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SEARCH ROOM

June 13, 1961 D. L. BROWN ET AL 2,988,741

ELECTRONIC SCANNING ANTENNA

Filed Jan. 30, 1957 2 Sheets-Sheet 1

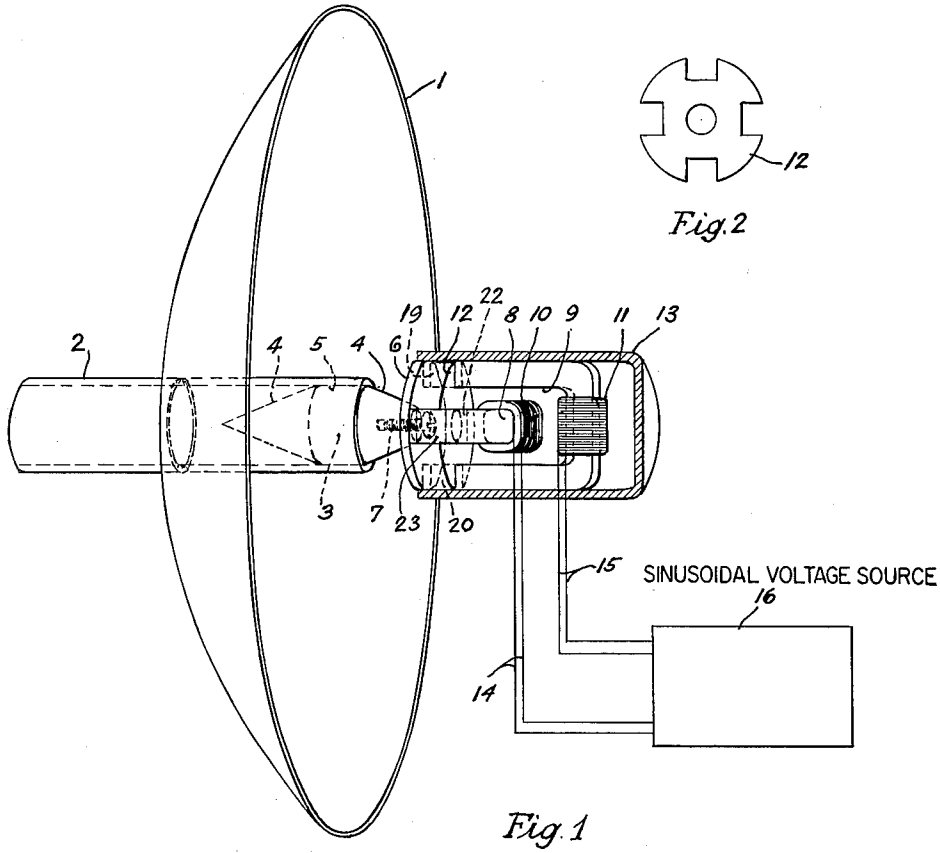


Fig. 1

Fig. 2

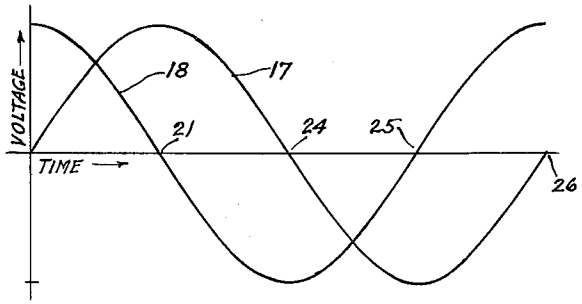


Fig. 3

INVENTORS
Donald L. Brown &
BY David W. Young, Jr.
ATTORNEY

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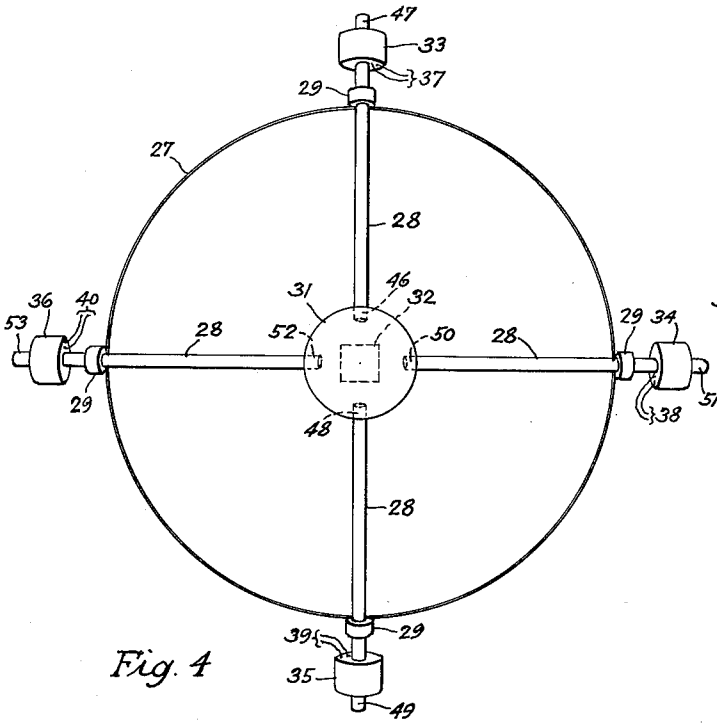


