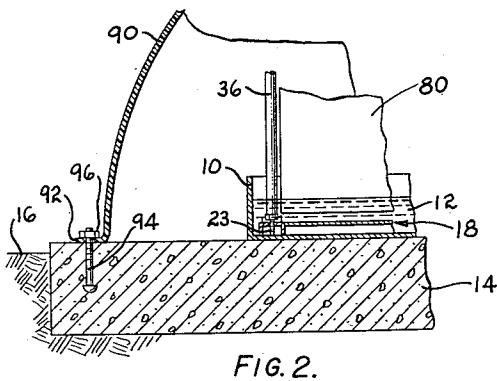
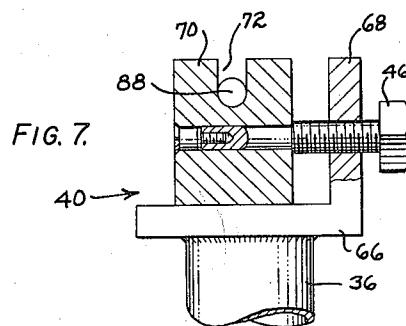
Jan. 19, 1960

G. L. HARDWICK ET AL
RADAR CORNER REFLECTOR WITH ELECTRICALLY
CONDUCTIVE LIQUID REFLECTIVE SURFACE

2,922,158

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2 Sheets-Sheet 1



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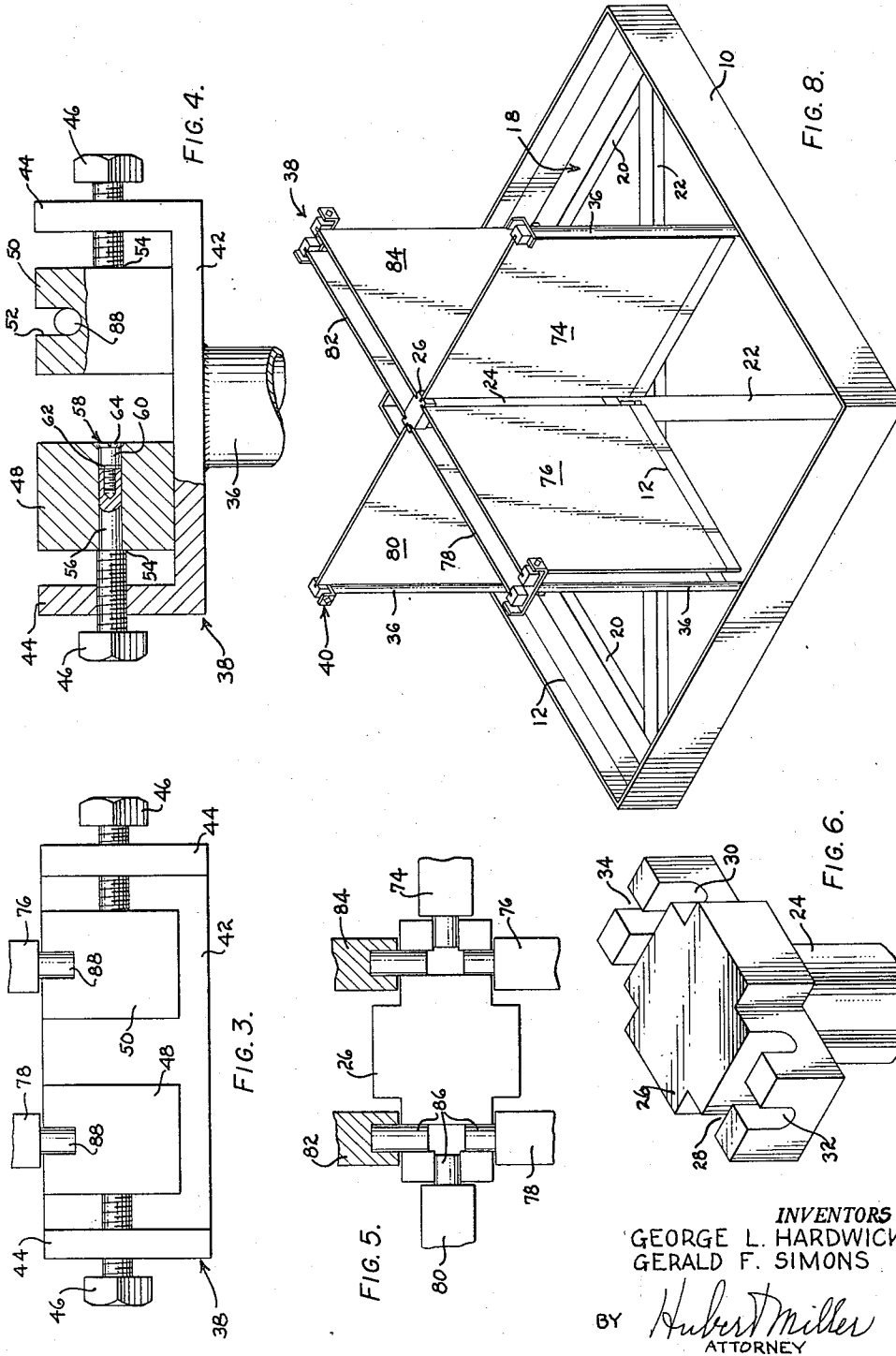
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RADAR CORNER REFLECTOR WITH ELECTRICALLY CONDUCTIVE LIQUID REFLECTIVE SURFACE

