United States Patent

[11] **3,568,205**

[72] Inventors **Albert C. Buxton**
Akron;
Jerrold S. Foley, Stow, Ohio

[21] Appl. No. **704,671**
[22] Filed **Feb. 12, 1968**
[45] Patented **Mar. 2, 1971**

[73] Assignee **Goodyear Aerospace Corporation**
Akron, Ohio

---

[54] **NOVEL HELICAL ANTENNA**
8 Claims, 8 Drawing Figs.

[52] **U.S. Cl.** **343/749,** 343/834, 343/895
[51] **Int. Cl.** **H01g 1/36,** H01g 9/00
[50] **Field of Search** 343/834, 895, 731, 749

[56] **References Cited**

UNITED STATES PATENTS

1,718,255	6/1929	Ranzini	343/895X
3,019,438	1/1962	Pan	343/895X
3,184,747	5/1965	Kaech	343/895X
1,898,661	2/1933	Hagen	343/731

FOREIGN PATENTS

576,159	3/1946	Great Britain	343/731
1,129,191	5/1962	Germany	343/895

OTHER REFERENCES

" Antennas" Kraus McGraw Hill New York 1950 TK7872 A6K7 pages 173— 174 and 179— 183

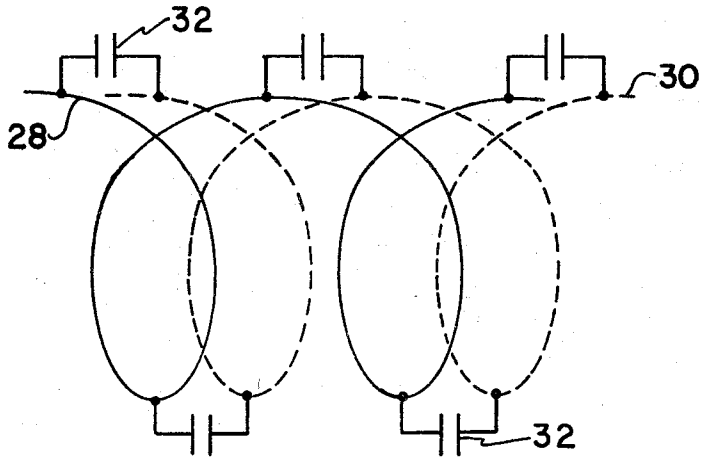
Harris " A Helical Beams for Citizen' s Radio" In ELECTRONICS March 1953 Vol 26 TK 7800 E58 pages 134— 135

Kraus; ANTENNAS McGraw-Hill N.Y. 1950 TK 7872 Title page and pages 175— 178

Walter TRAVELLING WAVE ANTENNAS N.Y. McGraw-Hill 1950 TK7872 A6 W33 Title page and pages 331— 333

Primary Examiner—Herman Karl Saalbach
Assistant Examiner—Marvin Nussbaum
Attorney—J. G. Pere

ABSTRACT: A directional electromagnetic radiating antenna with circular polarization capable of operating over wide frequency bands and having a greater electrical length than actual physical length. The invention applies basically to a helical antenna utilizing one or more unifilar or multifilar windings which possess the characterizing feature of having an increased electrical path length whereby the operating characteristics of the antenna will resemble that of a larger physical structure than is actually necessary to support the hardware comprising the antenna.