Fig. 4

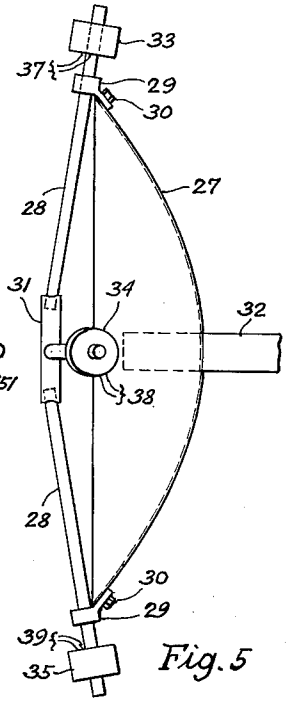


Fig. 5

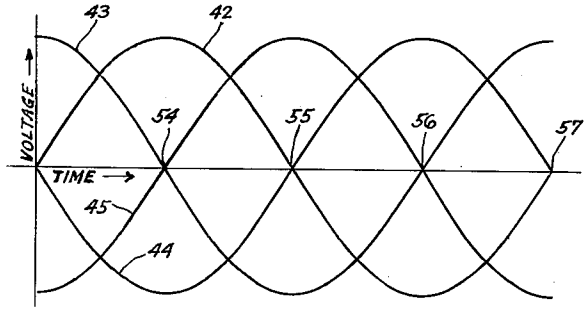


Fig. 7

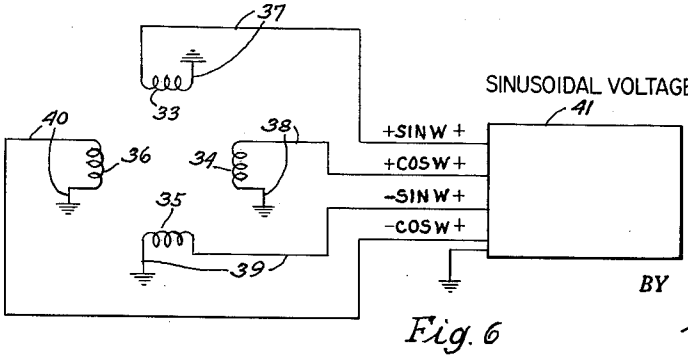


Fig. 6

INVENTORS
Donald L. Brown &
David W. Young, Jr.

BY

Oldham
ATTORNEY

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2,988,741

ELECTRONIC SCANNING ANTENNA

Donald L. Brown, Mogadore, Ohio, and David W. Young, Jr., Van Nuys, Calif., assignors to Goodyear Aircraft Corporation, Akron, Ohio, a corporation of Delaware

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8 Claims. (Cl. 343—754)

This invention relates to a radar search antenna operating at microwave frequencies and more particularly to an antenna wherein scan is produced by electrically modulating the output beam.

Heretofore, the conventional parabolic reflector of a radar antenna was physically moved by mechanical devices to move the radar beam so as to search within certain areas. Such devices consist of gears, cams, gimbals, and the like. Due to the mechanical basis for producing such beam movements, not only are scan rates of limited speed or scope but also mechanical wear causes inaccuracies and equipment breakdown.

It is the general object of this invention to provide a radar search antenna in which the search beam is electrically displaced without physical displacement of the antenna itself.

It is a further object of this invention to provide a radar search antenna capable of high scan rates and which is simple, efficient, and economical in construction, operation, and maintenance.

Other objects and advantages of this invention will become apparent hereinafter as the description proceeds; the novel features, arrangements, and combinations being clearly delineated in the specification, as well as in the appended claims.