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13 Claims. (Cl. 343—18)

This invention relates to radar reflectors capable of reflecting microwave energy directly back to the emanating source.

Radar reflectors involving the use of fixed trihedral reflector plates are now old and fairly well known. However, the efficiency of a microwave reflector of this type is dependent upon the degree of flatness of the surfaces of the reflector plates coupled with the ability to keep these surfaces in at true 90° corner relationship with each other. For certain uses it is considered necessary to provide reflector plates as large as 10 feet x 10 feet. The larger the reflecting area the more pronounced has been the difficulty in originally achieving and in subsequently maintaining the plates in a precise perpendicular relationship. The present invention obviates this difficulty.

Accordingly, one important object of the present invention is to provide a microwave reflector in which the reflecting surfaces of the plates will remain planar in character and also mutually perpendicular, thereby producing a radar reflector that will be highly efficient in its reflective action.

Another very important object of the invention is to provide a radar reflector, the reflective plates of which are self aligning, thereby facilitating the erection and installation of the reflector structure and of course cooperating in the continued maintenance of an efficient reflector as mentioned in the preceding paragraph.

A further object of the invention is to provide a reflector that will be effective for all different angles of approach.

A still further object of the invention is to provide a radar reflector that is relatively portable in nature, thereby enhancing its usability at different locations.

Yet another object of the invention is to provide a reflector that can be constructed at a relatively low cost. In this regard it may be noted that many permanent installations cost from \$10,000 to \$15,000 per unit, whereas reflectors of the same size built in accordance with the teachings of the instant invention will cost from \$2000 to \$2500 per unit.

All in all, the above aims of the invention result in the reflector presently to be described as being especially well suited for the following applications:

(1) A point target for the calibration and testing of airborne radar systems.

(2) Markers to define runways for radar landings by aircraft.

(3) Cross country beacons located at specified distances along airways or as reflective signals to outline other specific areas.

(4) A target for practice bombing and for carrying out other missile operations of a tactical nature.

(5) Markers to define practice bombing areas.

The invention, together with other objects attending its production, will be more clearly understood when the following description is read in connection with the accompanying drawings, in which:

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Figure 1 is a top plan view of a radar reflector exemplifying the invention;

Figure 2 is a sectional view taken in the direction of line 2—2 of Figure 1;

Figure 3 is an enlarged top plan view of one of the reflective plate adjustment mechanisms;

Figure 4 is a view in elevation corresponding to Figure 3, portions thereof being sectionalized to show to better advantage the specific construction that the adjusting mechanism may assume;

Figure 5 is a top plan view of the central pivot block serving as a support for the adjacent sides of all six reflective plates;

Figure 6 is a perspective detail view of the pivot block without the presence of the plate portions included in Figure 5;

Figure 7 is a view resembling Figure 4, but illustrating the form that the adjusting mechanism may take when employed to actuate a single panel, and

Figure 8 is a perspective view of our radar reflector with the plastic dome of Figure 1 removed.

