April 8, 1969 H. W. EHRENSPECK 3,438,043

SHORT BACKFIRE ANTENNA

Filed June 2, 1968

FIG. 3

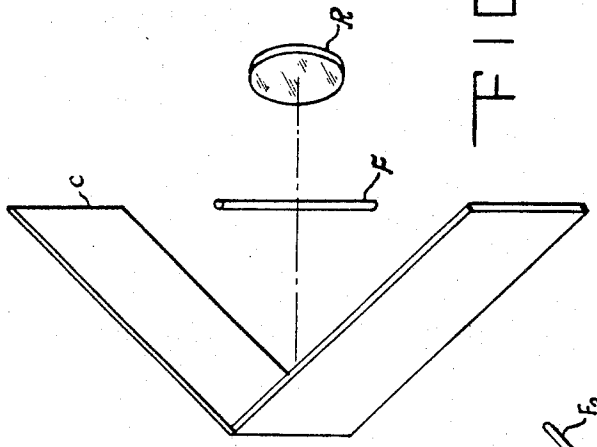


FIG. 2

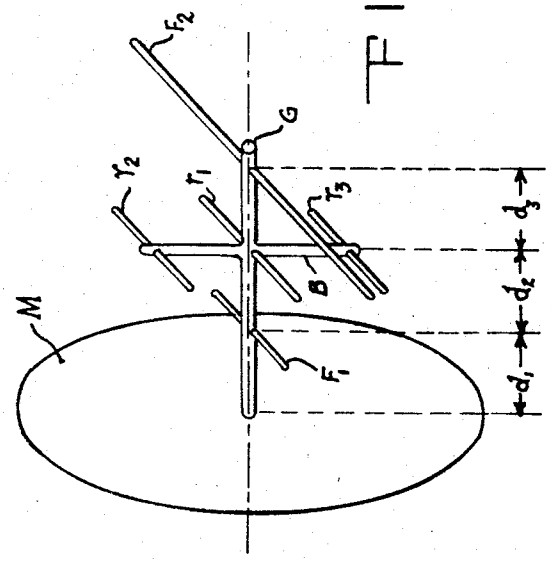
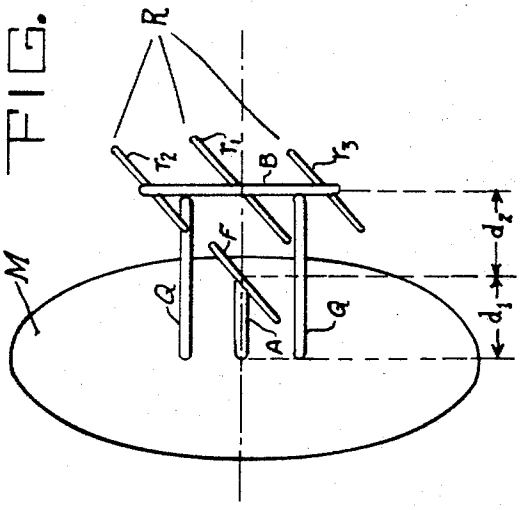


FIG. 1



INVENTOR
HERMANN W. EHRENSPECK

BY Harry A. Herbert Jr. and
Sherman W. Goldman
ATTORNEYS

United States Patent Office 3,438,043
Patented Apr. 8, 1969

3,438,043

SHORT BACKFIRE ANTENNA

Hermann W. Ehrenspeck, 94 Farnham St., Belmont, Mass. 02178

Continuation-in-part of application Ser. No. 446,128, Apr. 6, 1965. This application July 2, 1968, Ser. No. 745,078
Int. Cl. H01q 19/16, 19/18, 21/10
U.S. Cl. 343—819
10 Claims

ABSTRACT OF THE DISCLOSURE

A short backfire antenna comprising a pair of reflectors with a feed interposed therebetween. One of the reflectors is a full, planar reflector or a 90° corner reflector while the other reflector is a smaller partial reflector having planar characteristics. The spacing between the reflectors is electrically approximately one-half wavelength or multiples thereof in order to provide the resultant antenna with the properties associated with resonant cavity antennas. An additional feed may be provided in order to enable the covering of an extended bandwidth or of two discrete frequency ranges.

Cross-reference to related application

This is a continuation-in-part of application Ser. No. 446,128, filed Apr. 6, 1965, now abandoned.

Background of the invention

This invention relates generally to directional antennas and, more particularly, to a modification of the type of antenna known as a backfire antenna to render it in accord with resonant cavity principles. Backfire antennas have been described in Patent No. 3,122,745, which was issued Feb. 25, 1964, to Hermann W. Ehrenspeck.