In the drawings:

FIG. 1 is a perspective view, partly in section, showing one embodiment of the antenna of the invention;

FIG. 2 is a side view of one of the components of FIG. 1;

FIG. 3 is a graphical representation of the relationships of the input voltages to the electromagnets forming a part of the apparatus of FIG. 1;

FIG. 4 is a front elevation of a second embodiment of the antenna of the invention;

FIG. 5 is a side elevation of the antenna of FIG. 4;

FIG. 6 is an electrical schematic of the circuitry used in the antenna of FIG. 4; and

FIG. 7 is a graphical representation of the relationships of the input voltages to the electromagnets of FIG. 4.

In FIG. 1, a parabolic reflector **1** has centrally mounted therein in conventional manner, a circular cross-section wave guide **2**. An electrically transparent antenna feed **3** is closely fitted into the wave guide **2** and is formed of inwardly and outwardly directed, conical tapered end portions **4** joined by a cylindrical center portion **5**. The outwardly protruding end portion **4** has mounted thereon a thin cylindrical disk **6** of ferrite composition (as hereinafter described) by a screw **7** threaded into the conical portion **4**. A first and a second U-shaped electromagnet, **8** and **9** respectively, are shown, and are displaced 90 degrees relative to each other. Each of the electromagnets **8** and **9** is provided, as shown, with a wound coil, **10** and **11** respectively, around the base portion of the U-shape. A non-magnetic, disc-like spacer **12** is provided of approximate cruciform shape as shown in FIG. 2.

As can be seen in FIG. 1, the electromagnets **8** and **9** contact the disc **6** and coengage the spacer **12**, which in turn overlies the ferrite disc **6**. The entire assembly of electromagnets, spacer, and ferrite disc are assembled with a suitable adhesive, and a protective cover **13** is then placed over the assembly and affixed to the disc **6**. As will be understood as the description proceeds, more than two electromagnets can be used to polarize the disc **6**.

In the operation of the antenna apparatus described, the coils **10** and **11** are each driven by sinusoidal voltages, differing in phase, applied to the coil leads **14** and **15**, respectively, from a suitable voltage source **16**, which may be of any conventional type. One such phase arrangement is to drive coil **10** with a voltage which is a function of sine wt and coil **11** with a voltage which is a function of cosine wt. The term w represents the voltage frequency multiplied by 2π and the term t represent time in conventional manner. This phase relationship is shown in FIG. 3, wherein the curve **17** represents the voltage supplied to the coil **10**, and the curve **18** the voltage supplied to coil **11**.

As the driving voltages are applied to the coils **10** and **11**, the magnet extremities are consequently presenting a continually changing polarity as to the ferrite disc **6**, with which they are in contact. As a result of the driving voltages, at zero time on the time axis of FIG. 3, no polarity is present in electromagnet **8** as the voltage is zero, and maximum polarity is present in electromagnet **9**, as the voltage is maximum. For purposes of clarity of description, at zero time polarity in electromagnet **9** is assumed to be a North (hereinafter abbreviated as N) pole at the tip **19** (FIG. 3) of the electromagnet **9**, and a South (hereinafter abbreviated as S) at the tip **20** of the electromagnet **9**. At point **21** on the time axis, there is no polarity present at the tips **19** and **20** as the voltage is zero, and there is a N-pole and a S-pole at tips **22** and **23**, respectively, of the electromagnet **8**. At point **24** on the time axis, there is no polarity present at tips **22** and **23**, and a N-pole and a S-pole at tips **20** and **19**, respectively. At point **25** on the time axis, there is no polarity present at tips **19** and **20**, and a N-pole and a S-pole at tips **23** and **22**, respectively. At point **26** on the time axis, the same condition is present as at zero time; namely, no polarity at tips **22** and **23**, and a N-pole and a S-pole a tips **19** and **20**, respectively.

The result of this rapidly rotating polarity is a corresponding induced polarity in the ferrite disc **6**. For reasons unknown precisely to us, such induced fluctuating polarity causes a varying force field around the ferrite disc **6**. The electromagnetic beam issuing from the waveguide outlet is affected by such force field and directed thereby to strike the parabolic reflector in such manner as to produce an outlet beam from the antenna which scans in circular pattern.

The effect of such fluctuating force field evidently presents to the wave beam a reflecting obstacle which is electrical in nature. The result on deflecting the beam is the same as though the disc **6** were a conventional splash plate which is nutated mechanically to produce circular scan. As to the wave beam, the fact that the obstacle is electrical in nature as compared to one physical in structure appears immaterial. Both have the same effect thereon; namely to redirect the beam.