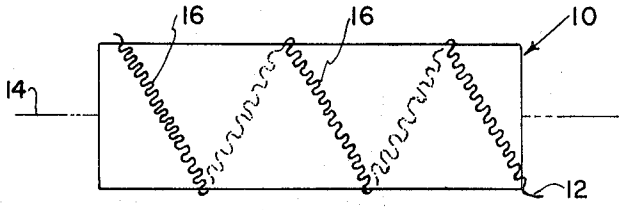


FIG.-1

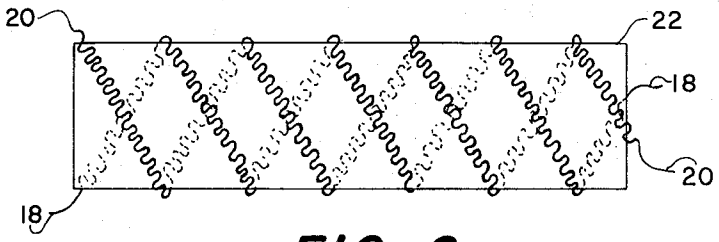


FIG.-2

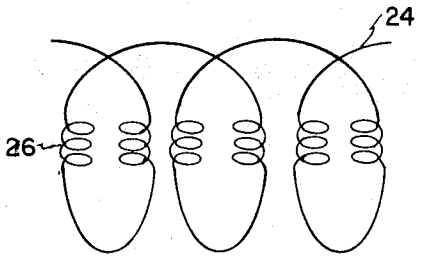


FIG.-3

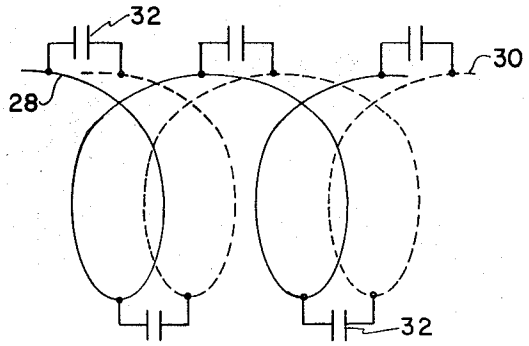


FIG.-4

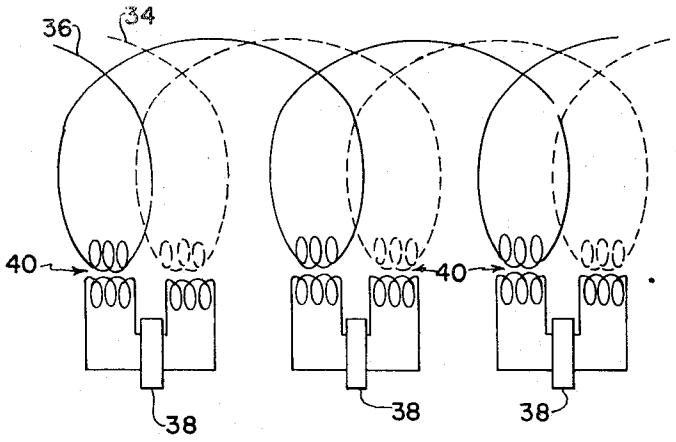


FIG.-5

INVENTORS
ALBERT C. BUXTON
JERROLD S. FOLEY
BY:
Oldham & Oldham
ATTORNEYS

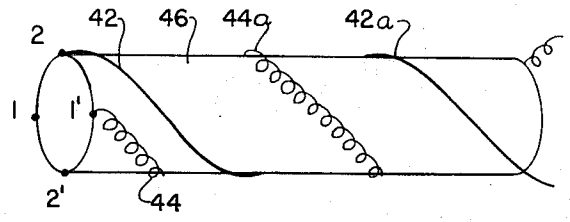


FIG.-6

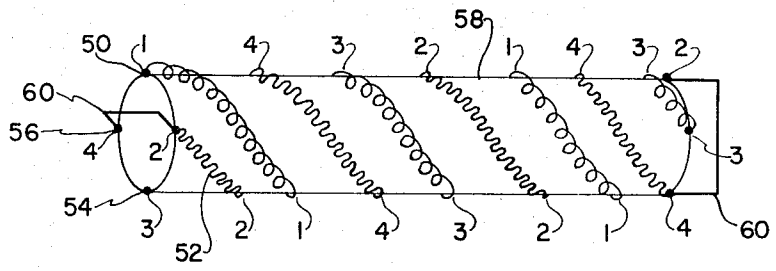


FIG.-7

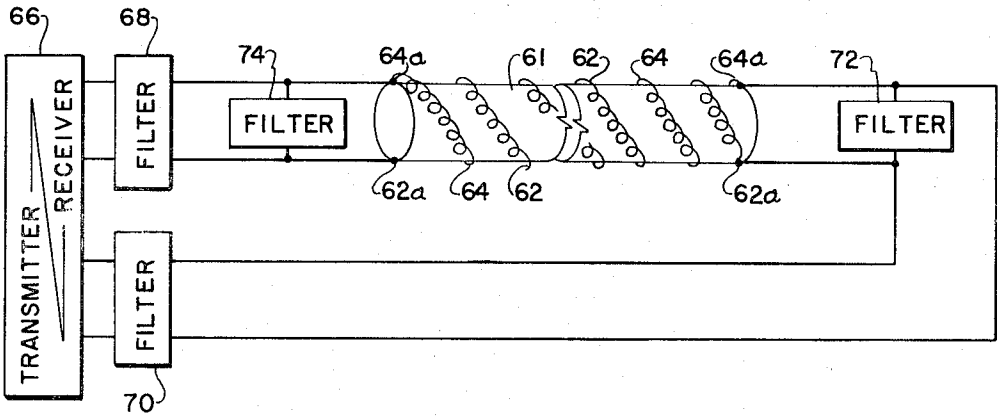


FIG.-8

INVENTORS
ALBERT C. BUXTON
JERROLD S. FOLEY
BY:
Oldham & Oldham
ATTORNEYS

NOVEL HELICAL ANTENNA

Heretofore, it has been well-known to utilize helical antennae to obtain a circularly polarized radiating element for the purpose of endfiring, backfiring, or broadside firing, to obtain highly directional or omnidirectional radiating patterns. It is also well-known to utilize unifilar or multifilar windings with such antennae, with such windings acting as the radiators, and being electrically actuated separately to obtain an enhanced radiation pattern. However, the primary problem associated with such multiple radiating elements in a helical antenna has been to obtain a greater range and more power in a unidirectional radiation pattern. There have been attempts made to reduce the physical size of such antennae while still maintaining particular electrical radiation characteristics and these have met with only limited success. Such techniques are necessary for the utilization of such antennae on aircraft or satellites where size and configuration are both very important to weight and aerodynamic flow considerations.

Therefore, it is the general object of the present invention to meet the needs of the art by providing a unidirectional or omnidirectional electromagnetic radiating device, depending upon how it is fired, which utilizes circular polarization, and is capable of operating over a wide frequency band that has less physical size than its radiating electrical characteristics would indicate.