Referring now in detail to the drawings, it will be observed that the radar reflector exemplifying the present invention includes a pan 10 containing any liquid 12, having a sufficient degree of electrical conductivity that its surface will efficiently reflect radar waves, such as ordinary tap water. As can be seen from Figure 2, the pan rests on a suitable concrete foundation 14 which is formed in the ground 16.

Within the pan 10 is placed a rectangular base 18 composed of four inverted channel members 20 reinforced by diagonally extending struts 22. For the sake of permanent rigidity the channels 20 and their struts 22 may be of welded construction as evidenced in Figure 1, thus forming the unitary base 18. Through the medium of four leveling screws 23, one at each corner, the base 18 may be leveled within the pan 10.

At the center or intersection of the struts 22 is an upright standard in the form of a column or cylinder 24 on the upper end of which is fixedly carried a central journal block 26. The block is formed with a pair of parallel U-shaped grooves 28, 30 plus a pair of similar relatively short U-shaped grooves 32, 34 extending transversely at right angles to said grooves 28, 30, respectively.

Auxiliary standards comprising four upright columns 36 are mounted on the side channels 20 of the base 18 at substantially the mid-portions of these sides. While the columns or cylinders 36 can be of identical construction, the jacking or actuating mechanisms disposed atop these columns consist of two pairs of mechanisms, one pair differing somewhat from the other pair. Accordingly, it will be discerned that two opposite columns 36 have compound actuating mechanisms designated by the numeral 38 fixedly attached to their upper ends, whereas the remaining two oppositely located columns 36 carry in similar fashion single actuating mechanisms denoted by the numeral 40. Although these actuating mechanisms appear in Figures 1 and 8, they are pictured more clearly on a larger scale in Figures 3, 4 and 7.

Describing first the compound actuating mechanism 38, it will be observed from Figures 3 and 4 that the mechanism 38 includes a U-shaped bracket 42 welded to the upper extremity of its associated column 36. The upstanding sides 44 of the bracket 42 are drilled and tapped for the accommodation of a pair of jacking bolts 46. These bolts 46 have respective engagement with individually movable journal blocks 48, 50, each with a U-shaped groove 52 similar to the earlier mentioned U-shaped grooves but extending only part way across the blocks 48, 50. In order that the bolts 46 may both propel and repel their blocks 48, 50 the screws are of two diameters, the larger being threaded to form a shoulder at 54 and

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the smaller being unthreaded at 56. The unthreaded or barrel portion 56 is received within a tubular bore provided in each of the blocks 48, 50. As visible in the sectionalized half of Figure 4, the portion 56 is tapped for the accommodation of a smaller screw 58 having a cylindrical shank 60 of the same diameter as the bolt portion 56, there being a compressible washer 62 such that when the screw 58 is tightened securely with respect to each bolt 46 there is a constant pressural action applied to the threads of the screw 58 so that it will not work itself loose. By reason of a beveled or coned head 64 and a complemental chamfer on the block's bore, it can be appreciated that all of the bolts 46 can move their associated journal blocks 48, 50 in reciprocal directions.

Directing attention now to Figure 7, it can be seen that the actuating mechanism 40 is comprised of a bracket 66 in the form of an angle member welded to its associated column 36 and an upstanding leg 68 drilled and tapped for the accommodation of a jacking bolt identical with the previously mentioned ones and therefore bearing the same numeral 46. In this instance only a single journal block 70 is provided for each of the two mechanisms 40, having engagement with its bolt 46 and being formed with a U-shaped groove 72.

The various journal blocks 26, 48, 50, 70, together with their respective grooves, are utilized for the suspension of a plurality of reflector plates 74, 76, 78, 80, 82 and 84 made of any suitable material having a sufficient degree of electrical conductivity that its surface will efficiently reflect radar waves. Preferably each of the reflective plates may constitute a panel of cast aluminum having the reflecting surfaces machined and then surface ground so that a good planar surface will be presented to the transmitted microwave energy which is to be reflected. Plates of stainless steel or plates of glass coated with an electrically conductive material may also be used, although the cast aluminum has been found superior as far as maintaining an excellent planar surface once such surface has originally been achieved by the aforesaid grinding operation. As hereinbefore pointed out, one of the advantages to be derived from use of this invention is that the reflective plates need not be limited as to their size, so no specific dimensions need be given, although the standards 24, 36 should be of adequate proportions to support the weight of the plates.