In the FIGS. 4 and 5 another embodiment of the invention is shown. A parabolic reflector **27** has spaced along the outer circumferential edge thereof at intervals of 90 degrees, four cylindrical rods **28** of ferrite. The rods **28** are affixed to the reflector **27** by collars **29** and bolts **30**. At the focal point of the reflector **27**, a splash plate **31**, of metal such as aluminum, is shown. The splash plate **31** has recesses therein to coengage the rods **28** and thus further support not only the rods **28** but also the splash plate **31**. An antenna wave guide **32** is mounted on the centerline of the reflector **27** in conventional manner.

Adjacent to the outer protruding extremities of the rods **28** are four driving coils **33**, **34**, **35**, and **36** having supply leads thereto **37**, **38**, **39**, and **40** respectively. As shown in FIG. 6, the leads **37**, **38**, **39**, and **40** are connected to a conventional voltage source **41** to supply sinusoidal voltages of differing phase to the respective

coils. One such phase arrangement, as shown in FIG. 6, is where coil 33 is driven by a voltage which is a function of positive sine *wt*, coil 34 by a voltage which is a function of positive cosine *wt*, coil 35 by a voltage which is a function of negative sine *wt*, and coil 36 by a voltage which is a function of negative cosine *wt*. The resulting phase relationship is shown in FIG. 7 wherein curve 42 represents the positive sine *wt* voltage driving coil 33, curve 43 the positive cosine *wt* voltage driving coil 34, curve 44 the negative sine *wt* voltage driving coil 35, and curve 45 the negative cosine *wt* voltage driving coil 36. A typical cycle of operation may be seen by reference to FIGURE 7. At zero time there is no polarity at the tips 46 and 47, as the voltage supplied to the driving coil 33 is zero; furthermore, there is no polarity at the tips 48 and 49 as the voltage supply to the driving coil 35 is also zero. However, at zero time the voltage supply to the driving coil 34 is maximum causing, for example, a N-pole at tip 50 and a S-pole at tip 51. Likewise at zero time the voltage to the driving coil 36 is maximum and opposed in polarity to the voltage driving coil 34 and thereby causes tip 52 to become a S-pole and tip 53 to become a N-pole.

At point 54 on the time axis tips 47 and 48 are N-poles, tips 46 and 49 are S-poles, and tips 50, 51, 52 and 53 have no polarity. At the point 55 on the time axis tips 51, and 52 are N-poles, tips 50 and 53 are S-poles, and tips 46, 47, 48 and 49 have no polarity. At point 56 on the time axis, tips 46 and 49 are N-poles, tips 47 and 48 are S-poles, and tips 50, 51, 52, and 53 have no polarity. At point 57 on the time axis the cycle repeats and the same polarities are present as were previously described in connection with the zero time point.

Thus as can be seen from the foregoing description, a continually changing polarity is sequentially presented to the beam issuing from the wave guide 32 and reflected from the reflector 27 to thereby cause a scanning effect of the outlet beam. This polarity is induced in each rod by the voltage applied to the respective drive coil therefor. It will be understood that other rod arrangements can be used from three rods symmetrically spaced to any higher number of rods. As previously indicated, the exact theoretical reason for the effect resulting from the coaction of the varying force fields described and the electromagnetic beam is unknown to us.

The material used in the ferrite disc 6 or the ferrite rods of FIGS. 4 and 5 may be of any of the class of ferromagnetic ferric-oxide compounds which are compositions of one or more oxides of bivalent metals such as Cu, Ni, Zn, Mn, Mg, and Cd, and mixed crystals of two or more ferrites, and which are sintered to produce a material having high initial permeability. These materials and the methods of manufacture have been fully described in U.S. Patent No. 2,751,354, issued on June 19, 1956, to F. G. Brockman and entitled "Method of Manufacturing a Magnetic Ferrite Core."

By the apparatus of the invention exceedingly high scan rates are achieved. Scan rates in the order of 1000–2000 cycles per second have been experimentally obtained, and it will be obvious that with proper coil design and circuit parameters, scan rates of an even higher order can be had. It will be appreciated that the scan rates are a direct function of the frequency of the driving voltages; i.e., a modulation frequency of 300 cycles per second results in a scan rate of 18,000 revolutions per minute. Thus by the apparatus of the invention, scanning is had without necessarily cumbersome and complex mechanical displacement systems which are subject to wear, and, as a result, progressively increasing errors in operation.