Backfire antennas have heretofore required the utilization of a slow wave structure, since the theory of operation of these devices required the binding of the reflected signals to the array axis.

It has been found that with short antennas, a slow wave structure need not be utilized, and all of the director structure may be omitted. It is believed that the maintenance of a short distance of travel of energy from the feed to the full reflector and backward toward the partial reflector keeps the uncontrolled release of energy from the array. Optimization of the parameters, i.e., the spacing between elements, brought forth the realization that resonance and the production of a standing wave on the antenna is a critical factor in the operation of the resultant device.

It was also heretofore believed that a planar reflector was required; however, it was found that a corner reflector could be utilized providing the angle between the sides of the reflector was maintained at substantially 45° or 90°. Variations of this angle caused a reduction in gain. A corner reflector provides similar results to that of a planar reflector since energy which impinges thereon from the feed is reflected to a second surface thereof and then directed back along the axis of the antenna structure. Since the path from the feed to the first side and thence the second plus the distance back to the feed is constant, the phase shift is constant such that the field at the feed progressing toward the emitting end of the antenna is in phase. The cavity length for resonance in this case is represented approximately by the path taken by the plane wave from the feed to the first reflector, thence to the second reflector, to the feed and finally to the partial reflector.

Addition of an extra feed does not disturb the cavity effect of the cavity structure, and there is increased gain

at the lower frequencies when the second feed is properly spaced from the cavity structure.

Summary of the invention

A short backfire antenna is provided in accordance with resonant cavity principles to produce an extremely short antenna having high gain and directivity.

Accordingly, it is a primary object of this invention to provide a backfire antenna which eliminates the use of slow wave structures.

It is another object of this invention to provide a backfire antenna which produces increased gain with less structure than that heretofore achieved while maintaining an efficiency of more than 80%.

It is still another object of this invention to provide a short backfire antenna having only two reflectors in addition to a feed with spacings between them being such that the device operates in accordance with resonant cavity principles.

It is a further object of this invention to provide a backfire antenna which utilizes a pair of feeds.

It is a still further object of this invention to provide a backfire antenna which utilizes a 45° or 90° corner reflector as one of a pair of reflectors in conjunction with a feed.

Still another object of this invention is to provide short backfire antennas which are easily and economically produced of conventional, currently available materials that lend themselves to standard mass production manufacturing techniques.

These and other advantages, features and objects of the invention will become more apparent from the following description taken in connection with the illustrative embodiment in the accompanying drawings wherein:

Description of the drawings

FIGURE 1 is a schematic representation of a short backfire antenna employing a feed between a partial and a full reflector;

FIGURE 2 shows an antenna similar to that of FIGURE 1 with the addition of a second feed on the axis of the antenna beyond the partial reflector; and

FIGURE 3 is a schematic representation of a short backfire antenna utilizing a corner reflector in place of a planar reflector.

Description of the preferred embodiments

The antennas of this invention conform to a structure which produces the same results as cavity resonators. When a pair of parallel plates, one being fully reflecting and one partially reflecting, are both mounted orthogonally to a longitudinal axis an integral number of half wavelengths apart, the space between the parallel plates comprises a cavity. An example of such a system would be a laser cavity wherein the cavity length produces multiple reflections of the laser energy between the plates. It has been found that reducing the length of the cavity to as little as one half wavelength still allows for resonance. Half wavelength antennas are of great interest in that their radiation patterns in the H and E-planes are easily adjusted and they may be made extremely simple and sturdy. The schematic example shown in FIGURE 1 may be made with a length of only one half wavelength or an integral multiple thereof with the limitation that the length should not be so great as to allow uncontrolled release of energy which would destroy the cavity effect.

In FIGURE 1, M marks a circular planar reflector, F the cavity feed supported by a piece of tubing A with the energizing cable inside, and R the reflector built as a combination of three dipoles r_1, r_2, r_3 which are mounted on a supporting rod B at a distance of about ⅓ wave-

length from each other. For obtaining patterns with low side and backlobes the dipoles r_2 and r_3 are about 10% shorter than the center dipole r_1; Q indicates two metal or plastic rods which hold the reflector combination R at a certain distance from, and parallel to, the planar reflector M; d_1 marks the spacing between M and F, d_2 between F and R. For obtaining maximum gain d_1+d_2 should be electrically about 0.50 wavelength or a multiple thereof in order to produce the resonant cavity effect and cause multiple reflections between the reflectors. The radiation pattern can be adjusted for equal half power beamwidth in the H and E-planes, or for the smallest possible half power beamwidth in the H or E-plane by varying d_1 and d_2 from the optimum position. By arranging an adjusting device for d_2 in the antenna construction, for example, by means of length-adjustable supporting rods Q, these variations in the radiation pattern can be obtained even after the antenna has been mounted in its working position. The reflector combination can be fabricated as one unit, or, for example, as a disc or its equivalent

The position of the feed between the reflectors is not critical with respect to the functioning of the device in accordance with cavity principles; however, the input impedance is changed with position, thus allowing for matching between the transmission line and feed.