A further object of the invention is to provide a compact, rigid, and reliable helical antenna which may be packaged and deployed because of its physical characteristics, and is physically smaller than its electrical characteristics because the radiating element is formed with characteristics to lengthen the electrical path length thereof.

These and other objects of the invention which will become apparent as the description proceeds are achieved by providing a directional electromagnetic radiating device which comprises in combination a support housing and a radiating element helically wrapped in uniformly spaced convolutions around said housing whereby the convolutions are concentrically aligned to a straight axis, which element is provided with characteristics to lengthen the electrical path while maintaining a physically reduced size.

For better understanding of the invention reference should be had to the accompanying drawings wherein:

FIG. 1 is a schematic illustration of a basic embodiment of the invention with a single radiating element possessing desired electrical path characteristics;

FIG. 2 is a schematic illustration of the basic embodiment of the invention with two radiating elements;

FIG. 3 is a schematic illustration of a modification of the winding of the radiating element that might be utilized with periodic inductive loading;

FIG. 4 is a schematic illustration of a modified embodiment of the invention comprising two or bifilar helical windings with periodic capacitor loading;

FIG. 5 is a schematic illustration of a modified embodiment of the invention comprising two or multifilar helical windings with active elements for control of mutual coupling between windings;

FIG. 6 is a schematic illustration of another embodiment of the invention utilizing two band helical antennae with a conventional unifilar winding and a slow wave unifilar winding;

FIG. 7 is a schematic illustration of a modified embodiment of the invention comprising a strapped duobifilar backfire antenna to achieve improved directional capability; and

FIG. 8 is a schematic block diagram illustration of a modified embodiment of the invention comprising a multifrequency helical antenna.