Coming now to the specific manner in which the various plates 74, 76, 78, 80, 82, and 84 are supported, it is to be noted that each plate is provided with a pair of lateral pivot pins 86, 88 projecting or issuing from opposite plate edges at a locus near the top edge, these pins 86, 88 being press fitted into their respective plates and of slightly smaller radius than is the radius of curvature at the bottom of the various U-shaped grooves 28, 30, 32, 34, 52 and 72 for freedom of pivotal movement therein. Thus, inasmuch as these plates 74, 76, 78, 80, 82, and 84 are each swingingly supported on an axis in exact vertical alinement with their respective centers of gravity, they will in every instance seek a vertical plane. If desired, a small amount of lubricant may be initially placed in each journal groove, thereby facilitating the self aligning or pivoting action produced by the gravitational forces to which the plates are subjected at all times.

With the base 18 rendered level through the proper turning of its four leveling screws 23, all that need be done additionally is to turn the various jacking bolts 46 in the correct direction until each plate is adjusted to a true angle of 90° with respect to each adjacent plate, for the plates will pivot in a horizontal direction about their supporting pins 86 to the small degree necessary to accomplish the required perpendicularity. No adjustment is necessary as far as obtaining a normal or 90° relationship with the liquid 12, since gravity itself takes care of this adjustment in an automatic manner stemming from the described suspension type of support incorporated into this reflector structure.

Once having made the above adjustments a radome 90 is placed over the reflector assemblage. This radome or protective hood may be made of any material which is opaque to light and transparent to microwave energy. From Figures 1 and 2 it can be discerned that the radome is equipped with a circumferential flange 92 resting on the concrete base 14 and anchored thereto by a series of bolts 94 having their heads embedded in the concrete with nuts 96 applied to their exposed, upper ends. The rigid radome 90 precludes transient pressure differentials and adverse wind effects.

From the foregoing description it is believed readily apparent that our radar reflector presents four trihedral angles formed by the ionic liquid 12 and the various plates. In regard to the plates 74 and 80 it will be understood that each face of these two plates is to be surface ground to give a good planar condition, whereas with respect to the plates 76, 78, 82, and 84 only one side need be truly planar. By utilizing six plates it will be recognized that the center journal block 26 may be quite sturdy so as to bear its load, yet for all intents and purposes permitting the adjacent edges of any two plates forming a single corner to meet substantially, thereby further enhancing the overall reflective properties of the radar reflector. In any event, it will be appreciated that the various plates are at all times self aligning as far as their perpendicular relation with the reflective surface provided by the ionic liquid 12. It will be understood by those familiar with this art that all welds on the entire plate supporting structure of the described unit should be normalized after assembly. With the internal stresses thus relieved subsequent distortion and possible relative movement of the various components are prevented, and the properly adjusted relationship of both the plate and liquid reflecting surfaces will be maintained indefinitely beneath the protective dome. It will also be understood that by using only two plates having their lower edges submerged in an electrically conductive liquid a single corner reflector or trihedron can be constructed in accordance with this invention.

Having described the invention with sufficient clarity to enable those familiar with this art to construct and use it, we claim:

1. A radar reflector comprising: a confined body of electrically conductive liquid; a pair of plates of an electrically conductive material each having at least one truly planar surface, the plates being arranged so that their planar surfaces and the surface of the body of liquid form a trihedron; and means for independently and pivotally suspending each plate along separate horizontal axes which are located above the center of gravity of the respective plates, each pivot axis being parallel to the true planar surface of its respective plate and the two pivot axes being normal to each other, the lower edges of the thus pivotally suspended plates being submerged in said body of liquid.

2. A radar reflector comprising: first reflective means including the surface of a confined body of electrically conductive liquid; second reflective means including a member having an electrically conductive planar surface; third reflective means including another member having an electrically conductive planar surface; support means for pivotally suspending the first-mentioned member so that its planar surface resides in a vertical plane; and further support means for pivotally suspending the second-mentioned member so that its planar surface also resides in a vertical plane, said respective support means angularly orienting said members so that the planar surfaces thereof are adjacent and normal to each other as well as to the surface of the said liquid, said members forming said second and third reflective means having their lower edges submerged in said liquid of said first reflective means.