An experimental model of a short backfire antenna according to FIGURE 1, with an annular flange or rim at the periphery of the planar reflector as taught in Patent No. 3,218,646 to Hermann W. Ehrenspeck, issued Nov. 16, 1965, and consisting of a circular reflector of two wavelengths diameter, a feed dipole at $d_1=0.25$ wavelength distance from M, and a three-reflector combination at $d_2=0.32$ wavelength distance from F, showed the following results when used for receiving a horizontally polarized field:

	Degrees
Half power beamwidth in horizontal plane ------	30.5
Half power beamwidth in vertical plane ---------	30.5

These results indicate an area efficiency of more than 80%.

For an adjusting range $d_2=0.15$ to 0.45 wavelength, the half power beamwidth could be varied as follows:

In the horizontal plane from 27° to 37°,

In the vertical plane from 48° to 26°.

Over the entire adjusting range, the first sidelobe always remained at least 10 db, mostly 15 to 20 db, and all lobes within ±90° from the backward direction in both planes were 25 to 35 db below the maximum.

The operation of the device in accordance with resonant cavity principles is dependent on the length of the antenna. As it increases in multiples of a half wavelength, the amount of uncontrolled energy release increases to the point where multiple reflections are not significant enough to increase the antenna gain appreciably. It has been found that reflector M, although shown circular, may be of other shapes such as square, rectangular or other polygonal form of about the same area.

With a half wavelength antenna, the area of reflector M, for example, with a circular reflector, requires a disc of about two wavelengths for maximum gain, and the gain falls off with diameters greater than 2.2 wavelengths rather than causing an increase, as with antennas utilizing planar or curved reflectors operating on other principles. The area of the partial reflector should be that produced by a disc of approximately a half wavelength diameter. Increasing this dimension appreciably causes a decrease in gain and creates multilobed patterns. As the area of the partial reflector approaches that of reflector M it would cause the antenna to operate as a low gain, multilobed, slot antenna with the slots represented by the space between the outer circumferences of M and R.

Thus, an antenna having extremely low sidelobes and high gain requires its operation in accordance with the principles of a resonant cavity wherein the spacing between the reflectors is approximately an electrical half wavelength and the full reflector and the partial reflector provide areas as represented by circles of approximately 2.2 wavelengths and .5 wavelength, respectively. The interaction between elements may cause small variations from the dimensions given to provide the resonance and production of a standing wave on this array with multiple reflections.

Larger reflector sizes than those specified above may be used when the cavity length is a multiple of a half wavelength, within the limits discussed supra relative to uncontrolled release of energy.

The short backfire antenna can be converted into an antenna which covers two discrete frequency ranges if a second feed, optimized for the lower of the two frequency ranges, is attached in front of reflector R. A schematic sketch of a useful configuration is shown in FIGURE 2. M, r_1, r_2, r_3, d_1, d_2 and B have the same meaning as in FIGURE 1. G is a rod or tube supporting all elements of the antenna, while F_1 marks the feed for the higher frequency, and F_2 for the lower frequency range.

This antenna represents a combination of a short backfire cavity antenna for the higher frequencies, consisting of reflector M, feed F_1 and the reflector dipoles r_1, r_2 and r_3, and of a reflector antenna for the lower frequencies, consisting of reflector M and feed F_2. d_3 indicates the spacing between r_1 and F_2. In the higher frequency range, feed F_2 cannot cause essential perturbations because it is located outside the cavity antenna; at the lower frequency range, the dipoles F_1, r_1, r_2 and r_3, practically, do not disturb the pattern because they are short compared to the wavelength.

It has been found that reflector r_1, if it is given the appropriate length and shape, can serve as reflector for the cavity antenna and as feed for the reflector antenna at the same time. The added structure for F_2 would be omitted for this case. Best results are obtainable from a folded dipole with its center point connected to the supporting rod G, and the two open ends used as feed terminals for the lower frequency range. If the dimensions of r_1 are chosen such that the two frequency ranges are overlapping, an antenna combination with a fairly broad bandwidth is obtained.