With reference to the form of the invention illustrated in FIG. 1 of the drawings, the numeral 10 illustrates generally a conventional supporting structure or housing upon which radiating element or winding 12 is wrapped in a helical pattern to define uniform spaced convolutions about a central axis 14 defined by the structure or housing 10. In most preferred instances, the structure or housing 10 will be of some dielectric material, and preferably will be cylindrically shaped, and

either solid or hollow as the structural requirements may demand. However, cords in tension over a supporting framework may provide a suitable lightweight structure to support the antenna. For some circumstances a conical shape or other uniform geometric shape might be preferable. In any event, the structure 10 must not possess any metal or other characteristic that will interfere with the radiating pattern developed by winding 12 when it is properly loaded with electrical energy, all in the manner conventionally known in the art.

The features of the winding 12 which form the essence of the invention reside in the fact such winding 12 is provided with electrical characteristics to lengthen its electrical path. Because of the increased path length electrical loading of the winding 12 results in a radiation pattern that would normally be required of a much larger structure. The electrical path of winding 12 is lengthened in the preferred embodiment of the invention shown in FIG. 1 by having the winding 12 being compacted or actually follow a meandering path as it defines the helical convolutions around the outer surface of structure 10, and this path is particularly illustrated at 16 in FIG. 1 of the drawings. Of course, it should be understood that path 16 of winding 12 is not actually meandering in its normal meaning since it is necessary that in effect each meander of the path of winding 12 be periodically repetitious. If effect, any periodically repeating curving or meandering path, such as a sine wave or a sawtooth pattern, could be utilized to achieve the objects of the invention. Specifically, the radiation characteristics of the winding 12 will depend upon the compaction or meandering ratio with respect to the pitch ratio of the helical convolutions. The relationship between the meandering ratio and the pitch ratio will be related to the firing mode and frequency range at which the element will be operated. A way to define the meandering ratio would be in terms of the length of wire it would take to cover the distance without any compaction or meandering divided into the length of wire it actually takes to cover the distance with compaction or meandering. Ratios of between about 1.2 to about 2.5 appear to best satisfy the objects of the invention.

Specifically, it has been found that an operation in a backfire mode is favored by a larger pitch angle for the helical convolutions than operation in an endfire mode, with operation in a broadside mode falling somewhere in between. Similarly, it has been found that the wavelength to the diameter of the helical convolutions is a larger fraction in the backfire mode than the endfire mode with the broadside mode again falling somewhere in between. It should be understood, as is well known to anyone skilled in the art, that the same antenna may operate in backfire, endfire, or broadside mode depending upon the frequency of the electrical energization, although operation in any of the modes is greatly enhanced by utilizing the optimum meandering ratio and pitch ratio. Thus, it should be understood that the essence of the invention resides in a loading technique which makes a physically smaller antenna radiate at an electrical longer wavelength, thereby enhancing the phase constant of the antenna, and being able to operate the antenna at two or more frequencies simultaneously by making the antenna compound multifilar, or compound unifilar as shown in FIG. 6. The dual frequency operation is due to the difference in meandering of the two windings.

FIG. 2 illustrates a modified embodiment of the invention utilizing two helical wrapped radiating elements 18 and 20 formed in equally spaced convolutions around a supporting structure or housing 22. It is important to this embodiment of the invention as well as to the basic embodiment illustrated in FIG. 1 that the convolutions be equally spaced from each other, and that the electrical path length of each element be increased by utilizing the compaction or meandering pattern to the elements themselves in their helically wrapped convolutions. In this embodiment of the invention, however, the elements may be fired with different frequencies thereby creating a much broader band of radiation, or achieving an enhanced radiation pattern by the combination of the two separate

frequencies operating simultaneously to enhance each other. Thus, it should be understood that the meandering ratio of elements 18 and 20 may vary depending upon the desired frequency at which elements will be electrically driven, but that the pitch ratio of the helical convolutions must remain the same so that the equal spacing between adjacent convolutions is maintained. Variable pitch may be used to increase bandwidth where directivity may be sacrificed.