It will be appreciated that the principles of the invention can be utilized with various types of radar antennas and with various shapes of splash plates and reflectors to provide beams of desired shape.

While certain representative embodiments and details have been shown for the purpose of illustrating the invention, it will be apparent to those skilled in this art that various changes and modifications may be made therein without departing from the spirit or scope of the invention.

What is claimed:

1. An object locating antenna utilizing high frequency electromagnetic waves comprising beam concentrating reflector means, a wave guide to carry electromagnetic waves and coupled to the reflector means, a peripherally notched structure of ferrite composition between said wave guide and said reflector means in the path of the electromagnetic waves, and means including magnetizable poles at said peripheral notches for polarizing the ferrite structure in periodic and sequential manner.

2. An object locating antenna utilizing high frequency electromagnetic waves comprising beam concentrating reflector means, a wave guide to carry electromagnetic waves and coupled to the reflector means, a peripherally notched structure of ferrite composition in the path of the electromagnetic waves between the reflector means and wave guide, and means for sequentially inducing polarity in the ferrite structure including magnetizable pole pieces at the peripheral notches of said structure, energizing coils for said pole pieces, and means for supplying each of said coils with a sinusoidal voltage 90 degrees out-of-phase with an immediately adjacent coil.

3. An object locating antenna utilizing high frequency electromagnetic waves comprising a parabolic reflector, a wave guide coupled to the reflector, a ferrite disc in overlying but spaced relation relative to the wave guide outlet and presenting one face thereof to the outlet opening, at least two U-shaped electromagnets each having an energizing coil associated therewith, means to orient the electromagnets in a position such that the angles therebetween are all substantially equal and with the tips of the legs of the U-shape of each electromagnet in contact with the other side of the ferrite disc, means to supply a sinusoidal voltage to each energizing coil with each coil voltage being 90 degrees out-of-phase relative to the voltage supplied to an adjacent coil.

4. An object locating antenna utilizing high frequency electromagnetic waves comprising a parabolic reflector, a wave guide coupled to the reflector, a ferrite disc in overlying but spaced relation relative to the wave guide outlet and presenting one face thereof to the outlet opening, a first and a second U-shaped electromagnet each having an energizing coil associated therewith, means to position the electromagnets at substantially 90 degrees to each other and with the tips of the legs of the U-shape in contact with the other side of the ferrite disc, a first and a second sinusoidal voltage source connected to the energizing coils of the first and second electromagnets respectively, the first sinusoidal voltage source being out of phase with the second.

5. An object locating antenna utilizing high frequency electromagnetic waves comprising a parabolic reflector, a wave guide coupled to the reflector, a splash plate, at least three rods of ferrite composition spaced at equal angles around and extending radially on the concave side of the reflector, said rods coupled to the reflector and affixed at the inner end thereof to and supporting the splash plate at the focal point of the reflector, and means for inducing polarity in each rod in sequential and periodic manner.

6. An object locating antenna utilizing high frequency electromagnetic waves comprising a parabolic reflector, a wave guide coupled to the reflector, a splash plate, at least three rods of ferrite composition spaced at equal angles around and extending radially on the concave side of the reflector, said rods coupled to the reflector and affixed at the inner end thereof to and supporting the splash plate at the focal point of the reflector, energizing coils each coupled to a respective rod, and means for supplying sinusoidal voltages to each coil with each coil voltage being 90 degrees out-of-phase relative to the voltage supplied to an adjacent coil.

7. An object locating antenna utilizing high frequency electromagnetic waves comprising a parabolic reflector, a wave guide coupled to the reflector, a splash plate, four rods of ferrite composition spaced at 90 degree intervals and extending radially on the concave side of the reflector, said rods affixed at the inner end thereof to and supporting the splash plate at the focal point of the reflector, means intermediate the rod lengths affixing each rod to the reflector, four energizing coils each coupled to a respective rod, and means for supplying sinusoidal voltages to each coil with each coil voltage being 90 degrees out-of-phase relative to the voltage supplied to an adjacent coil.

8. In a radar antenna, a stationary concave reflector, a stationary splash plate positioned at the center of focus of the reflector, a wave guide extending fixedly and axially through the reflector and terminating short of the splash plate for discharging high frequency electromagnetic waves against the splash plate which bounces the waves against the reflector which in turn reflects the waves into space, and means polarizing the splash plate with a periodically and sequentially varying electromagnetic field to effect a rotational scanning movement of the waves passing out from the reflector into space.

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