Many more combinations can be thought of. For example, in addition to the feed of the cavity antenna, two or more feeds can be arranged on a more widely extended supporting rod G. These feeds have to be optimized for the desired frequency and mounted at appropriate positions along rod G. A limit, however, is imposed by the size of reflector M, which has to be large enough to act as an efficient reflector for the lowest frequency to be covered.

The antennas of FIGURES 1 and 2 are basically the short backfire resonant cavity antenna which has a length of approximately a half wavelength with slight variations of d_2 utilized for producing pattern changes. When the second feed is added, as shown in FIGURE 2, the antenna length, of course, is increased by the spacing d_3 between the second feed and the partial reflector.

The antenna of FIGURE 3 comprises a corner reflector C which is substituted for the planar reflector M of FIGURE 1. Energy from the feed F impinges upon one side of the reflector C and is reflected to the second side and back along the axis of the antenna.

The cavity resonance in this case is represented approximately by a plane wave impinging from feed F on (a) the upper side of the reflector C, then being reflected downwardly to the lower side and thence back along the axis of the antenna, and on (b) the lower side of the reflector C, there being reflected upwardly to the upper side and thence likewise back along the axis. It should be noted that the path length from the feed back to the feed is the same in both cases, (a) and (b); therefore, the field in the virtual aperture will be everywhere in phase. This

condition is not true when angles other than 45° or 90° are utilized and, accordingly, the gain drops for conditions other than that of the planar or 45° or 90° corner reflector.

For a 90° reflector, spacings between the feed and the apex of the corner reflector is approximately .4λ which gives approximately .25λ spacing between the feed dipole and a perpendicular to either of the sides of the corner reflector. When a corner reflector is utilized, the spacing between the feed and the partial reflector R, shown here as a small disc of metal, will be approximately one full wavelength for maximum gain. The total length, therefore, is greater than the length of a short backfire resonant cavity antenna using a planar reflector; however, the gain per unit of antenna length is much greater than that of other antennas not utilizing the resonant cavity principle. For a 90° corner reflector the cavity length would be electrically about 3/2 wavelengths.

Although the invention has been described relative to particular embodiments, it should be understood to those skilled in the art that the invention is capable of a variety of alternative embodiments. For example, the reflector R, as well as the reflectors M and C, may be made of closely spaced rods, plates or any of the alternatives taught in the aforementioned Patent No. 3,122,745.

I claim:

1. A short backfire antenna comprising
a feed,
a full reflector on one side of said feed of a size to reflect substantially all of the energy impinging thereon, and
a second reflector on the other side of said feed, said second reflector being a partial reflector,
the spacing between reflectors being substantially an integral multiple of an electrical half wavelength to produce a resonant cavity effect whereby a standing wave is produced such that the field slowly decays from its maximum value on the antenna axis and is everywhere in phase.

2. An antenna as defined in claim 1 wherein said full reflector is a planar reflector.

3. An antenna as defined in claim 1 wherein said partial reflector has characteristics equivalent to a planar reflector.

4. An antenna as defined in claim 1 including
second feed means on the side of said second reflector opposite from the side of said first-mentioned feed.

5. An antenna as defined in claim 1 wherein said partial reflector comprises a series of dipoles, one of said dipoles being oriented on the antenna axis and comprising a second feed for said antenna.

6. An antenna as defined in claim 1 wherein said full reflector is a corner reflector such that the path of energy from the feed to any one side of said corner reflector, thence to the other side of said corner reflector and back to said feed and to said partial reflector is an integral multiple of an electrical half wavelength.

7. A short backfire antenna comprising a pair of reflectors aligned on an axis, a feed on said axis interposed between said reflectors, one of said reflectors being a full, planar reflector and the other of said reflectors being a partial reflector having characteristics equivalent to a planar reflector, the spacing between reflectors being such as to allow for resonance and the production of a standing wave on the antenna wherein the energy at the emitting end of said antenna is in phase.

8. A antenna as defined in claim 7 wherein said full reflector is of an area approximately equivalent to a circle of a diameter of two wavelengths.

9. An antenna as defined in claim 7 wherein said partial reflector is of an area approximately equivalent to a circle of a diameter of a half wavelength.

10. An antenna as defined in claim 7 wherein said spacing in multiple of a half wavelength is limited to those spacings which inhibit an appreciable uncontrolled release of energy from said antenna.

References Cited

UNITED STATES PATENTS

2,407,057 9/1946 Carter ---------- 343—840

ELI LIEBERMAN, *Primary Examiner.*

U.S. Cl. X.R.

343—836, 837