FIG. 3 illustrates a modified helically wrapped embodiment differing slightly from the meandering relationship illustrated in FIGS. 1 and 2, but which will achieve the same purpose of providing an increased electrical path length to such helical convolutions. In this embodiment, the helical element 24 is provided with periodic inductive loading at 26, where the periodic nature is uniform with respect to each convolution so the same electrical characteristics are present along the length of the supporting structure about which such element is wrapped. Any convenient type of inductive loading might be utilized, or in some cases the element 24 might be coiled throughout its length to form a reduced diameter helical winding in and of itself, in addition to the total element being formed to a helical configuration. For practical winding purposes the helical winding to achieve the desired meandering ratio is probably the easiest and least expensive.

FIG. 4 illustrates a further modified embodiment of the invention which is applicable only to plural helical windings. In this embodiment, the windings 28 and 30 are connected with periodic capacitor loading circuits 32, where again the periodic nature is uniform with respect to each phase helical convolution. This configuration achieves an increase in electrical path length for each element 28 and 30.

FIG. 5 again represents a modified embodiment of the invention applicable to at least two 180° phase spaced helical wound radiating elements 34 and 36, respectively. In this embodiment, active circuits, indicated generally by numeral 38 are periodically coupled by transformers 40 to the elements 34 and 36 again to increase electrical path length, while at the same time providing a control of the mutual coupling between the elements 34 and 36. The active circuits 38 might, for example, comprise an amplifier with controlled gain and phase shift, which type circuits are well-known to those skilled in the art. Naturally the periodic nature of the active circuits 38 is uniform with respect to each convolution to the helical pattern to which the elements 34 and 36 are wrapped with respect to a carrying structure or housing.

Thus, it should be understood that the basic purpose of the invention is to modify the propagation along the path of the radiating element of the electrical wave by increasing the electrical path length, and which increase in electrical path length can, also, in certain circumstances by utilized to control coupling between the radiating elements. This basic purpose is extended to multifilar elements which are phase spaced on the supporting structure. For example, a bifilar combination would have 180° phase spacing, a trifilar 120°, and so on.

FIG. 6 illustrates a modified embodiment of the invention which is particularly adapted to provide a directional electromagnetic radiating device capable of operating over several frequency bands. This embodiment specifically combines a conventional bifilar helical conductor 42, 42*a* and a bifilar slow wave helical conductor 44, 44*a*, each separate conductor wrapped in alternating uniformly phase spaced helical convolutions about a supporting structure or housing 46. The conductors are spaced 90° apart. In this embodiment of the invention, the inclusion of the two slow wave conductors 44 and 44*a* extends the capability of the antenna to lower frequencies and lower frequency bands. This combination can be used in the backfire mode and in the conventional endfire mode over a ground plane. As illustrated, the slow wave windings 44 and 44*a* utilize a helical convolution within themselves but might utilize the meander or other type loading to lengthen their electrical path characteristic in the same manner as defined in the embodiments above. However, the helical conductors 42 and 42*a* do not utilize any combination of the invention techniques to lengthen their electrical paths. Thus this embodiment of the invention represents a two frequency band helical antenna in combination on a single structural housing, where the conventional conductor might be unifilar or multifilar, with the same being applicable to the slow wave winding, so long as all windings are properly phase spaced. It should clearly be understood that such combination greatly enlarges the operating frequency bands of the combination.

The embodiment of the invention illustrated in FIG. 7 of the drawings utilizes four separate windings 50 through 56, respectively, wrapped in equally phase spaced helical convolutions about a supporting housing 58. However, in this embodiment, the radiating elements 50 and 54 are active while elements 52 and 56 are parasitic. The parasitic elements have propagation velocities very near those of the active elements, and therefore appear electrically to possess backfire wavelengths near the backfire wavelength of the active pair. The invention contemplates providing electrical connecting straps 60 at each end of the parasitic windings which strapping permits the currents to circulate in the parasitic elements 52 and 56 to provide a coupled system. It should be noted that this will provide a broadening of the frequency response by achieving a difference in backfire wavelengths between the active elements 50 and 54 and the parasitic elements 52 and 56. Again, each of the elements has provided for increased electrical path length by utilizing a helical winding or meandering ratio within each element itself. Thus, this embodiment of the invention provides a means for radiating a broad electromagnetic spectrum with a reduced physical size antenna, while still maintaining high directivity over the radiating band.