3. A radar reflector in accordance with claim 2 in which said members are plates and are connected to their

support means adjacent their respective upper marginal edges.

4. A radar reflector comprising: a confined body of electrically conductive liquid; support means including a base, a centrally disposed upright standard, and four additional upright standards disposed adjacent to the periphery of said base at approximately equal distances apart; a plurality of reflective plates of electrically conductive material; and cooperating means on the standards and on each plate for pivotally suspending the plates along horizontal axes near their respective upper edges with their lower edges submerged in the liquid, the plates being independently suspended in positions to form four orthogonal trihedrons with the surface of the liquid, arranged corner adjacent corner.

5. A radar reflector in accordance with claim 4 including means for leveling said base.

6. A radar reflector in accordance with claim 4 including an adjusting mechanism at the upper end of each of said four additional upright standards for angularly orienting said plates to produce a 90° relationship between adjacent plates.

7. A radar reflector comprising: four rectangular reflector plates each having at least one electrically conductive surface arranged in two intersecting vertical planes which are normal to each other; an upright standard located near the intersection of said vertical planes, each plate having one upright edge adjacent said standard; four additional upright standards, one adjacent the opposite upright edge of each plate; cooperating means on the respective opposite upright edges of each plate and on each of the five standards for pivotally suspending the plates from the standards along two intersecting horizontal axes which are normal to each other and lie in the intersecting planes in which the plates lie, the plate pivot axes being located well above the centers of gravity of the respective plates; and a confined body of electrically conductive liquid beneath said plates and in which their respective lower ends are submerged.

8. A radar reflector in accordance with claim 7 including means on each of said four additional standards for individually adjusting the angular pivotally suspended relationship of each plate to those plates adjacent it.

9. A radar reflector comprising: six upright reflecting plates of electrically conductive material, a first pair of said plates lying in a first vertical plane with a vertical edge of one plate lying in contiguous relationship with a vertical edge of the other plate; a second pair of said plates lying in a second vertical plane with vertical edges in similar contiguous relationship, said first and second planes being closely adjacent and parallel and the respective plates of one pair being arranged substantially back to back with the plates of the other pair; a third pair of said plates lying in a third vertical plane and arranged with vertical edges in similar contiguous relationship, said third plane being normal to said first and second planes and passing between the contiguous vertical edges of the first and second pairs of plates; means for independently pivotally suspending the plates along horizontal axes lo-

cated near their respective upper ends, said axes being located in the respective planes in which the plates lie; a confined body of electrically conductive liquid arranged beneath said plates and in which their respective lower ends are submerged, the surface of the liquid together with the visible reflecting surfaces of the six plates together constituting four separate but adjacent trihedrons together capable of reflecting microwave energy emanating from any source located above the horizontal plane in which the surface of the liquid lies.

10. A radar reflector in accordance with claim 9 in which the suspending means includes a centrally disposed standard carrying at its upper end a journal block grooved for the accommodation of adjacent pivot pins projecting laterally from the adjacent vertical inner edges of the six plates, said support means further including four equally spaced additional standards located adjacent the respective vertical outer edges of said plates, two of which additional standards each carries a pair of journal blocks grooved for the accommodation of pivot pins on the outer vertical edges of said first and second pairs of plates, and the other two additional standards each carrying a grooved journal block for the accommodation of pivot pins on the outer vertical edges of the third pair of plates.

11. A radar reflector in accordance with claim 10 including means for horizontally adjusting the position of each of the journal blocks associated with said additional standards to vary the included angle between the adjacent reflecting surfaces of adjacent plates.

12. A radar reflector comprising: a liquid holding pan; a body of electrically conductive liquid in said pan, the surface of the liquid constituting a radar wave reflector; reflector supporting means associated with the pan and above the surface of the liquid therein; and a pair of electrically conductive wave reflecting plates arranged in planes normal to each other and suspended from and independently and pivotally supported by said reflector supporting means, the lower portions of said plates extending into said body of liquid, the independent pivotal suspension of the plates affording relative swinging movement in planes normal to each other, the adjacent surfaces of the plates and the surface of the liquid in the pan thus cooperating to form a trihedron, due to gravity influence on the plates and the liquid.

13. The reflector described in claim 12 in which the reflector suspending means is adjustable to facilitate suspension of the plates in planes normal to each other.

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