FIG. 8 is a block diagram schematic illustration of a multifrequency helical antenna. Specifically, the antenna comprises a housing 61 upon which is wound a helical similarly coiled bifilar windings consisting of conductors 62 and 64, each having equal space between adjacent coils. The ends of conductor 62 are identified as 62*a*, while the ends of conductor 64 are identified by 64*a*. A transmitter and/or receiver 66 drives through band-pass filters 68 and 70 to feed or receive from both ends of the antenna with filter 68 driving into a band-pass filter 74 and filter 70 into band-pass filter 72. The band-pass filters 72 and 74, respectively, provide the proper resistance value to the windings 62 and 64 at the operating frequency. The filters 72 and 74 are electrically similar to filters 68 and 70, but are integral to the housing 61, rather than the receiver 66. The band-pass filter 72 drives with one frequency into ends 62*a* and 64*a* adjacent thereto, and band-pass filter 74 drives with another frequency into ends 62*a* and 64*a* adjacent thereto.

If one assumes that for purposes of explanation channel 1 supplied by filter 68 operates at a lower frequency than a channel 2 supplied by filter 70, the antenna operates in a backfire mode with respect to channel 1 and an endfire mode with respect to channel 2. Thus, operation of channel 1 in the backfire mode requires feeding that winding on the left end and operation of channel 2 in the endfire mode requires feeding that winding from the right end. Thus, both frequencies can be used giving a dual frequency transmission or reception capability to the antenna. It should be pointed out that the transmission lines supplying the feed to the antenna may be conveniently placed within the interior of the housing 61, even though it is shown on the exterior in FIG. 8 for sake of clarity.

While in accordance with the patent statutes only the preferred embodiments of the invention have been illustrated and described in detail, it is to be particularly understood that the invention is not limited thereto or thereby, but that the inventive scope is defined in the appended claims.

We claim:

1. A directional electromagnetic radiating device with circular polarization capable of operating over a side frequency band which includes:

a supporting structure;

at least one radiating element wound in helical fashion around the supporting structure with each convolution

substantially uniformly spaced from the adjacent convolution;

circuit means connected periodically to the radiating elements to increase the electrical path length thereof; and

means to drive at least one radiating element.

2. The device according to claim 1 wherein an even number of radiating elements are provided with alternate ones of the elements forming first and second sets of radiating elements, respectively, and the circuit means periodically couple the first and second sets of radiating elements.

3. The device according to claim 2 wherein the circuit means comprise periodic capacitor loading circuits.

4. The device according to claim 2 wherein the circuit means comprise amplifiers with controlled gain and phase shift.

5. The device according to claim 1 wherein the circuit means comprises inductive loadings uniformly periodic with respect to each convolution.

6. A directional electromagnetic radiating device with circular polarization capable of operating over a wide frequency band which includes:

a supporting structure;

a first conductor wound in helical fashion around the supporting structure with each convolution uniformly spaced from the adjacent convolutions;

a second conductor with a lengthened electrical path wound in helical fashion around the support structure with each convolution uniformly spaced from the adjacent convolutions of the first conductor; and

means to drive at least one of the conductors.

7. The device according to claim 6 wherein each conductor is multifilar, each conductor has the same number of elements, and the elements of the first and second conductors alternate along the supporting structure in uniformly spaced relation.

8. The device according to claim 6 wherein the first conductor also has an increased electrical path length, each conductor has two elements, the elements of the first and second conductors alternate along the supporting structure in uniformly spaced relation, the first conductor is active and the other conductor is parasitic, and electrical connection straps connect the parasitic elements in a closed loop.